BURNS & McDONNELL

NYISO 2019-2020 ICAP Demand Curve Reset

Dec 11, 2019

2019-2020 Demand Curve Reset (DCR)

Technology Screening

Proposed Screening Technology Criteria

- **Standard generating facility technology – available to most market participants**
  - **Technology not limited by geographical region or other aspects**
- **Mature market technology**
  - **Commercial operating experience in North America**
- **Unit characteristics that can be economically dispatched**
- **Ability to cycle and provide energy or ancillary services**
- **Capable of being designed to meet applicable environmental and other operating requirements, including NYSDEC/EPA air quality standards**

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Initial Technology Options

Aero SCGT Technology Overview

- Number of starts does not impact maintenance schedule
- Fast start-up time (~10 minutes) – base technology option
- Can provide both dry-type and wet-type combustion system for NOx control
  - New Source Performance Standard (NSPS) and other environmental regulations may require selective catalytic reduction (SCR) catalyst
- Typical capacity range is 50MW -100MW

- **Recommended representative technology option: GE LMS100**
  - Offers two (2) models –
    - (PA+) – wet injection for NOx control during NG and FO operation
    - (PB+) – dry-low NOx on NG availbility – no FO operation availability
  - Representative cost (initial screening indicates this is likely the lowest base capital cost of comparable technologies)
  - ISO Heat Rate 8,567 Btu/kWh HHV

SCGT – Simple Cycle Gas Turbine

Aeroderivative Comparative Technology

Aeroderivative Combustion Turbine	Experience	ISO Capacity (MW)	Initial Screening Cost Estimate ($/kW)[1]	HHV Heat Rate (Btu/kWh)[2]
GE LM6000 PC	First model introduced in 1997, mature technology in North America	45	$1,200	9,603
GE LMS100 PA+	First introduced in 2006, mature technology in North America	117	$900	8,567
Siemens SGT-A65; Formerly RR Trent 60	First introduced in 2016, fleet leader has >110,000 EOH	70.8	$1,150	9,149
Siemens SGT-A45 (Wet Injection)	Core technology based on A65 model	44	$1,300+	9,409
P&W (MHPS) FT4000	First introduced in 2012	70 single / 140 (twin-pac)	$1,200+	9,174 / 9,152

1 Preliminary capital cost estimate for screening purposes
2 HHV based on typical US pipeline quality gas heating value
**All technologies compared are wet-injection based performances
* Information provided publicly available information published by manufacturer

Frame SCGT Technology Overview

- Frame technology is continuously evolving – larger and more efficient units of proven frame models
- Dry Low NOx combustion
- Can provide significant capacity in ~10 minutes and full load in 30 minutes; turndown capability has improved
- Lower capital cost ($/kW) than aeroderivative options
- Maintenance cost impacted by number of starts

- **Recommended representative technology options: GE 7F.05 or 7HA.02**
  - Representative cost (initial screening indicates the GE models are similar or lower than other comparable technology options)
  - Differing capacity profile at ISO conditions: 243MW (7F.05) / 384MW (7HA.02)
  - Differing ISO Heat Rates: 9,513 (7F.05) / 8,890 (7HA.02) Btu/kWh HHV
  - F Class has longer operating history; H Class has < 2 years of operating experience in SCGT arrangement with SCR

SCGT – Simple Cycle Gas Turbine

Frame SCGT Comparative Technology

Frame SCGT	Experience	ISO Capacity (MW)	Initial Screening Cost Estimate ($/kW)[1]	HHV Heat Rate (Btu/kWh)[2]
GE 7HA.02	First year introduced 2017, fleet operating hours of 205,000 EOH	384	$550	8,890
Siemens SGT6-9000HL	No units in commercial operation in North America (First delivery accepted in Nov 2019)	405		8,891
MHPS 501JAC	No units in commercial operation in North America	425		9,082
Siemens SGT6-8000H	Installed fleet has accumulated >1MM EOH	310	$640	9,468
MHPS 501GAC	First commercial operation in 2014, mature technology	283		9,469
GE 7FA.05	First FA.05 in operation in 2014 - F-Class is GE fleet leader	243	$570	9,513
Siemens SGT6-5000F	Installed fleet has accumulated >15MM EOH	260		9,588

1 Preliminary capital cost estimate for screening purposes
2 HHV based on typical US pipeline quality gas heating value
*Information provided publicly available information published by manufacturer

