ADLER POLLOCK & SHEEHAN P.C.

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September 12, 2017

Via Federal Express/Electronic Mail

Todd Anthony Bianco, EFSB Coordinator
RI Energy Facilities Siting Board
89 Jefferson Blvd.
Warwick, RI 02888

Re: Invenergy Docket No. SB-2015-06

Dear Mr. Bianco:

On behalf of Invenergy Thermal Development LLC and the Clear River Energy Center Project ("Invenergy"), enclosed please find an original and three (3) copies of Invenergy's Responses to the Town of Burrillville's 34th Set of Data Requests.

Please let me know if you have any questions.

Very truly yours,

ALAN M. SHOER
ashoer@apslaw.com

Enclosures

cc: Service List

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
ENERGY FACILITY SITING BOARD

IN RE:	Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center	Docket No. SB-2015-06

INVENERGY THERMAL DEVELOPMENT LLC'S RESPONSES TO
THE TOWN OF BURRILLVILLE'S 34th SET OF DATA REQUESTS

Request 34-1	We understand that RIDEM issued an Edge Verification (No. 15-0239) on January 28, 2016. Please provide a copy.
Response 34-1	Please see **Exhibit 34-1**, which includes the Rhode Island Department of Environmental Management's ("RIDEM's") issued Edge Verification (No. 15-0239).
RESPONDENT:	Jason Ringler, ESS Group, Inc.
DATE:	September 12, 2017

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
ENERGY FACILITY SITING BOARD

IN RE:	Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center	Docket No. SB-2015-06

INVENERGY THERMAL DEVELOPMENT LLC'S RESPONSES TO
THE TOWN OF BURRILLVILLE'S 34th SET OF DATA REQUESTS

Request 34-2	We understand that RIDEM tendered a letter on June 13, 2017 regarding site-specific flora and fauna survey protocols. Please provide a copy.
Response 34-2	Please see **Exhibit 34-2**, which includes RIDEM letter dated June 13, 2017 regarding survey protocols.
RESPONDENT:	Jason Ringler, ESS Group, Inc.
DATE:	September 12, 2017

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
ENERGY FACILITY SITING BOARD

IN RE:	Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center	Docket No. SB-2015-06

INVENERGY THERMAL DEVELOPMENT LLC'S RESPONSES TO
THE TOWN OF BURRILLVILLE'S 34th SET OF DATA REQUESTS

Request 34-3 Please provide a copy of Invenergy's mitigation package, as referenced on page 9 of Mr. Ringler's testimony.

Response 34-3 A Compensatory Wetland Mitigation Plan following the New England District Compensatory Mitigation Guidance in cooperation with resource agencies will be developed. Invenergy Thermal Development LLC ("Invenergy") intends to work with RIDEM and the United States Army Corps of Engineers ("USACE") to determine which potentially available parcel(s) appear best suited to offset project-related wetland and other impacts. It is anticipated that the Compensatory Wetland Mitigation Plan will include a description of project impacts, objectives, mitigation site selection procedures, site protection information and monitoring standards in addition to all required graphics and information. It is anticipated that the final mitigation package will primarily consist of land preservation and possibly some restoration should a viable project be identified.

RESPONDENT: Jason Ringler, ESS Group, Inc.

DATE: September 12, 2017

IN RE:	Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center	Docket No. SB-2015-06

INVENERGY THERMAL DEVELOPMENT LLC'S RESPONSES TO
THE TOWN OF BURRILLVILLE'S 34th SET OF DATA REQUESTS

Request 34-4	Please provide a copy of the written responses provided by RIDEM on July 16, 2016, as referenced on pages 11-12 in Mr. Ringler's testimony.
Response 34-4	Please see **Exhibit 34-4**, which includes the July 15, 2016 written response from RIDEM.
RESPONDENT:	Jason Ringler, ESS Group, Inc.
DATE:	September 12, 2017

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
ENERGY FACILITY SITING BOARD

IN RE: Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center — Docket No. SB-2015-06

INVENERGY THERMAL DEVELOPMENT LLC'S RESPONSES TO
<u>THE TOWN OF BURRILLVILLE'S 34th SET OF DATA REQUESTS</u>

Request 34-5 Please identify which turbines you considered in addition to the GE 7HA.02 and explain why each was rejected. Please explain why you feel that the GE HA.02 is the most efficient combustion turbine available in the market and provide comparative details.

Response 34-5 Invenergy considered advanced class combustion turbine technologies available in the United States market at the time of the equipment procurement which consisted of equipment manufactured by General Electric, Mitsubishi Hitachi Power Systems and Siemens Energy. The combined cycle efficiency of the three technologies at ISO Standard conditions (59 °F, 60% relative humidity, sea level) are summarized below based on data published in the industry benchmarking resource Gas Turbine World 2017 Performance Specs included in **Exhibit 34-5**.

GTW Combined Cycle Specs – Advanced Class Units (60 Hertz) One-on-One Configuration (Unfired) ISO Conditions Performance Summary Comparison				
Manufacturer	**Model**	**Net Output**	**Net Heat Rate (LHV)**	**Net Efficiency**
General Electric	7HA.02	560,000 kW	5408 BTU/kWh	63.1%
Mitsubishi Hitachi	501JAC	540,000 kW	5408 BTU/kWh	63.1%
Siesmens Energy	SCC5-8000H	460,000 kW	5611 BTU/kWh	61.0%

The GE 7HA.02 was determined through the evaluation process to provide the highest efficiency across the ambient temperature range and also provided superior operability benefits including lower minimum load and higher ramp rate capability than the alternatives.

Invenergy additionally compared the commercial terms and GE's was superior and we should note that from a fleet perspective the 7HA.02 will have more operating hours than the other bidders by the time CREC will be operational which is important when considering all of the bids were for new models.

