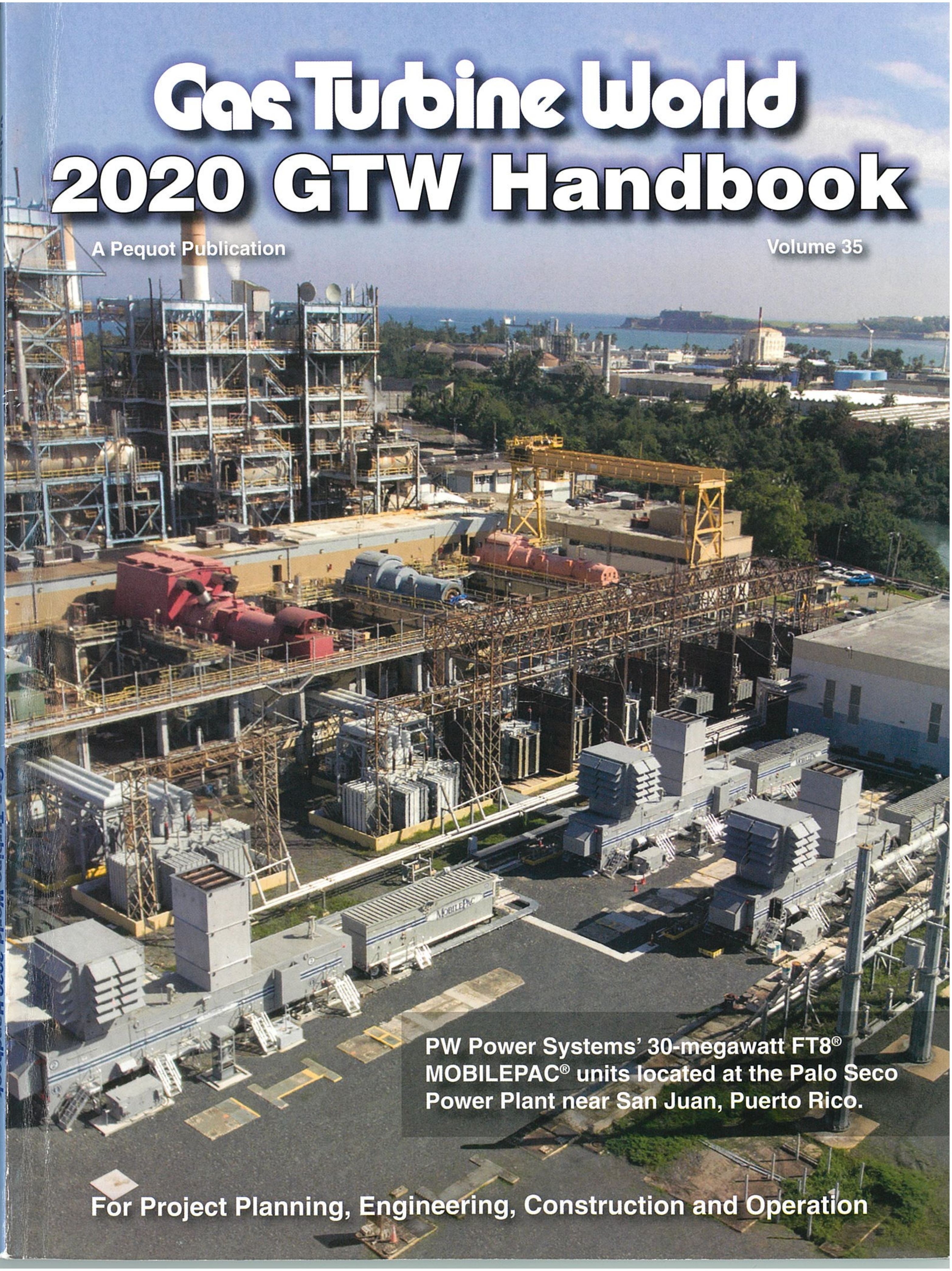
Gas Turbine World

2020 GTW Handbook

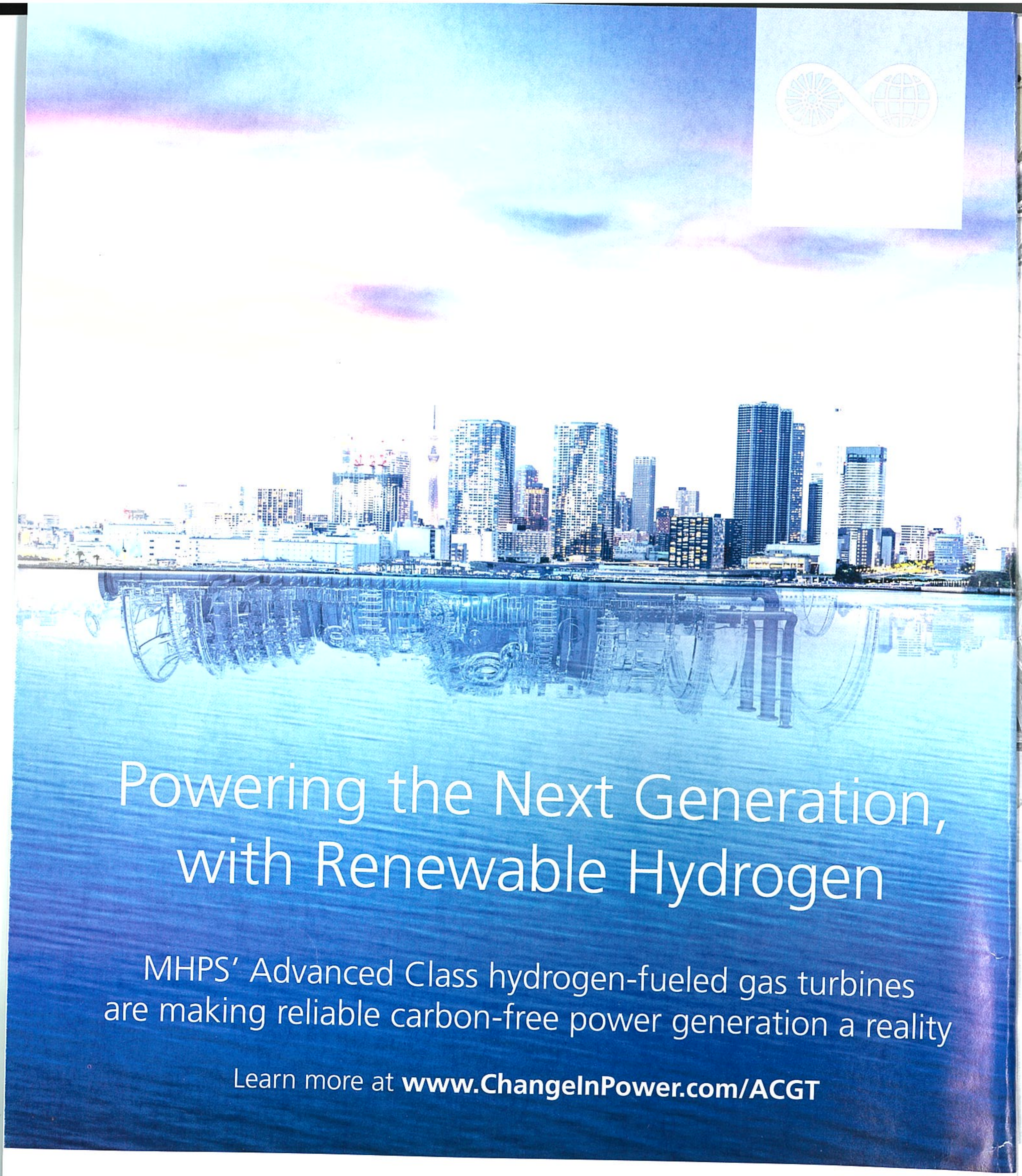
A Pequot Publication

Volume 35



PW Power Systems' 30-megawatt FT8® MOBILEPAC® units located at the Palo Seco Power Plant near San Juan, Puerto Rico.

For Project Planning, Engineering, Construction and Operation



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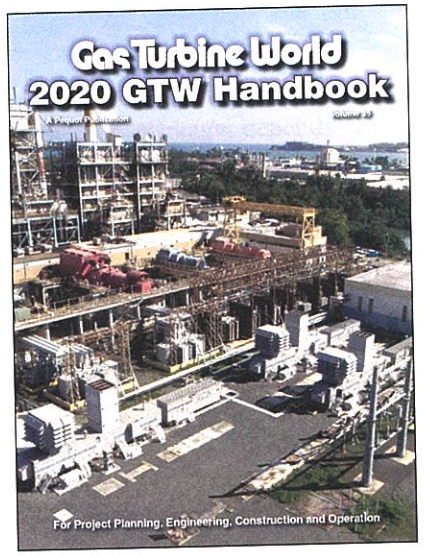

On the Cover
Three 30 megawatt PW Power Systems FT8 MobilePac units in Puerto Rico provide critical support delivering highly-flexible mobile power for peaking, backup and emergency needs.

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Section 1

GT Model Prices

2020 Simple Cycle Genset Price

Equipment-only budget price for standard gas turbine power generating units without add-on options

The price of a simple cycle gas turbine generator package depends on unit size, design technology (frame vs. aero) and scope of equipment supply.

Besides those factors directly affecting manufacturer's costs, dynamic market forces –both local and global - also come into play in commercial pricing decisions. Aggressive competition among OEMs in a lingering depressed market, especially for large utility units, continues to depress market price levels.

GTW simple cycle plant budget prices are based on packaged bare bones single-fuel gas fired units. Without add-on options and customized design features offered by OEMs at additional cost.

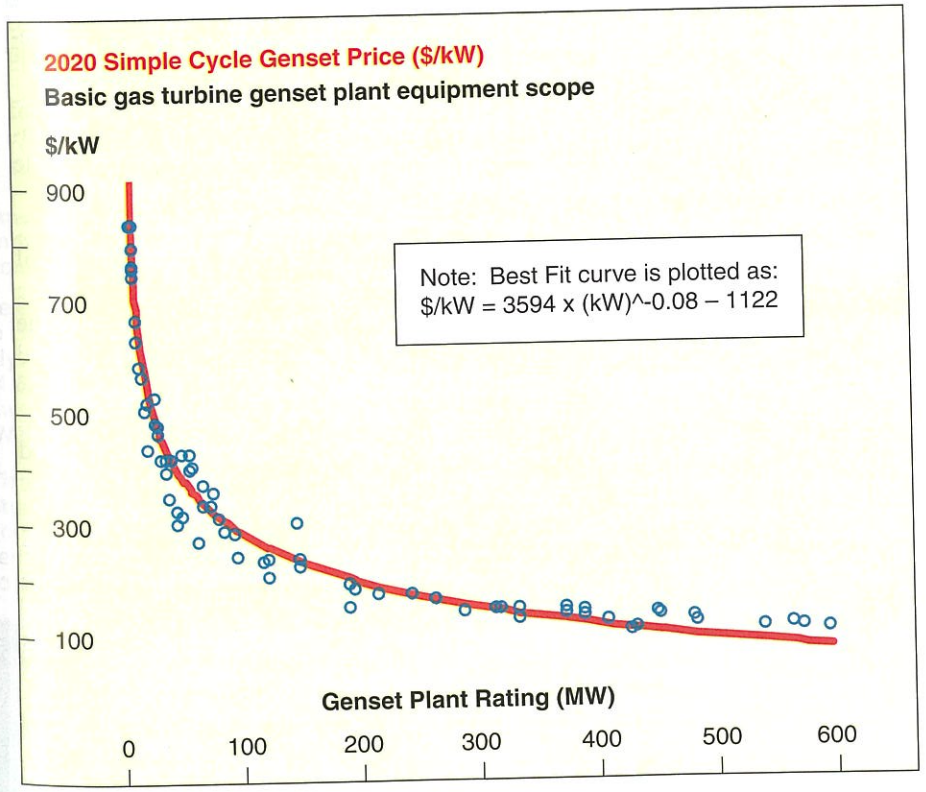
All prices are estimated in US dollars, FOB factory, for single-unit purchases. They do not cover transportation, plant engineering, construction, project-specific options or owner's project costs.

Market/Price update. Despite a general stabilizing in global orders, aggressive competition for a larger share of the lingering depressed market continues to keep prices on a downward trend.

Particularly for large utility plants over 200MW in unit output which again are expected to be selling at a discount over previous years.

Since the average size of new units sold is increasing, with growing percentage of "jumbo" gas turbines over 300MW in the mix, industry's total unit orders continues to fall and impact factory utilization.

Specifically, although global MW orders increased by over 20% in 2019 (year-over-year), the market in terms of units sold decreased by almost that same amount.



But even with last year's market rebound, the total MW capacity sold was still about 33% below 2015 levels, and total units sold down by about 50%. Market data reference: *2020-2029 Industrial Gas Turbine Market Forecast, Gas Turbine World, et. al.* See website for details: *https://gasturbineworld.com/publications/*

Negative forces in electric utility markets are largely due to exponential worldwide growth of renewable wind and solar energy. Both are increasingly being enhanced by new battery storage developments and sharply falling cost of photovoltaic technology.

But the growth of renewable sources is increasing demand for aeroderivative gas turbine technology, giving a boost in demand and price support for that sector of the market.

There is concern for the Oil & Gas sector where investment in new and expanded gas turbine projects is very sensitive to world oil price levels which have recently fallen to an 18-year low of $20 per barrel.

The near-term forecast in that regard is very murky, although there are promising signs of new market demand from large gas pipeline upgrade projects and growth in LNG supply, both of which rely on natural gas prices that are lower than oil.

Significant over-capacity of manufacturing space continues to drive all major gas turbine OEMs to strategic corrective measures including temporary shutdowns, permanent closures and repurposing or selling their factories for other products.

This is on top of resorting to increasingly aggressive marketing tactics, such as discounts on long-term service contracts and extended warranties, and lower equipment pricing.

On the positive side, continued low

natural gas prices into the foreseeable future, increased LNG supplies into Asia, and a steady stream of coal-plant retirements in North America, Europe, and even in China, help to buoy the large-unit market and support price levels.

Although there will always be exceptions, as we have learned in field interviews, GTW expects that prices for the larger utility power generation units in the 2020-2021 time frame *will slide by as much as 10% from 2019 levels.*

Equipment scope. Budget price applies to minimum scope of equipment supply comprising a basic gas turbine generating unit including associated mechanical and electrical auxiliary and balance of plant systems, including controls:

- **Gas turbine**. Skid-mounted gas turbine engine, starting motor, reduction gearbox (if any), onboard lube oil, hydraulic fluid and pneumatic systems, compressor water wash, fuel handling and control (w/o fuel boost compressor), external turbine cooling (if any), interconnecting piping.
- **Generator**. Standard air-cooled generator package; hydrogen or enclosed water-air cooled (TEWAC) usually offered as options for larger units. Generator exciter is typically included in the standard package.
- **Balance of plant**. Standard auxiliary items include air intake filter, ducting and silencer, exhaust ducting and stack (short) with silencer, vibration monitoring, mechanical and electrical auxiliary packages.

Mechanical and electrical auxiliaries are usually supplied as pre-assembled packages in separate skid-mounted enclosures. An acoustic enclosure with ventilation and fire protection systems, are commonly included to house the gas turbine,

Mechanical packages include lube oil and hydraulic, sumps, pumps, controls and coolers. Electrical auxiliaries include batteries, motor control center, voltage regulator and surge protection, and digital control system. Remote system monitoring and control are optional.

Auxiliary transformers for conditioning power supply for plant motors (starting, lube oil pump and cooling fans, etc.) are usually optional, as is main power step-up transformer.

Other OEM options include liquid or dual-fuel (gas and liquid) combustion, self-cleaning inlet filter, inlet air chilling, isolated phase bus, fuel gas compression, liquid fuel handling, etc.

Price and performance. Gas turbine power output, heat rate and efficiency data in the Simple Cycle Genset Price table are OEM-specified design ratings (gross) for base load operation at ISO standard (59°F ambient and sea level) conditions on natural gas fuel.

A best-fit relationship between \$/kW and kW is plotted and the equation is provided to assist in calculating the cost of comparably sized models not listed.

Besides unit size, other design factors that enter into variations in gas turbine prices are gas turbine type (i.e., frame vs. aero), standard engineering features (e.g., DLE combustion, adjustable inlet guide vanes, etc.) and technology levels, such as firing temperature and pressure ratio, which are reflected in engine performance.

We note that lower \$/kW of more advanced heavy-duty designs (G, H, J-class) reflect their larger unit size, thus negating cost impact of more expensive materials, coatings and manufacturing processes.

Bid quotes

Actual real-world bid prices are quoted for customer-specified scope and with OEM warranties on net power and heat rate (efficiency) at site-specific conditions and specified fuel composition.

Quotations commonly reflect performance margin of 0.5% to 1% on power and heat rate to allow for normal variations in manufacturing tolerances and test uncertainties.

Quoted performance parameters are always based on "factory new and clean" condition, without allowance for degradation in power and heat rate with usage.

Contract language usually specifies a tight limit in operating time before performance testing must be conducted.

Other factors entering into a commercial price quote include number of units ordered (i.e., quantity discounts), scope of supply, site-specific design requirements, transportation, geographic location and OEM's local market position.

Continued depressed market conditions are increasingly leading to negotiated packaged deals, including options and long-term service agreements.

Variation in currency valuations also play a role depending on which countries (i.e., currencies) are involved in the gas turbine's manufacture, purchase, and installation.

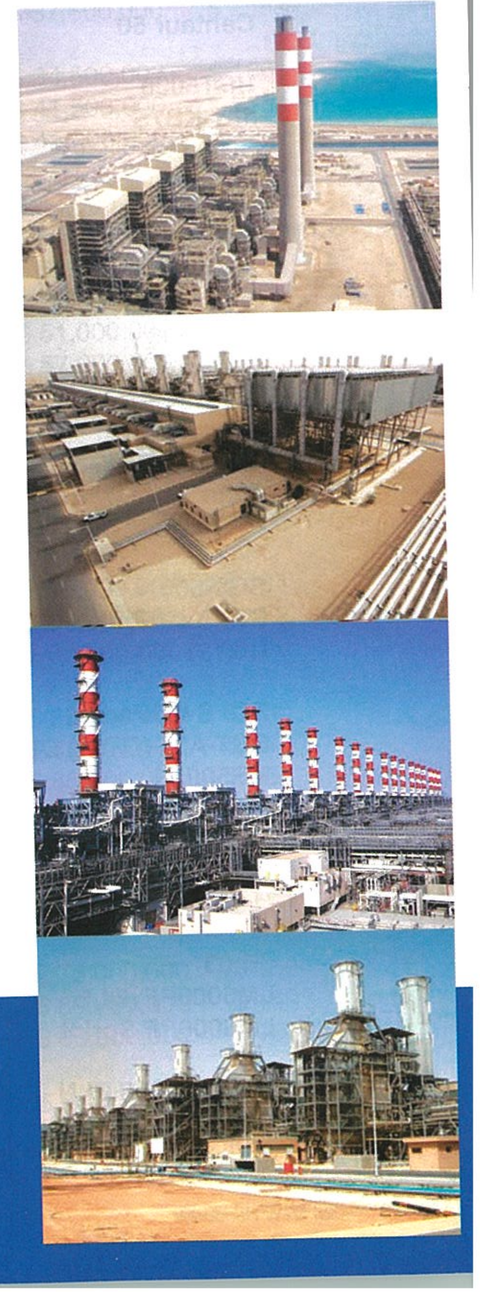
Gas turbine gensets designed for onshore oil and gas pipeline operation typically are priced around 10% higher than industrial or utility units. Due primarily to the cost of compliance with special packaging and safety requirements such as found in API specifications.

Offshore platform gas turbine packages command an additional price premium to cover costs such as specialized mountings and housing, marine-resistant coatings or ultra-efficient intake filter systems designed to handle salt-water laden air.

Benchmark. This reference section of the GTW Handbook should serve as a benchmarking tool for estimating the equipment cost of different size and type plants.

To allow for uncertainties, the estimated budget prices should be treated as having a plus or minus 15% range of accuracy.

