Status Update on Peaking Unit Technology Capital Cost Estimates

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Agenda

1. Executive Summary
2. Technology Comparison
3. Combustion Turbine Technology Experience
4. Plant Cooling Requirements
5. Evaluation of Peaking Unit Operating Hour Restrictions to Avoid Major Source Status
6. Application of SCR on Frame Combustion Turbines
7. Conceptual Design Assumptions
8. Preliminary Capital Cost Estimates











Executive Summary

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- Peaking unit technology options recommended by Lummus Consultants:
  - Aeroderivative CT - GE LMS100PA+
  - Frame Simple Cycle - Siemens SGT6-5000F5
  - Reciprocating Internal Combustion Engine (RICE) – Wartsila 18V50SG/DF
- Other technologies were considered






Executive Summary (con't)

- The frame unit "H" class in simple cycle was eliminated from consideration as the peaking unit because there are no units with commercial operating experience in this configuration
  - Potential "H" class units operating in simple cycle have been proposed and are currently in various stages of permitting (See Slide 28)
  - Even if permitted and proceed with construction, none of these proposed units are anticipated to enter commercial operation prior to the end of the ongoing reset
- Although eliminated from consideration as the peaking unit, the frame unit "H" class will be considered as a technology option for the informational combined cycle configuration
  - There are currently 14 Siemens "H" class units (Siemens 8000H) in commercial operation in combined cycle configurations











Potential Peaking Unit Technology Comparison

Frame Combustion Turbine Comparison

- Frame Combustion Turbine Comparison
  - GE & Siemens both offer proven F class combustion turbines
  - Very competitive in cost, output and performance

Recommend the Siemens F technology be considered as a potential peaking unit technology representative of F class frame technology

Aeroderivative Combustion Turbines

- Aeroderivative Combustion Turbines
  - Compared largest aeroderivative combustion turbines
  - GE LMS100PA+ and PWPS FT4000 SwiftPac 120 are very competitive for a 200-250 MW size peaking plant
  - LMS100 has extensive operating experience
  - FT4000 has only been operating since June 2015

Recommend GE LMS100PA+ be considered as a potential peaking unit technology representative of aeroderivative combustion turbines

Reciprocating Internal Combustion Engine

- RICE Options
  - Wartsila and Mann offer the largest gas and dual fuel reciprocating engine generators (17-18 MW)
  - Other RICE options are ≤10 MW
  - Larger units result in lower $/kW capital cost
  - Wartsila 18V50SG/DF and Mann 51/60G/DF engines are very competitive
  - Wartsila 18V50SG/DF has more worldwide experience

Recommend Wartsila 18V50SG/DF be considered as a potential peaking unit technology representative of the RICE technology

Combustion Turbine/RICE Experience

	Number of Operating Units
LMS100	60
FT4000	3
Siemens 5000F	633
Wartsila 18V50SG/DF	84 gas engines (24 in US)/ 134 dual fuel engines (10 in US)
Mann 51/60G/DF	0 gas engines/47 dual fuel engines (0 in US)






Environmental Requirements

Environmental Discussion Topics

- Plant cooling requirements
- Evaluation of peaking unit operating hour restrictions to avoid major source status
- SCR systems on frame combustion turbines











Plant Cooling Requirements

Plant Cooling Requirements

- Combined Cycle Power Plants
  - Major source of heat rejection is the steam turbine condenser
  - New combined cycle (CC) power plants typically use mechanical draft cooling towers or air cooled condensers (ACCs)
  - Both cooling methods can meet Clean Water Act Section 316(b) Rule requirements for new facilities
  - NYSDEC Policy CP-#52 seeks a performance goal of dry cooling for industrial facilities sited in coastal zones and the Hudson River up to Troy
  - At some locations new combined cycle power plants are moving towards ACC - driven by environmental and/or water scarcity concerns






