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For Discussion
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Responses to Comments
Demand Curve Reset Study Report

Presentation to NYISO ICAP Working Group

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Simple Cycle F-class Frame Turbine

- In 2007 and 2010 DCRs:
  - *LMS100 was chosen as the proxy unit in Zones J and K because SCR was required for NOx control.*
  - *7FA.05 <u>without SCR</u> was chosen as proxy in ROS because annual emissions of 7FA without SCR at the operating hours predicted by NERA were less than applicable major source thresholds*
    - *Consequently, BACT/LAER evaluations were not required and SCRs were not needed to reduce NOx emissions*
- In the 2013 DCR:
  - *All technologies exceed the major source threshold for CO2e (~750 hours as a minimum) and PSD Significant Levels for NOx and CO*
  - *Results of NNSR and PSD evaluations require CO catalyst and SCRs for unrestricted operation regardless of Zone or technology*
  - *PSD evaluation will require BACT for CO2e*
- We have reviewed F-Class CTs with and without an SCR to address comments received

SCR on Frame CT in Simple Cycle Operation Technical Challenges

- Catalysts are available for a large operating range of temperature
  - *Optimum NOx removal efficiency occurs in 600°F - 850°F range*
- With F-class CT exhaust temperatures operating near 1,100°F and possibly as high as 1,200°F, catalyst sinters (forming glassy material) and fails (high NH_3 slip).
- The challenge is to reduce CT exhaust temperature sufficiently to achieve SCR performance requirements (NOx removal efficiency, ammonia slip, pressure drop, catalyst life)
  - *CT exhaust temperatures can be reduced with the addition of supplemental ambient air using dilution air fans.*
    - *Difficult to thoroughly mix gases with large density differences (hot exhaust gas and cool air)*
  - *Typical simple cycle SCR specifications for flow and temperature distributions entering the face of the catalyst:*
    - *Flow variations not to exceed +/- 15% rms*
    - *Temperature variation less than +/- 25°F*

SCR on Frame CT in Simple Cycle Operation Technical Challenges

- Remedies
  - *Design inlet plenum with mixers, vanes, perforated plates/distribution grids to prevent "hot spots" on catalyst*
  - *Add tempering air with dilution air fans*
    - *Flow of tempering air is at least 7-17% of turbine exhaust flow to achieve desired reduction in temperature of flow to the SCR*
    - *Redundant fan configuration (1, 2, 3 x 100%)*
    - *Speed control of dilution air fans*
- Difficult to control the flow and temperature distribution during startup and upset conditions
- Additional temperature monitoring requirements
- CT performance loss (increase in heat rate, less net electrical output) due to higher exhaust pressures and more auxiliary power loads