RESPONDENT: Mark Wiitanen, HDR, Inc.
John Niland, Invenergy Thermal Development LLC

DATE: September 12, 2017

INVENERGY THERMAL DEVELOPMENT LLC
By its Attorneys,

/s/ Alan M. Shoer
Alan M. Shoer, Esq. (#3248)
Richard R. Beretta, Jr. Esq. (#4313)
Nicole M. Verdi, Esq. (#9370)
ADLER POLLOCK & SHEEHAN, P.C.
One Citizens Plaza, 8th Floor
Providence, RI 02903-1345
Tel: 401-274-7200
Fax: 401-351-4607
Dated: September 12, 2017

CERTIFICATE OF SERVICE

I hereby certify that on September 12, 2017, I delivered a true copy of the foregoing responses to the Town of Burrillville's 34th Set of Data Requests via electronic mail to the parties on the attached service list.

/s/ Alan M. Shoer

EXHIBIT 34-1

RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
235 Promenade Street, Providence, RI 02908-5767 TDD 401-222-4462

January 28, 2016

Algonquin Gas Transmission, LLC
Michael J. Dirrane, Director Marketing
890 Winter Street
Waltham, MA 02451

RE: Application No. 15-0239 in reference to the property located:

Approximately 500 feet west and south of Algonquin Road and approximately 1,000 feet southwest of its intersection with Wallum Lake Road, Assessor's Plat No. 135, Lot No. 002, Plat 137, Lot Nos. 002 and 003 and Assessor's Plat 153, Lot Nos. 001 and 002, Burrillville, RI

Dear Mr. Dirrane:

Kindly be advised that the Department of Environmental Management's ("DEM") Freshwater Wetlands Program ("Program") has completed its review of your **Request to verify the delineated edge of freshwater wetlands**. This review included an inspection of the above referenced property ("subject property") as described by the site plans submitted with your application and received on January 12, 2016.

Based upon the Program's observations and review, it is our determination that freshwater wetlands are present on or are in close proximity to the subject property. These freshwater wetlands are regulated by this Department and include, but are not limited to, at least the following types:

- Swamps and associated 50-foot Perimeter Wetland (that area of land within 50 feet of the edge of any bog, marsh, swamp, or pond)
- Forested Wetlands
- Rivers (unnamed tributaries to Dry Arm Brook), 100-foot Riverbank Wetland (that area of land within one hundred feet (100') of the edge of any flowing body of water having a width of less than ten feet (10') during normal flow) and Floodplain
- River (Iron Mine Brook), 200-foot Riverbank Wetland (that area of land within two hundred feet (200') feet of the edge of any flowing body of water having a width of ten feet (10') or more) and Floodplain
- Stream(s) with 100-foot Riverbank Wetland and Floodplain
- Area(s) Subject to Storm Flowage (ASSF channels)

The DEM has completed an inspection and review of the requested wetland edges delineated by you on-site. It is our determination that:

The wetland edges delineated on-site are accurate. These requested wetland edges have been shown on the site plans in red submitted with your application and are referenced below by a brief description of the general locus of the verified delineated edges and the corresponding flag number sequence:

Wetland 1: Delineated swamp edge south and east of the existing dirt cart path ("woods road") on Sheets 8, 9, 10 and 12, starting at Wallum Lake Road:

1. Flags 1-1 through 1-52a, including flag nos. 1-34, 1-34a through 1-34c, 1-16c though 1-1c/1-37, 1-38a, 1-38b, 1-38b1, 1-38b2, 1-39a through142a, 142a2, 1-43a to 1-50a, 150a2, 151a to 1-52a.

Wetland 1: Delineated swamp edge north and west of the woods road on Sheets 6, 8, 9 and 10:

1. Flags 1-18 through 1-33, including flag nos. 1-18 through 1-29, 1-29a, 1-30 through 1-33, delineating a fringe of swamp along stream corridor near Wallum Lake Road on Sheet 10.
2. Flags 1a-1 through 1a-7 (patch of swamp north of the woods path culverted to the other side, Sheet 10).
3. Flags 1-16a through 1-42d, including flag nos. 1-16a through 122a, 123, 1-24a through 1-26a2, 1-26a, 1-27a, 1-28a2, 1-28a, 1-29a2, 1-29a, 1-30a2, 1-30a, 1-31a, 1-32a2, 1-32a, 1-33a, 1-33b, 1-33c, 1-33d, 1-34a, through 1-37a, 1-37a1, 1-37a2, 1-37a3, 1-37a4, 1-37a5, 1-37a6, 1-37a7,1-38a, 1-39a, 1-39a2 to 1-40d, 1-40d1a, 1-40d1, 1-40d2, 1-4d3,1-40d4,1-41d, 1-42d verified on Sheets 6 and 9.
4. Forested Wetland: Flags 1b-1 through 1b-5 (Sheet 8).

Wetland 2: Delineated Swamp edge (Sheets 3, 4, 5, 6, 7, 8) - further west from Wetland 1

1. Flags 2-2a through 2-2e and 2-1a through 2-1g (small fringe of swamp along portions of maintained right-of-way (ROW) associated with a stream (Sheet 3).
2. Flags 2-95, 2-96g through 2-96a, 2-97 through 2-100 (Sheets 3 and 4).
3. Flags 2-69 through 2-75 (Sheets 3 and 4).
4. Flags 2-2 through 2-34, including 2-2 through 2-25, 2-25a, 2-25b, 2-26, 2-27, 2-27a, 2-27b, 2-28 through 2-32, 2-32a, 2-33, 2-33a, 2-34 on Sheets 5, 7 and 8.
5. Wetland 2 (western portion of edge opposite the above sequence) flags 2-42 through 2-57, including Flags 2-42 through 2-53, 2-53a, 2-54, 2-54a, 2-55 through 2-57 on Sheets 5 and 7.