Plant Cooling Requirements - Continued

- Simple Cycle Power Plants
  - Minor heat rejection requirements for simple cycle combustion turbine plants compared to combined cycle plants
  - GE LMS100 has a compressor inter-stage cooling requirement that can be met with wet or dry cooling options
  - GE has indicated that the vast majority of orders for the LMS100 include dry cooling
- Summary of design assumptions for plant cooling:
  - LMS100 inter-stage cooling is assumed to be dry in all zones
  - CC condenser cooling uses air cooled condensers for zones F, G, J, and K
  - CC condenser cooling uses wet mechanical draft cooling towers in zone C









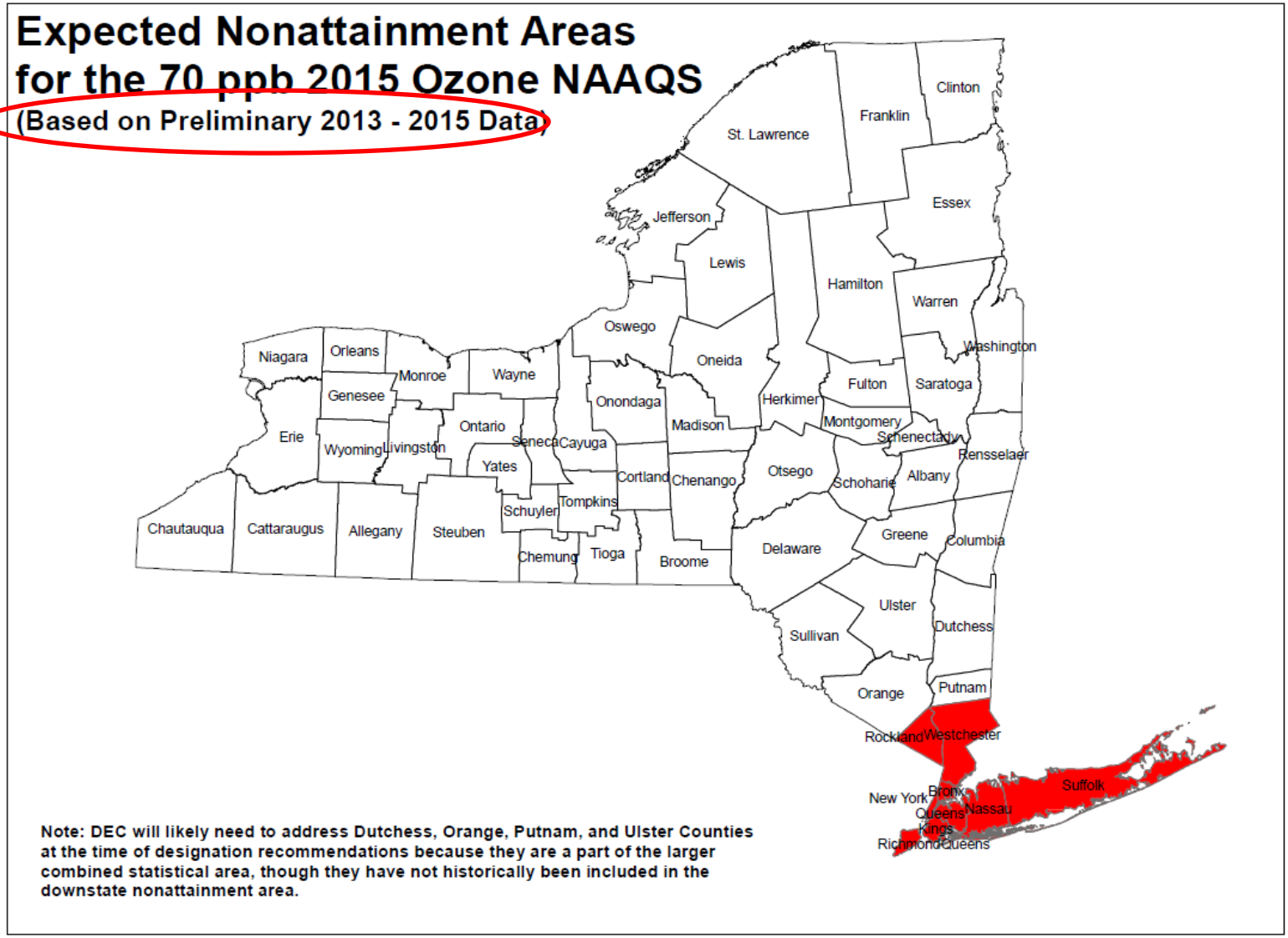


Evaluation of Peaking Unit Operating Hour Restrictions to Avoid Major Source Status