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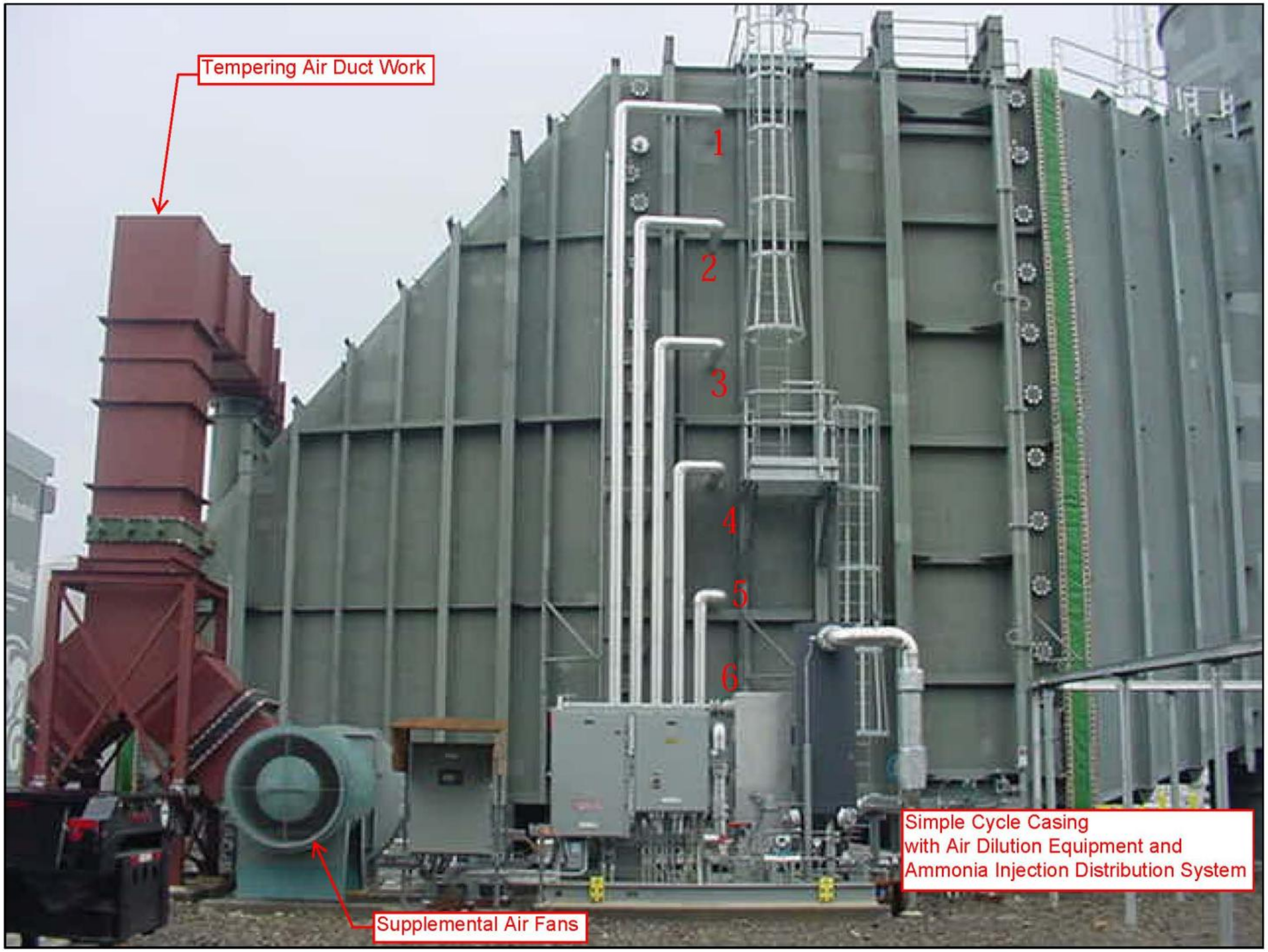
SCR on Frame CT in Simple Cycle Operation



Source: Hamon Research-Cottrell Presentation

SCR on Frame CT in Simple Cycle Operation Industry Experience

- SCRs have been successfully applied to simple cycle aeroderivatives and frame turbines with exhaust temperatures less than 850 - 900°F
  - *Some installations include tempering air*
- SCRs have not been successfully applied to CTs with higher exhaust temperatures. Examples:
  - *Riverside Generating Company, Frankfurt, KY*
  - *Puerto Rico Electric Power Authority, Central Cambalache facility*
- Our experience is that clients often choose aeroderivatives or combined cycles to avoid technical and operational issues
- One plant with four simple cycle SGT6-5000F(4) CTs with SCRs has recently begun operation near Antioch, CA
  - *NRG's Marsh Landing Generation Station: Developed by GenOn; Mitsubishi is SCR vendor; Kiewit is constructor*
  - *Emissions data are publicly available and will be monitored*

Comparison to LMS100 in 2007 DCR

- S&L recommended consideration of LMS100 in 2007 when only one unit was in operation
  - *Incremental technology innovation based on successful prototypes*
    - *Single vendor with successful record of introducing new technologies*
  - *Early signs of market acceptance*
    - *38 units proposed in US—half in CA, quarter in NY; 70-80% of the proposed peaking MWs in either NY or CA were LMS100s*
    - *10 units in NYISO interconnection queue; 2 in DEC permitting process*
    - *No simple cycle F-class CTs were in the NYISO interconnection queue or proposed to the California Energy Commission for 2008-10 time period.*
- In 2013 (as well as 2007 and 2010), S&L recommends that proxy unit not be based on simple cycle F-class CT with SCR because of technical challenges, unsuccessful projects, and lack of market acceptance
  - *To the best of our knowledge, there are no simple cycle F-class CTs with SCR under construction or consideration other than Marsh Landing*
  - *Developers have readily available substitutes—CCs and aeroderivative CTs*