The data plot and best-fit curve show the strong relationship of cost to unit size, clearly displaying the economies of scale which allow OEMs to reduce manufacturing costs (per kW) as unit power ratings and physical size increase. ■



2020 Simple Cycle Genset Price

Equipment-only budget price for standard bare bones gas turbine genset without add-on options (in fixed 2020 US dollars)

Gas Turbine Model	Freqency Hz	ISO Base Output	Heat Rate Btu/kWh	Efficiency	Budget Price	$/kW
C200	50/60	200 kW	10,300 Btu	33.1%	$ 230,000	$ 1150
C1000S	50/60	1,000 kW	10,300 Btu	33.1%	$ 1,000,000	$ 1000
M1A-17D	50/60	1,810 kW	12,160 Btu	28.1%	$ 1,500,000	$ 829
OP16-3A	50/60	1,876 kW	13,585 Btu	25.1%	$ 1,550,000	$ 826
501-KB5S	50/60	3,980 kW	11,504 Btu	29.7%	$ 3,300,000	$ 829
Centaur 50	50/60	4,600 kW	11,630 Btu	29.3%	$ 3,500,000	$ 761
UGT5000	50/60	5,100 kW	11,010 Btu	31.0%	$ 3,850,000	$ 755
501-KB7S	50/60	5,380 kW	10,570 Btu	32.3%	$ 4,250,000	$ 790
SGT-100	50/60	5,400 kW	11,006 Btu	31.0%	$ 4,000,000	$ 741
UGT6000	50/60	6,200 kW	11,300 Btu	30.2%	$ 4,150,000	$ 669
SGT-300	50/60	7,901 kW	11,158 Btu	30.6%	$ 5,000,000	$ 633
Taurus 70	50/60	8,180 kW	9,920 Btu	34.4%	$ 4,850,000	$ 593
Mars 100	50/60	11,350 kW	10,365 Btu	32.9%	$ 6,500,000	$ 573
SGT-400	50/60	14,326 kW	9,647 Btu	35.4%	$ 7,400,000	$ 517
UGT15000	50	16,500 kW	9,980 Btu	34.2%	$ 7,500,000	$ 455
Titan 130	50/60	16,530 kW	9,605 Btu	35.4%	$ 8,750,000	$ 529
Titan 250	50/60	23,100 kW	8,775 Btu	38.9%	$ 11,500,000	$ 498
LM2500DLE	60	23,200 kW	9,317 Btu	36.6%	$ 12,500,000	$ 539
SGT-600	50/60	24,480 kW	10,161 Btu	33.6%	$ 11,750,000	$ 480
FT8 SwiftPac 25 DLN	60	25,371 kW	8,993 Btu	38.0%	$ 12,500,000	$ 493
UGT25000	50	25,680 kW	9,590 Btu	35.6%	$ 11,250,000	$ 438
FT8 SwiftPac 30	60	30,892 kW	9,327 Btu	36.6%	$ 12,850,000	$ 416
SGT-A35 (GT61) DLE	50/60	32,130 kW	8,681 Btu	39.3%	$ 14,000,000	$ 436
MS5002E	50/60	32,800 kW	9,517 Btu	38.5%	$ 12,250,000	$ 373
LM2500+ G4 DLE	60	34,500 kW	8,709 Btu	39.2%	$ 15,000,000	$ 435
SGT-750	50/60	39,810 kW	8,456 Btu	40.3%	$ 14,000,000	$ 352
H-25	50/60	41,030 kW	9,432 Btu	36.2%	$ 13,600,000	$ 331
6B.03	50/60	44,000 kW	10,180 Btu	33.5%	$ 15,000,000	$ 341
LM6000PF DLE	60	45,000 kW	8,097 Btu	42.1%	$ 20,000,000	$ 444
LM6000PF Sprint	60	50,000 kW	8,097 Btu	42.1%	$ 21,000,000	$ 420
2xFT8 SP50 DLN	60	51,058 kW	8,938 Btu	38.2%	$ 22,750,000	$ 446
LM6000 DLE PF+	60	54,000 kW	8,162 Btu	41.8%	$ 23,000,000	$ 426
SGT-800	50/60	57,000 kW	8,502 Btu	40.1%	$ 17,000,000	$ 298
SGT-A65 DLE	50	61,900 kW	7,874 Btu	43.3%	$ 24,500,000	$ 396
FT8 SwiftPac 60	50/60	62,086 kW	9,281 Btu	36.8%	$ 22,250,000	$ 358
LM9000 Low NOx	50/60	68,000 kW	8,107 Btu	42.1%	$ 24,500,000	$ 360
FT4000 SwiftPac 60	60	70,836 kW	8,269 Btu	41.3%	$ 27,000,000	$ 381
SGT-A65 WLE ISI	50	76,506 kW	8,198 Btu	41.6%	$ 26,000,000	$ 340
AE64.3A	50/60	80,000 kW	9,374 Btu	36.4%	$ 25,500,000	$ 319
6F.03	50/60	88,000 kW	9,277 Btu	36.8%	$ 27,500,000	$ 313
7E.03	60	91,000 kW	10,060 Btu	33.9%	$ 25,000,000	$ 275
M501DA	60	113,950 kW	9,780 Btu	34.9%	$ 30,000,000	$ 263
LMS100 PA	60	119,100 kW	8,056 Btu	42.3%	$ 40,000,000	$ 336
SGT6-2000E	60	117,000 kW	9,639 Btu	35.4%	$ 31,500,000	$ 269
H-100	50	116,450 kW	8,909 Btu	38.3%	$ 27,800,000	$ 239
FT4000 SwiftPac 120	50/60	141,567 kW	8,248 Btu	41.4%	$ 46,500,000	$ 328
M701DA	50	144,090 kW	9,810 Btu	34.8%	$ 38,600,000	$ 268
9E.04	50	145,000 kW	9,210 Btu	37.0%	$ 37,500,000	$ 259
M501F	60	185,400 kW	9,230 Btu	37.0%	$ 34,500,000	$ 186
AE94.2	50	190,000 kW	9,400 Btu	36.3%	$ 41,500,000	$ 218
SGT5-2000E	50	187,000 kW	9,349 Btu	36.5%	$ 42,000,000	$ 225
GT13E2	50	210,000 kW	8,980 Btu	38.0%	$ 43,500,000	$ 207
7F.05	60	239,000 kW	9,019 Btu	37.8%	$ 50,000,000	$ 209
SGT6-5000F	60	260,000 kW	8,530 Btu	40.0%	$ 52,000,000	$ 200
M501GAC	60	283,000 kW	8,531 Btu	40.0%	$ 51,000,000	$ 180
SGT6-8000H	60	310,000 kW	<8,530 Btu	>40%	$ 57,000,000	$ 184
9F.05	50	314,000 kW	8,846 Btu	38.6%	$ 58,000,000	$ 185
SGT5-4000F	50	329,000 kW	8,322 Btu	41.0%	$ 60,000,000	$ 182
M501J	60	330,000 kW	8,105 Btu	42.1%	$ 55,000,000	$ 167
GT26	50	370,000 kW	8,322 Btu	41.0%	$ 65,000,000	$ 176
GT36-S6	60	369,000 kW	8,067 Btu	42.3%	$ 68,000,000	$ 184
7HA.02	60	384,000 kW	8,009 Btu	42.6%	$ 66,000,000	$ 172
M701F	50	385,000 kW	8,144 Btu	41.9%	$ 68,900,000	$ 179
SGT6-9000HL	60	405,000 kW	8,010 Btu	42.6%	$ 65,000,000	$ 160
M501JAC	60	425,000 kW	7,755 Btu	44.0%	$ 62,000,000	$ 146
7HA.03	60	430,000 kW	7,884 Btu	43.3%	$ 65,000,000	$ 151
M701JAC (2018)	50	448,000 kW	7,755 Btu	44.0%	$ 79,000,000	$ 176
SGT5-8000H	50	450,000 kW	<8322 Btu	>41%	$ 77,500,000	$ 172
M701J	50	478,000 kW	8,067 Btu	42.3%	$ 80,000,000	$ 167
SGT5-8000HL	50	481,000 kW	8,006 Btu	42.6%	$ 75,000,000	$ 156
GT36-S5	50	538,000 kW	7,972 Btu	42.8%	$ 80,000,000	$ 149
M701JAC (2015)	50	563,000 kW	7,826 Btu	43.6%	$ 86,000,000	$ 153
9HA.02	50	571,000 kW	7,740 Btu	44.1%	$ 84,000,000	$ 147
SGT5-9000HL	50	593,000 kW	7,972 Btu	42.8%	$ 85,000,000	$ 143

2020 Combined Cycle Plant Price

Equipment and EPC budget price for basic combined cycle plant without add-on options

GTW budget prices for combined cycle plants are based on OEM reference plant designs and typical EPC contractor costs.

Main factors that influence price include plant rating, type gas turbine (aero or heavy frame), design platform (E, F, G or advanced H and J-class technology) and multi-module vs. single-shaft plant configuration.

Generally, 2020 turnkey budget prices of combined cycle plants have changed little from 2019 levels although due to the variety of configurations possible, there is considerable scatter in price data for competitively sized plants.

Market/Price factors. Increasing reliance on renewable energy for new capacity additions, most notably in North American and Europe, continues to suppress electric utility demand for new gas-fired power generation.

But that weakness in traditionally strong gas turbine markets is offset by growing energy needs of developing countries and interest in advanced-generation high-efficiency combined cycle technology for base load power generation.

Market growth is largely supported by widespread availability of shale gas and access to secure and relatively low-cost LNG fuel supply.

A potentially large market for plants is developing in China, for example, where a rush to add more coal-fired steam plants has come to a screeching halt for building new gas-fired combined cycle capacity.

Although heightened competition among major equipment OEMs and construction companies kept combined cycle plant prices low, the inflationary trend in the global engineering/construction industry is having the opposite effect.

This is typical of regions with shortages of skilled labor and key materials or where import duties are affecting costs. Net overall result is expected to be price stabilization in the large power project industry.

Price caveats. GTW's objective is to provide project developers and owner operators with benchmark budget prices for single-fuel combined cycle plants (gas fired) with conservative bottoming (steam) cycle design and without HRSG duct firing.

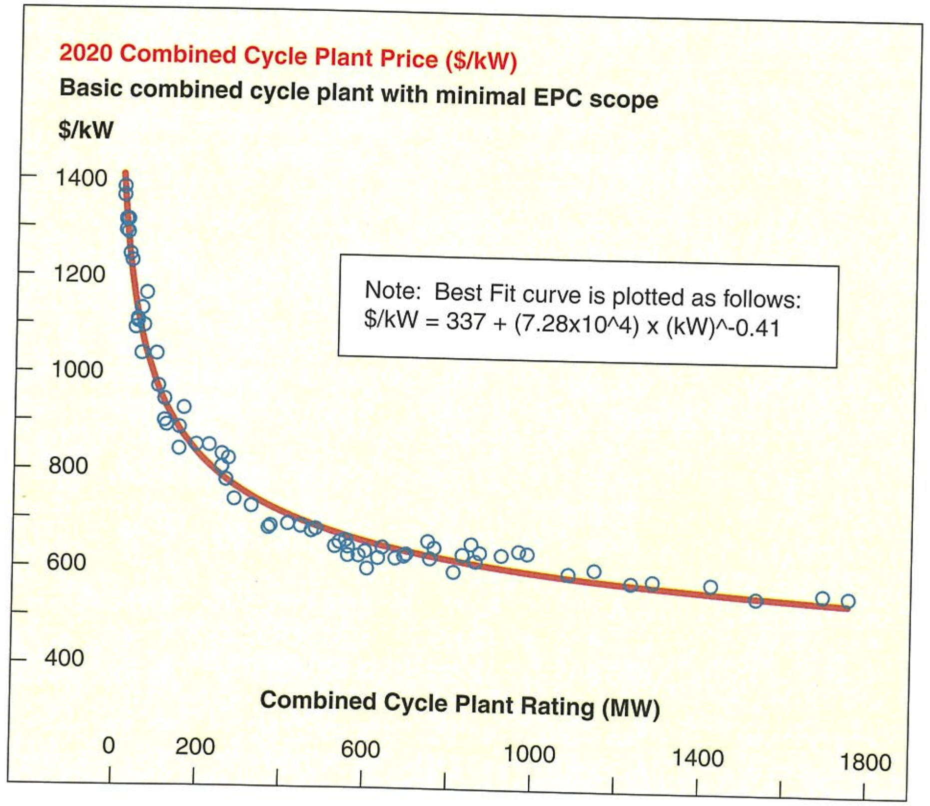
Those prices are for *"turnkey"* scope, including major equipment supply, engineering services and plant construction. But they exclude commonly built-in EPC allowances for project risk or contingency (typically 10% or greater).

Nor do they include highly variable project-specific costs such as transportation and delivery, equipment and system options, and owner's project costs (project development, land, fuel delivery, utility connections, etc.).

Resultant "bare bones" budget prices are based on minimum scope of supply for plants designed around one or more gas turbine generators, with matching HRSGs and separate single steam turbine generator (or steam turbine with clutch for single-shaft combined cycle designs), water-cooled condenser design, and integrated plant controls.

Publicized combined cycle project costs are often found to be well above our GTW Handbook budget price levels. Given project scope uncertainty, we attach a plus or minus accuracy of 15% to the estimated budget price of combined cycle plants.

All plant unit prices (i.e., in $/kW) are referenced to *net* baseload power ratings for OEM designs at ISO standard (59°F ambient and sea level) site conditions.



Power block equipment typically consists of:

- **Gas turbine.** Single-fuel skid mounted DLE gas turbine with acoustic enclosure, starting motor, control systems, plus standard mechanical and electrical auxiliaries normally supplied with simple cycle gas turbine package (standard inlet but without stack).
- **Steam turbine**. Condensing subcritical design, with single or dual-pressure levels for small plants, triple-pressure levels with reheat for larger plants. Axial or downward exhaust, steam bypass and controls, enclosure and water-cooled condenser. Plus auxiliary skid, all valves and controllers (typically hydraulic) optimized plant.
- **Unfired HRSG**. Heat recovery steam generator for outdoor installation, ductwork and short exhaust stack with silencing. Dual or triple-pressure reheat design as dictated by gas turbine and steam turbine size and technology.
- **Generator**. Open air-cooled design for small gas turbines and enclosed water-air-cooled (TWAC) or hydrogen-cooled designs for large units. Neutral grounding cubicle and bus to main breaker included with generator packages.
- **Control system**. Distributed control system (DCS) for integrating gas turbine, HRSG and steam turbine controls with overall combined cycle plant control and operation.
- **Clutch**. For single-shaft arrangements, synchro-self-shifting clutch is placed between steam turbine and generator (enables gas turbine generator to operate independent of the steam turbine during start-up, shutdown and for part-load operation).

Balance-of-plant equipment for the combined cycle plant covers:

- **Mechanical auxiliaries**. Critical water handling systems with pumps, sumps, and piping for boiler feed water, condenser cooling water and condensate.
- **Electrical auxiliaries**. Auxiliary power transformers and switchgear, voltage regulators, bus and breakers needed for plant operation, minimal control room installation. (Price does not include main step-up transformers for connecting plant output to the utility substation.)

EPC Scope. Allowance is made for plant design and engineering, foundations, structures, and installation assuming non-union labor. (Site preparation work is excluded due to its project specificity.)

Excluded options. Popular customer-specified options considered outside budget prices for a standard bare bones combined cycle plant include:

- **Bypass stack**. Allows independent operation of the gas turbine in simple cycle mode for quick start and flexible dispatch; option includes a mechanical damper in exhaust ducting to redirect flow.
- **Inlet cooling**. Evaporative and/or mechanical chilling systems that can boost plant output by up to 10% on a 90°F hot day and 30% relative humidity operation. (Some aero gas turbine models already include compressor inlet spray intercooling {ISI} for power boost.)
- **Duct firing**. Supplementary duct firing to increase steam turbine output; also requires upgrades in steam and water handling systems.
- **Catalysts.** Catalytic reactor section for HRSG (to limit CO and NOx emissions) plus associated ammonia storage and feed systems.
- **Back-up fuel**. Storage and delivery of liquid fuel for back-up to natural gas fuel supply. Usually includes fuel unloading station and alternative provisions for NOx control, such as water injection.

Boundary limits. Defined scope of supply is based on narrow boundary limits that exclude utility grid interconnections, transmission lines, natural gas fuel pipelines, or service/access roads external to the plant site.

Within the plant site, project-specific balance of plant equipment such as fuel gas booster compressors, water treatment systems, waste water systems and cooling towers are excluded.

So are the "first fill" of operating consumables such as lube oil, chemicals, catalysts, special tooling and replacement parts and spares, which, although not a significant percentage of total costs, are worth noting by cost estimators.

Price estimates are restricted to overnight cost, excluding time-dependent costs such as escalation and interest during construction.

Likewise excluded are project-specific owner expenses such as land, plant site preparation, project development, financing, permits, insurance, taxes, etc.

Size matters. As one might expect, unit prices ($/kW) for combined cycle power plants strongly exhibit the cost advantages of economies of scale.

The plotted curve of combined cycle plant unit price versus power shows correlation and sharp decline with increasing plant size, with trend leveling off at the high end of the size range.

Scatter in the plotted price data primarily reflects range of gas turbine technology and plant configuration options (single- vs. multi-shaft), and influence of 50Hz vs. 60Hz designs on equipment physical size and power density.

Compared to simple cycle equipment price ($/kW) vs. size, the flatness of the curve for the larger high-efficiency combined cycle plants reflects the effect of the large percentage of total plant cost attributed to more costly steam bottoming cycle and associated plant equipment.

Impact of steam portion increases with higher cost of advanced-design steam turbines and support equipment specified for larger plants designed to operate at >60% efficiencies.

High-efficiency plants feature advanced technology gas turbines, where high firing temperatures require sophisticated cooling designs and new materials and manufacturing processes.

However, in terms of $/kW, this is largely countered, and even overcome, by the gains in power output with the latest gas and steam technology advances. ■

2020 Combined Cycle Plant Price

Equipment and construction budget price for bare bones combined cycle plant without add-on options (in fixed 2020 US dollars)

No. & Model Gas Turbine	Net Plant Output	Heat Rate Btu/kWh	Efficiency	Steam Turbine	Budget Plant Price	$/kW
2 x THM 1304-12N	34.0 MW	7720 Btu	44.2%	11.0 MW	$ 46,000,000	$ 1353
1 x SGT-600	35.9 MW	6843 Btu	49.9%	12.6 MW	$ 48,000,000	$ 1337
1 x FT8 SP 30	41.1 MW	6950 Btu	49.1%	12.0 MW	$ 52,000,000	$ 1267
1 x SGT-A35 RB DLE	42.6 MW	6464 Btu	52.8%	12.6 MW	$ 55,000,000	$ 1291
1 x SGT-700	45.2 MW	6517 Btu	52.4%	14.4 MW	$ 57,000,000	$ 1262
1 x LM2500+ G4 DLE	47.7 MW	6239 Btu	54.7%	14.5 MW	$ 61,500,000	$ 1289
1 x SGT-750	51.6 MW	6407 Btu	53.3%	13.5 MW	$ 63,000,000	$ 1222
1 x LM6000 DLE (50)	58.0 MW	6179 Btu	55.2%	14.4 MW	$ 70,000,000	$ 1207
1 x 6B.03	68.0 MW	6614 Btu	51.6%	25.6 MW	$ 73,000,000	$ 1074
1 x SGT-A65 TR DLE	73.0 MW	6249 Btu	54.6%	****	$ 79,500,000	$ 1089
2 x SGT-600	73.3 MW	6702 Btu	50.9%	26.5 MW	$ 80,000,000	$ 1091
1 x SGT-A65 TR DLE ISI	83.0 MW	6301 Btu	54.2%	****	$ 85,000,000	$ 1024
2 x FT8 SP-30	83.1 MW	6878 Btu	49.6%	24.6 MW	$ 92,500,000	$ 1113
1 x SGT-800	88.0 MW	5782 Btu	59.0%	27.7 MW	$ 95,000,000	$ 1080
2 x SGT-700	91.6 MW	6424 Btu	53.1%	30.0 MW	$ 105,000,000	$ 1146
2 x LM6000 DLE (50)	117.0 MW	6161 Btu	55.4%	29.1 MW	$ 120,000,000	$ 1026
1 x AE64.3A	120.0 MW	6126 Btu	56.4%	40.5 MW	$ 115,000,000	$ 958
1 x 6F.03	135.0 MW	5998 Btu	56.9%	49.4 MW	$ 120,000,000	$ 889
2 x 6B.03	137.0 MW	6551 Btu	52.1%	51.6 MW	$ 128,000,000	$ 934
1 x 7E.03	142.0 MW	6505 Btu	52.5%	56.3 MW	$ 125,000,000	$ 880
1 x H-100 (50Hz)	171.0 MW	5945 Btu	57.4%	58.3 MW	$ 150,000,000	$ 877
1 x SGT6-2000E	174.0 MW	6533 Btu	52.2%	60.0 MW	$ 145,000,000	$ 833
2 x SGT-800	180.0 MW	5687 Btu	60.0%	59.4 MW	$ 165,000,000	$ 917
1 x M701DA	212.5 MW	6635 Btu	51.4%	70.4 MW	$ 179,000,000	$ 842
2 x AE64.3A	243.0 MW	6050 Btu	56.4%	82.6 MW	$ 205,000,000	$ 844
2 x 6F.03	272.0 MW	5944 Btu	57.4%	100.9 MW	$ 225,000,000	$ 827
1 x SGT5-2000E	275.0 MW	6341 Btu	53.8%	93.0 MW	$ 220,000,000	$ 800
2 x 7E.03	287.0 MW	6439 Btu	53.0%	110.0 MW	$ 235,000,000	$ 819
1 x M501F	285.1 MW	5976 Btu	57.1%	102.4 MW	$ 221,000,000	$ 775
1 x GT13E2	305.0 MW	6189 Btu	55.1%	100.3 MW	$ 225,000,000	$ 738