Process Used to Evaluate Operating Hour Restrictions to Avoid Major Source Status

- Confirmed with NYSDEC that based on the latest ozone monitoring data, the 2015 ozone NAAQS is not expected to result in changes to nonattainment major source thresholds and offset requirements for NOx and volatile organic compounds (VOC) (see next slide)
- Determined operating hour restrictions of peaking plants to avoid being a major Prevention of Significant Deterioration (PSD) source
- Determined operating hour restrictions to avoid being subject to nonattainment new source review (NNSR) based on NOx and VOC major source thresholds
- More restrictive operating hours (PSD or NNSR) were identified for each technology for each Load Zone
- For dual-fuel plants; evaluated emissions for both 500 hours/year and 720 hours/year of operation using ultra-low sulfur diesel (ULSD)

Expected Nonattainment Areas for the 2015 Ozone NAAQS



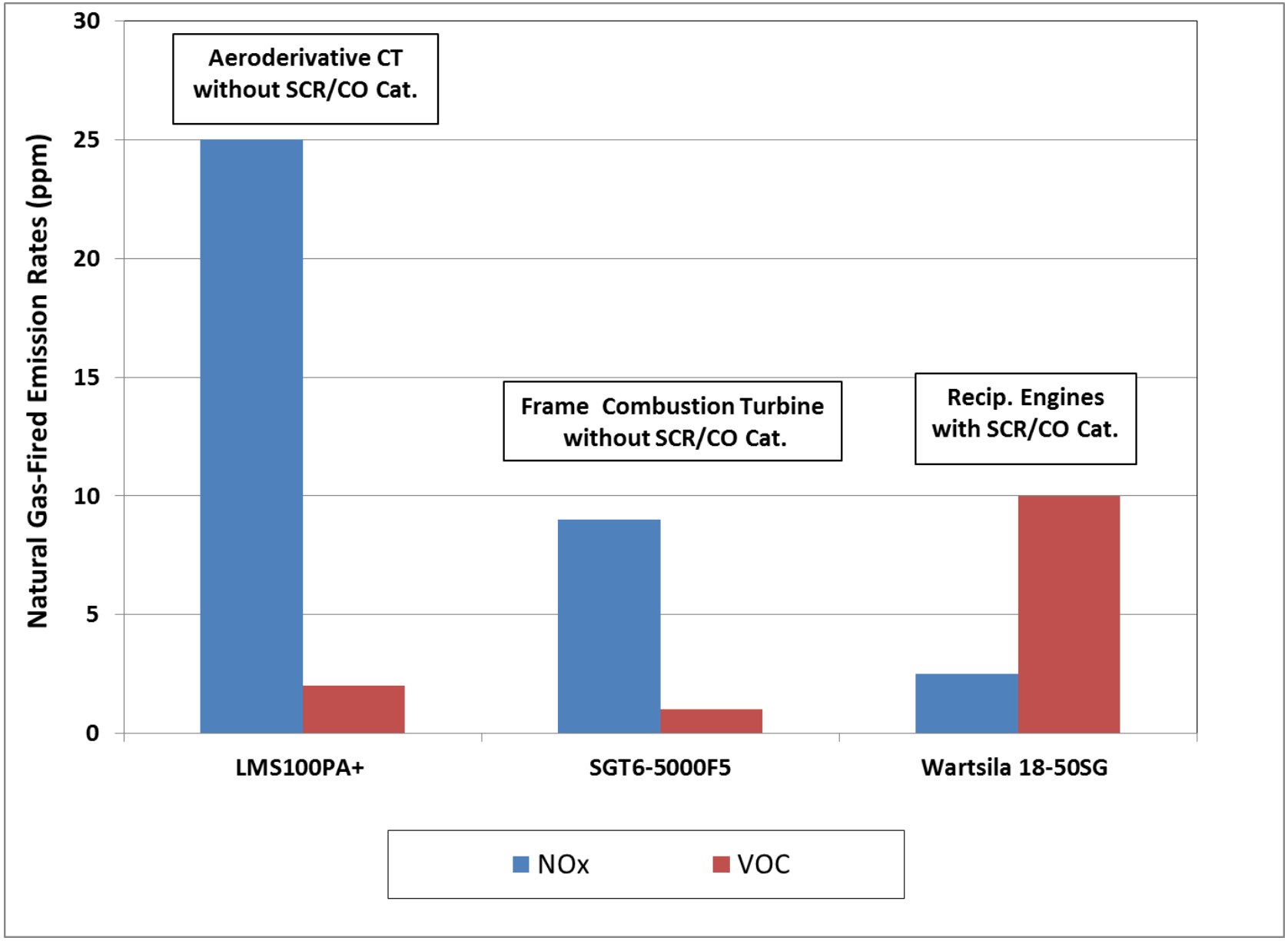
Source: New York State Department of Environmental Conservation