SCR on Frame CT in Simple Cycle Operation Additional Permitting Hurdles

- A simple cycle Frame CT with SCR also could be challenged as not being BACT for reduction of GHGs—specifically CO2
  - *Table shows that the LMS100 and combined cycle produce less CO2 per MWh than simple cycle Frame CT*
- If the proposed project is defined as a peaking plant, combined cycle units may be excluded from the BACT analysis because they do not meet all of the project's goals and objectives
- An applicant can attempt to demonstrate that changing to aeroderivative technology is too costly

	Heat Rate HHV (Btu/kWh)	CO2 Emissions (lb/MWh)
Simple Cycle SGT6-5000F(5)	10,855	1,219
Combined Cycle SGT6-5000F(5)	7,243	799
LMS100	9,352	1,085

Heat Rate includes effects of SCR and tempering air if needed

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Simple Cycle Frame CT without SCR

- Simple cycle SGT6-5000F(5) without SCR will be a major source for CO2e if operated about 750 hours per year or more on NG or about 570 hours per year or more on ULSD
  - *BACT or LAER requirements could be applicable if annual emissions exceed the applicable thresholds for NOx, VOC, or CO*
- Assuming the simple cycle Siemens SGT6-5000F(5) without SCR is deemed a major source from GHG emissions, S&L calculated the annual operating hour caps to avoid BACT/LAER requirements for NOx, VOC, or CO
  - *Calculated caps for both operation on NG and on ULSD*
  - *BACT requirements:*
    - *SCR (if emissions at projected operating hours exceeds NOx threshold)*
    - *CO catalyst (if emissions at projected operating hours exceed CO or VOC threshold)*
    - *Air quality impact analysis*
    - *Additional impact analysis*

Applicable Annual Thresholds

- NOx and VOC thresholds:
  - *Zones C and F: 40 tons per year*
  - *Zones J and K: 2.5 tons per year*
  - *Zone G:*
    - *Rockland County: 2.5 tons per year*
    - *Other counties: 40 tons per year*
- CO threshold = 100,000 tons per year in all zones

Results – One Unit Plant (206.5 MW ICAP)

- Albany: annual operations cap of 1,075 hours
  - *Syracuse would be similar*
- New York City:
  - *Annual operations cap of 66 hours on NG and 14 hours on ULSD*
  - *Long Island would be similar*
- Lower Hudson Valley:
  - *Rockland County: Annual operations cap of 66 hours on NG and 14 hours on ULSD*
  - *Dutchess County: Annual operations cap of 1,056 on NG and 226 hours on ULSD*
    - *Other counties would be similar to Dutchess County*
- Annual operations cap (hours) for CO or VOC is greater than cap for NOx

Comments

- Annual operating hours cap would be halved for a two-unit plant
  - *Annual tonnage thresholds apply to the facility*
- Assuming the simple cycle SGT6-5000F(5) without SCR is deemed a major source from GHG emissions, it also could be challenged as not being BACT for reduction of GHGs—specifically CO2
  - *If the proposed project is defined as a peaking plant, the combined cycle may be excluded from BACT analysis because it does not match the project definition*
  - *An applicant can demonstrate that changing to aeroderivative technology is more costly*
  - *The plant will have a cap on operating hours to stay below the NOx threshold, thereby limiting potential CO2 emissions*

Recommended Approach

- Add one unit simple cycle SGT6-5000F(5) without SCR as technology option in Zones C and F with annual operations cap of 1,075 hours
  - *Econometric analysis shows annual operation of 982 – 1,025 hours in 2014-16 period in Zone F*
- Simple cycle SGT6-5000F(5) without SCR in Zones G, J and K have too few run hours to be practical alternatives
  - *Limited by 2.5 tons per year NOx threshold in Rockland and Westchester Counties, and Zones J and K, plus dual fuel operation on ULSD in other Zone G counties*
- Simple cycle SGT6-5000F(5) with SCR is not considered due to technical challenges, operating risks, lack of successful operating experience, and potential permitting hurdles

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Basis for Technology Choices

- Section IIA of the draft report identifies five screening criteria:
  - *Compliance with environmental requirements*
  - *Commercially available and replicable*
  - *Utility plant scale*
  - *Available to most developers*
  - *Dispatchable by NYISO to meet daily and peak loads*
- Three natural gas technologies met the criteria and were examined in more detail
  - *Combustion turbines in simple cycle*
  - *Combustion turbines in combined cycle*
  - *Reciprocating internal combustion engines*
- Among the many turbine and engine models met the criteria, we chose models based on:
  - *Competitive heat rate*
  - *Diversity of equipment manufacturers*
  - *Operational flexibility*
  - *Able to meet New York State environmental requirements*