No. & Model Gas Turbine	Net Plant Output	Heat Rate Btu/kWh	Efficiency	Steam Turbine	Budget Plant Price	$/kW
2 x H-100 (50Hz)	346.0 MW	5884 Btu	58.0%	120.6 MW	$ 250,000,000	$ 723
1 x 7F.05	383.0 MW	5692 Btu	59.9%	147.7 MW	$ 260,000,000	$ 679
1 x SGT6-5000F	387.0 MW	5725 Btu	59.6%	133.0 MW	$ 265,000,000	$ 685
1 x M501GAC	427.0 MW	5640 Btu	60.5%	146.2 MW	$ 295,000,000	$ 691
1 x SGT6-8000H	460.0 MW	5611 Btu	60.8%	****	$ 315,000,000	$ 685
1 x M501J	484.0 MW	5504 Btu	62.0%	157.8 MW	$ 326,500,000	$ 675
1 x 9F.05	493.0 MW	5619 Btu	60.7%	186.0 MW	$ 335,000,000	$ 680
1 x GT26 CC1S	540.0 MW	5594 Btu	61.0%	****	$ 350,000,000	$ 648
2 x SGT5-2000E	551.0 MW	6341 Btu	53.8%	186.0 MW	$ 360,000,000	$ 653
1 x M701F	566.0 MW	5504 Btu	62.0%	186.7 MW	$ 373,000,000	$ 659
2 x M501F	572.2 MW	5955 Btu	57.3%	206.8 MW	$ 369,000,000	$ 645
1 x 7HA.02	573.0 MW	5381 Btu	63.4%	****	$ 360,000,000	$ 628
1 x SGT6-9000HL	595.0 MW	<5416 Btu	>63%	****	$ 375,000,000	$ 630
2 x GT13E2-2	613.0 MW	6153 Btu	55.5%	203.7 MW	$ 390,000,000	$ 636
1 x M501JAC	614.0 MW	5332 Btu	64.0%	193.7 MW	$ 370,200,000	$ 603
1 x 7HA.03	640.0 MW	5342 Btu	63.4%	****	$ 400,000,000	$ 625
1 x M701JAC 2018	650.0 MW	5332 Btu	64.0%	208.3 MW	$ 421,000,000	$ 648
1 x 9HA.01	680.0 MW	5356 Btu	63.7%	****	$ 425,000,000	$ 625
1 x M701J	701.0 MW	5477 Btu	62.3%	228.7 MW	$ 442,500,000	$ 631
1x SGT5-8000HL	708.0 MW	<5416 Btu	>63%	****	$ 450,000,000	$ 636
2 x 7F.05	756.0 MW	5640 Btu	60.5%	293.0 MW	$ 500,000,000	$ 661
1 x GT36 - S5	760.0 MW	5451 Btu	62.6%	****	$ 475,000,000	$ 625
2 x SGT6-5000F	775.0 MW	5715 Btu	59.7%	267.0 MW	$ 500,000,000	$ 645
1 x M701JAC 2015	818.0 MW	5332 Btu	64.0%	260.5 MW	$ 490,400,000	$ 600
1 x 9HA.02	838.0 MW	5320 Btu	64.1%	289.7 MW	$ 530,000,000	$ 632
2 x M501GAC	856.0 MW	5622 Btu	60.7%	294.4 MW	$ 560,000,000	$ 654
1 x SGT5-9000HL	870.0 MW	<5416 Btu	>63%	****	$ 540,000,000	$ 621
2 x 7HA.01	880.0 MW	5453 Btu	62.6%	316.2 MW	$ 560,000,000	$ 636
2 x SGT6-8000H	930.0 MW	5602 Btu	60.9%	325.0 MW	$ 590,000,000	$ 634
2 x M501J	971.0 MW	5486 Btu	62.2%	318.6 MW	$ 625,000,000	$ 644
2 x 9F.05	989.0 MW	5603 Btu	60.9%	374.7 MW	$ 630,000,000	$ 637
2 x GT26	1,083.0 MW	5594 Btu	61.0%	320.0 MW	$ 650,000,000	$ 600
2 x 7HA.02	1,148.0 MW	5365 Btu	63.6%	397.2 MW	$ 700,000,000	$ 610
2 X M501JAC	1,231.0 MW	5315 Btu	64.2%	364.8 MW	$ 715,000,000	$ 581
2 x 7HA.03	1,282.0 MW	5331 Btu	64.0%	437.6 MW	$ 750,000,000	$ 585
2 x SGT5-8000HL	1,416.0 MW	<5416 Btu	>63%	464.0 MW	$ 825,000,000	$ 583
2 x GT36-S5	1,525.0 MW	5433 Btu	62.8%	****	$ 850,000,000	$ 557
2 x 9HA.02	1,680.0 MW	5306 Btu	64.3%	557.6 MW	$ 950,000,000	$ 565
2 x SGT5-9000HL	1,740.0 MW	<5416 Btu	>63%	****	$ 975,000,000	$ 560

2020 Mechanical Drive Price

Equipment-only budget price for bare bones packaged mechanical drive without add-on options.

GTW budget prices for mechanical drive gas turbines are based on single-fuel (gas only) packaged units designed primarily for oil & gas and petrochemical industry applications.

Prices are quoted in US dollars FOB factory for equipment-only single unit orders. They do not cover cost of transportation, installation and add-on options.

Market/Price update

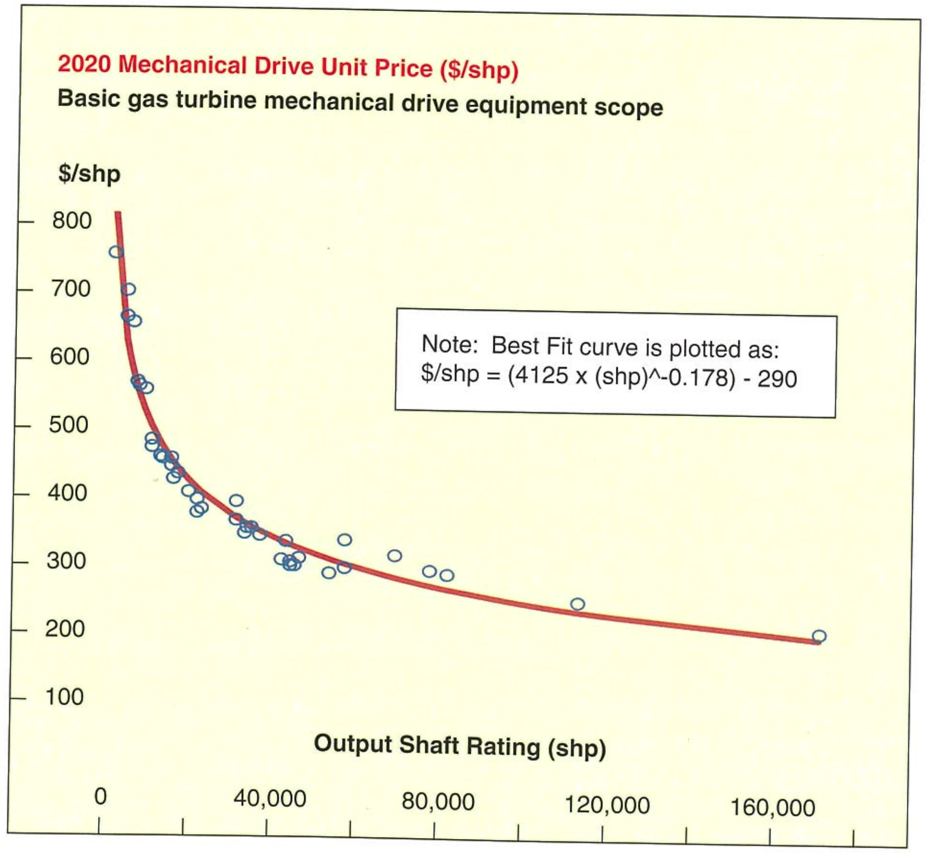
Investment in the oil & gas sector, being highly sensitive to the global price of oil, is expected to hit the brakes again after an anemic and short-lived recovery in recent years.

With the price of crude dropping to an 18-year low of under $20 per barrel, and signs of a potential global slowdown, there is considerable uncertainty in the market for new capital equipment.

The consensus forecast is that industrial equipment price levels will not only retract from recent gains but trend even lower.

On that basis, GTW estimated mechanical drive gas turbine price levels for 2020-2021 show a general decrease of some 3-5% compared to last year.

Mechanical drive gas turbine prices demonstrate typical economies of scale with increasing unit size. Prices fall off steeply from around $750 per hp for a 1600 hp unit to around $300 at 40,000 hp, after which prices gradually level off to $240 per hp out to 110,000 hp and larger.


2020 Mechanical Drive Unit Price ($/shp)

Basic gas turbine mechanical drive equipment scope

Equipment scope

Although a growing number of gas turbine OEMs are now offering complete turbo-compressor packages, GTW budget prices apply only to gas turbine drive equipment.

Standard scope of supply includes gas turbine, reduction gearbox (when needed), inlet air filter, ducting, auxiliaries, and dry low NOx combustion (when available):

- **Packaged unit**. Skid mounted single-fuel gas turbine, output driveshaft coupling, starting motor (electric or hydraulic).and lube oil system.
- **Output gearbox**. Parallel-shaft gearbox is usually standard for aero units. Epicyclic gearing is more compact and efficient,but adds to the price. (Most aero and industrial frame gas turbines are direct drive.)
- **Inlet and exhaust**. Air inlet filter, ducting and silencer plus exhaust duct, silencer and short stack. (Options such as multi-stage inlet filtration, pulse-jet cleaning, anti-icing, air inlet chilling and water or steam injection for power augmentation are not included.)
- **Auxiliaries**. Lube oil system (pump, cooler, etc.), vibration monitoring, compressor washing, speed and temperature instrumentation, automated digital controls, typically including variable speed operation (for two-shaft designs), and fire protection systems.

Market factors

Budget prices are for single-unit orders, and do not reflect discounts that can be negotiated for large multi-unit orders where buyers have bargaining leverage and suppliers can pass along savings of maintaining factory volume.

Many of the leading gas turbine OEMs offer the alternative supply of customized package deals that integrate the prime mover and driven equipment as a complete turbine-compressor package.

Smaller gas turbine OEMs and packagers compete by becoming niche or "boutique" suppliers enabling them to capture and retain small segments of the market and remain profitable.

Aeroderivative gas turbines, which account for most mechanical drive applications, command higher prices than do traditional industrial frame gas turbine designs. This explains much of the scatter for similar size gas turbine units in the plotted price data.

Pricing factors

Historically, for a variety of reasons, mechanical drive gas turbine packages typically cost more than simple cycle gensets powered by an identical gas turbine model despite the extra cost of their electric generator and associated auxiliaries.

One explanation is that standardized industry-wide engineering design specifications reduce the manufacturing cost of electric power generation equipment, which is not the case for mechanical drives.

Oil & gas pipeline and petrochemical buyers generally dictate their own in-house specifications for mechanical drive packages developed and proven over years of extensive operating experience and concerns.

Despite some progress toward standardization, price levels for mechanical drive gas turbines still reflect the high cost of "tailor-made" solutions to meet requirements peculiar to an industry application and, often, to a specific customer.

Strict regulations for industrial operating environments also inflate prices. Gas turbine packages for pipeline, offshore platform and petrochemical installations must be specially designed to operate in explosive, flammable and other extreme industrial environments.

Compliance with strict international standards as mandated by API, ISO and PED specifications (European directive for pressurized equipment) add substantially to the cost of engineering and manufacturing.

These factors make the mechanical drive sector of the gas turbine market uniquely different and far more demanding than other sectors regarding automated operational safety, reliability, availability and durability. ■

2020 Mechanical Drive Gas Turbine Price

Equipment-only budget price for pipeline and petrochem bare bones mechanical drive package without add-on options (in fixed 2020 US dollars)

Gas Turbine Model	Base Load Output	Heat Rate Btu/hp-hr	Efficiency	Budget Price	$/shp
Saturn 20	1,590 shp	10,360 Btu	24.6%	$1,200,000	$755
Centaur 40	4,700 shp	9,100 Btu	28.0%	$3,100,000	$660
VPS4	4,877 shp	8,511 Btu	29.9%	$3,400,000	$697
Centaur 50	6,130 shp	8,485 Btu	30.0%	$4,000,000	$653
SGT-100	7,640 shp	7,738 Btu	32.9%	$4,300,000	$563
Taurus 60	7,700 shp	7,950 Btu	32.0%	$4,300,000	$558
MGT6200	9,250 shp	7,480 Btu	34.0%	$5,100,000	$551
Taurus 70	11,110 shp	7,190 Btu	35.4%	$5,200,000	$468
SGT-300	11,216 shp	7,315 Btu	34.8%	$5,350,000	$477
Mars 90	13,220 shp	7,655 Btu	33.2%	$6,000,000	$454
GTU-10P	13,759 shp	7,831 Btu	32.5%	$6,200,000	$451
Mars 100	15,900 shp	7,395 Btu	34.4%	$7,000,000	$440
THM1304-12N	16,090 shp	8,210 Btu	31.0%	$7,250,000	$451
GTU-12P	16,629 shp	7,355 Btu	34.6%	$7,000,000	$421
NovaLT12	17,499 shp	6,933 Btu	36.7%	$7,500,000	$429
SGT-400	20,006 shp	6,908 Btu	36.8%	$8,000,000	$400
GTU-16P	22,087 shp	6,878 Btu	37.0%	$8,150,000	$369
UGT 16000	22,400 shp	7,955 Btu	32.0%	$8,700,000	$388
Titan 130	23,470 shp	7,020 Btu	36.2%	$8,800,000	$375
PGT25	31,638 shp	6,823 Btu	37.3%	$12,250,000	$387
Titan 250	31,900 shp	6,360 Btu	40.0%	$11,500,000	$361
SGT-600	33,847 shp	7,344 Btu	34.6%	$11,500,000	$340
GTU-25P	34,330 shp	6,492 Btu	39.2%	$12,000,000	$350
UGT 25000	35,800 shp	6,975 Btu	36.5%	$12,500,000	$349
FT8	37,940 shp	6,580 Btu	38.7%	$12,750,000	$336
PGT25+	42,962 shp	6,348 Btu	40.1%	$13,000,000	$303
SGT-A30 RB DLE	44,230 shp	6,306 Btu	40.3%	$14,500,000	$328
SGT700	45,151 shp	6,661 Btu	38.2%	$13,500,000	$299
MS5002(E)	45,300 shp	6,884 Btu	37.0%	$13,250,000	$292
PGT25+G4	46,385 shp	6,296 Btu	40.4%	$13,600,000	$293
L30A	47,600 shp	6,100 Btu	41.7%	$14,500,000	$305
SGT750	54,994 shp	6,122 Btu	41.6%	$15,500,000	$282
MS6001B	58,380 shp	7,647 Btu	33.3%	$17,000,000	$291
LM6000PF	58,809 shp	5,917 Btu	43.0%	$19,500,000	$332
LM6000PG	70,787 shp	5,890 Btu	43.2%	$22,000,000	$311
SGT-A65 DLE	79,249 shp	5,731 Btu	44.4%	$22,750,000	$287
SGT-A65 DLE ISI	83,545 shp	5,859 Btu	43.4%	$23,500,000	$281
MS7001(EA)	115,630 shp	7,718 Btu	33.0%	$28,000,000	$242
MS9001(E)	174,520 shp	7,348 Btu	34.6%	$35,500,000	$203

Section 2

GT Model Changes

New Gas Turbine Models
Designs introduced over the past 5 years range from 1.8MW in unit output to mega-sized units rated at over 560MW 20

Gas Turbine Upgrades
OEMs regularly offer retrofit packages with new engineering technology to improve performance and service life 24

Retired Gas Turbine Models
Non-competitive models may be replaced by a new generation design, licensed to another supplier or simply be abandoned 30

New Gas Turbine Models (2015-2019)

OEMs have come out with close to 30 new gas turbine designs over the last 5 years that range up to over 500 MW unit output and 44% simple cycle efficiency.

Gas Turbine Builder	Model	ISO Base Load (kW)	Heat Rate Btu/kWh	Efficiency	Intro Year
Kawasaki	M5A-01D	4,710 kW	10450 Btu	32.6%	2017
Baker Hughes GE	NovaLT5-1	5,600 kW	11,127 Btu	30.7%	2015
Centrax	CX300	8,500 kW	9855 Btu	34.6%	2015
Siemens	SGT-400 (11 MW)	10,360 kW	9802 Btu	34.8%	2018
UEC Gas Turbines	GTA-25	23,300 kW	9426 Btu	36.2%	2017
Siemens	SGT-A35 34 MW DLE	32,537 kW	8907 Btu	38.3%	2015
Siemens	SGT-A35 34 MW non-DLE	33,158 kW	8873 Btu	38.5%	2015
GE Power	LM2500XPRESS	34,300 kW	8628 Btu	39.5%	2019
Baker Hughes GE	PGT25+G5	36,585 kW	9135 Btu	39.4%	2018
Siemens	SGT-A35 RB	37,400 kW	8600 Btu	39.7%	2017
Mapna	MGT-40	42,200 kW	10,597 Btu	32.2%	2017
Siemens	SGT-A45	44,000 kW	8477 Btu	40.3%	2017
GE Power	LM6000DLE	54,000 kW	8162 Btu	41.8%	2016
Siemens	SGT-800	54,000 kW	8725 Btu	39.1%	2016
GE Power	LM6000PF+ Sprint	57,000 kW	8256 Btu	41.3%	2016
GE Power	LM9000 (68)	68,000 kW	8107 Btu	42.1%	2017
GE Power	LM9000 (76)	76,000 kW	8053 Btu	42.4%	2017
Baker Hughes GE	LMS100PB+	107,025 kW	5844 Btu	43.5%	2016
Baker Hughes GE	LMS100PA+	109,550 kW	5542 Btu	44.0%	2016
Mapna	MGT-70(3)	185,000 kW	9374 Btu	36.4%	2016

Gas Turbine Builder	Model	ISO Base Load (kW)	Heat Rate Btu/kWh	Efficiency	Intro Year
GE Power	9F.04	288,000 kW	8810 Btu	38.7%	2015
Mitsubishi Hitachi	M501JAC	425,000 kW	7775 Btu	44.0%	2015
Ansaldo Energia	GT36-S6	369,000 kW	8067 Btu	42.3%	2016
Siemens	SGT6-9000HL	405,000 kW	8010 Btu	42.6%	2017
GE Power	7HA-03	430,000 kW	7884 Btu	43.3%	2019
Mitsubishi Hitachi	M701JAC	448,000 kW	7755 Btu	44.0%	2018
Siemens	SGT5-8000HL	481,000 kW	8034 Btu	42.6%	2017
Ansaldo Energia	GT36-S5	538,000 kW	7972 Btu	42.8%	2016
Siemens	SGT5-9000HL	593,000 kW	7972 Btu	42.8%	2017

GTW 2020 Ten-Year Market Forecast

CLIENTS. Sales & marketing managers and operational executives responsible for company planning and funding, consultants, investors and financial community.

FORECAST. Deals exclusively with Electric Power Utility and Oil & Gas sectors of the world market for Heavy Frame, Light Industrial and Aeroderivative gas turbine segments.

KEY PLAYERS. We track and evaluate the comparative standing of 15 Gas Turbine OEMs around the world who together accounted for more than 95% of Unit orders last year.

SCOPE. Predicted orders for these OEM suppliers are analyzed on a year-by-year basis, identified by OEM model designation and rating separately for the EPU and O&G sectors.

VARIABLES. Market activity is evaluated at three different levels: "Baseline" for business as usual subject to known market drivers and influence factors; "Upside" for better than anticipated market; "Downside" for adverse market developments.

RESEARCH. Based on interviews with management, marketing and engineering segments of the gas turbine industry plus interviews with electric utility and oil & gas company executives.

RESOURCES. Global government energy reports and statistics, in-house gas turbine project databases, energy legislation, economic and political policies, fuel availability and pricing – all in the context of competitive OEM offerings and market position.

DELIVERABLES. Packaged as two separate files. One is a PDF narrative file with detailed 5-year and 10-year forecasts of OEM unit sales and market share including key factors driving the market. The second file contains Excel spreadsheets for detailed analysis and manipulation of 10-year Baseline, Upside and Downside forecast data.

Solidly based on industry interviews, unique database, in-depth analysis

Check out our website www.gasturbineworld.com for a copy of the T of C. Or contact GTW's publisher, Victor deBiasi, at (203) 259-1912 or vdebiasi@gasturbineworld.com for more information.

Gas Turbine World

Gas Turbine Upgrades (2015-2019)

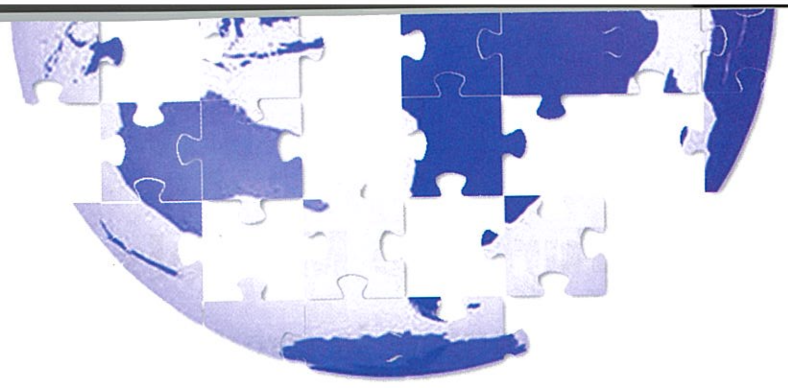
OEMs regularly offer retrofit packages with advanced engineering technology to improve performance and service life.