New Peaking Unit Assumptions

- Types of peaking generating facilities evaluated for major source emission thresholds
  - Advanced frame combustion turbines
    - Siemens SGT6-5000F5 (9 ppmvd @ 15% O_2 NOx on natural gas)
  - Aeroderivative combustion turbines
    - GE LMS100PA+ (25 ppmvd @ 15% O_2 NOx on natural gas) (1)
- Emissions evaluated without selective catalytic reduction (SCR) systems or carbon monoxide (CO) catalysts
- Emissions evaluated for both "gas-only" and "dual-fuel" operations
- For this preliminary screening, emissions estimates are based on ISO conditions and do not include startup and shutdown emissions.
- Reciprocating engines were not evaluated to determine operating hour restrictions to potentially avoid BACT or LAER emission controls, as all reciprocating engine projects in the U.S. are expected to include SCR/CO catalyst systems

(1) Emissions from the LMS100PA+ without SCR was included for comparison with the emissions from the SGT6-5000F5 without SCR. However, the LMS100PA+ is likely to require an SCR in order to meet the EPA New Source Performance Standard (NSPS) for stationary combustion turbines > 850 MMBtu/hour heat input.

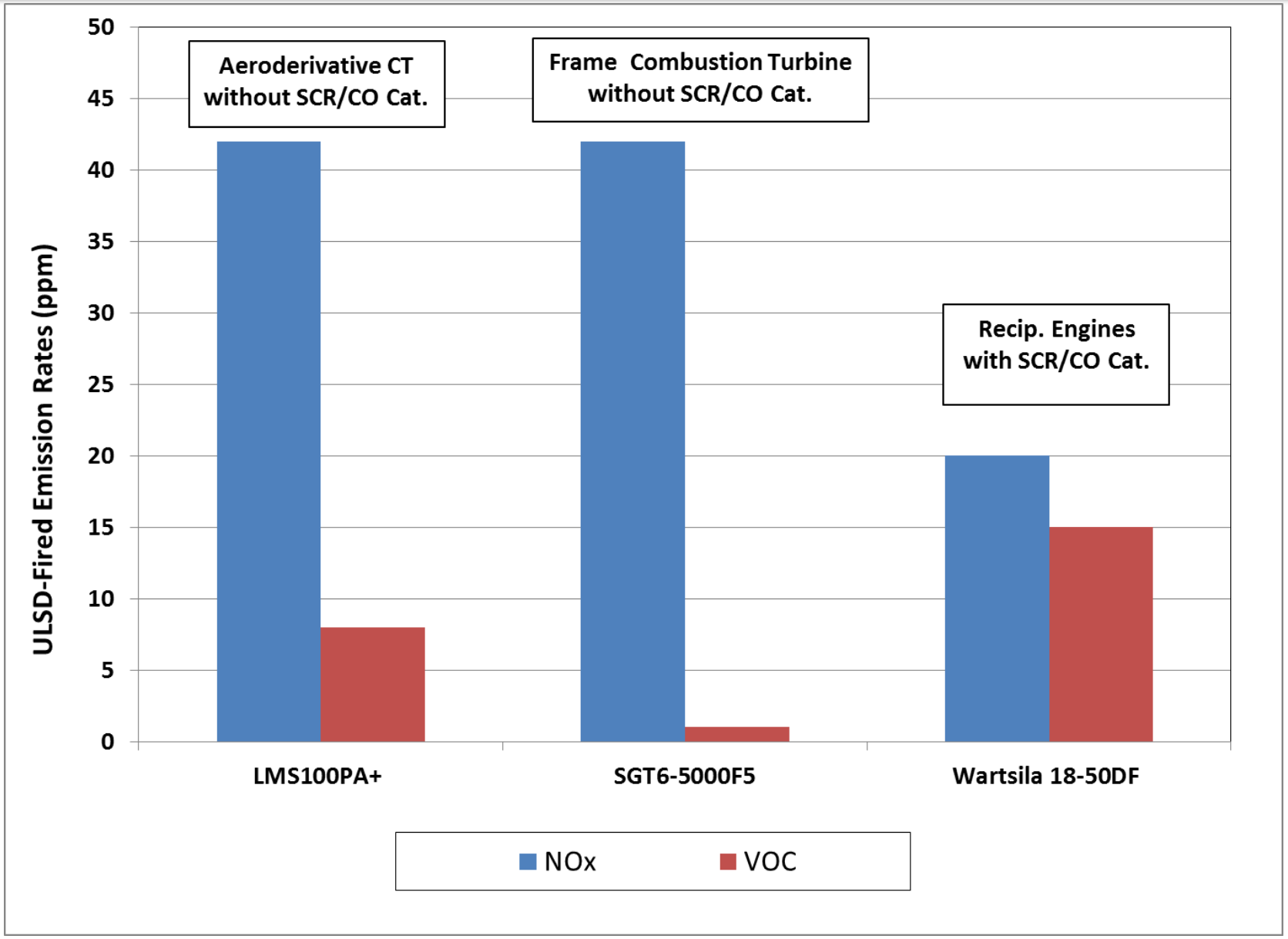
Comparison of Full Load NOx and VOC Emission Rates – Natural Gas Firing








Comparison of Full Load NOx and VOC Emission Rates – Ultra-Low Sulfur Diesel Firing