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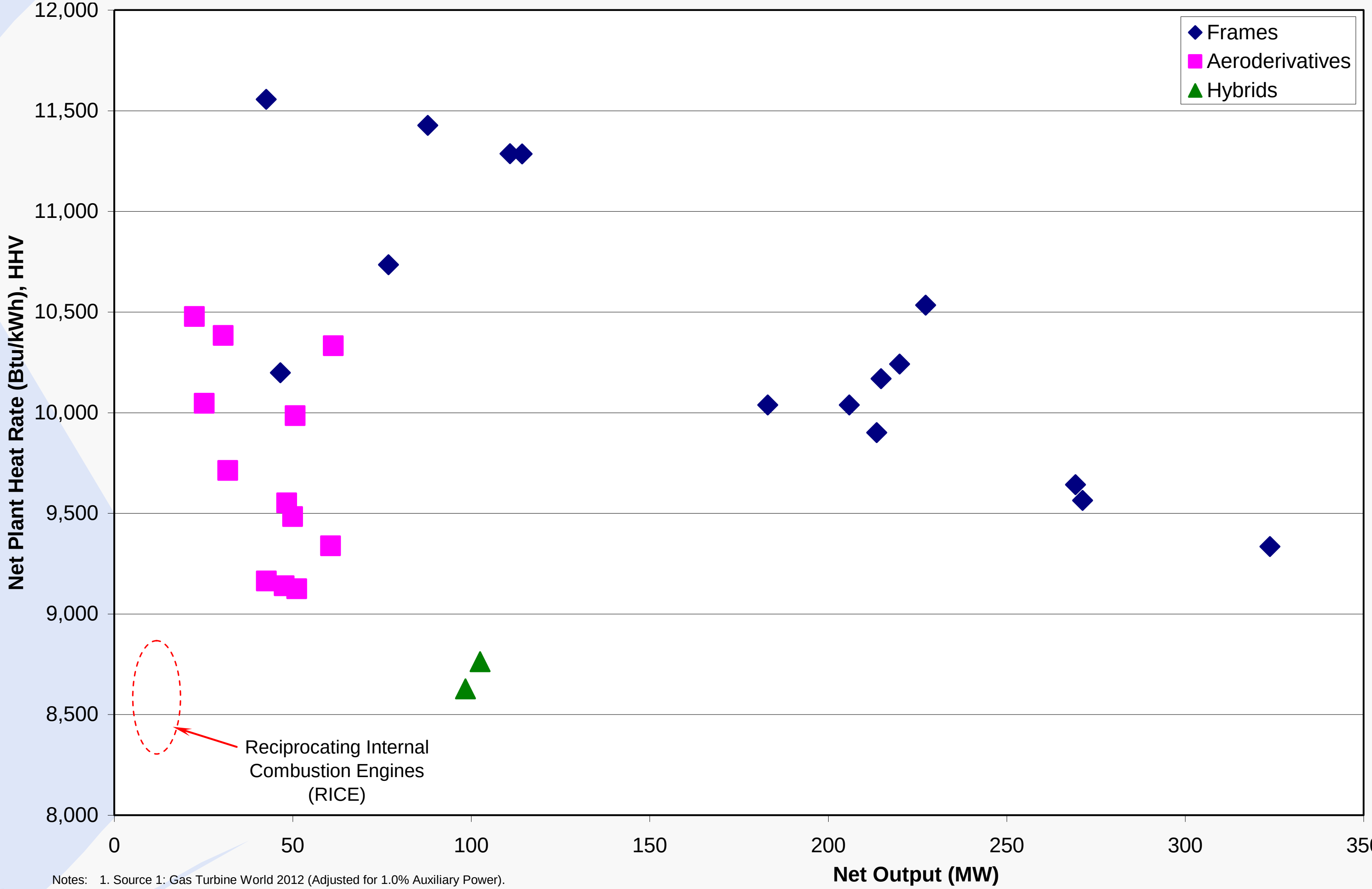
Comparison of CTs in Simple Cycle



Notes: 1. Source 1: Gas Turbine World 2012 (Adjusted for 1.0% Auxiliary Power).
2. Source 2: S&L Internal Simple Cycle Performance Information (Adjusted for 1.0% Auxiliary Power).
3. ISO Conditions (59 °F, 60% RH, 0 Feet AMSL).
4. CTG model number not shown since some Information may be Confidential or Proprietary.