SCGT – Simple Cycle Gas Turbine

Reciprocating Engine (RICE) Technology Overview

- Small output units that can be installed in multi-unit blocks (low energy density)
- Fast start-up time (5 minutes)
  - Assuming engine jacket temperature has been maintained – high O&M due to auxiliary load
- Performance not impacted by ambient conditions (elevation or temperature)
- Low natural gas pressure requirements (Max 135 psi-g)
- Maintenance independent of number of starts

- **Recommendation: Not recommending consideration of this technology option for this reset**
  - Initial cost screening and results of prior resets indicate that a RICE unit is not likley to be a lowest cost option among other fossil-fuel fired technologies
  - Helps facilitate the capability to assess other technology options (energy storage, as well as F class and H class for frame turbines)

RICE Technology Overview

Reciprocating Engine	Experience	ISO Capacity (MW)	Initial Screening Cost Estimate ($/kW)[1]	HHV Heat Rate (Btu/kWh)[2]
Wartsila 18V50SG (NG only option)	Mature technology in North American market – market leader	18.76	$1,150	7,797
Wartsila 18V50DF (Dual Fuel Option)	Mature technology in North American market – market leader	16.94	$1,250	8,452
Fairbanks Morse MAN51	Not widely utilized in North American market	18.43	$1,300+	NA

1 Preliminary capital cost estimate for screening purposes

2 HHV based on typical US pipeline quality gas heating value

* Information provided publicly available information published by manufacturer

** 9MW options available but increases $/kW capital costs due to low energy density

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Combined Cycle Technology

CCGT Technology Overview

- Consistent with the last reset, a high level assessment of a combined cycle unit will be conducted for informational purposes
- 2x1 combined cycle configurations have economy of scale over 1x1 – but 1x1 more comparable to other peaking installations
- Higher fixed cost ($/kW) but significantly lower variable cost ($/MWh)
- Use of heat recovery steam generator (HRSG) optimizes temperature for SCR catalyst
- Start-up time and hold points largely set by HRSG design and use of auxiliary boilers, etc.

- **Recommended information technology design: 1 x 1 GE 7HA.02**
  - Representative cost (initial screening indicates this may be the lowest capital cost among comparable options)
  - ISO Capacity (unfired) 573 MW
  - ISO Heat Rate 5,973 Btu/kWh HHV

CCGT – Combined Cycle Gas Turbine

CCGT Technology Overview

1x1 CCGT	ISO Capacity (MW)	Initial Screening Cost Estimate ($/kW)[1]	HHV Heat Rate (Btu/kWh)[2]	Start-Up Time
GE 7HA.02	573	$920	5,973	< 30 minutes
Siemens SGT6-9000HL	595		6,012	< 30 minutes
MHPS 501J	484		62% Plant Efficiency	< 30 minutes
Siemens SGT6-8000H	460	$1,070	6,228	< 30 minutes
MHPS 501GAC	427		60% Plant Efficiency	< 30 minutes
GE 7FA.05	376	$920	6,270	25 minutes
Siemens SGT6-5000F	387		6,355	< 30 minutes

1 Preliminary capital cost estimate for screening purposes
2 HHV based on typical US pipeline quality gas heating value
* Information provided publicly available information published by manufacturer

CCGT – Combined Cycle Gas Turbine

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Battery Storage Technology

Battery Technology Overview

- Lithium-ion battery based technology provides ~80% of market installations
  - Electric vehicles and battery production driving cost declines to lithium-ion
  - Only 700MW of battery installations in the world is Flow Battery Technology
  - Other battery chemistries: Na-metal, PB-acid, Other
- Use case is the most important factor in technology selection
  - Chemistry, cycling, hours of storage, optimal resting charge, lifetime discharge cycles, fast charging impacts, recycling, etc.
- Batteries involve a host of considerations that are different than fossil-fuel peaking technology options

- **Recommended technology options: Lithium-Ion Battery (4 hour and 6 hour)**

Battery Technology Overview

Battery Technology	Experience	Power Capacity / Energy Capacity	Initial Screening Cost Estimate ($/kW)[1]	Round Trip Efficiency
Lithium Ion	Current battery technology typically deployed, typically < 4 hr duration due to cost/market conditions	200 MW / 400 MWh	$1,004	~85%
		200 MW / 800 MWh	$1,384	~85%
		200 MW / 1,200 MWh	$1,765	~85%
		200 MW / 1,600 MWh	$2,146	~85%
Flow	Not widely utilized in North American market at large scale	200 MW / 1,600 MWh	Varies	~70%
CAES	Larger sized deployments more typical	300 MW / 2,400 MWh	Varies	~60%

1 Preliminary capital cost estimate for screening purposes; Lithium Ion based on NREL 2019 ATB