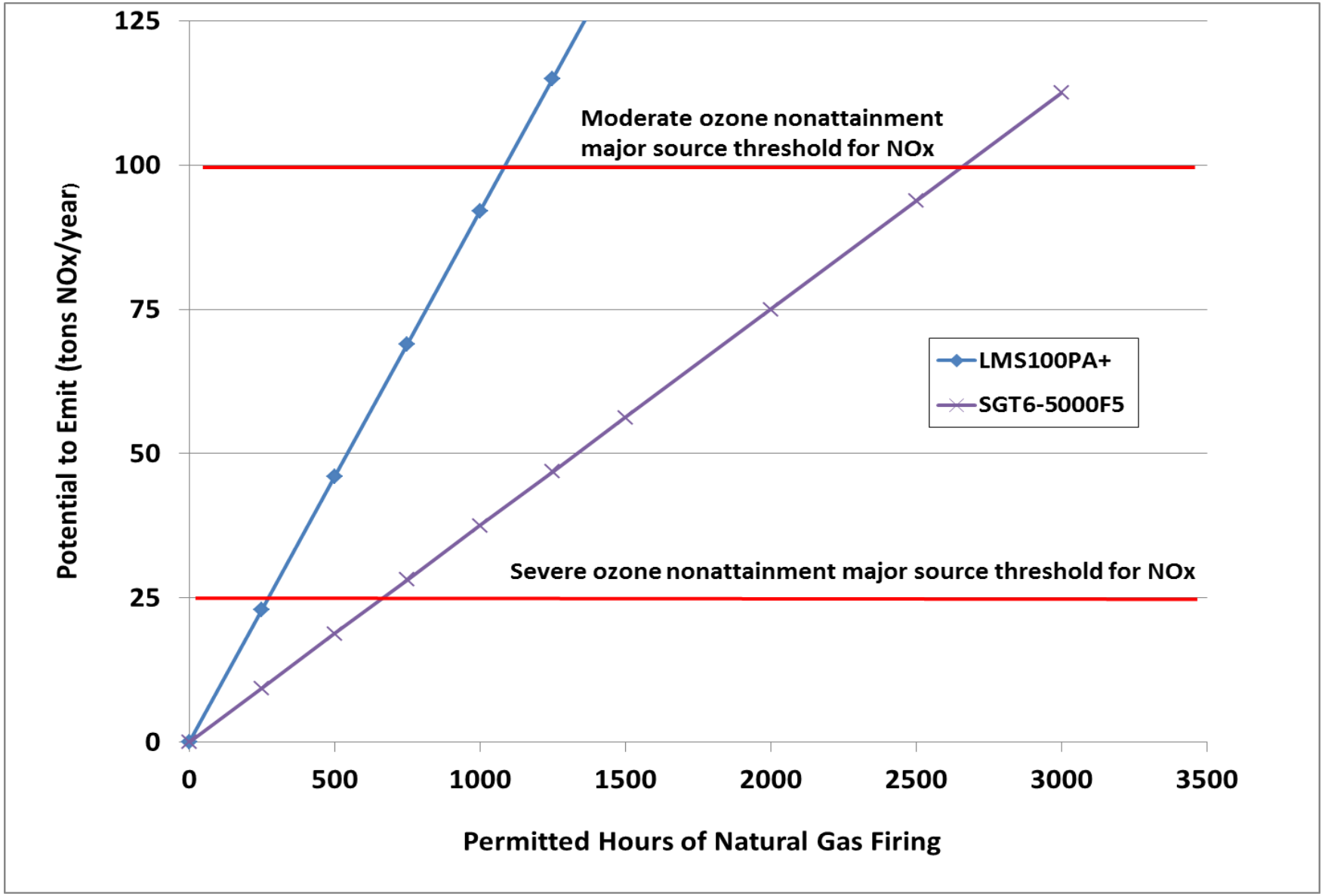



Ozone Nonattainment Classification and Major Source Thresholds by Zone

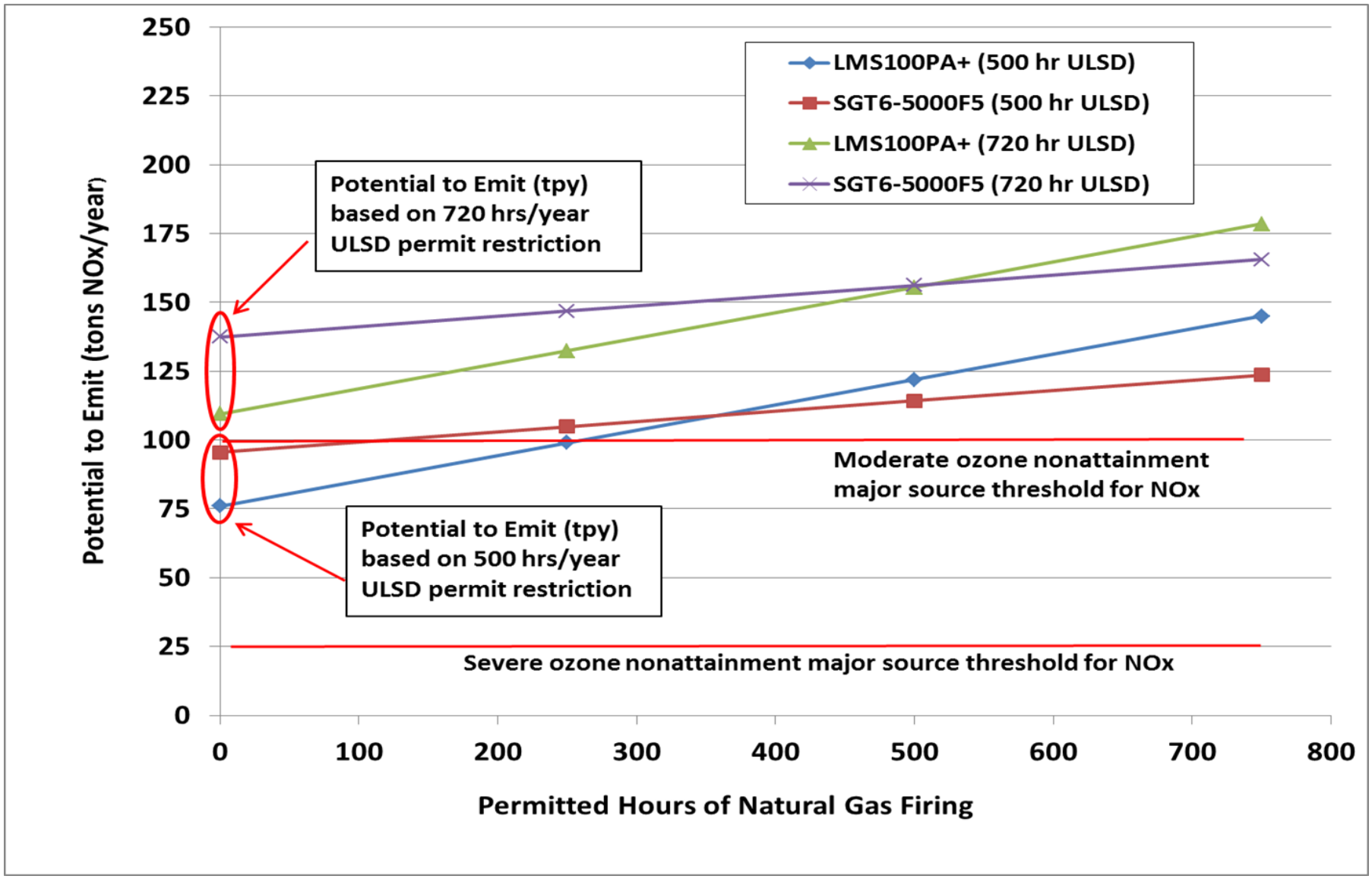
	K-Long Island	J-NYC	G-Dutchess	G-Rockland	F-Capital	C-Central
PSD Major Source Threshold (tons/year)	250	250	250	250	250	250
Ozone nonattainment classification[(1)]	Severe	Severe	Moderate	Severe	Moderate	Moderate
NNSR NOx Major Source Threshold (tons/year)	25	25	100	25	100	100
NNSR VOC Major Source Threshold (tons/year)	25	25	50	25	50	50

[(1)]Moderate classification due to location being in the Ozone Transport Region (OTR)

Estimates of Potential to Emit Gas Only Operation (no SCR)



Estimates of Potential to Emit Dual Fuel Operation (no SCR)



Air Permit Operating Hour Restrictions

- Base-load combined cycle projects
  - Typically permitted for 8,760 hours per year (i.e., no hours limitation)
- Peaking projects
  - Operating hour limitations vary by project
  - Going forward, peaking units unlikely to seek operating hour restrictions that would subject the unit to the Carbon Pollution Standards for New Units, i.e., capacity factor limited to design efficiency (net lower heating value basis)
- Oil-fired operating hours for dual-fuel plants
  - Varies by individual air permit
  - Permit operating hours limits are typically conservative and do not represent expected hours of operation on liquid fuel






Application of SCR on Frame Combustion Turbines

SCR on Frame Combustion Turbines

- The technical feasibility of applying an SCR on simple cycle frame combustion turbines was extensively reviewed during the last reset
- It is Lummus Consultants opinion that there have been no new developments that would change the conclusion that the F class frame unit with SCR is a viable technology for gas-only or dual-fuel projects in all Load Zones