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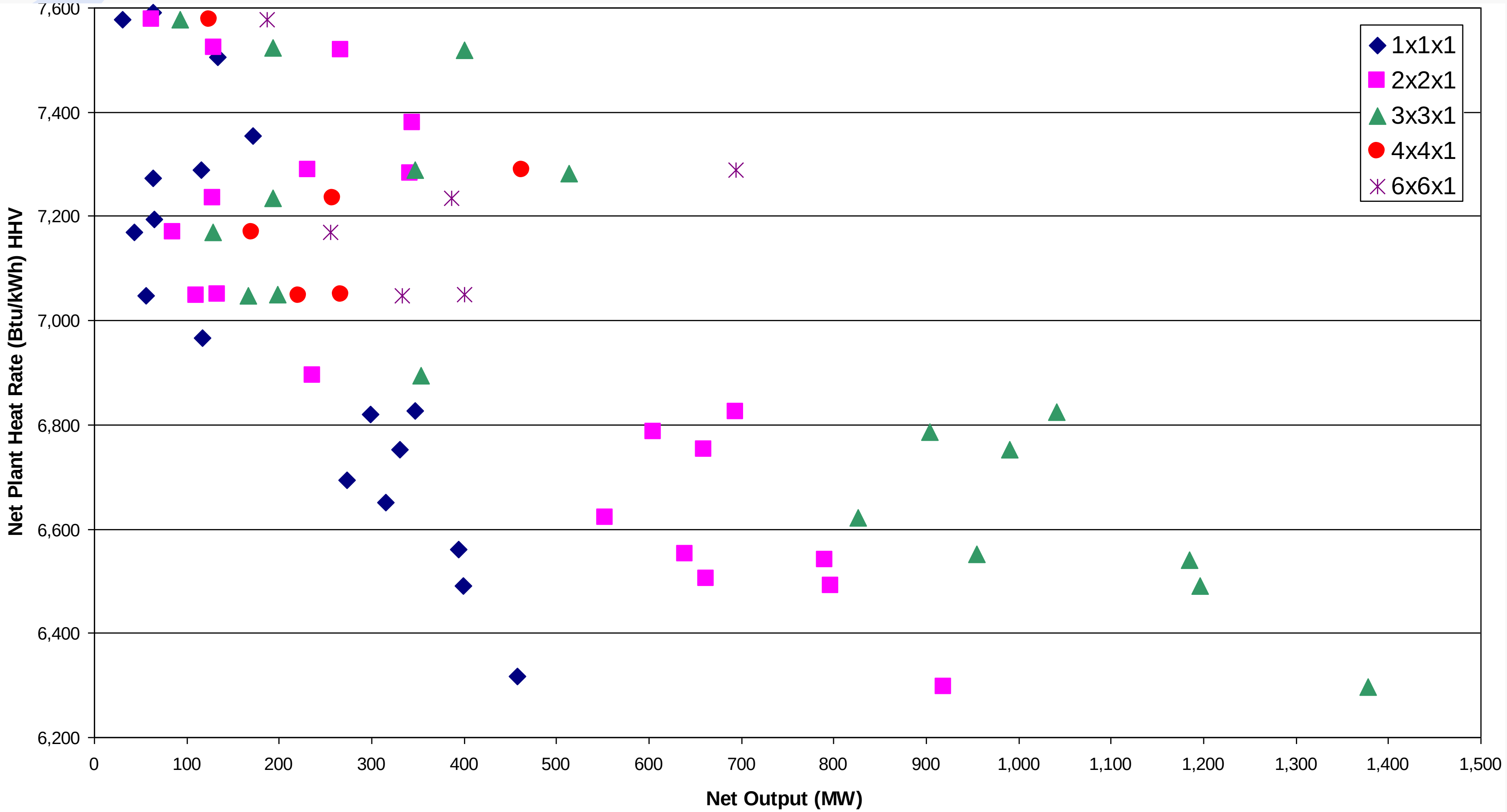
Comparison of CTs in Combined Cycle



1. ISO Conditions (59 °F, 60% RH, 0 Feet AMSL)
2. Natural Gas Fired CT, No Supplemental Firing of HRSG.
3. Source: Gas Turbine World 2012 (Adjusted for 2.5% Auxiliary Power).
4. Only a sample of the aeroderivative models are shown, performance may vary based on the actual model chosen
5. CTG model number not shown since some Information may be Confidential or Proprietary.