Wetland 3: Delineated Forested Wetland edge: Flag Nos. 3-1 through 3-4 and 3-27 through 3-32.

Wetland 4: Delineated Forested Wetland edge: Flags 4-1 through 4-11.

Please note that our inspection of the subject property has revealed the presence of other freshwater wetlands not specifically delineated by you. Therefore, you should not infer that any verification of wetland edges carried out by this Department to date represents a determination that this is the extent of all wetlands on your property. The Department has verified only those requested edges delineated and shown by you on-site and on site plans submitted with your application and as qualified in this letter. Should you wish to verify the edge of these additional wetlands, an additional application will be required. Please note that an ASSF (not depicted) flows down the woods path into Wetland 2 near Flag 2-74.

This letter <u>does not</u> constitute an approval or permit for any proposed project on the subject property. Pursuant to Section 2-1-21(a) of the Freshwater Wetlands Act and the Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (Rules) a permit is required from this Program prior to the commencement of any activity which impacts or alters freshwater wetlands.

This Program assumes that the edges of freshwater wetlands, as flagged or marked on site, have been accurately surveyed and portrayed on site plans submitted in support of your application. This Program makes no guarantee or representation that such survey is accurate.

In addition, you should note that freshwater wetlands are present on this property which may be regulated under Section 404 of the Clean Water Act (Federal Water Pollution Control Act, as amended 33 U.S.C. 1344). Accordingly, a permit may be required from the U.S. Army Corps of Engineers for alteration of these wetland areas.

In accordance with Rule 8.03(H) of the Rules, this verification of the delineated edge of freshwater wetlands is valid for a limited period of four (4) years from the date of issue. **You are hereby advised** that on July 10, 2015, significant revisions to the RI Freshwater Wetlands Act (R.I.G.L. Section 2-1-18 *et. seq.*) were signed into law. These revisions modify, among other things, the "jurisdictional areas" recognized by the State of Rhode Island. The Department is currently in the process of amending the Rules. If you are contemplating a project on your property, and submit the application prior to the promulgation of the revised Rules, you can expect the wetlands jurisdictional areas to correspond as described in this verification letter.

Any application submitted after promulgation of the Rules will be expected to conform to the then existing and duly promulgated Rules. While these changes will not affect the location of flagged wetland edges as verified in this letter, they may affect how activities located in adjacent jurisdictional upland areas will be regulated. You are advised, in the meantime, to monitor the rulemaking process, which will include opportunities for public input and comment.

Please contact me at telephone: (401-222-6820, ext. 7408) should you have any questions regarding this letter.

Sincerely,

Nancy L. Freeman

Nancy L. Freeman, Senior Environmental Scientist
Office of Water Resources
Freshwater Wetlands Program
NLF/nlf

xc: Craig Wood, PWS, ESS Group, Inc.
Alexander H. Patterson, ESS Group, Inc.

EXHIBIT 34-2

RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
235 Promenade Street, Providence, RI 02908-5767 TDD 401-222-4462

FIRST CLASS MAIL

June 13, 217

Mike Feinblatt
ESS, Group, Inc.
10 Hemingway Drive, 2nd Floor
East Providence, RI 02915

Re: Clear River Energy Center Biodiversity Inventory Summary

Dear Mr. Feinblatt:

On behalf of the Clear River Energy Center (the "Project") which is currently before the Energy Facilities Siting Board ("EFSB") ESS, Group Inc. ("ESS") submitted a summary of the inventory methodology to be utilized to survey the biodiversity that exists at the proposed project location. DEM offers the following comments:

Migratory and Breeding Birds

- Any behaviors indicative of breeding and the locations of those behaviors should be recorded for each species detected.

Amphibians

- Pitfall traps alone will be insufficient for amphibians. DEM recommends supplementing that effort with other sampling methods, including log-rolling (or stone rolling in streams) and dip-netting in wetlands.
- Call surveys are useful for frogs.

Reptiles

- Visual encounter surveys will not be sufficient as snakes are either nocturnal or live under the ground. Detection of snakes can be enhanced by using black plastic sheeting cover patches as described by *Litvitis et al.* (J Widl Mgt).

Large Mammals

- How many camera stations are planned? Recommend a minimum of at least $1/km^2$.
- Camera stations should also be placed in natural corridors, trails, habitat types, etc., and at least a couple should incorporate some sort of attractant such as fatty acid discs or broad spectrum long distant call lure (e.g. "Gusto") used for trapping carnivores.
- It can also be helpful to use a visual attractant such as a bird wing or feathers suspended on a piece of fishing line.

Small Mammals

- Utilizing only Sherman traps will underrepresent or fail to detect a number of species. Thus, DEM recommends utilizing other methods in conjunction with Sherman traps.
- Traps should be placed along transects (~150 m) in a variety of habitats with two traps at each station, with stations spaced 10-15 m apart. Traps should be checked twice a day.
- What is the effort (how many traps) will be at night? DEM recommends an effort of at least 500 (ex. 100 Sherman traps set for five nights).
- Pitfalls combined with drift fences will be more effective at capturing shrews, moles, and jumping mice, and provide a greater representative picture of what is at the site. Pitfalls must be deep enough (15"), and have a type of lid to prevent escape, or use water.
- Pitfall arrays should be set in a variety of habitats (open grassy areas under powerline, dry woods, wet woods, etc.).
- Due to the time constraints DEM would consider forgoing randomization of trap array placement and allow for placement of traps where you think/expect the animals to be located.
- Some animals may require increased effort
    - Flying squirrels – a few rat-sized snap traps attached to trees, particularly those with cavities can be effective. These can be covered to prevent birds from seeing them or placed in a small box that has a 2-3" opening.
    - Weasels – the setup described for flying squirrels works well for weasels if the box is placed along a stone wall.
    - Water shrews/star-nosed moles – recommend using pitfalls placed within the stream corridor below the top of the bank. Small buckets placed at strategic locations (small sandbars, on a bend) and used with a short drift fence can be very effective.