Additional Information on Frame Combustion Turbines with SCRs

- To our knowledge their have not been any new simple cycle frame combustion turbines (CTs) with SCR that have started commercial operations since the last reset
- Marsh Landing (simple cycle F class frame CT, gas only operation) now has close to three years operating experience. An August 2015 Permit Evaluation and Statement of Basis by the Bay Area Air Quality Management District does not reveal any compliance issues with these units
- There are projects in development that have proposed simple cycle frame CTs with SCR systems (gas-only and dual-fuel (See next slide)
- Our discussions with SCR suppliers indicate commercial guarantees are available for both gas-only and dual-fuel operations and for ammonia slip levels of 5 or 10 ppm
- Dual-fuel experience with simple cycle aeroderivative CTs equipped with SCR provides transferrable operating experience to dual-fuel Frame CTs

Projects in Development with Simple Cycle Frame Combustion Turbines with SCR Systems

Project	State	Fuel	Combustion Turbine Model(s)	Air Permit Status
Canal Unit 3	MA	Dual Fuel	GE 7HA.02 (or equivalent)	Not issued
Fredonia Generating Station Expansion	WA	Dual Fuel	Options include three F Class CTs as well as LMS100	Issued
Puente Power Project	CA	Gas Only	GE 7HA.01	Not Issued
Friendswood Energy Genco. LLC	TX	Gas Only	Siemens 501D	Issued
EXTEX LaPorte	TX	Gas Only	Siemens GT6-5000F	Issued






Conceptual Design Assumptions and Preliminary Capital Cost Estimates

Preliminary Conceptual Design Assumptions

	K-Long Island	J-NYC	G-Dutchess	G-Rockland	F-Capital	C-Central
Combined Cycle Cooling	Dry	Dry	Dry	Dry	Dry	Wet
LMS100PF+ Cooling	Dry	Dry	Dry	Dry	Dry	Dry
Fuel Scenario	Dual Fuel	Dual Fuel	Dual Fuel	Dual Fuel	Dual Fuel	Dual Fuel
2 x Aero CTs, 1 x F Class Frame, and RICEs Post Combustion Controls	SCR/CO Catalyst	SCR/CO Catalyst	SCR/CO Catalyst	SCR/CO Catalyst	SCR/CO Catalyst	SCR/CO Catalyst

Preliminary Capital Cost Estimate ($2015 million)

Summary of Preliminary Lummus Consultants Capital Cost Estimates ($ million, 2015$)						
	K - Long Island	**J - NYC**	**G - (Dutchess)**	**G - (Rockland)**	**F – Capital**	**C – Central**
Total Capital Investment ($ million)						
2x0 LMS100PF+	$317	$341	$286	$289	$273	$269
1x0 Siemens 5000F5	$251	$269	$223	$226	$210	$207
12x0 Wartsila 18V50DF	$393	$413	$348	$351	$329	$321

Capital Investment includes Engineering, Procurement, Construction Contract, Owner's Cost, Financing Costs, Working Capital and Fuel and Non-Fuel Inventories

Preliminary Capital Cost Estimate ($2015/kW)

Summary of Preliminary Lummus Consultants Capital Cost Estimates ($2015/kW)						
	K - Long Island	**J - NYC**	**G – (Dutchess)**	**G - (Rockland)**	**F – Capital**	**C – Central**
Total Capital Investment ($/kW)						
2x0 LMS100PF+	$1,640	$1,760	$1,480	$1,490	$1,410	$1,390
1x0 Siemens 5000F5	$1,120	$1,200	$1,000	$1,010	$940	$920
12x0 Wartsila 18V50DF	$1,960	$2,060	$1,740	$1,750	$1,640	$1,600

Capital Investment includes Engineering, Procurement, Construction Contract, Owner's Cost, Financing Costs, Working Capital and Fuel and Non-Fuel Inventories

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