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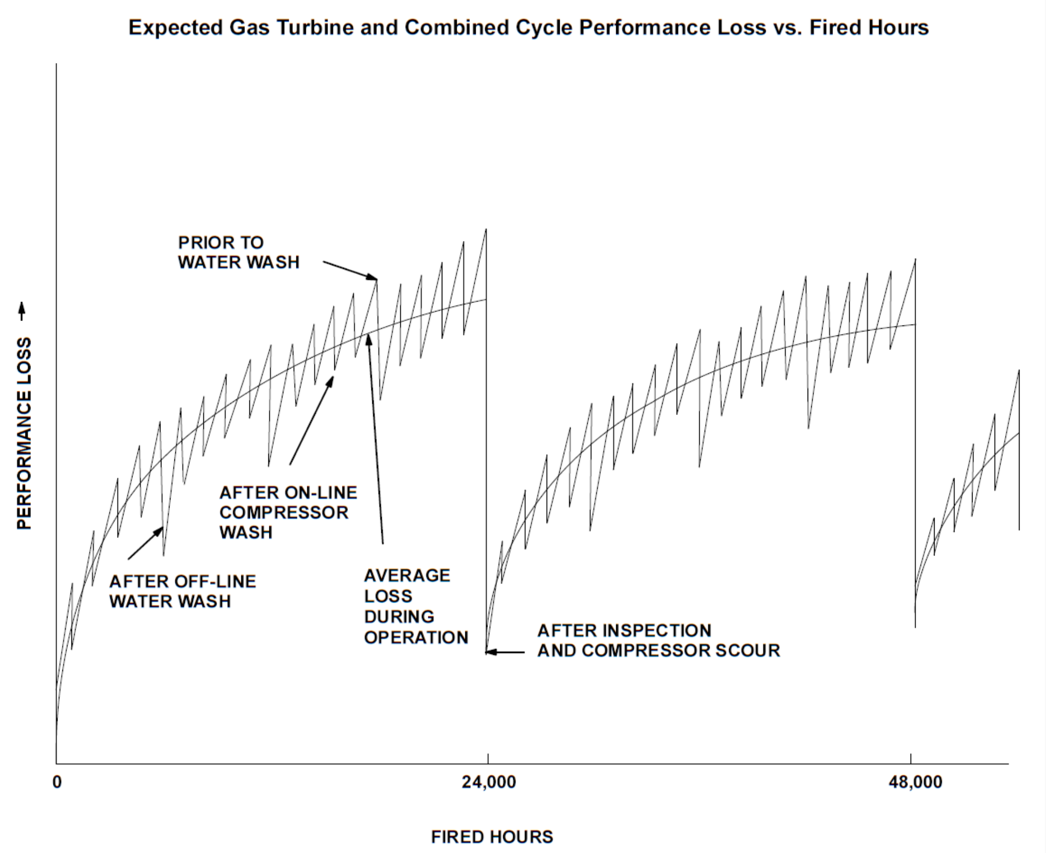
Average Degradation of Capacity Between Overhauls

- Based on experience, S&L uses a 1.5% factor for the typical average degradation value to smooth the irregular shape of the gas turbine degradation curve.
- Actual degradation would be worse prior to a major overhaul and better following a major overhaul.
- A capacity degradation value of 3.7% is very conservative. With good maintenance practices and overhauls scheduled as recommended by the OEM, these values can be reduced.