Plants

- In addition to the proposed survey plots, DEM recommends some general reconnaissance in each habitat type to look for rare or uncommon species. Particular attention should be given to specific habitat types (stream banks, flood plains, rock ledges, etc.) that tend to support diverse and/or habitat-specialist species.
- Plants are not evenly distributed across landscapes and as a result utilizing only a plot method is likely to overlook many species.

Terrestrial Invertebrates

- Ending the survey in June will likely preclude detection of a whole range of species that have later flight seasons. DEM recommends that surveys should be continued throughout the whole summer to obtain a better representation.
- Regarding light traps, how many will be used? How many nights? Who will ID the specimens?

General

- Provide a map depicting locations of sample sites for each survey performed and a narrative explaining the placement of transects, spacing, habitats covered, etc.
- Provide the level of effort for each survey methodology.

- It is important to document all species detected. Adequate photographs (or recordings of frogs) should be taken of each species detected, and these should be retained for confirmation and reference.
- All unique species that die as a result of capture methods should be retained as voucher specimens, and arrangements can be made to deposit them in an appropriate institution.

Based on the season during which surveys are proposed to be conducted for each taxa DEM understands that ESS may not be able to incorporate all of DEM's comments on inventory methodology. To the extent that DEM's comments can be incorporated it would assist DEM with developing its responses to the advisory opinion questions posed to DEM by the EFSB.

Should you have any questions, do not hesitate to contact me at (401) 222-4700 ext. 7500. Thank you for your time and attention to this matter.

Best regards,

Ronald N. Gagnon

Ronald N. Gagnon, P.E., Chief
Office of Customer and Technical Assistance

cc: Terry Gray, DEM
Christina Hoefsmit, Esq., DEM
Amanda Freitas, DEM

EXHIBIT 34-4

Jason Ringler

Subject: FW: Using RIWAP for wildlife habitat analyses

From: Jordan, Paul (DEM) [mailto:paul.jordan@dem.ri.gov]
Sent: Friday, July 15, 2016 4:50 PM
To: Joshua Burgoyne <jburgoyne@essgroup.com>
Cc: Craig Wood <cwood@essgroup.com>; Jason Ringler <jringler@essgroup.com>
Subject: Re: Using RIWAP for wildlife habitat analyses

F&W biologists had a strong opinion about the impacts of development spreading beyond the actual building foot print or backyard. So we did buffer development by 30 meters and used that as a mask.

Utility ROWs are not considered developed nor forest since the vegetation is managed regularly. Where they are mapped as brush or ROW they break up the forest.

From: Joshua Burgoyne <jburgoyne@essgroup.com>
Sent: Friday, July 15, 2016 11:21:20 AM
To: Jordan, Paul (DEM)
Cc: Craig Wood; Jason Ringler
Subject: Using RIWAP for wildlife habitat analyses

Hi Paul,

We have had discussions here at ESS recently about incorporating the 2015 Rhode Island Wildlife Action Plan as a basis for our Rhode Island projects that involve wildlife habitat assessments and impact analyses. I want to confirm the following two points regarding the GIS-based Conservation Opportunities tool that was produced to support the RIWAP and I was wondering if you could help me out.

1) Is it true that all unfragmented forest blocks are offset from developed areas by 30 meters?
2) Is it true that utility ROWs, regardless of size, are not considered developed areas and therefore do not interrupt unfragmented forest blocks?

Thanks,

Joshua Burgoyne | Environmental Scientist
ESS Group, Inc.
10 Hemingway Drive, 2nd Floor, East Providence, RI 02915 p
401.330.1209 | jburgoyne@essgroup.com | www.essgroup.com