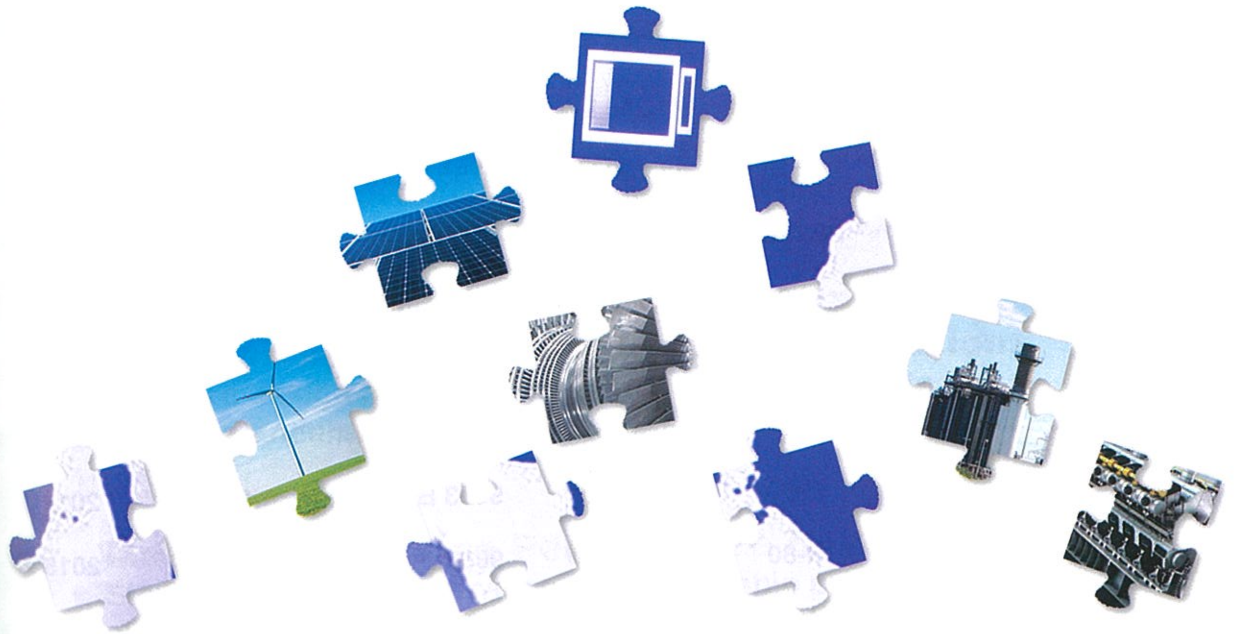
OEM & Model	New Rating	Prior Rating	Net Change	Net Benefit
Ansaldo				
AE64.3A	80.0 MW (2018) 9374 Btu/kWh	78.0 MW (2014) 9450 Btu/kWh	2.0 MW 76 Btu	2.5% higher 0.1% lower
	78.0 MW (2014) 9450 Btu/kWh	75.0 MW (1996) 9505 Btu/kWh	3.0 MW 55 Btu	4% higher 0.6% lower
AE94.2	190.0 MW (2018) 9400 Btu/kWh	185.0 MW (2014) 9426 Btu/kWh	5.0 MW 26 Btu	2.7% higher 0.3% lower
	185.0 MW (2014) 9426 Btu/kWh	170.0 MW (2011) 9825 Btu/kWh	15.0 MW 399 Btu	8.8% higher 4.1% lower
AE94.3A (2011)	340.0 MW (2018) 8467 Btu/kWh	310.0 MW (2013) 8573 Btu/kWh	30.0 MW 106 Btu	9.7% higher 1.2% lower
GT36-S6	369.0 MW (2018) 8067 Btu/kWh	340.0 MW (2016) 8322 Btu/kWh	29.0 MW 255 Btu	8.5% higher 3.1% lower
GT26	370.0 MW (2018) 8322 Btu/kWh	345.0 MW (2015) 8509 Btu/kWh	25.0 MW 187 Btu	7.3% higher 2.2% lower
GT36-S5	538.0 MW (2018) 7972 Btu/kWh	500.0 MW (2016) 8222 Btu/kWh	38.0 MW 250 Btu	7.6% higher 3% lower
Baker Hughes GE				
NovaLT12	12.6 MW (2020) 9566 Btu/kWh	12.2 MW (2014) 9566 Btu/kWh	0.4 MW 0 Btu	3.3% higher no change
NovaLT16	16.9 MW (2019) 9396 Btu/kWh	16.2 MW (1992) 9456 Btu/kWh	0.7 MW 60 Btu	4.3% higher 0.6% lower
LM9000 w .98 gen	65.7 MW (2019) 8100 Btu/kWh	63.7 MW (1992) 8100 Btu/kWh	2.0 MW 0 Btu	3.1% higher no change
Centrax				
CX501-KB5	3.95 MW (2015) 11747 Btu/kWh	3.90 MW (1992) 11747 Btu/kWh	0.05 MW 0 Btu	1.3% higher no change
CX501-KB7	5.67 MW (2019) 10631 Btu/kWh	5.34 (2015) 10631 Btu/kWh	0.33 MW 0 Btu	6.2% higher no change
	5.34 MW (2015) 10631 Btu/kWh	5.25 (1993) 10848 Btu/kWh	0.09 MW 217 Btu	1.7% higher 2.0% lower
CX300	8.6 MW (2020) 10526 Btu/kWh	8.5 (2015) 9855 Btu/kWh	0.1 MW 671 Btu	1.2% higher 6.9% higher
GE Power				
LM2500 DLE	22.4 MW (2015) 9626 Btu/kWh	21.8 MW (1981) 9345 Btu/kWh	0.6 MW 281 Btu	2.8% higher 3.0% higher
LM2500+	30.0 MW (2015) 9624 Btu/kWh	29.3 MW (1993) 9287 Btu/kWh	0.7 MW 337 Btu	2.4% higher 3.6% higher
LM2500+ DLE	31.1 MW (2015) 9169 Btu/kWh	30.0 MW (1996) 8854 Btu/kWh	1.1 MW 315 Btu	3.7% higher 3.6% higher
6B.03	44.0 MW (2015) 10180 Btu/kWh	43.0 MW (1978) 10307 Btu/kWh	1.0 MW 127 Btu	2.3% higher 1.2% lower
6F.01	57.0 MW (2017) 8880 Btu/kWh	52.0 MW (2003) 8880 Btu/kWh	5.0 MW 0 Btu	9.6% higher no change
6F.03	88.0 MW (2017) 9277 Btu/kWh	82.0 MW (2015) 9470 Btu/kWh	6.0 MW 193 Btu	7.3% higher 2.0% lower
	82.0 MW (2015) 9470 Btu/kWh	80.3 MW (2003) 9470 Btu/kWh	1.7 MW 0 Btu	2.1% higher no change
7E.03	91.0 MW (2015) 10060 Btu/kWh	88.7 MW (1984) 10192 Btu/kWh	2.3 MW 132 Btu	2.6% higher 1.3% lower
9E.03	132.0 MW (2015) 9860 Btu/kWh	128.2 MW (1992) 9980 Btu/kWh	3.8 MW 120 Btu	3.0% higher 1.2% lower
GT13E2	210.0 MW (2017) 8980 Btu/kWh	203.0 MW (2012) 8980 Btu/kWh	7.0 MW 0 Btu	3.5% higher no change
9F.03	265.0 MW (2015) 9020 Btu/kWh	261.3 MW (1996) 9146 Btu/kWh	3.7 MW 126 Btu	1.4% higher 1.4% lower
9F.04	288.0 MW (2015) 8810 Btu/kWh	281.0 MW (1996) 8830 Btu/kWh	3.7 MW 20 Btu	1.3% higher no change
9F.05	314.0 MW (2017) 8930 Btu/kWh	299.0 MW (2003) 8810 Btu/kWh	15.0 MW 120 Btu	5.0% higher 1.3% higher
7HA.02	384.0 MW (2017) 8030 Btu/kWh	372.0 MW (2014) 8020 Btu/kWh	12.0 MW 10 Btu	3.2% higher no change

OEM & Model	New Rating	Prior Rating	Net Change	Net Benefit
9HA.01	448.0 MW (2020) 7960 Btu/kWh	446.0 MW (2011) 7910 Btu/kWh	2.0 MW 50 Btu higher	0.4% higher 0.65% higher
9HA.02	571.0 MW (2017) 7740 Btu/kWh	557.0 MW (2017) 7760 Btu/kWh	14.0 MW 20 Btu	2.5% higher no change
	557.0 MW (2017) 7760 Btu/kWh	544.0 MW (2014) 7766 Btu/kWh	13.0 MW 6 Btu	2.4% higher no change
Kawasaki				
M7A-01D	5.47 MW (2015) 11550 Btu/kWh	5.40 MW (1993) 11660 Btu/kWh	0.07 MW 110 Btu	1.3% higher 0.9% lower
LS30A	34.4 MW (2018) 8460 Btu/kWh	30.1 MW (2012) 8502 Btu/kWh	4.3 MW 42 Btu	14.3% higher 0.5% lower
MAN				
MGT6100	6.63 MW (2016) 10610 Btu/kWh	6.50 MW (2012) 10660 Btu/kWh	0.13 MW 50 Btu	2.0% higher 0.5% lower
Mapna				
MGT-70(3)	185.0 MW (2018) 9374 Btu/kWh	183.0 MW (2016) 9479 Btu/kWh	2.0 MW 105 Btu	1.1% higher 1.1% lower
Mitsubishi Hitachi				
H-100 (60 Hz)	105.8 MW (2016) 8930 Btu/kWh	101.3 MW (2010) 9036 Btu/kWh	4.5 MW 106 Btu	4.4% higher 1.2% lower
M501GAC (60 Hz)	283.0 MW (2016) 8531 Btu/kWh	276.0 MW (2011) 8574 Btu/kWh	7.0 MW 43 Btu	2.5% higher 0.5% lower
M501J (60 Hz)	330.0 MW (2016) 8105 Btu/kWh	327.0 MW (2011) 8325 Btu/kWh	3.0 MW 220 Btu	0.9% higher 2.6% lower
M501JAC (60Hz)	425.0 MW (2018) 7775 Btu/kWh	400.0 MW (2017) 7775 Btu/kWh	25.0 MW 0 Btu	6.3 % higher no change
	400.0 MW (2017) 7775 Btu/kWh	370.0 MW (2016) 8010 Btu/kWh	30.0 MW 235 Btu	8.1 % higher 2.9% lower
	370.0 MW (2016) 8010 Btu/kWh	310.0 MW (2015) 8320 Btu/kWh	60.0 MW 310 Btu	19.4% higher 3.7% lower
M701J (50 Hz)	478.0 MW (2016) 8067 Btu/kWh	470.0 MW (2014) 8325 Btu/kWh	8.0 MW 258 Btu	1.7% higher 3.1% lower
M701JAC (50 Hz)	563.0 MW (2018) 7826 Btu/kWh	493.0 MW (2016) 7954 Btu/kWh	70.0 MW 128 Btu	14.2% higher 1.6% lower
	493.0 MW (2016) 7954 Btu/kWh	445.0 MW (2015) 8320 Btu/kWh	48.0 MW 366 Btu	10.8% higher 4.4% lower

OEM & Model	New Rating	Prior Rating	Net Change	Net Benefit
PW Power Systems				
FT8 MobilePac (50 Hz)	28.5 MW (2016) 9834 Btu/kWh	26.2 MW (2005) 9775 Btu/kWh	2.3 MW 59 Btu higher	8.8% higher 0.6% higher
Siemens				
SGT-A05 AE (501-KB5S)	4.0 MW (2016) 11504 Btu/kWh	3.9 MW (1993) 11747 Btu/kWh	0.1 MW 243 Btu	2.6% higher 2.1% lower
SGT-A05 AE (501-KB7S)	5.4 MW (2016) 10570 Btu/kWh	5.3 MW (1999) 10848 Btu/kWh	0.1 MW 278 Btu	1.9% higher 2.6% lower
SGT-700	32.8 MW (2015) 9170 Btu/kWh	32.2 MW (2012) 9255 Btu/kWh	0.6 MW 85 Btu	1.9% higher 0.9% lower
SGT-750	39.8 MW (2018) 8456 Btu/kWh	37.0 MW (2012) 8644 Btu/kWh	2.8 MW 188 Btu	7.6% higher 2.2% lower
SGT-800	49.9 MW (2020) 8670 Btu/kWh	47.5 MW (2010) 9048 Btu/kWh	2.4 MW 378 Btu	5.1% higher 4.2% lower
SGT-A65 DLE (60 Hz)	59.6 MW (2018) 7895 Btu/kWh	54.0 MW (2015) 8023 Btu/kWh	8.9 MW 128 Btu	16.4% higher 1.6% lower
SGT-A65 DLE (50 Hz)	61.9 MW (2018) 7874 Btu/kWh	53.0 MW (2015) 7983 Btu/kWh	8.9 MW 109 Btu	16.8% higher 1.4% lower
SGT-A65 DLE ISI (60 Hz)	64.9 MW (2018) 7877 Btu/kWh	61.8 MW (2015) 7867 Btu/kWh	3.1 MW 10 Btu higher	5.0% higher 1.3% higher
SGT-A65 DLE ISI (50 Hz)	65.9 MW (2018) 7799 Btu/kWh	64.4 MW (2017) 7772 Btu/kWh	1.5 MW 27 Btu higher	2.3% higher 0.4% higher
	64.4 MW (2017) 7772 Btu/kWh	63.5 MW (1996) 7888 Btu/kWh	0.9 MW 116 Btu	1.4% higher 1.5% lower
SGT-A65 WLE ISI (50 Hz)	76.5 MW (2018) 8198 Btu/kWh	67.4 MW (2018) 8269 Btu/kWh	9.1 MW 71 Btu	13.5% higher 0.9% lower
	67.4 MW (2018) 8269 Btu/kWh	66.0 MW (2015) 8217 Btu/kWh	1.4 MW 48 Btu higher	21.2 % higher 0.6% higher
SGT-A65 DLE ISI (50 Hz)	70.8 MW (2018) 8242 Btu/kWh	65.7 MW (2015) 8303 Btu/kWh	1.5 MW 61 Btu	2.3% higher 0.7% lower
SGT6-2000E	117.0 MW (2016) 9705 Btu/kWh	114.0 MW (1981) 9949 Btu/kWh	3.0 MW 244 Btu	2.6% higher 2.5% lower
SGT5-2000E	187.0 MW (2016) 9426 Btu/kWh	172.0 MW (1989) 9659 Btu/kWh	15.0 MW 233 Btu	8.7% higher 2.4% lower

OEM & Model	New Rating	Prior Rating	Net Change	Net Benefit
SGT6-5000F	260.0 MW (2018) 8530 Btu/kWh	250.0 MW (2016) 8682 Btu/kWh	10.0 MW 152 Btu	4.0% higher 1.8% lower
	250.0 MW (2016) 8682 Btu/kWh	242.0 MW (2015) 8749 Btu/kWh	8.0 MW 67 Btu	3.3% higher 0.8% lower
	242.0 MW (2015) 8749 Btu/kWh	232.0 MW (2013) 8794 Btu/kWh	10.0 MW 45 Btu	4.3% higher 0.5% lower
SGT6-8000H	310.0 MW (2016) 8530 Btu/kWh	305.0 MW (2015) 8530 Btu/kWh	5.0 MW 0 Btu	1.6% higher no change
	305.0 MW (2015) 8530 Btu/kWh	296.0 MW (2014) 8530 Btu/kWh	9.0 MW 0 Btu	3.0% higher no change
	296.0 MW (2014) 8530 Btu/kWh	274.0 MW (2010) 8530 Btu/kWh	22.0 MW 0 Btu	8.0% higher no change
SGT6-9000HL	405.0 MW (2018) 8010 Btu/kWh	386.0 MW (2017) 8123 Btu/kWh	19.0 MW 113 Btu	4.9% higher 1.4% lower
SGT5-4000F	329.0 MW (2016) 8385 Btu/kWh	307.0 MW (2015) 8532 Btu/kWh	22.0 MW 147 Btu	7.2% higher 1.7% lower
	307.0 MW (2015) 8532 Btu/kWh	295.0 MW (2013) 8581 Btu/kWh	12.0 MW 71 Btu	4.1% higher 0.8% lower
SGT5-8000H	450.0 MW (2018) 8322 Btu/kWh	420.0 MW (2016) 8530 Btu/kWh	30.0 MW 208 Btu	7.1% higher 2.4% lower
	420.0 MW (2016) 8530 Btu/kWh	400.0 MW (2015) 8530 Btu/kWh	20.0 MW 0 Btu	5.0% higher no change
	400.0 MW (2015) 8530 Btu/kWh	375.0 MW (2008) 8530 Btu/kWh	25.0 MW 0 Btu	6.7% higher no change
SGT5-8000HL	481.0 MW (2018) 8034 Btu/kWh	465.0 MW (2017) 8123 Btu/kWh	16.0 MW 189 Btu	3.4% higher 2.3% lower
SGT5-9000HL	593.0 MW (2018) 7972 Btu/kWh	564.0 MW (2017) 8123 Btu/kWh	30.0 MW 151 Btu	5.3% higher 1.9% lower
Solar Titan 130	16.5 MW (2016) 9605 Btu/kWh	15.0 MW (1998) 9695 Btu/kWh	1.5 MW 90 Btu	10.0% higher 0.9% lower





Retired Gas Turbine Models (2015-2019)

Discontinued units no longer in production are sometimes available on special order from the OEM or licensed supplier.

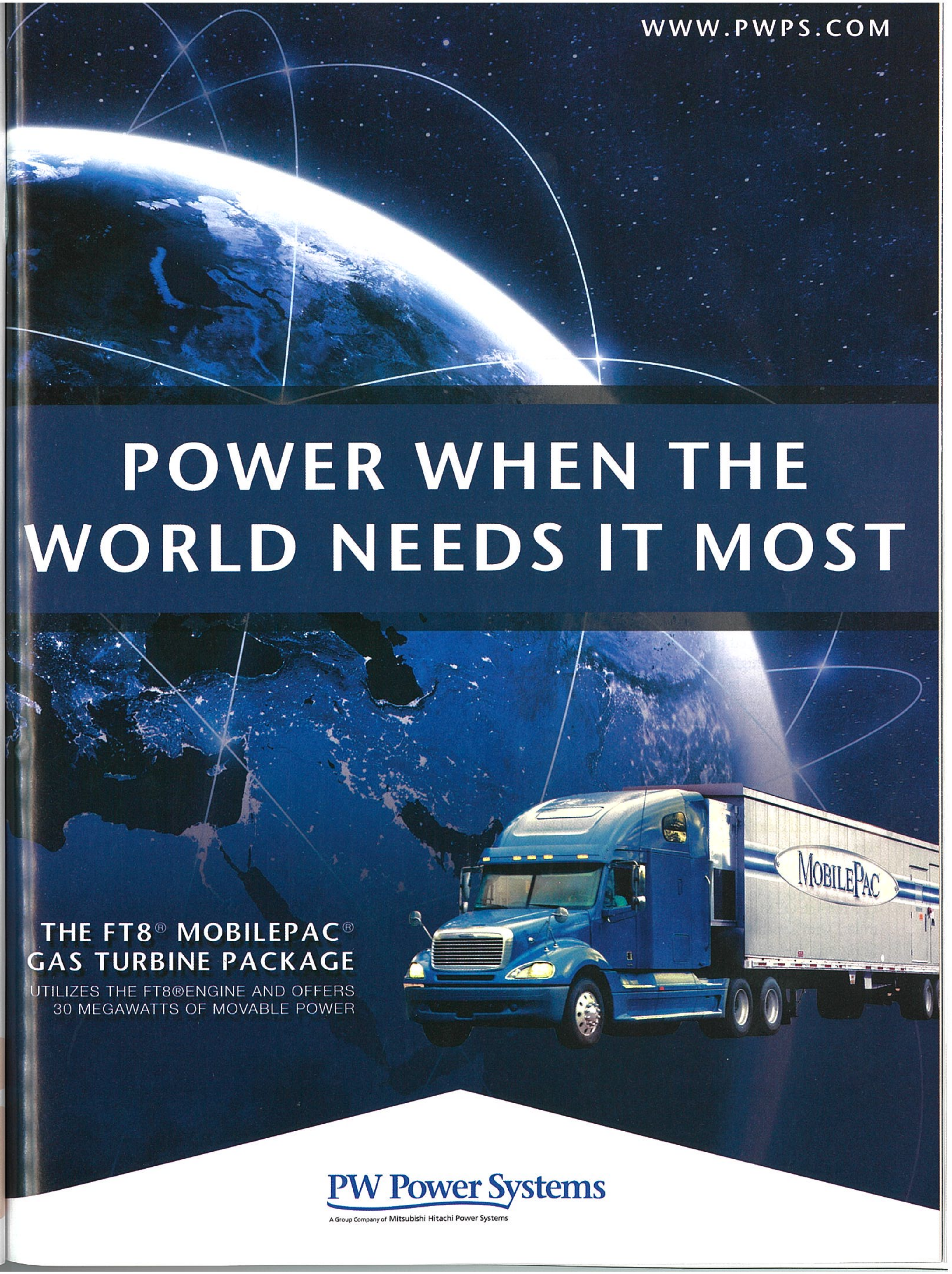
Gas Turbine Builder	Model	ISO Base Load (kW)	Heat Rate Btu/kWh	Intro Year	Retired Year
Centrax	CXRB211	32,130 kW	8681 Btu/kWh	2010	2015
GE Aero	LM2500PK/PR	29,316 kW	9287 Btu/kWh	1995	2015
GE Oil & Gas	GE10-1	11,250 kW	10,867 Btu/kWh	2000	2019
GE Oil & Gas	PGT16	13,720 kW	9758 Btu/kWh	1989	2015
GE Oil & Gas	PGT20	17,464 kW	9704 Btu/kWh	2000	2019
GE Power	9f.06	342,000 kW	8310 Btu/kWh	2016	2018
Mapna	MGT-70(2)	172,000 kW	9862 Btu/kWh	2013	2018
MHPS	H-15	16,900 kW	9950 Btu/kWh	1990	2015
MHPS	H-50	57,450 kW	9013 Btu/kWh	2015	2018
MHPS	H-80	110,610 kW	9080 Btu/kWh	2010	2015
Rolls-Royce	RB211-H63	42,473 kW	8679 Btu/kWh	2010	2015
Siemens	SGT-A05 AE (Ind 501-KH5)	6,620 kW	7954 Btu/kWh	1985	2019
Siemens	SGT-900	49,500 kW	10,450 Btu/kWh	1982	2015

Section 3

Gas Turbine Design Ratings

Simple Cycle GTW Design Ratings

Refer to "rule-of-thumb" editorial box on page 34 for adjustment factors that will enable you to estimate gas turbine design ratings at non-ISO operating and site conditions.