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Temperature Correction for DMNC Ratings

- Table A-1 of the report shows elevation, temperature and relative humidity for each zone used in capacity and heat rate calculations
- Table A-2 shows capacity calculated by technology by zone using these assumptions
- Capacity at average summer and winter temperature from Table A-2 is currently used for DMNC temperature corrections in the demand curve model
- NYISO’s process for temperature corrections for DMNC ratings uses the average of the ambient conditions at the time of the summer system peak and the winter system peak for the last four years
- NYISO has looked up the temperature at time of the summer and winter system peak in each zone over the last eight years
- S&L will include in Table A-2 the capacity of each technology in each zone corresponding to the average temperature at the time of the summer and winters peaks

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Summer and Winter DMNC Temperatures

Zone	Number of Units in Zone	Avg. Summer Temperature	Recommended
C - CENTRL	9	88.0	90.0
F - CAPITL	13	90.9	90.0
G - HUD VL	2	90.2	90.0
J - N.Y.C.	119	90.4	90.0
K - LONGIL	56	90.7	90.0
	Avg.	90.0	

Zone	Number of Units in Zone	Avg. Winter Temperature	Recommended
C - CENTRL	9	16.2	18.5
F - CAPITL	13	18.3	18.5
G - HUD VL	2	20.6	18.5
J - N.Y.C.	119	27.9	28.0
K - LONGIL	56	19.6	18.5
	Non-NYC Avg.	18.6	

Dual Fuel in Zones G-K

- Section II F 1 d of the report cites LDC tariffs that appear to require or support dual fuel capabilities
  - *Orange & Rockland and Central Hudson in Zone G*
  - *Con Ed in Zones H, I and J*
  - *National Grid in Zone K*
- Most generators connected in recent years or planning to connect directly to interstate pipelines also are dual fuel
- Example breakout of dual fuel costs (for LMS100 @ Rockland County)

CT/SCR	$2,000,000
Tanks, pumps, piping, valves	$1,648,000
Labor	$1,961,000
Indirects	$1,086,000
Contingency	$669,000
Non-EPC costs	$1,200,000
Total	$8,564,000

Interconnection Cost Estimates

- Cost estimates for MIS costs are based on:
  - *S&L's estimate of the cost for a substation expansion at the point of interconnection, plus*
  - *The average of costs for Protection SUFs, Headroom payments and CTO AFs taken from representative projects from CY 2009-2011 studies*
- While some of the projects in CY09 and CY10 declined their cost allocations, and projects in CY11 have not made decisions, their costs for protection SUFs, Headroom payments and CTO AFs are representative of the range of these types of MIS costs
- While certain Headroom accounts for SUFs underlying the Headroom payments for CY09 and CY10 projects have expired, these payments are representative of Headroom payments a future project may be expected to pay

EFORd

- Obtained NYISO data for EFORd and in-service date for all CTs and CCs in NYCA for 2008-2012
- Reviewed results for frame units, aeroderivative units, and CC plants for units less than 10 years old; median value used in econometric model
  - *CCs: 2.04%*
  - *CTs: 2.17%*
    - *Not enough units to distinguish between aeroderivatives and frame units*
- Values are representative of EFOR values recommended by OEMs and consistent with O&M cost assumptions
- No EFOR data on reciprocating engines; used 1.0% based on S&L experience and OEM recommendations

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Abbreviation Summary

- AF – Attachment Facility
- AMSL – Above Mean Sea Level
- BACT – Best Available Control Technology
- Btu – British Thermal Unit
- CC – Combined Cycle
- CO – Carbon Monoxide
- CO2e – Carbon Dioxide Equivalents
- CT, CTG – Combustion Turbine
- CTO – Connecting Transmission Owner
- CY – Class Year
- DB – Dry Bulb
- DCR – Demand Curve Reset
- DEC – New York State Department of Environmental Conservation
- DMNC – Demonstrated Maximum Net Capability
- EFOR – Equivalent Forced Outage Rate
- GHG – Greenhouse Gases
- HRSG – Heat Recovery Steam Generator
- HHV – High Heating Value
- ISO – International Standards Organization
- kWh – kilowatt hour
- LAER – Lowest Achievable Emissions Rate
- LDC – Local Distribution Company
- MIS – Minimum Interconnection Standard
- MW – Megawatt
- NG – Natural gas
- NH3 - Ammonia
- NOx – Nitrogen Oxides
- NNSR – Non-Attainment New Source Review
- NYCA – New York Control Area
- OEM – Original Equipment Manufacturer
- PSD – Prevention of Significant Deterioration
- RH – Relative Humidity
- rms – root mean square
- ROS – Rest of State
- SCR – Selective Catalytic Reduction
- SUF – System Upgrade Facilities
- ULSD – Ultra Low Sulfur Diesel
- VOC – Volatile organic compounds