<u>EXHIBIT 34-5</u>

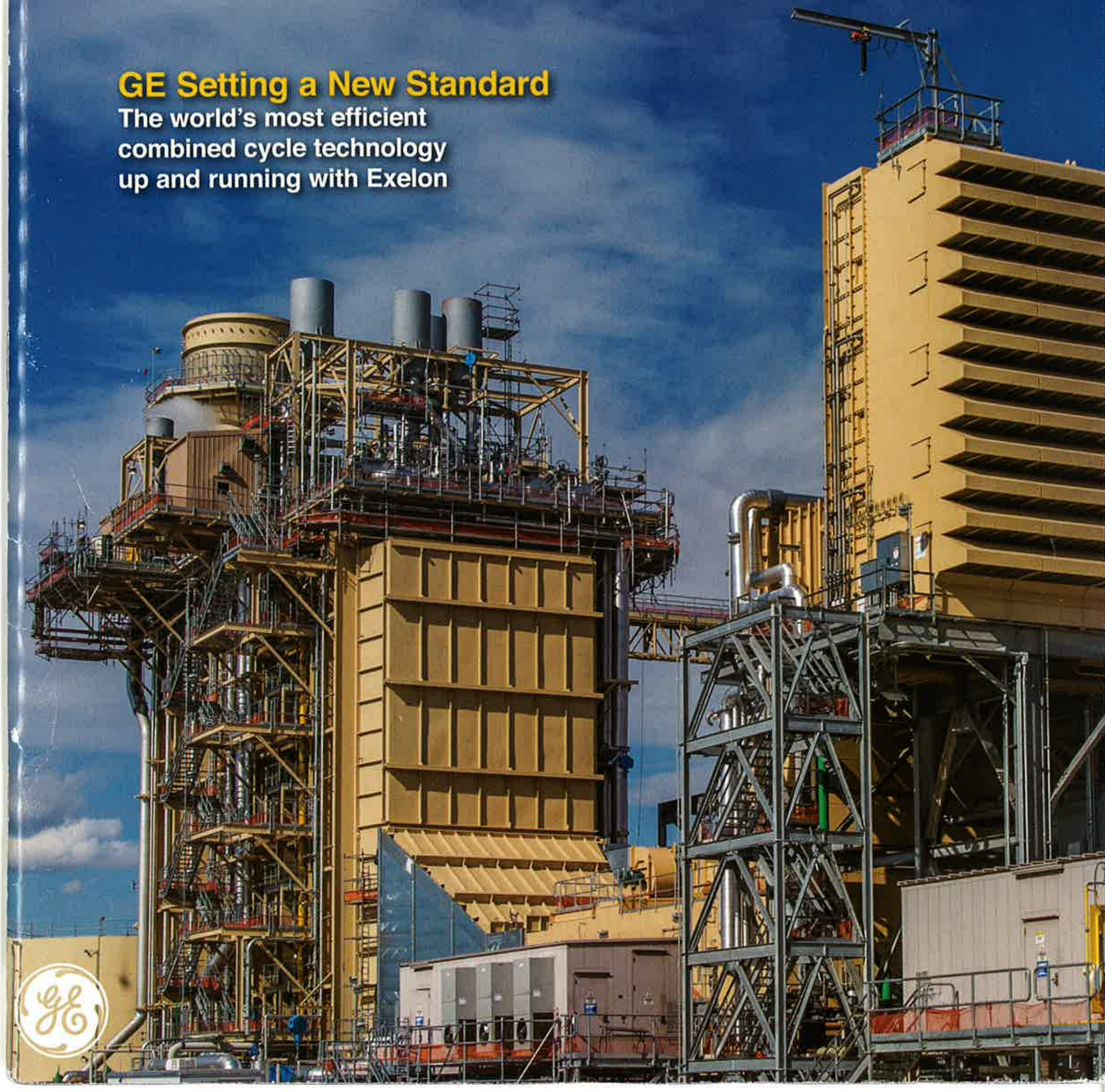
Gas Turbine World

2017 Performance Specs

33rd Edition

GE Setting a New Standard

The world's most efficient combined cycle technology up and running with Exelon



Combined Cycle Performance Specs

Standard design performance ratings and adjustments for actual site and operating conditions

Conditions

Combined cycle design ratings apply to OEM reference plant performance at ISO conditions: 59°F ambient air (15°C) temperature, 14.7 psia (1.015 bar) sea level elevation and 60% relative humidity.

Standardized reference plants are typically designed around one or more gas turbines, multi-pressure reheat HRSGs without supplementary duct firing, no selective catalytic emissions reduction, no water or steam injection for power augmentation or emissions abatement.

Rules vary

Unlike the performance ratings for simple cycle gas turbines, which include engine design parameters such as pressure ratio, mass flow and exhaust temperature, there is no industry standard specifying the internal cycle design parameters for calculating combined cycle performance.

Plant performance specifications reported by different suppliers can be inconsistent or vague due to lack of design detail and differing scope of supply or boundary limits.

Depending on their business approach, some consider their combined cycle offering as consisting solely of the so-called "power block" or "power island".

Others consider the complete plant, which includes the combined cycle power block plus all BOP auxiliaries needed to operate the plant.

Net or gross?

This could lead to some ambiguity in defining "net performance" as tabulated here. Where the data refers to a full plant, "net" is defined as power output of the GT and ST generators, minus power consumed by the turbine-generator auxiliary packages and all of the plant's parasitic loads.

For combined cycle plants, parasitic power goes to operating system mechanical auxiliaries such as the boiler feedwater, condensate and cooling water circulating pumps, cooling fans, controls and other electrical auxiliaries (up to main step-up transformer), etc.

If performance ratings represent the power block only, "net" is defined as power output of the GT and ST generators less the parasitic power losses associated with only those systems that must operate the power block iso-

Adjusting ISO ratings to match site and operating conditions

Rule-of-thumb correction factors to estimate impact on combined cycle performance for non-standard site conditions and operating factors:

Ambient temp. There is about a 2.5% reduction in ISO rated power output per 10°F rise in air temperature above 59°F and a corresponding increase in capacity with decreasing ambient temperatures below 59°F. Impact on heat rate (up and down, respectively) is about 0.5% per 10°F change in air temperature.

Site elevation. For each 1000 ft. increase in site elevation above sea level, there is about a 3.5% reduction in ISO rated power output. Impact on heat rate is only about 0.2% per 1000 ft. increase in elevation.

Water temp. For plants operating in hot climates there can be a 2% reduction in plant capacity and a corresponding 2% rise in heat rate if effective cooling water temperatures increase 25°F-30°F above assumed design temperature.

Plant age. Over an extended 10-15 years of operation, plant capacity will deteriorate by approximately 3-5% from its as-new rating and heat rate will have increased by 3-5%, despite regular maintenance and plant overhauls.

Fouling. Depending on operating environment and filtration, compressor fouling can cause gradual deterioration of up to 2% in plant capacity with 1.2% increase in heat rate. Can occur even with routine on-line compressor cleaning and typical 4,000-hr interval between offline washing.

lated from the balance of the plant.

Both performance ratings are correct depending on definition of plant scope. OEMs that focus on complete turnkey plants are inclined to quote net plant performance. Those who primarily supply the GTs and STs, but do not specify balance of plant, quote net performance of the power block.