Simple Cycle Rating Parameters

ISO standard ratings with correction factors to adjust for actual site and operating conditions.

GTW Simple Cycle design ratings provide access to updated OEM gas turbine performance data in a consistent format that enables evaluation and comparison of competitively sized units on an apples-to-apples basis.

Conditions

Performance ratings are quoted for base load operation at ISO standard site conditions: 59°F ambient air (15°C) temperature, 14.7 psia (1.015 bar) sea level site elevation, 60% relative humidity.

Unless otherwise stated, ratings are for natural gas fuel and gross power output excluding deductions for inlet and exhaust losses, and power consumed by auxiliaries.

Net ratings include deducts typical of standard packaged plants, covering inlet losses for high-efficiency filter and ducting (~ 4 in. H_2O), exhaust losses for stack and silencer (~ 5 in. H_2O) and power consumed by mechanical and electrical auxiliary systems. (See editorial box for "Rule of Thumb" adjustment factors.)

In either case, all ratings are for "factory new and clean" equipment, having less than 200 hours of operation.

Adjusting ISO ratings to match site and operating conditions

Rule of thumb factors for adjusting ISO-based ratings to estimate actual performance at non-ISO site and operating conditions:

■ **Ambient temperature.** Expect about a 0.4% reduction in power output plus 0.1% increase in heat rate for each 1°F (0.56°C) rise in ambient temperature above 59°F (15°C).The reverse holds true below 59°F ambient temperature.

■ **Site elevation.** For each 1,000-ft increase in site elevation above sea level, there is about a 3.5% loss in power output. The effect is minimal on heat rate.

■ **Inlet losses.** For each inch H_2O of added inlet pressure drop, figure on about a 0.4% reduction in power output and 0.1% increase in heat rate.

■ **Outlet losses.** For each inch H_2O of added outlet or exhaust pressure drop, you can expect a 0.1% reduction in power output and 0.1% increase in heat rate.

■ **Fuel type.** Figure on around 2-3% less power and 1-2% higher heat rate when burning distillate fuel as compared to natural gas. Check with OEM on any derating for out-of-spec fuels.

■ **Overall plant.** Figure on reduction in gross power output of about 2-3% and 1% increase in heat rate due to common operating losses including inlet and exhaust system pressure drops and parasitic loads associated with mechanical and electrical auxiliaries.

Format

Gas turbine OEMs appear in alphabetic order, with separate groups for 50Hz, 60Hz and 50/60 Hz power generation. Within each group, models are listed in ascending order by power rating.

For comparative evaluation purposes, the rating parameters are the same for all OEM listings (see column headings):

- **Model**. A number or alphabetic letter ending the model designation denotes an evolutionary upgrade.

- **Year.** Year original gas turbine series was (or will be) commercially introduced.

- **ISO base load.** Gross power output (kW) at ISO standard site conditions, rated for base load operation, i.e., over 6,000 hours per year with normal service and maintenance intervals.

- **Heat rate.** Lower heating value (LHV) of natural gas fuel unless otherwise stated.

- **Efficiency.** Percentage of 'energy-out" to "energy-in" at base load output, calculated as 3412 Btu/kWh divided by LHV heat rate.

- **Pressure ratio.** Turbine compressor discharge divided by inlet pressure. High pressure ratio is characteristic of high efficiency design.

- **Mass Flow.** Compressor flow plus combustion gas flow at base load output, without water or steam injection.

- **Turbine speed.** Power turbine out-

put shaft rotating speed, generally specified at 3000/3600 rpm for 50/60 Hz direct drive power generation or 1500/1800 rpm and higher rpm into speed reduction gearbox.

- **Exhaust temperature.** Hot gas flow leaving the gas turbine outlet duct at base load output.

Engineering design ratings are based on 'new and clean' performance, typically confirmed by full-load factory testing before shipment for smaller units and by field testing shortly after commissioning for larger units.

OEMs typically place a contractual limit on fired hours before field verification testing in the field, and on calendar time after delivery. If testing is not completed within the specified time limits, it is deemed to have been completed, and contractual requirements met.

Degradation

All gas turbines experience degradation in power output and efficiency during their operating lifetimes. To a limited extent most of those losses are recoverable.

Compressor fouling is a common cause of fall-off in performance. Partial recovery can be achieved by online water washing at regular intervals, and supplemented by various mechanical cleaning methods during shutdowns.

Recovery of degradation due to normal wear and tear calls for component repair or replacement during minor and major maintenance outages.

Typically, power and heat rate will degrade by 2-6% points during the first 24,000 to 30,000 hours of operation (routine interval for a hot gas path inspection).

Replacing worn parts normally will restore performance to within 1 to 1.5% points of original factory-new levels.

Many OEMs offer retrofitting gas turbines during overhaul shutdowns with improved technology components that will increase power and efficiency, "beating the degradation curve".

Due diligence

Remember that published design ratings are subject to change as the result of engineering upgrades and design modifications, often without OEM notification.

Considering that the specs data have been recently updated, our Handbook ratings are well suited for preliminary planning studies and gas turbine performance evaluation.

But as projects develop, and more detailed studies become necessary, it is imperative to confirm those ratings with gas turbine OEMs before making any firm engineering or approval decisions.

This is also the time to inquire about potential near-term upgrades in the works or pending new gas turbine ready for introduction that might better fit project requirements and still meet your project timetable.

Gas turbine OEM sales and marketing engineers are adept at optimizing off-design performance of their machines that can be tailored to satisfy special environmental permit and/or operating requirements.

You are encouraged to inform our editors if any ratings listed here appear to be questionable. We'll check it out with the OEM and alert our readers to any corrections.

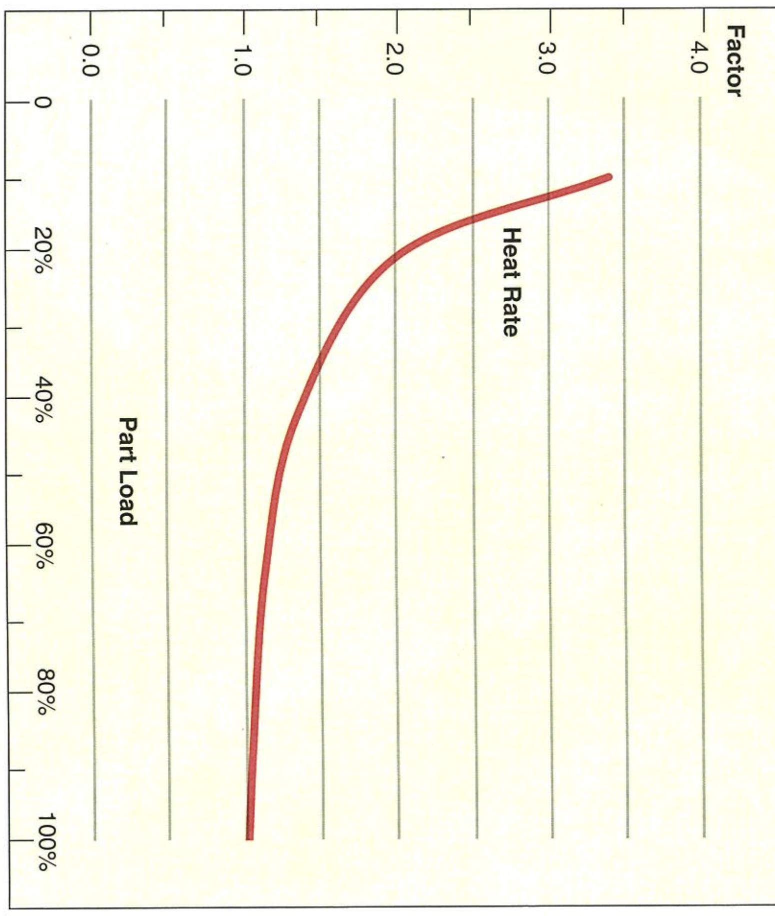
Adjusting for part load

OEM ratings for base load (i.e. continuous full load) performance do not reflect *effective performance* of the gas turbine since gensets typically spend considerable time at part load.

Includes time spent at specified part-load "hold" settings, as might be required by system dispatch operators, as well as time at part load during normal startup and shutdown operations.

To determine actual fuel consumption and operating economics during typical real-world field operation, you must know the *effective heat rate*. ■

Effective heat rate. To estimate effective heat rate at part load (to determine fuel consumption) multiply percent load by the adjustment factor to obtain percent of full load fuel consumption.



2020 GTW Simple Cycle Specs

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Ansaldo Energia											
AE-T100	2000	100 kW	11 374 Btu	30.0%	4.5	1.8 lb	70000 rpm	518 F	6 100 lb	13 x 3 x 6 ft	
AE64.3A	1996	80 000 kW	9 374 Btu	36.4%	18.3	474.0 lb	3000/3600	1076 F	134 000 lb	19 x 10 x 10 ft	includes gearbox (90 Hz GT)
AE94.2	1981	190 000 kW	9 400 Btu	36.3%	12.0	1224.0 lb	3000 rpm	1022 F	522 000 lb	33 x 13 x 12 ft	
AE94.2K	1981	170 000 kW	9 348 Btu	36.5%	12.0	1190.0 lb	3000 rpm	1013 F	538 000 lb	33 x 13 x 12 ft	low LHV fuel
AE94.3A	1995	340 000 kW	8 467 Btu	40.3%	19.5	1664.0 lb	3000 rpm	1099 F	698 000 lb	35 x 17 x 16 ft	
GT26	2011	370 000 kW	8 322 Btu	41.0%	35.0	1634.0 lb	3000 rpm	1157 F	904 000 lb	41 x 16 x 18 ft	with gas compressor
GT36-S6	2016	369 000 kW	8 067 Btu	42.3%	24.0	1565.3 lb	3600 rpm	1166 F	791 000 lb	37 x 16 x 19 ft	weight & size for transport
GT36-S5	2016	538 000 kW	7 972 Btu	42.8%	26.0	2248.7 lb	3000 rpm	1150 F	1 272 000 lb	44 x 19 x 22 ft	weight & size for transport
	Note: ISO conditions: 100% CH4 natural gas fuel: all weights include auxiliaries										
Baker Hughes GE (50/60 Hz Aero)											
NovaLT5-1	2015	5 600 Kw	11 127 Btu	30.7%	14.8	43.2 lb	16630 rpm	1065 F	63 900 lb	20 x 8 x 10 ft	DLE 25ppm Nox
NovaLT12	2014	12 553 kW	9 566 Btu	35.4%	19.0	93.2 lb	8900 rpm	905 F	92 594 lb	25 x 8 x 13 ft	DLN 15ppm Nox
NovaLT16	2014	16 922 kW	9 396 Btu	36.4%	19.3	120.4 lb	7800 rpm	899 F	110 230 lb	33 x 12 x 13 ft	DLN 25ppm Nox
PGT25	1981	22 417 kW	9 401 Btu	36.3%	17.9	151.9 lb	6500 rpm	976 F	83 005 lb	30 x 11 x 11 ft	
PGT25+	1996	30 226 kW	8 610 Btu	39.6%	21.5	185.8 lb	6100 rpm	932 F	67 790 lb	21 x 12 x 13 ft	
PGT25+G4	2005	33 057 kW	8 605 Btu	39.7%	23.2	197.7 lb	6100 rpm	950 F	68 010 lb	21 x 12 x 13 ft	
PGT25+G5	2018	36 585 kW	9 135 Btu	39.4%	24.9	203.9 lb	6100 rpm	1022 F	68 010 lb	21 x 12 x 13 ft	
LM6000PD	1997	43 069 kW	8 173 Btu	41.7%	28.0	275.0 lb	3600 rpm	851 F	68 345 lb	31 x 14 x 14 ft	DLE 25 ppm Nox
LM6000PF	2006	43 069 kW	8 173 Btu	41.7%	28.0	275.0 lb	3600 rpm	851 F	68 345 lb	31 x 14 x 14 ft	DLE 15 ppm Nox
LM6000PG	2008	51 204 kW	8 142 Btu	41.9%	30.0	317.3 lb	3911 rpm	878 F	65 645 lb	32 x 15 x 15 ft	standard combustor
LM6000PF+	2017	52 671 kW	8 173 Btu	41.7%	32.0	319.0 lb	3911 rpm	890 F	65 645 lb	32 x 15 x 15 ft	DLE 25 ppm Nox
LM9000 w/ .98 gen	2017	65 660 kW	8 100 Btu	42.1%	33.0	395.0 lb	3000/3600	850 F	81 079 lb	45 x 16 x 15 ft	DLE 15 ppm Nox
LMS100PA+	2016	109 550 kW	5 542 Btu	44.0%	42.2	496.0 lb	3600 rpm	782 F	209 000 lb	59 x 15 x 15 ft	standard combustor
LMS100PB+	2016	107 025 kW	5 844 Btu	43.5%	42.4	493.0 lb	3600 rpm	790 F	201 000 lb	59 x 15 x 15 ft	DLE 25 ppm Nox

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Baker Hughes GE (50/60 Hz Frame)											
MS5001	1987	26 830 kW	12 025 Btu	28.4%	10.5	276.1 lb	5094 rpm	901 F	192 750 lb	38 x 11 x 12 ft	MS heavy frame series
MS5002E	2003	32 800 kW	9 517 Btu	35.8%	17.4	226.0 lb	1500-1800	964 F	257 940 lb	56 x 11 x 13 ft	DLN-2
MS6001B	1978	42 100 kW	10 644 Btu	32.1%	12.2	311.0 lb	5163 rpm	1016 F	211 645 lb	52 x 11 x 12 ft	
MS7001EA	1984	85 400 kW	10 417 Btu	32.7%	12.7	652.5 lb	3600 rpm	995 F	266 760 lb	38 x 11 x 12 ft	60 Hz
MS9001E	1976	126 100 kW	10 094 Btu	33.8%	12.7	921.0 lb	3000 rpm	1004 F	479 505 lb	73 x 15 x 21 ft	50 Hz
	Note: All BHGE units with standard combustor; weights and sizes without enclosure										
Bharat Heavy Electricals											
MS5001PA	1988	26 500 kW	11 886 Btu	28.7%	10.5	273.7 lb	5094 rpm	905 F	185 220 lb	38 x 11 x 12 ft	standard combustor
MS6001B(6B.03)	2000	44 000 kW	10 180 Btu	33.5%	12.7	320.0 lb	5163 rpm	1019 F	220 450 lb	49 x 11 x 12 ft	standard combustor
6F.01	2003	54 000 kW	8 880 Btu	38.4%	21.4	****	7266 rpm	1117 F	154 350 lb	32 x 16 x 15 ft	DLN combustor
MS6001FA(6F.03)	2003	82 000 kW	9 420 Btu	36.2%	16.4	****	5231 rpm	1123 F	220 500 lb	32 x 16 x 15 ft	DLN combustor
MS9001E(9E.03)	2012	132 000 kW	9 860 Btu	34.6%	13.1	924.0 lb	3000 rpm	1012 F	471 800 lb	46 x 41 x 28 ft	standard combustor
MS9001E(9E.04)	1976	145 000 kW	9 210 Btu	37.0%	12.3	916.0 lb	3000 rpm	1007 F	482 896 lb	32 x 16 x 15 ft	DLN combustor
MS9001FA(9F.03)	1976	265 000 kW	9 020 Btu	37.8%	16.7	1466.0 lb	3000 rpm	1104 F	679 850 lb	46 x 41 x 28 ft	standard combustor
MS9001FA(9F.04)	1996	287 000 kW	8 810 Btu	38.7%	16.9	****	3000 rpm	1151 F	679 850 lb	74 x 16 x 18 ft	DLN combustor
MS9001FB(9F.05)	2004	314 000 kW	8 930 Btu	38.2%	18.3	****	3000 rpm	1184 F	709 100 lb	74 x 16 x 18 ft	DLN combustor
9HA.01	****	446 000 kW	7 910 Btu	43.1%	23.5	****	3000 rpm	1164 F	694 400 lb	74 x 16 x 18 ft	DLN combustor
9HA.02	****	544 000 kW	7 766 Btu	43.9%	23.8	****	3000 rpm	1177 F	716 800 lb	74 x 16 x 18 ft	DLN combustor
Capstone Turbine											
C30	1998	30 kW	13 100 Btu	26.0%	3.6	0.7 lb	96000 rpm	530 F	891 lb	5 x 3 x 6 ft	all grid parallel with
C65	2000	65 kW	11 800 Btu	29.0%	4.0	1.1 lb	96000 rpm	588 F	1 671 lb	6 x 3 x 7 ft	other configs available
C200S	2017	200 kW	10 300 Btu	33.0%	4.0	2.9 lb	61000 rpm	535 F	11 400 lb	8 x 10 x 10 ft	
C600S	2015	600 kW	10 300 Btu	33.0%	4.0	8.8 lb	61000 rpm	535 F	24 800 lb	19 x 10 x 10 ft	
C800S	2015	800 kW	10 300 Btu	33.0%	4.0	11.7 lb	61000 rpm	535 F	31 100 lb	25 x 10 x 10 ft	
C1000S	2015	1 000 kW	10 300 Btu	33.0%	4.0	14.7 lb	61000 rpm	535 F	37 700 lb	30 x 10 x 10 ft	
Centrax Gas Turbine											
CX501-KB5	1992	3 947 kW	11 747 Btu	29.1%	10.3	34.8 lb	14571 rpm	1031 F	85 980 lb	30 x 9 x 10 ft	Siemens SGT-A05 4 MW
CX501-KB7	1993	5 670 kW	10 631 Btu	32.4%	13.9	46.6 lb	15741 rpm	923 F	85 980 lb	30 x 9 x 10 ft	Siemens SGT-A05 6 MW
CX300 (7.9 MW)	2011	7 900 kW	10 973 Btu	31.0%	13.8	66.6 lb	14010 rpm	997 F	126 000 lb	40 x 8 x 12 ft	Siemens SGT-300 7.9 MW
CX300 (8.6 MW)	2015	8 600 kW	10 526 Btu	34.2%	13.8	66.8 lb	11500 rpm	940 F	165 000 lb	61 x 9 x 13 ft	Siemens SGT-300 8.6 MW

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Centrax Gas Turbine (cont'd)											
CX400 (10.1 MW)	2011	10 100 kW	10 831 Btu	34.5%	15.5	73.6 lb	11500 rpm	966 F	165 000 lb	61 x 9 x 13 ft	Siemens SGT-400 10.1 MW
CX400 (12.9 MW)	2011	12 900 kW	9 815 Btu	34.8%	16.8	86.9 lb	9500 rpm	1031 F	165 000 lb	61 x 9 x 13 ft	Siemens SGT-400 12.9 MW
CX400 (14.32 MW)	2012	14 320 kW	9 647 Btu	35.4%	18.9	97.0 lb	9500 rpm	1004 F	165 000 lb	61 x 9 x 13 ft	Siemens SGT-400 14.3 MW
EthosEnergy											
TG20B7/8UG	2014	45 400 kW	10 843 Btu	31.5%	11.5	369.0 lb	4918 rpm	989 F	176 320 lb	22 x 10 x 10 ft	50/60 Hz
TG50D5U	2007	144 500 kW	9 850 Btu	34.6%	14.8	1063.0 lb	3000 rpm	951 F	433 429 lb	36 x 13 x 13 ft	50 Hz
GE Power Frame (50/60 Hz)											
6B.03	1978	44 000 kW	10 180 Btu	33.5%	12.7	319.7 lb	5163 rpm	1023 F	220 450 lb	41 x 13 x 13 ft	
6F.01	2003	57 000 kW	8 880 Btu	38.4%	21.4	291.4 lb	7266 rpm	1152 F	154 350 lb	21 x 14 x 14 ft	
6F.03	2003	88 000 kW	9 277 Btu	36.8%	16.4	482.4 lb	5231 rpm	1151 F	220 500 lb	33 x 12 x 15 ft	
GE Power Frame (50 Hz)											
9E.03	1992	132 000 kW	9 860 Btu	34.6%	13.1	924.4 lb	3000 rpm	1012 F	471 800 lb	37 x 17 x 17 ft	
9E.04	2014	145 000 kW	9 210 Btu	37.0%	13.3	917.1 lb	3000 rpm	1007 F	482 896 lb	37 x 17 x 17 ft	
GT13E2	2012	210 000 kW	8 980 Btu	38.0%	18.2	1370.4 lb	3000 rpm	959 F	772 000 lb	36 x 18 x 18 ft	
9F.03	1996	265 000 kW	9 020 Btu	37.8%	16.7	1466.2 lb	3000 rpm	1104 F	679 850 lb	35 x 15 x 16 ft	
9F.04	2015	288 000 kW	8 810 Btu	38.7%	16.9	1459.0 lb	3000 rpm	1150 F	679 850 lb	35 x 15 x 16 ft	
9F.05	2003	314 000 kW	8 846 Btu	38.6%	18.3	1572.7 lb	3000 rpm	1170 F	709 100 lb	35 x 16 x 16 ft	
9HA.01	2011	448 000 kW	7 960 Btu	42.9%	22.8	1869.0 lb	3000 rpm	1199 F	851 550 lb	35 x 16 x 16 ft	
9HA.02	2014	571 000 kW	7 740 Btu	44.0%	23.8	2292.5 lb	3000 rpm	1184 F	951 800 lb	35 x 16 x 16 ft	
GE Power Frame (60 Hz)											
7E.03	1984	91 000 kW	10 060 Btu	33.9%	13.0	650.4 lb	3600 rpm	1026 F	293 000 lb	38 x 12 x 12 ft	
7F.04	2009	198 000 kW	8 840 Btu	38.6%	16.7	1013.2 lb	3600 rpm	1151 F	392 000 lb	28 x 13 x 13 ft	
7F.05	2009	239 000 kW	9 019 Btu	37.8%	19.2	1189.0 lb	3600 rpm	1212 F	443 400 lb	28 x 13 x 13 ft	
7HA.01	2012	290 000 kW	8 120 Btu	42.0%	21.6	1293.7 lb	3600 rpm	1158 F	547 000 lb	30 x 13 x 14 ft	
7HA.02	2014	384 000 kW	8 009 Btu	42.6%	23.1	1609.4 lb	3600 rpm	1202 F	602 000 lb	32 x 13 x 14 ft	
7HA.03	2019	430 000 kW	7 884 Btu	43.3%	23.7	1718.0 lb	3600 rpm	1217 F	645 000 lb	34 x 14 x 15 ft	
	Note: All GE Frame models with inlet loss, exhaust loss and shaft driven auxiliaries losses										
GE Power Aero (50/60 Hz)											
LM6000 SAC PC	1997	46 000 kW	8 458 Btu	40.3%	29.6	284.4 lb	3600 rpm	824 F	104 500 lb	30 x 14 x 15 ft	w/ water inj, w/ gearbox in 50Hz
LM6000 SAC PC Sprint	1998	52 000 kW	8 458 Btu	40.3%	29.6	296.0 lb	3600 rpm	853 F	104 500 lb	30 x 14 x 15 ft	w/ water inj, w/ gearbox in 50Hz
LM6000 SAC PG	2009	56 500 kW	8 524 Btu	40.0%	33.5	315.9 lb	3900 rpm	879 F	104 500 lb	30 x 14 x 15 ft	w/ water injection, with gearbox
LM6000 SAC PG Sprint	2009	59 000 kW	8 524 Btu	40.0%	33.5	318.2 lb	3900 rpm	896 F	104 500 lb	30 x 14 x 15 ft	w/ water injection, with gearbox

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
GE Power Aero (50/60 Hz) (cont'd)											
LM6000 DLE PF	1997	45 000 kW	8 097 Btu	42.1%	29.8	277.0 lb	3600 rpm	861 F	104 500 lb	30 x 14 x 15 ft	with gearbox in 50Hz
LM6000 DLE PF Sprint	2006	50 000 kW	8 097 Btu	42.1%	29.8	292.4 lb	3600 rpm	864 F	104 500 lb	30 x 14 x 15 ft	w/ water inj, w/ gearbox in 50Hz
LM6000 DLE PF+	2016	54 000 kW	8 162 Btu	41.8%	33.5	307.3 lb	3900 rpm	927 F	104 500 lb	30 x 14 x 15 ft	with gearbox
LM6000 DLE PF+ Sprint	2016	59 000 kW	8 162 Btu	41.8%	33.5	329.6 lb	3900 rpm	908 F	104 500 lb	30 x 14 x 15 ft	w/ water injection, w/ gearbox
	Note: All GE Aero 50/60 Hz models without inlet conditioning										
GE Power Aero (50 Hz)											
TM2500	****	34 300 kW	9 665 Btu	35.3%	24.5	214.4 lb	3000 rpm	963 F	81 600 lb	54 x 11 x 13 ft	with water injection
LM2500	1981	23 800 kW	10 053 Btu	33.9%	19.0	157.2 lb	3000 rpm	986 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500 DLE	1981	22 400 kW	9 626 Btu	35.4%	18.1	150.9 lb	3000 rpm	1017 F	88 000 lb	16 x 11 x 11 ft	
LM2500+	1995	30 000 kW	9 624 Btu	35.5%	23.1	197.3 lb	3000 rpm	920 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500+ DLE	1995	31 100 kW	9 169 Btu	37.2%	23.6	195.8 lb	3000 rpm	1003 F	88 000 lb	16 x 11 x 11 ft	
LM2500+ G4	2005	34 500 kW	9 676 Btu	35.3%	24.6	212.9 lb	3600 rpm	966 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500+ G4 DLE	2005	33 400 kW	9 166 Btu	37.2%	24.0	205.1 lb	3600 rpm	1026 F	88 000 lb	16 x 11 x 11 ft	
LM2500XPRESS	2020	34 100 kW	8 703 Btu	39.2%	24.7	201.8 lb	3000 rpm	992 F	88 000 lb	16 x 11 x 11 ft	
LM9000 Low NOx	2017	68 000 kW	8 107 Btu	42.1%	33.5	410.5 lb	3000 rpm	880 F	150 000 lb	52 x 14 x 15 ft	
LM9000 Sprint	2017	76 000 kW	8 053 Btu	42.4%	34.0	446.3 lb	3000 rpm	880 F	150 000 lb	52 x 14 x 15 ft	
LMS100 PA	2005	116 100 kW	7 787 Btu	43.8%	44.4	519.7 lb	3000 rpm	782 F	449 000 lb	60 x 51 x 22 ft	with water injection
LMS100 PB	2013	109 600 kW	7 741 Btu	44.1%	44.2	510.6 lb	3000 rpm	787 F	449 000 lb	60 x 51 x 22 ft	
	Note: All GE Aero 50 Hz models without inlet conditioning										
GE Power Aero (60 Hz)											
TM2500	****	37 100 kW	9 171 Btu	37.2%	24.7	214.3 lb	3600 rpm	950 F	81 600 lb	54 x 11 x 13 ft	with water injection
LM2500	1981	24 800 kW	9 729 Btu	35.1%	19.0	156.9 lb	3600 rpm	977 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500 DLE	1981	23 200 kW	9 317 Btu	36.6%	18.0	150.3 lb	3600 rpm	1002 F	88 000 lb	16 x 11 x 11 ft	
LM2500+	1995	31 800 kW	9 252 Btu	36.9%	23.1	196.9 lb	3600 rpm	914 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500+ DLE	1995	31 900 kW	8 785 Btu	38.8%	23.1	192.9 lb	3600 rpm	978 F	88 000 lb	16 x 11 x 11 ft	
LM2500+ G4	2005	37 100 kW	9 171 Btu	37.2%	24.7	212.8 lb	3600 rpm	950 F	88 000 lb	16 x 11 x 11 ft	with water injection
LM2500+ G4 DLE	2005	34 500 kW	8 709 Btu	39.2%	23.6	201.7 lb	3600 rpm	995 F	88 000 lb	16 x 11 x 11 ft	
LM2500XPRESS	2020	34 300 kW	8 628 Btu	39.5%	24.6	201.1 lb	3600 rpm	985 F	88 000 lb	16 x 11 x 11 ft	

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
GE Power Aero (60 Hz) (cont'd)											
LM9000 Low NOx	2017	68 000 kW	8 107 Btu	42.1%	33.5	410.5 lb	3600 rpm	880 F	150 000 lb	52 x 14 x 15 ft	
LM9000 Sprint	2017	76 000 kW	8 053 Btu	42.4%	34.0	446.3 lb	3600 rpm	880 F	150 000 lb	52 x 14 x 15 ft	
LMS100 PA	2005	119 100 kW	7 635 Btu	44.7%	44.3	518.8 lb	3600 rpm	770 F	449 000 lb	60 x 51 x 22 ft	with water injection
LMS100 PB	2013	110 300 kW	7 703 Btu	44.3%	44.0	509.3 lb	3600 rpm	780 F	449 000 lb	60 x 51 x 22 ft	
Hitachi Zosen											
GT10	2006	4 130 kW	11 582 Btu	29.5%	10.4	34.3 lb	14200 rpm	1050 F	1 270 lb	7 x 3 x 3 ft	501-KB5S, steam injection
GT13	2006	5 600 kW	10 646 Btu	32.1%	14.3	47.0 lb	14600 rpm	940 F	1 691 lb	9 x 4 x 3 ft	501-KB7S, steam injection
VHP6	2006	6 260 kW	8 847 Btu	38.6%	12.5	40.0 lb	14600 rpm	991 F	1 270 lb	8 x 3 x 3 ft	501-KH5, gas fuel
IHI Power Systems (50/60 Hz)											
IM270	1996	2 000 kW	13 880 Btu	24.6%	12.2	21.3 lb	20300 rpm	1013 F	4 409 lb	8 x 3 x 3 ft	dry low NOx
LM2500RB	2006	31 970 kW	8 720 Btu	39.2%	23.0	193.9 lb	6100 rpm	958 F	31 228 lb	19 x 8 x 9 ft	
LM6000PG	2009	54 621 kW	8 365 Btu	40.8%	35.0	315.9 lb	3930 rpm	871 F	16 240 lb	16 x 7 x 7 ft	
LM6000PG Sprint	2009	55 985 kW	8 490 Btu	40.2%	35.0	321.8 lb	3930 rpm	876 F	16 240 lb	16 x 7 x 7 ft	
LM6000PF+	2016	51 430 kW	8 182 Btu	41.7%	32.9	300.0 lb	3930 rpm	917 F	****	****	
LM6000PF+ Sprint	2016	55 240 kW	8 241 Btu	41.4%	32.9	318.7 lb	3930 rpm	892 F	****	****	
IHI Power Systems (50 Hz)											
LM2500PE	1976	21 900 kW	10 290 Btu	33.2%	20.0	154.3 lb	3000 rpm	986 F	7 815 lb	15 x 6 x 6 ft	
LM2500PR	1981	29 642 kW	9 281 Btu	36.8%	23.0	195.1 lb	3000 rpm	982 F	****	****	
LM2500RD	2005	32 612 kW	8 916 Btu	38.3%	23.0	203.7 lb	3000 rpm	1009 F	****	****	
LM2500RC	2005	35 788 kW	9 203 Btu	37.1%	23.0	212.2 lb	3000 rpm	981 F	****	****	
LM6000PC	1997	43 367 kW	8 516 Btu	40.1%	30.0	282.0 lb	3000 rpm	821 F	15 498 lb	16 x 7 x 7 ft	
LM6000PC Sprint	1997	48 718 kW	8 477 Btu	40.3%	30.0	293.4 lb	3000 rpm	839 F	15 498 lb	16 x 7 x 7 ft	
LM6000PF	2006	42 547 kW	8 273 Btu	41.2%	31.0	274.8 lb	3000 rpm	851 F	19 158 lb	16 x 7 x 7 ft	DLE
LM6000PF Sprint	2006	47 482 kW	8 256 Btu	41.3%	31.0	290.8 lb	3000 rpm	846 F	19 158 lb	16 x 7 x 7 ft	DLE
IHI Power Systems (60 Hz)											
LM2500PE	1976	22 800 kW	9 960 Btu	34.3%	20.0	154.3 lb	3600 rpm	968 F	7 815 lb	15 x 6 x 6 ft	
LM2500RD	2005	32 941 kW	8 826 Btu	38.7%	23.0	200.9 lb	3600 rpm	981 F	****	****	
LM2500RC	2005	36 150 kW	9 111 Btu	37.4%	23.0	211.8 lb	3600 rpm	966 F	****	****	
LM6000PC	1997	43 805 kW	8 431 Btu	40.5%	30.0	282.0 lb	3600 rpm	821 F	15 498 lb	16 x 7 x 7 ft	
LM6000PC Sprint	1997	49 210 kW	8 392 Btu	40.7%	30.0	293.4 lb	3600 rpm	839 F	15 498 lb	16 x 7 x 7 ft	
LM6000PF	2006	42 977 kW	8 190 Btu	41.7%	31.0	274.8 lb	3600 rpm	851 F	19 158 lb	16 x 7 x 7 ft	DLE
LM6000PF Sprint	2006	47 961 kW	8 174 Btu	41.7%	31.0	290.8 lb	3600 rpm	846 F	19 158 lb	16 x 7 x 7 ft	DLE

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Kawasaki Heavy Industries											
M1A-13A	1989	1 490 kW	14 104 Btu	24.2%	9.4	17.8 lb	1500/1800	970 F	7 209 lb	8 x 5 x 7 ft	
M1A-13D	1995	1 490 kW	14 246 Btu	24.0%	9.6	17.6 lb	1500/1800	988 F	7 518 lb	8 x 4 x 7 ft	DLE
M1A-17D	2010	1 810 kW	12 160 Btu	28.1%	10.5	17.8 lb	1500/1800	972 F	7 826 lb	10 x 5 x 7 ft	DLE
M1T-13A	1989	2 930 kW	14 312 Btu	23.8%	9.4	35.6 lb	1500/1800	970 F	13 668 lb	8 x 7 x 6 ft	
M1T-13D	1995	2 930 kW	14 445 Btu	23.6%	9.6	35.3 lb	1500/1800	988 F	13 801 lb	8 x 7 x 7 ft	DLE
M5A-01D	2017	4 710 kW	10 450 Btu	32.6%	15.4	38.3 lb	1500/1800	952 F	5 732 lb	9 x 5 x 5 ft	DLE
M7A-01	1993	5 530 kW	11 510 Btu	29.6%	13.1	47.9 lb	1500/1800	1013 F	9 921 lb	12 x 5 x 6 ft	
M7A-02	1997	6 800 kW	11 250 Btu	30.3%	15.9	59.5 lb	1500/1800	960 F	11 023 lb	12 x 5 x 6 ft	
M7A-01D	1993	5 470 kW	11 550 Btu	29.5%	13.1	47.8 lb	1500/1800	1007 F	10 340 lb	12 x 5 x 6 ft	DLE
M7A-02D	1997	6 740 kW	11 270 Btu	30.3%	15.9	59.5 lb	1500/1800	955 F	11 470 lb	12 x 5 x 6 ft	DLE
M7A-03D	2006	7 800 kW	10 190 Btu	33.6%	15.6	59.9 lb	1500/1800	973 F	12 700 lb	14 x 5 x 6 ft	DLE
L20A	2001	18 522 kW	9 948 Btu	34.3%	18.6	131.8 lb	1500/1800	1006 F	36 377 lb	22 x 7 x 9 ft	DLE
L30A	2012	34 380 kW	8 460 Btu	40.3%	25.8	204.1 lb	1500/1800	936 F	68 343 lb	24 x 11 x 12 ft	DLE
Magellan Aerospace											
OGT2500	1994	2 670 kW	12 780 Btu	26.7%	12.0	33.1 lb	1500/1800	860 F	5 512 lb	10 x 4 x 7 ft	
OGT6000	1993	6 200 kW	11 299 Btu	30.2%	14.0	68.3 lb	3000/3600	797 F	9 921 lb	15 x 6 x 6 ft	
OGT8000	2002	8 300 kW	10 597 Btu	32.2%	17.0	74.3 lb	3000/3600	891 F	11 023 lb	15 x 6 x 6 ft	
OGT16000	1991	15 500 kW	11 115 Btu	30.7%	13.0	211.6 lb	3000/3600	662 F	35 274 lb	19 x 9 x 10 ft	
OGT15000	1996	16 500 kW	9 977 Btu	34.2%	20.0	156.5 lb	3000/3600	788 F	28 219 lb	20 x 7 x 8 ft	
OGT25000	1996	25 600 kW	9 612 Btu	35.5%	21.0	194.0 lb	3000/3600	905 F	35 274 lb	21 x 8 x 9 ft	
	Note: all Magellan models weights and size, engine only										
MAN Energy Solutions											
MGT6000	2012	6 630 kW	10 610 Btu	32.2%	15.0	57.5 lb	1500/1800	941 F	****	47 x 10 x 23 ft	includes filter house
MGT6000	2018	7 800 kW	10 270 Btu	33.2%	16.0	64.8 lb	1500/1800	914 F	****	47 x 10 x 23 ft	includes filter house
THM1304-10N	1980	10 080 kW	11 690 Btu	29.2%	10.0	102.5 lb	1500/1800	914 F	169 785 lb	52 x 9 x 17 ft	
THM1304-12N	2004	11 520 kW	11 460 Btu	29.8%	11.0	106.0 lb	1500/1800	977 F	169 785 lb	52 x 12 x 21 ft	
Mapna Group											
MGT-30	2014	25 000 kW	9 505 Btu	35.9%	22.0	196.2 lb	3000 rpm	882 F	33 290 lb	21 x 8 x 8 ft	
MGT-40	2017	42 200 kW	10 597 Btu	32.2%	12.3	324.0 lb	5160 rpm	1018 F	94 799 lb	21 x 11 x 11 ft	
MGT-70(3)	2016	185 000 kW	9 374 Btu	36.4%	12.0	1221.0 lb	3000 rpm	1011 F	410 059 lb	33 x 13 x 12 ft	GT body