GTW combined cycle plant performance specifications provide a way to distinguish between the two groups by also listing gross GT and ST power output ratings. For performance specifications based on total plant performance, gross plant output (GT power plus ST power) should be around 2% higher than net plant power output rating.

The difference between a plant rated at 211 MW gross and 207 MW net indicates that 4 MW (~2%) is lost to operating the plant's auxiliary systems and the 207 MW remains as saleable power.

Less than 1% difference and the ratings are probably based on only the GT and ST generator power output. The difference between a gross rating of 213 MW and net rating of 212.5 MW would indicate 500 kW is lost to GT and ST auxiliary power consumption.

Correction factors

As with the simple cycle performance specs, there are real-world site factors for adjusting the GTW combined cycle ISO performance ratings (see editorial box) to allow for the effect of non-standard site conditions, and also the impact of in-service wear and tear.

Basically, they are tools for estimating the impact on performance of variation of cycle operating factors including ambient temperature and elevation, cooling-water temperature (on steam turbine power), deterioration in plant capacity with ageing and effect of compressor fouling on plant efficiency.

Condenser pressure

The steam condenser design and coolant (water or air) temperature can have a significant impact on combined cycle performance. Thermodynamically, the lower the heat sink temperature (and the closer the condenser saturation temperature can approach it), the higher the plant efficiency (lower heat rate).

The condenser temperature sets the condenser vacuum pressure and affects steam turbine power output. Lower condenser temperature means lower pressure and more steam turbine power, reducing plant heat rate (and vice versa).

There is no agreed-upon standard for coolant temperature nor for condenser design parameters (e.g. approach temperature difference) that apply when specifying combined cycle plant performance.

To fill that void, GTW asks the OEMs to specify the condenser pressure design ratings assumed in their performance calculations.

As shown in GTW's combined cycle ratings, the reported spread ranges from around 1.5 inch Hg for moderate design to a low of 1.0 inch Hg) for a more aggressive engineering approach.

Depending on condenser design, this range can reflect a substantial difference in assumed plant cooling water temperature.

Design tradeoff

For an apples-to-apples evaluation some adjustment to the data is necessary when extreme differences are noted.

An approximate rule-of-thumb: a decrease of 0.5 inch Hg (1.7 kPa) in condenser vacuum pressure results in about 0.5% increase in plant power output and a similar decrease in plant heat rate.

For plants with an air-cooled condenser and vacuum pressure 5 inch Hg or higher, plant output will decrease and heat rate increase by 3% or more from water-cooled plant ISO rating, depending on ambient air temperature and condenser design.

Other areas where inconsistencies in reported performance may arise by assumptions made in the selection of internal design parameters (such as HRSG approach temperature differences and pinch point) and in main throttle and reheat steam temperatures and pressures.

Losses over time

Plant capacity and heat rate deterioration is due mainly to degradation in gas turbine performance over time despite regular maintenance and plant overhauls.

Other areas subject to normal wear and tear or fouling that contribute to performance degradation include steam turbine flow surfaces and seals, heat transfer surfaces (particularly in the HRSG), cooling tower interiors (often due to algae growth), filters, piping, etc.

Typically, over 15 years (120,000 operating hours), capacity will have decreased by approximately 3% and heat rate will have increased by about 1.5%.

Caveat

In theory, the OEM ratings reported by the GTW performance specification are based on standard plant designs.

Actual quoted performance ratings in response to a bid request or competitive situation will invariably be different for several reasons.

When evaluating specific OEM ratings, you can expect that moderate versus aggressive design choices and cycle parameter assumptions will come into play. Sometimes adjustments will be needed to level the playing field.

Ultimately, when relying on published ratings for an actual project under development, it always pays to ask OEMs to confirm their ratings -- especially during final stages of comparative evaluation and choice of competitive units. ■

Model	Intro Year	Gross Plant Output (kW)	Net Plant Output (kW)	Net Heat Rate (Btu/kWh)	Net Plant Efficiency	Net Heat Rate (kJ/kWh)	Condenser Pressure	Gas Turbine Power (kW)	Steam Turbine Power (kW)	No. & Type Gas Turbine	Comments
GE Gas Power Systems (60 Hz) Aero (continued)											
LMS100	2015	138 938 kW	137 000 kW	6606 Btu	51.7%	6970 kJ	1.2 inch Hg	118 000 kW	20 924 kW	1 x LMS100	2P non reheat
LMS100	2015	278 890 kW	275 000 kW	6587 Btu	51.8%	6950 kJ	1.2 inch Hg	236 000 kW	42 861 kW	2 x LMS100	2P non reheat
GE Gas Power Systems (60 Hz) Frame											
7E.03	1977	144 170 kW	142 000 kW	6505 Btu	52.5%	6893 kJ	1.2 inch Hg	90 596 kW	53 574 kW	1 x 7E.03	2P non reheat
7E.03	1979	291 190 kW	287 000 kW	6439 Btu	53.0%	6793 kJ	1.2 inch Hg	181 192 kW	109 998 kW	2 x 7E.03	2P non reheat
7F.04	2009	309 470 kW	305 000 kW	5715 Btu	59.7%	6030 kJ	1.2 inch Hg	196 650 kW	112 820 kW	1 x 7F.04	3P reheat
7F.04	2009	623 090 kW	615 000 kW	5676 Btu	60.1%	5989 kJ	1.2 inch Hg	393 300 kW	229 790 kW	2 x 7F.04	3P reheat
7F.05	2009	381 100 kW	376 000 kW	5660 Btu	60.3%	5972 kJ	1.2 inch Hg	236 390 kW	144 710 kW	1 x 7F.05	3P reheat
7F.05	2009	765 800 kW	756 000 kW	5640 Btu	60.3%	5972 kJ	1.2 inch Hg	472 780 kW	293 020 kW	2 x 7F.05	3P reheat
7F.06	2016	401 400 kW	396 000 kW	5574 Btu	61.2%	5881 kJ	1.2 inch Hg	268 966 kW	132 434 kW	1 x 7F.06	3P reheat
7F.06	2016	806 380 kW	797 000 kW	5548 Btu	61.5%	5854 kJ	1.2 inch Hg	537 932 kW	268 448 kW	2 x 7F.06	3P reheat
7HA.01	2012	441 770 kW	436 000 kW	5497 Btu	62.1%	5799 kJ	1.2 inch Hg	292 872 kW	147 000 kW	1 x 7HA.01	3P reheat
7HA.01	2012	887 500 kW	877 000 kW	5466 Btu	62.4%	5767 kJ	1.2 inch Hg	585 744 kW	299 000 kW	2 x 7HA.01	3P reheat
7HA.02	2014	567 070 kW	560 000 kW	5408 Btu	63.1%	5706 kJ	1.2 inch Hg	375 071 kW	188 000 kW	1 x 7HA.02	3P reheat
7HA.02	2014	1 136 080 kW	1 122 000 kW	5398 Btu	63.2%	5695 kJ	1.2 inch Hg	750 142 kW	378 000 kW	2 x 7HA.02	3P reheat
IHI Power Systems (50/60 Hz)											
LM2500PE	1986	32 500 kW	31 790 kW	7093 Btu	48.1%	7484 kJ	****	22 230 kW	10 270 kW	1 x LM2500PE	
LM2500RB	2006	43 980 kW	43 120 kW	6497 Btu	52.5%	6855 kJ	****	31 430 kW	12 550 kW	1 x LM2500RB	
LM2500RC	2005	48 760 kW	47 780 kW	6818 Btu	50.0%	7193 kJ	****	34 660 kW	14 100 kW	1 x LM2500RB	
LM2500RD	2005	44 790 kW	43 900 kW	6533 Btu	52.2%	6893 kJ	****	31 350 kW	13 440 kW	1 x LM2500RB	
Note: All IHI ratings with inlet and exhaust losses											
IHI Power Systems (50 Hz)											
LM6000PC	1997	56 320 kW	55 250 kW	6687 Btu	51.0%	7055 kJ	****	42 900 kW	13 420 kW	1 x LM6000PC	
LM6000PC	1997	113 330 kW	111 130 kW	6649 Btu	51.3%	7015 kJ	****	85 800 kW	27 530 kW	2 x LM6000PC	
LM6000PC Sprint	1997	63 290 kW	62 120 kW	6655 Btu	51.3%	7021 kJ	****	48 430 kW	14 860 kW	1 x LM6000PC	
LM6000PC Sprint	1997	127 240 kW	124 820 kW	6623 Btu	51.5%	6988 kJ	****	96 860 kW	30 380 kW	2 x LM6000PC	
LM6000PF	1997	56 220 kW	55 180 kW	6402 Btu	53.3%	6754 kJ	****	42 260 kW	13 960 kW	1 x LM6000PF	
LM6000PF	1997	113 110 kW	110 970 kW	6366 Btu	53.6%	6717 kJ	****	84 520 kW	28 590 kW	2 x LM6000PF	
LM6000PF Sprint	1997	60 930 kW	59 830 kW	6474 Btu	52.7%	6830 kJ	****	46 460 kW	14 470 kW	1 x LM6000PF	
LM6000PF Sprint	1997	122 530 kW	120 220 kW	6443 Btu	53.0%	6798 kJ	****	92 920 kW	29 610 kW	2 x LM6000PF	