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Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Mitsubishi Hitachi Power Systems (50/60 Hz)											
H-25	2008	41 030 kW	9 432 Btu	36.2%	17.9	253.0 lb	7280 rpm	1056 F	121 000 lb	26 x 13 x 13 ft	without losses
Mitsubishi Hitachi Power Systems (50 Hz)											
H-100	2013	116 450 kW	8 909 Btu	38.3%	18.0	652.0 lb	3000 rpm	1087 F	476 000 lb	46 x 16 x 20 ft	without losses
M701DA	1981	144 090 kW	9 810 Btu	34.8%	14.0	999.0 lb	3000 rpm	1008 F	440 917 lb	41 x 17 x 17 ft	
M701G	1997	334 000 kW	8 630 Btu	39.5%	21.0	1664.0 lb	3000 rpm	1089 F	925 926 lb	60 x 20 x 20 ft	
M701F	1992	385 000 kW	8 144 Btu	41.9%	21.0	1650.0 lb	3000 rpm	1167 F	1 058 220 lb	57 x 19 x 19 ft	
M701JAC	2018	448 000 kW	7 755 Btu	44.0%	25.0	1687.0 lb	3000 rpm	1226 F	1 234 590 lb	60 x 23 x 23 ft	
M701J	2014	478 000 kW	8 067 Btu	42.3%	23.0	1977.0 lb	3000 rpm	1166 F	1 234 590 lb	60 x 23 x 23 ft	
M701JAC	2015	563 000 kW	7 826 Btu	43.6%	25.0	2181.0 lb	3000 rpm	1201 F	1 234 590 lb	60 x 23 x 23 ft	
Mitsubishi Hitachi Power Systems (60 Hz)											
H-100	2010	105 780 kW	8 930 Btu	38.2%	18.4	646.0 lb	3600 rpm	993 F	386 000 lb	40 x 15 x 18 ft	without losses
M501DA	1980	113 950 kW	9 780 Btu	34.9%	14.0	780.0 lb	3600 rpm	1009 F	319 665 lb	38 x 19 x 14 ft	
M501G	1997	267 500 kW	8 730 Btu	39.1%	20.0	1349.0 lb	3600 rpm	1113 F	734 140 lb	50 x 18 x 18 ft	
M501GAC	2011	283 000 kW	8 531 Btu	40.0%	20.0	1364.0 lb	3600 rpm	1143 F	595 250 lb	50 x 18 x 18 ft	
M501J	2011	330 000 kW	8 105 Btu	42.1%	23.0	1367.0 lb	3600 rpm	1176 F	698 870 lb	50 x 18 x 18 ft	
M501JAC	2015	425 000 kW	7 755 Btu	44.0%	25.0	1626.0 lb	3600 rpm	1201 F	765 000 lb	50 x 19 x 19 ft	
	Note: All MHPS ratings on natural gas, LHV at generator terminals with inlet and exhaust losses, except for H-25 and H-100 models										
OPRA Turbine											
OP16-3A	2004	1 876 kW	13 585 Btu	25.1%	6.7	19.8 lb	26000 rpm	1063 F	3 594 lb	8 x 4 x 5 ft	
OP16-3B DLE	2004	1 876 kW	13 585 Btu	25.1%	6.7	19.8 lb	26000 rpm	1063 F	3 594 lb	8 x 4 x 5 ft	DLE
OP16-3C	2014	1 876 kW	13 585 Btu	25.1%	6.7	19.8 lb	26000 rpm	1063 F	4 325 lb	8 x 4 x 5 ft	for low Btu fuels
PW Power Systems (50 Hz)											
FT8 MOBILEPAC	2005	28 528 kW	9 834 Btu	34.7%	21.3	203.0 lb	3000 rpm	924 F	****		combustor water injection, transportable
FT8 SWIFTPAC 30	1990	30 748 kW	9 383 Btu	36.4%	21.3	202.0 lb	3000 rpm	922 F	****		combustor water injection
FT8 SWIFTPAC 60	1990	61 607 kW	9 366 Btu	36.4%	21.3	405.0 lb	3000 rpm	922 F	****		combustor water injection
FT8 SWIFTPAC 25 DLN	2003	25 323 kW	9 016 Btu	37.9%	19.5	186.0 lb	3000 rpm	863 F	****		
FT8 SWIFTPAC 50 DLN	2003	50 904 kW	8 970 Btu	38.0%	19.5	373.0 lb	3000 rpm	863 F	****		
FT4000 SWIFTPAC 60	2012	70 154 kW	8 352 Btu	40.9%	37.6	401.0 lb	3000 rpm	793 F	****		combustor water injection, wet compression, inlet fogging
FT4000 SWIFTPAC 120	2012	140 376 kW	8 348 Btu	40.9%	37.6	803.0 lb	3000 rpm	793 F	****		combustor water injection, wet compression, inlet fogging
PW Power Systems (60 Hz)											
FT8 MOBILEPAC	2005	30 941 kW	9 312 Btu	36.7%	21.3	202.0 lb	3600 rpm	916 F	****		combustor water injection, transportable
FT8 SWIFTPAC 30	1990	30 892 kW	9 327 Btu	36.6%	21.3	202.0 lb	3600 rpm	916 F	****		combustor water injection
FT8 SWIFTPAC 60	1990	62 086 kW	9 281 Btu	36.8%	21.3	404.0 lb	3600 rpm	916 F	****		combustor water injection
FT8 SWIFTPAC 25 DLN	2003	25 371 kW	8 993 Btu	38.0%	19.5	186.0 lb	3600 rpm	861 F	****		
FT8 SWIFTPAC 50 DLN	2003	51 058 kW	8 938 Btu	38.2%	19.5	372.0 lb	3600 rpm	861 F	****		
FT4000 SWIFTPAC 60	2012	70 836 kW	8 269 Btu	41.3%	37.6	401.0 lb	3600 rpm	785 F	****		combustor water injection, wet compression, inlet fogging
FT4000 SWIFTPAC 120	2012	141 567 kW	8 248 Btu	41.4%	37.6	802.0 lb	3600 rpm	784 F	****		combustor water injection, wet compression, inlet fogging
	Note: All PWPS ratings on natural gas fuel, zero installation losses										

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Siemens Gas and Power (50/60 Hz)											
SGT-A05 (Ind 501-KB5S)	1993	3 980 kW	11 504 Btu	29.7%	10.3	33.9 lb	14200 rpm	1040 F	80 000 lb	30 x 9 x 10 ft	
SGT-A05 (Ind 501-KB7S)	1999	5 380 kW	10 570 Btu	32.3%	13.9	47.0 lb	14600 rpm	921 F	80 000 lb	30 x 9 x 10 ft	
SGT-A05 (Ind 501-KB7HE)	2017	5 820 kW	10 282 Btu	33.2%	14.1	47.2 lb	14600 rpm	972 F	80 000 lb	30 x 9 x 10 ft	
SGT-100 (5.1 MW)	1997	5 050 kW	11 291 Btu	30.2%	14.0	43.0 lb	17384 rpm	1013 F	77 000 lb	36 x 9 x 13 ft	
SGT-100 (5.4 MW)	2010	5 400 kW	11 006 Btu	31.0%	15.6	46.0 lb	17384 rpm	1006 F	77 000 lb	36 x 9 x 13 ft	
SGT-300	1995	7 901 kW	11 158 Btu	30.6%	13.7	66.6 lb	14010 rpm	1008 F	130 000 lb	39 x 9 x 13 ft	
SGT-400 (11 MW)	2018	10 360 kW	9 802 Btu	34.8%	16.0	74.5 lb	11500 rpm	946 F	184 800 lb	45 x 10 x 14 ft	
SGT-400 (13 MW)	1997	12 900 kW	9 815 Btu	34.8%	16.8	86.8 lb	9500 rpm	1031 F	184 800 lb	46 x 10 x 14 ft	
SGT-400 (15 MW)	2010	14 326 kW	9 647 Btu	35.4%	18.9	97.7 lb	9500 rpm	1004 F	184 800 lb	46 x 10 x 14 ft	
SGT-600	1981	24 480 kW	10 161 Btu	33.6%	14.0	179.2 lb	7700 rpm	1009 F	330 000 lb	62 x 15 x 13 ft	
SGT-700	1999	32 820 kW	9 170 Btu	37.2%	18.7	209.0 lb	6500 rpm	991 F	373 000 lb	62 x 15 x 13 ft	
SGT-750	2012	39 810 kW	8 456 Btu	40.3%	24.3	253.5 lb	6100 rpm	875 F	385 809 lb	67 x 16 x 14 ft	
SGT-800 (50 MW)	2010	49 900 kW	8 670 Btu	39.4%	19.8	274.9 lb	6600 rpm	1041 F	628 300 lb	68 x 24 x 22 ft	
SGT-800 (54 MW)	2010	54 000 kW	8 725 Btu	39.1%	21.6	298.7 lb	6600 rpm	1045 F	639 300 lb	91 x 24 x 22 ft	
SGT-800 (57 MW)	2010	57 000 kW	8 502 Btu	40.1%	22.0	301.1 lb	6600 rpm	1049 F	628 300 lb	68 x 24 x 22 ft	
SGT-800 (62 MW)	2010	62 500 kW	8 302 Btu	41.1%	21.1	298.7 lb	6600 rpm	1104 F	661 400 lb	80 x 24 x 22 ft	
SGT-A35 (G62) DLE	1993	27 216 kW	9 387 Btu	36.4%	20.6	201.0 lb	4800 rpm	934 F	****	****	Ind RB211-G62 DLE
SGT-A30 (G62)	1991	28 390 kW	9 282 Btu	36.8%	21.3	205.0 lb	4800 rpm	934 F	****	****	Ind RB211-G62 non DLE
SGT-A35 (GT62) DLE	1999	29 845 kW	9 089 Btu	37.5%	21.7	209.0 lb	4800 rpm	937 F	****	****	Ind RB211-GT62 DLE
SGT-A35 (GT62)	1999	30 160 kW	9 071 Btu	37.6%	22.0	212.0 lb	4800 rpm	938 F	****	****	Ind RB211-GT62 non DLE
SGT-A35 (GT61) DLE	2000	32 130 kW	8 681 Btu	39.3%	21.6	207.0 lb	4850 rpm	950 F	****	****	Ind RB211-GT61 DLE
SGT-A35 (GT61)	2000	32 920 kW	8 677 Btu	39.3%	22.1	209.0 lb	4850 rpm	949 F	****	****	Ind RB211-GT61 non DLE
Siemens Gas and Power (50 Hz)											
SGT-A35 (GT30 34 MW) DLE	2015	31 917 kW	9 141 Btu	37.3%	22.6	218.6 lb	3000 rpm	939 F	****	****	Ind RB211-GT30 DLE
SGT-A35 (GT30 34 MW)	2015	32 172 kW	9 109 Btu	37.5%	22.9	220.0 lb	3000 rpm	937 F	****	****	Ind RB211-GT30 non-DLE
SGT-A35 (GT30 38 MW)	2017	36 600 kW	8 813 Btu	38.7%	25.4	244.7 lb	3000 rpm	912 F	****	****	Ind RB211-GT30 non-DLE
SGT-A65 DLE	1996	61 900 kW	7 874 Btu	43.3%	38.1	377.0 lb	3000 rpm	826 F	420 000 lb	87 x 15 x 17 ft	Industrial Trent 60 DLE
SGT-A65 DLE ISI	1996	65 900 kW	7 799 Btu	43.8%	39.6	392.4 lb	3000 rpm	808 F	420 000 lb	97 x 15 x 17 ft	Industrial Trent 60 DLE ISI
SGT-A65 WLE ISI	2011	76 506 kW	8 198 Btu	41.6%	40.5	378.1 lb	3000 rpm	779 F	420 000 lb	97 x 15 x 17 ft	Ind Trent 60 WLE ISI, water inj
SGT-A45 (at 32C)	2017	39 300 kW	8 914 Btu	38.3%	26.7	264.5 lb	3000 rpm	934 F	210 000 lb	122 x 25 x 28 ft	mobile unit as installed
SGT-A45 (at 15C)	2017	41 000 kW	8 777 Btu	38.9%	27.7	280.0 lb	3000 rpm	891 F	210 000 lb	122 x 25 x 28 ft	mobile unit as installed
SGT5-2000E	1981	187 000 kW	9 349 Btu	36.5%	12.8	1230.0 lb	3000 rpm	997 F	417 000 lb	34 x 13 x 13 ft	
SGT5-4000F	1995	329 000 kW	8 322 Btu	41.0%	20.1	1596.0 lb	3000 rpm	1110 F	701 000 lb	35 x 17 x 16 ft	
SGT5-8000H	2008	450 000 kW	<8322 Btu	>41%	21.0	2061.0 lb	3000 rpm	1166 F	981 000 lb	41 x 18 x 18 ft	

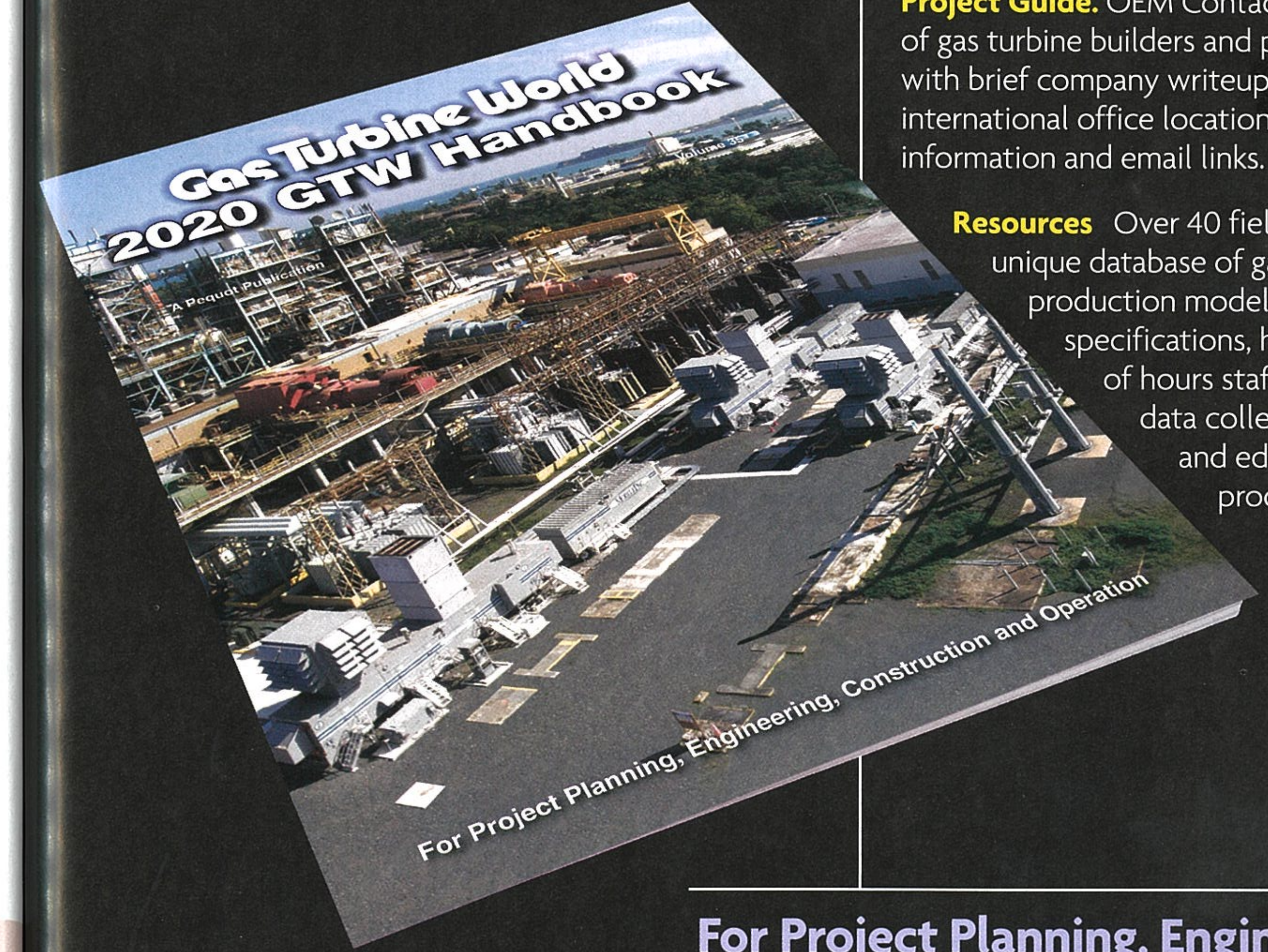
Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
Siemens Gas and Power (50 Hz) (cont'd)											
SGT5-8000HL	2017	481 000 kW	8 006 Btu	42.6%	24.0	1874.0 lb	3000 rpm	1256 F	1 095 700 lb	43 x 17 x 18 ft	
SGT5-9000HL	2017	593 000 kW	7 972 Btu	42.8%	24.0	2315.0 lb	3000 rpm	1238 F	1 095 700 lb	43 x 17 x 18 ft	
Siemens Gas and Power (60 Hz)											
SGT-A35 (GT30 34 MW) DLE	2015	32 537 kW	8 907 Btu	38.3%	22.3	215.8 lb	3600 rpm	932 F	****	****	Industrial RB211-GT30 DLE
SGT-A35 (GT30 34 MW)	2015	33 158 kW	8 873 Btu	38.5%	22.7	218.0 lb	3600 rpm	933 F	****	****	Ind RB211-GT30 non-DLE
SGT-A35 (GT30 38 MW)	2017	37 400 kW	8 600 Btu	39.7%	25.0	240.5 lb	3600 rpm	909 F	****	****	Ind RB211-GT30 non-DLE
SGT-A65 DLE	1996	59 600 kW	7 895 Btu	43.2%	36.6	363.8 lb	3600 rpm	829 F	420 000	87 x 15 x 17 ft	Industrial Trent 60 DLE
SGT-A65 DLE ISI	1997	64 900 kW	7 877 Btu	43.3%	38.0	377.0 lb	3600 rpm	819 F	420 000	97 x 15 x 17 ft	Industrial Trent 60 DLE ISI
SGT-A65 WLE ISI	2011	78 500 kW	8 019 Btu	42.5%	41.1	374.8 lb	3600 rpm	790 F	420 000	97 x 15 x 17 ft	Ind Trent 60 WLE ISI, water inj
SGT-A45 (at 30C)	2017	39 600 kW	8 660 Btu	39.4%	25.8	255.7 lb	3600 rpm	928 F	210 000 lb	122 x 25 x 28 ft	mobile unit as installed
SGT-A45 (at 15C)	2017	44 000 kW	8 477 Btu	40.4%	27.9	277.8 lb	3600 rpm	901 F	210 000 lb	122 x 25 x 28 ft	mobile unit as installed
SGT6-2000E	1989	117 000 kW	9 639 Btu	35.4%	12.0	811.0 lb	3600 rpm	990 F	238 000 lb	30 x 11 x 11 ft	
SGT6-5000F (215 MW)	1989	215 000 kW	8 638 Btu	39.5%	17.0	1054.0 lb	3600 rpm	1134 F	410 000 lb	30 x 15 x 13 ft	9 ppm NOx
SGT6-5000F (260 MW)	1989	260 000 kW	8 530 Btu	40.0%	19.5	1292.0 lb	3600 rpm	1098 F	483 000 lb	33 x 15 x 13 ft	9 ppm NOx
SGT6-8000H	2010	310 000 kW	<8530 Btu	>40%	21.0	1433.0 lb	3600 rpm	1193 F	637 000 lb	34 x 14 x 14 ft	
SGT6-9000HL	2017	405 000 kW	8 010 Btu	42.6%	24.0	1598.0 lb	3600 rpm	1238 F	672 400 lb	35 x 16 x 14 ft	
Siemens Oil & Gas											
Dresser-Rand KG2-3E	1989	1 919 kW	20 071 Btu	17.0%	4.7	33.0 lb	18800 rpm	1020 F	38 580 lb	22 x 7 x 9 ft	
Dresser-Rand KG2-3G	2014	2 000 kW	13 381 Btu	25.5%	7.0	20.9 lb	25500 rpm	1081 F	35 300 lb	22 x 7 x 9 ft	
Dresser-Rand KG2-3G/EF	2014	1 830 kW	13 927 Btu	24.5%	7.0	20.9 lb	25500 rpm	1016 F	35 300 lb	22 x 7 x 9 ft	
Solar Turbines											
Saturn 20	1960	1 210 kW	14 040 Btu	24.3%	6.7	14.3 lb	22300 rpm	945 F	22 500 lb	22 x 8 x 9 ft	
Centaur 40	1969	3 515 kW	12 240 Btu	27.9%	10.1	41.6 lb	15000 rpm	830 F	73 820 lb	32 x 9 x 11 ft	
Centaur 50	1985	4 600 kW	11 630 Btu	29.3%	10.6	41.8 lb	16500 rpm	950 F	83 300 lb	32 x 9 x 10 ft	
Mercury 50	1999	4 600 kW	8 865 Btu	38.5%	9.9	39.0 lb	15000 rpm	690 F	100 700 lb	37 x 10 x 12 ft	recuperated gas turbine
Taurus 60	1990	5 670 kW	10 830 Btu	31.5%	9.9	47.6 lb	15000 rpm	950 F	83 600 lb	32 x 9 x 10 ft	
Taurus 65	2006	6 500 kW	10 295 Btu	33.1%	15.0	46.7 lb	15000 rpm	1000 F	87 300 lb	32 x 9 x 11 ft	
Taurus 70	1995	8 180 kW	9 920 Btu	34.4%	17.6	58.8 lb	11000 rpm	960 F	136 215 lb	36 x 9 x 12 ft	
Mars 100	1978	11 350 kW	10 365 Btu	32.9%	17.7	93.1 lb	9500 rpm	905 F	181 000 lb	47 x 9 x 13 ft	
Titan 130	1998	16 530 kW	9 605 Btu	35.4%	17.1	123.1 lb	8500 rpm	915 F	208 100 lb	47 x 11 x 11 ft	
Titan 250	2009	23 100 kW	8 775 Btu	39.4%	24.1	153.9 lb	7000 rpm	865 F	311 100 lb	60 x 11 x 13 ft	