Model	Intro Year	Gross Plant Output (kW)	Net Plant Output (kW)	Net Heat Rate (Btu/kWh)	Net Plant Efficiency	Net Heat Rate (kJ/kWh)	Condenser Pressure	Gas Turbine Power (kW)	Steam Turbine Power (kW)	No. & Type Gas Turbine	Comments
Mitsubishi Hitachi Power Systems (50 Hz) (continued)											
MPCP1(M701G)	1997	499 500 kW	498 000 kW	5755 Btu	59.3%	6071 kJ	1.5 inch Hg	325 700 kW	172 300 kW	1 x M701G	
MPCP2(M701G)	1997	1 002 400 kW	999 400 kW	5735 Btu	59.5%	6051 kJ	1.5 inch Hg	651 400 kW	348 000 kW	2 x M701G	
MPCP1(M701J)	2014	703 200 kW	701 000 kW	5477 Btu	62.3%	5779 kJ	1.5 inch Hg	472 300 kW	228 700 kW	1 x M701J	
MPCP1(M701JAC)	2015	719 200 kW	717 000 kW	5408 Btu	63.1%	5706 kJ	1.5 inch Hg	487 000 kW	230 000 kW	1 x M701JAC	
Mitsubishi Hitachi Power Systems (60 Hz)											
MPCP1(H-100)	2010	150 000 kW	****	6193 Btu	55.1%	6534 kJ	1.2 inch Hg	102 500 kW	47 500 kW	1 x H-100	
MPCP2(H-100)	2010	305 700 kW	****	6083 Btu	56.1%	6418 kJ	1.2 inch Hg	205 000 kW	100 700 kW	2 x H-100	
MPCP1(M501)	1981	168 000 kW	167 400 kW	6635 Btu	51.4%	7000 kJ	1.5 inch Hg	112 100 kW	55 300 kW	1 x M501DA	
MPCP2(M501)	1981	337 300 kW	336 200 kW	6610 Btu	51.6%	6974 kJ	1.5 inch Hg	224 200 kW	112 000 kW	2 x M501DA	
MPCP3(M501)	1981	507 800 kW	506 200 kW	6585 Btu	51.8%	6947 kJ	1.5 inch Hg	336 300 kW	169 900 kW	3 x M501DA	
MPCP1(M501F)	1994	286 000 kW	285 100 kW	5976 Btu	57.1%	6305 kJ	1.5 inch Hg	182 700 kW	102 400 kW	1 x M501F	
MPCP2(M501F)	1994	574 000 kW	572 200 kW	5955 Btu	57.3%	6283 kJ	1.5 inch Hg	365 400 kW	206 800 kW	2 x M501F	
MPCP1(M501G)	1995	400 100 kW	398 900 kW	5843 Btu	58.4%	6165 kJ	1.5 inch Hg	264 400 kW	134 500 kW	1 x M501G	
MPCP2(M501G)	1995	803 000 kW	800 500 kW	5823 Btu	58.6%	6144 kJ	1.5 inch Hg	528 800 kW	271 700 kW	2 x M501G	
MPCP1(M501GAC)	2011	428 300 kW	427 000 kW	5640 Btu	60.5%	5951 kJ	1.5 inch Hg	280 800 kW	146 200 kW	1 x M501GAC	
MPCP2(M501GAC)	2011	858 600 kW	856 000 kW	5622 Btu	60.7%	5931 kJ	1.5 inch Hg	561 600 kW	294 400 kW	2 x M501GAC	
MPCP1(M501J)	2011	485 500 kW	484 000 kW	5504 Btu	62.0%	5807 kJ	1.5 inch Hg	326 200 kW	157 800 kW	1 x M501J	
MPCP2(M501J)	2011	974 000 kW	971 000 kW	5486 Btu	62.2%	5788 kJ	1.5 inch Hg	652 400 kW	318 600 kW	2 x M501J	
MPCP1(M501JAC)	2015	541 700 kW	540 000 kW	5408 Btu	63.1%	5706 kJ	1.5 inch Hg	365 100 kW	174 900 kW	1 x M501JAC	
MPCP2(M501JAC)	2015	1 086 300 kW	1 083 000 kW	5391 Btu	63.3%	5688 kJ	1.5 inch Hg	730 200 kW	352 800 kW	2 x M501JAC	
Note: All MHPS ratings on natural gas fuel, LHV at generator terminals, with inlet and exhaust losses											
PW Power Systems (50/60 Hz)											
FT8 SWIFTPAC 30	1990	42 100 kW	41 050 kW	6950 Btu	49.1%	7333 kJ	1.4 inch Hg	30 100 kW	12 000 kW	1 x FT8-3	
FT8 SWIFTPAC 60	1990	85 100 kW	83 100 kW	6878 Btu	49.6%	7257 kJ	1.4 inch Hg	60 500 kW	24 600 kW	2 x FT8-3	
FT4000 SWIFTPAC 60	2012	86 099 kW	84 608 kW	6868 Btu	49.7%	7247 kJ	1.5 inch Hg	69 347 kW	16 752 kW	1 x FT4000	
FT4000 SWIFTPAC 120	2012	173 271 kW	170 272 kW	6825 Btu	50.0%	7202 kJ	1.5 inch Hg	139 009 kW	34 262 kW	2 x FT4000	

Model	Intro Year	Gross Plant Output (kW)	Net Plant Output (kW)	Net Heat Rate (Btu/kWh)	Net Plant Efficiency	Net Heat Rate (kJ/kWh)	Condenser Pressure	Gas Turbine Power (kW)	Steam Turbine Power (kW)	No. & Type Gas Turbine	Comments
Siemens Energy (60 Hz)											
Industrial Trent 60 DLE	1998	****	66 400 kW	6374 Btu	53.5%	6725 kJ	1.5 inch Hg	51 674 kW	16 010 kW	1 x Trent 60	2P no reheat
Industrial Trent 60 DLE ISI	2010	****	77 500 kW	6376 Btu	53.5%	6727 kJ	1.5 inch Hg	60 200 kW	16 641 kW	1 x Trent 60	2P no reheat
Industrial Trent 60 WLE	2001	****	77 952 kW	6633 Btu	51.4%	6998 kJ	1.5 inch Hg	64 479 kW	18 291 kW	1 x Trent 60	2P unfired
Industrial Trent 60 WLE ISI	2011	****	80 300 kW	6723 Btu	50.7%	7093 kJ	1.5 inch Hg	64 036 kW	17 798 kW	1 x Trent 60	2P no reheat
SCC6-2000E 1X1	1989	****	174 000 kW	6533 Btu	52.2%	6893 kJ	****	117 000 kW	60 000 kW	1 x SGT6-2000E	
SCC6-2000E 2X1	1989	****	347 000 kW	6541 Btu	52.2%	6901 kJ	****	234 000 kW	119 000 kW	2 x SGT6-2000E	
SCC6-5000F 1X1	1989	****	370 000 kW	5863 Btu	58.2%	6186 kJ	****	250 000 kW	126 000 kW	1 x SGT6-5000F	3P reheat, 9 ppm NOx
SCC6-5000F 2X1	1989	****	746 000 kW	5813 Btu	58.7%	6133 kJ	****	500 000 kW	257 000 kW	2 x SGT6-5000F	3P reheat, 9 ppm NOx
SCC6-8000H 1S*	2010	****	460 000 kW	5611 Btu	61.0%	5920 kJ	****	****	****	1 x SGT6-8000H	3P reheat
SCC6-8000H 2X1	2010	****	930 000 kW	5602 Btu	61.0%	5910 kJ	****	620 000 kW	325 000 kW	2 x SGT6-8000H	3P reheat

*Siemens model 1S designates single shaft

CC Ratings