Model	Intro Year	ISO Base Load (kW)	Heat Rate (Btu/kWh)	Efficiency	Press Ratio	Mass Flow (lb/sec)	Turbine Speed	Exhaust Temp	Approx Weight	Approx LxWxH	Comments
UEC-Aviadvigatel											
GTU-2.5P	1994	2 560 kW	16 160 Btu	21.1%	5.9	56.4 lb	5500 rpm	682 F	146 170 lb	45 x 10 x 9 ft	with gearbox
GTU-4P	2000	4 130 kW	14 220 Btu	24.0%	7.3	65.7 lb	5500 rpm	777 F	150 930 lb	45 x 10 x 9 ft	with gearbox
GTU-6P	2004	6 140 kW	13 032 Btu	26.2%	8.7	74.7 lb	6925 rpm	885 F	161 820 lb	45 x 10 x 9 ft	with gearbox
GTU-12PG-2	2004	12 300 kW	10 469 Btu	32.6%	15.9	101.2 lb	6500 rpm	925 F	296 970 lb	59 x 10 x 14 ft	with gearbox
GTE-16PA	2007	16 300 kW	9 614 Btu	35.5%	19.9	124.0 lb	3000 rpm	898 F	389 400 lb	61 x 10 x 9 ft	w/o gearbox
GTE-16PA2	2017	16 400 kW	9 805 Btu	34.8%	19.5	123.7 lb	5300 rpm	923 F	400 000 lb	68 x 10 x 9 ft	with gearbox
GTE-25P	2008	23 000 kW	9 312 Btu	36.7%	27.3	169.1 lb	5000 rpm	883 F	467 710 lb	79 x 10 x 9 ft	with gearbox
GTE-25PA	2013	25 500 kW	9 174 Btu	37.2%	28.5	172.6 lb	5000 rpm	935 F	369 495 lb	74 x 25 x 14 ft	with gearbox
UEC-Gas Turbines											
GTES-2.5	2000	2 850 kW	13 123 Btu	26.0%	12.0	32.0 lb	14000 rpm	797 F	166 450 lb	52 x 17 x 34 ft	dual fuel burner available
GTA-6RM	2001	6 500 kW	14 458 Btu	23.6%	8.6	104.0 lb	3000 rpm	780 F	354 946 lb	72 x 49 x 35 ft	dual fuel burner available
GTA-8RM	2003	8 560 kW	13 984 Btu	24.4%	9.6	110.0 lb	3000 rpm	932 F	385 811 lb	72 x 49 x 35 ft	dual fuel burner available
GTA-10GT	2014	10 000 kW	9 890 Btu	34.5%	17.6	72.0 lb	4500 rpm	968 F	253 533 lb	79 x 43 x 27 ft	
GTA-16	2014	16 320 kW	10 499 Btu	32.5%	20.1	123.0 lb	5300 rpm	957 F	330 695 lb	92 x 28 x 31 ft	
GTA-25	2017	23 300 kW	9 426 Btu	36.2%	28.2	167.0 lb	5000 rpm	912 F	451 950 lb	95 x 95 x 34 ft	
Vericor											
VPS3	1978	3 152 kW	12 560 Btu	27.2%	8.8	28.3 lb	16000 rpm	1110 F	70 000 lb	27 x 8 x 23 ft	
VPS4	1999	3 522 kW	11 906 Btu	28.7%	10.1	30.4 lb	16000 rpm	1076 F	70 000 lb	27 x 8 x 23 ft	
Zorya-Mashproekt											
UGT 5000	2011	5 100 kW	11 010 Btu	31.0%	14.0	47.4 lb	1800/3000/3600	896 F	41 000 lb	21 x 12 x 11 ft	1500 rpm available, w/ gearbox
UGT 6000	2018	6 200 kW	11 300 Btu	30.2%	14.0	68.3 lb	1800/3000/3600	806 F	****	****	1500 rpm available, w/ gearbox
UGT 16000	2017	15 520 kW	11 150 Btu	30.6%	12.5	211.6 lb	3000 rpm	662 F	30 430 lb	20 x 7 x 8 ft	dual fuel
UGT 15000	2014	16 500 kW	9 980 Btu	34.2%	19.5	156.5 lb	3000 rpm	788 F	28 880 lb	19 x 8 x 8 ft	dual fuel
UGT 25000	2016	25 680 kW	9 590 Btu	35.6%	21.5	196.2 lb	3000 rpm	905 F	35 825 lb	21 x 8 x 8 ft	dual fuel
UGT 32000	2021	32 800 kW	9 050 Btu	37.7%	22.9	233.7 lb	3000 rpm	887 F	40 785 lb	21 x 8 x 8 ft	

Note: All Zorya moels with DLE

Combined Cycle GTW Design Ratings

Refer to "rule-of-thumb" editorial box on page 50 for adjustment factors that will enable you to estimate combined cycle plant ratings at non-ISO operating and site conditions.



Combined Cycle Rating Parameters

Standardized ratings with correction factors to adjust for actual site and operating conditions

GTW Combined Cycle design ratings provide access to updated OEM reference plant specifications data in a consistent format that enables evaluation and comparison of competitively sized plants on an apples-to-apples basis.

Conditions

Performance ratings apply to OEM reference plant operation at full base load output at ISO site conditions: 59°F ambient air (15°C) temperature, 14.7 psia (1.015 bar) sea level elevation and 60% relative humidity.

Combined cycle plants are typically designed around one or more gas turbines, single or multi-shaft configurations, 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 performance ratings for simple cycle gas turbines, which include engine design parameters such as pressure ratio, mass flow and exhaust temperature, no industry standards dictate internal cycle design parameters for calculating combined cycle performance.

Specifications issued by OEM suppliers are therefore inconsistent due to lack of design detail, especially regarding bottoming cycle design assumptions. Different scope of supply and plant boundary limits also contribute to inconsistencies.

Depending on business approach, some OEMs limit their combined cycle offerings to the major equipment comprising the so-called "power block" or "power island", i.e., gas turbine and steam turbine generators, HRSGs and plant controls.

Others supply the complete plant, including all BOP equipment and auxiliaries needed to operate the combined cycle plant.

Net or gross?

If they apply only to the power block, "net" ratings are defined as power output of the GT and ST generators less losses associated with the power block, as if isolated from the rest of the plant.

Where the data refers to a full plant, "net" is defined as output of the gas

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 conditions:

■ **Ambient temperature.** About a 2.5% reduction in power output per 10°F (5.6°C) rise in air temperature above 59°F (15°C) and a corresponding increase in capacity with decreasing ambient temperatures below 59°F (15°C). Impact on heat rate (up and down, respectively) is about 0.5% per 10°F (5.6°C) change in air temperature.

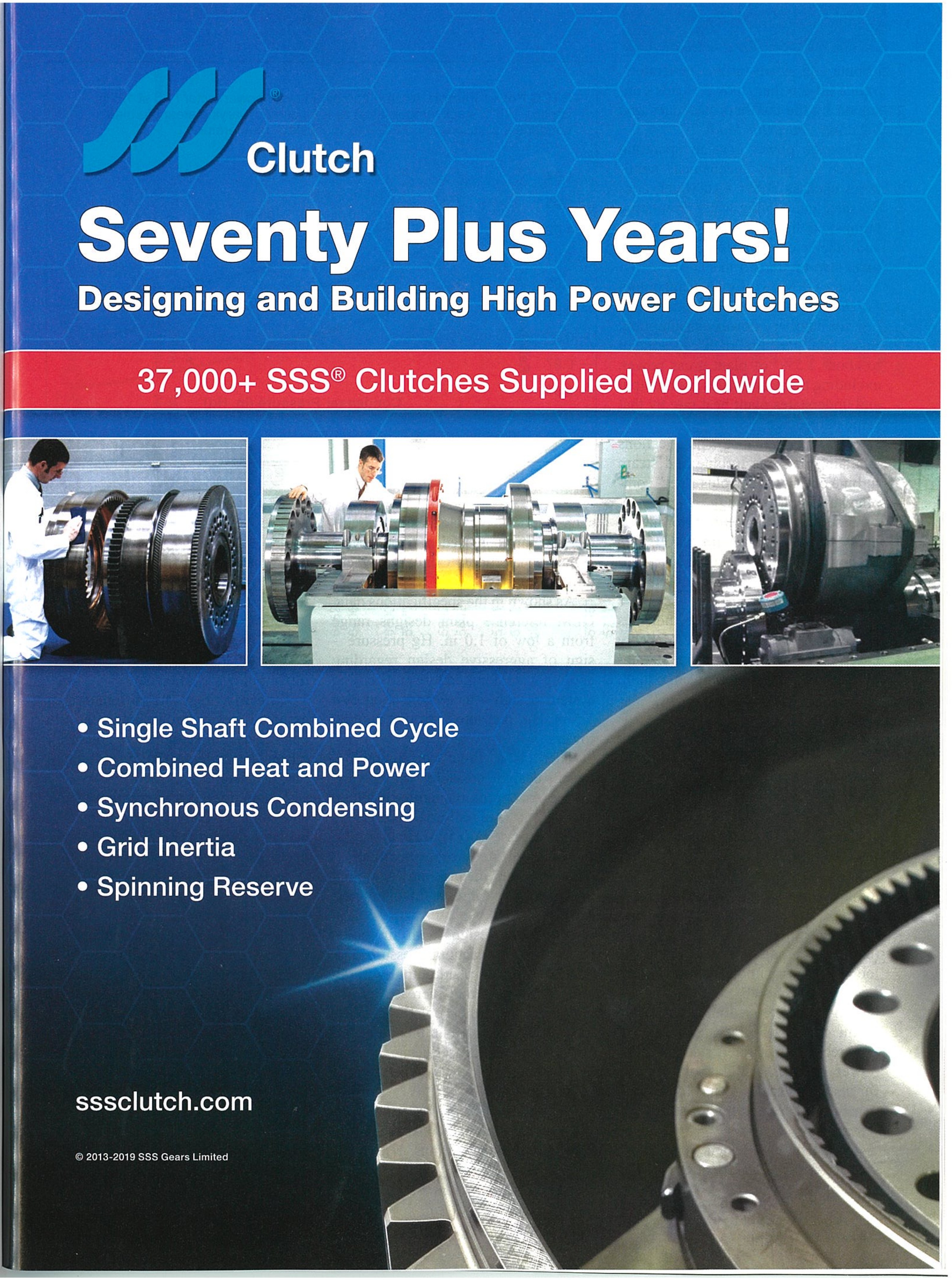
■ **Site elevation.** About 3.5% reduction in rated power output for each 1000 ft. increase in site elevation above sea level. Impact on heat rate is only about 0.2% per 1000 ft. increase in elevation.

■ **Cooling Water.** About 2% reduction in plant power output and corresponding 2% rise in heat rate for increase in effective cooling water temperature of 25°F-30°F (14°C-17°C) above assumed design temperature. (This stems from an increase steam turbine condenser pressure, due to warmer cooling water, where an increase of 1.0 in Hg results in about 2% reduction in plant power output.)

■ **Plant age.** Over an extended 10-15 years of operation, plant capacity will deteriorate by approximately 3-5% from its new and clean 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 gradually deteriorate 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 off-line washing,

■ **Cyclic operation.** To adjust for load-following operating profile typical of modern managed grid system applications, an estimate of "mean effective annual performance" may be obtained by using 75% of rated power and 96% of rated efficiency (heat rate increase of 4%).



turbine and steam turbine generators, minus all auxiliary power loads consumed by the auxiliary packages *and the plant's parasitic loads.*

Parasitic power goes to operating balance of plant mechanical auxiliaries such as boiler feed water, condensate, and cooling water circulating pumps; cooling fans; control systems and other electrical auxiliaries (up to main step-up transformer).

Some OEMs who quote plant output *"at the generator terminals"* do not allow for auxiliary power consumption. Since total parasitic loads can amount to about 2.5% of plant gross power, excluding them overstates plant output and understates plant heat rate by that same percentage.

GTW performance specifications tabulate gross gas turbine and steam turbine output ratings plus "net" combined cycle plant rating.

Based on *total plant* performance, gross power output (sum of GT plus ST power) on its own should be around 2.5% higher than net plant output rating.

Less than 1% difference indicates that the specified ratings are probably based on a power block scope of supply, and do not reflect *net* plant output.

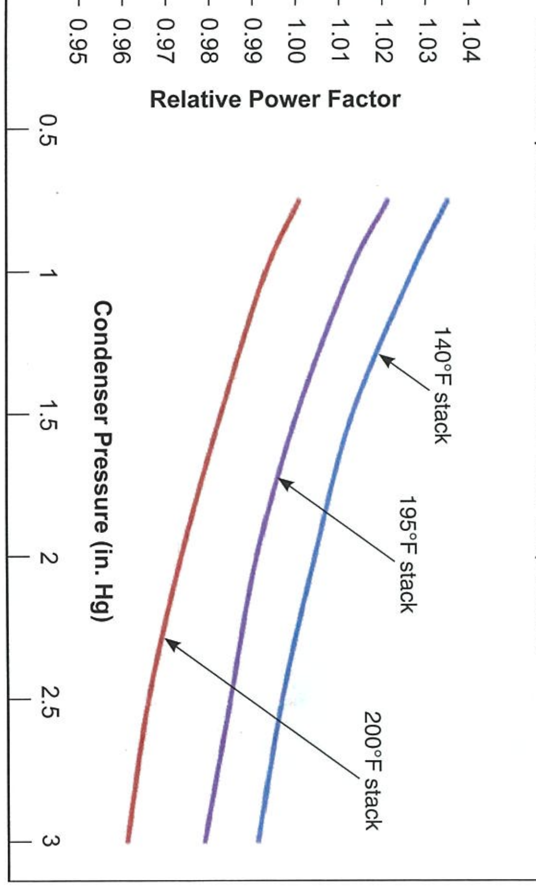
Correction factors

There are real-world site correction factors for adjusting combined cycle ratings that consider the effect of non-standard site and operating conditions on specified ratings.

Combined cycle performance is directly affected by OEM design assumptions related to the steam bottoming cycle, i.e., HRSG design, coolant type (water or air) and temperature, and cooling system configuration (e.g., direct open or indirect closed loop), with or without cooling tower

Since assumed cooling system design parameters ultimately set the steam condenser pressure, differences directly affect rated steam turbine power output. (Cold cooling water for instance usually means lower condenser pressure and higher steam turbine power.)

Unfortunately when specifying combined cycle performance, there is no agreed-upon industry standard for such bottoming cycle design parameter assumptions used in their performance calculations. Condenser vacuum pressure is a case in point.



GTCC Power Factor. Relative combined cycle power factor (1.0 at 1.5 in. Hg and 195°F stack temperature) as a function of varying steam turbine condenser pressure and HRSG exhaust stack temperature.

Source: Dr. Hans Wettstein, ABB

As shown in the specifications data, OEM reference plant designs range from a low of 1.0 in. Hg pressure – sign of aggressive design regarding cooling water temperature and cooling system design - to a more moderate 1.5 in. Hg, pressure with wet cooling towers.

There is a direct correlation between design pressure and performance. An approximate rule-of-thumb adjustment (see editorial box) says that a decrease of 0.5 in. Hg (1.7 kPa) in condenser pressure results in about 1.0% increase in plant power output and a similar decrease in plant heat rate.

For plant designs with air-cooled condenser and vacuum pressure of 3 in. 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.

Design trade-offs

Besides condenser pressure, there are other areas where inconsistencies in OEM performance ratings arise due to varying assumptions regarding certain internal design parameters.

One example is HRSG design where trade-offs between cost and performance determine the efficiency of converting gas turbine exhaust heat into steam.

This impacts steam turbine power output and directly affects exhaust stack temperature, a significant determinant of cycle efficiency.

Similarly, there are differences in assumed steam turbine main throttle conditions (temperature and pressure), reheat steam temperature and steam turbine design.

Where price is an important factor, an economic analysis is warranted to evaluate trade-offs between bottoming cycle design and performance.

Caveat

Despite attempts to report standardized performance ratings, inconsistencies in the specs data will occur. And although approximations to make corrections and adjustments are adequate for preliminary studies, they are not foolproof.

Ultimately, reliance on published ratings for an actual project under development can only go so far. It is always critical to confirm project-specific ratings with OEMs -- especially during final stages of comparative evaluation and choice of competitive units. ■

2020 GTW Combined Cycle Specs

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
Ansaldo Energia (50/60 Hz)											
1AE643-CC1S	1996	****	120 000 kW	6126 Btu	55.7%	6463 kJ	****	****	****	1 x AE64.3A	
2AE643-CC1M	1996	****	243 000 kW	6050 Btu	56.4%	6383 kJ	****	****	****	2 x AE64.3A	
	Note: ISO ambient conditions with direct cooling; 3 pressure RH cycles; 100% CH_4 nat gas fuel										
Ansaldo Energia (50 Hz)											
1AE942-CC1M	1981	****	287 000 kW	6115 Btu	55.8%	6452 kJ	****	****	****	1 x AE94.2	
2AE942-CC1M	1981	****	578 000 kW	6071 Btu	56.2%	6406 kJ	****	****	****	2 x AE94.2	
1AE943-CC1S	1995	****	495 000 kW	5687 Btu	60.0%	6000 kJ	****	****	****	1 x AE94.3A	
2AE943-CC1M	1995	****	992 000 kW	5659 Btu	60.3%	5970 kJ	****	****	****	2 x AE94.3A	
1GT26-CC1S	2011	****	540 000 kW	5594 Btu	61.0%	5902 kJ	****	****	****	1 x GT26	
2GT26-CC1M	2011	****	1 083 000 kW	5575 Btu	61.2%	5882 kJ	****	****	****	2 x GT26	
1GT36-S5-CC1M	2016	****	760 000 kW	5451 Btu	62.6%	5751 kJ	****	****	****	1 x GT36-S5	
2GT36-S5-CC1M	2016	****	1 525 000 kW	5433 Btu	62.8%	5732 kJ	****	****	****	2 x GT36-S5	
	Note: ISO ambient conditions with direct cooling; 3 pressure RH cycles; 100% CH_4 nat gas fuel										
Ansaldo Energia (60 Hz)											
1GT36-S6-CC1M	2016	****	520 000 kW	5477 Btu	62.3%	5778 kJ	****	****	****	1 x GT36-S6	
2GT36-S6-CC1M	2016	****	1 046 000 kW	5451 Btu	62.6%	5751 kJ	****	****	****	2 x GT36-S6	
	Note: ISO ambient conditions with direct cooling; 3 pressure RH cycles; 100% CH_4 nat gas fuel										
Bharat Heavy Electricals (50 Hz)											
CC105P	1988	39 520 kW	38 927 kW	8084 Btu	42.2%	8529 kJ	****	26 000 kW	13 520 kW	1 x MS5001	2P
CC205P	1988	79 300 kW	78 111 kW	8058 Btu	42.3%	8501 kJ	****	52 000 kW	27 300 kW	2 x MS5001	2P
CC305P	1988	119 340 kW	117 669 kW	8023 Btu	42.5%	8465 kJ	****	78 000 kW	41 340 kW	3 x MS5001	2P
CC106B	1997	64 600 kW	63 631 kW	6964 Btu	49.0%	7347 kJ	****	42 500 kW	22 100 kW	1 x MS6001B	2P
CC206B	1997	129 455 kW	127 513 kW	6950 Btu	49.1%	7332 kJ	****	85 000 kW	44 455 kW	2 x MS6001B	2P
CC106FA	2003	118 499 kW	116 722 kW	6342 Btu	53.8%	6691 kJ	****	76 500 kW	41 999 kW	1 x MS6001FA	3P non reheat
CC206FA	2003	243 117 kW	239 470 kW	6183 Btu	55.2%	6523 kJ	****	153 000 kW	90 117 kW	2 x MS6001FA	3P reheat
CC109E	2003	195 900 kW	192 900 kW	6607 Btu	51.6%	6971 kJ	****	127 700 kW	68 200 kW	1 x MS9001E	2P non reheat
CC209E	2003	394 100 kW	388 188 kW	6567 Btu	52.0%	6928 kJ	****	255 400 kW	138 700 kW	2 x MS9001E	2P non reheat
CC309E	2003	594 100 kW	585 500 kW	6531 Btu	52.2%	6890 kJ	****	383 100 kW	211 000 kW	3 x MS9001E	2P non reheat

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
Bharat Heavy Electricals (50 Hz) (cont'd)											
CC1.942	1998	237 500 kW	232 500 kW	6630 Btu	51.5%	6990 kJ	****	152 000 kW	85 500 kW	1 x V94.2	2P non reheat
CC2.942	1998	477 000 kW	467 500 kW	6600 Btu	51.7%	6960 kJ	****	304 000 kW	173 000 kW	2 x V94.2	2P
CC3.942	1998	715 000 kW	701 000 kW	6600 Btu	51.7%	6960 kJ	****	456 000 kW	259 000 kW	3 x V94.2	2P
CC109FA	2003	400 200 kW	394 900 kW	5995 Btu	56.9%	6325 kJ	****	258 700 kW	141 500 kW	1 x MS9001FA	3P reheat
CC209FA	2003	804 400 kW	794 100 kW	5965 Btu	57.2%	6290 kJ	****	517 400 kW	287 000 kW	2 x MS9001FA	3P reheat
CC109FB	2012	459 300 kW	452 600 kW	5765 Btu	59.2%	6080 kJ	****	295 300 kW	164 000 kW	1 x MS9001FB	3P reheat
CC209FB	2012	923 100 kW	910 100 kW	5765 Btu	59.5%	6050 kJ	****	590 600 kW	332 500 kW	2 x MS9001FB	3P reheat
EthosEnergy (50/60 Hz)											
TG20B7/8UG	2014	69 881 kW	68 395 kW	6632 Btu	51.5%	6996 kJ	1.2 inch Hg	44 001 kW	25 880 kW	1 x TG20B7/8UG	
TG20B7/8UG	2014	140 524 kW	137 491 kW	6598 Btu	51.7%	6961 kJ	1.2 inch Hg	88 002 kW	52 522 kW	2 x TG20B7/8UG	
EthosEnergy (50 Hz)											
TG50D5U	2007	214 370 kW	209 969 kW	6255 Btu	54.6%	6599 kJ	1.2 inch Hg	140 767 kW	73 603 kW	1 x TG50D5U	3P HRSG
TG50D5U	2007	431 074 kW	422 171 kW	6222 Btu	54.8%	6564 kJ	1.2 inch Hg	281 534 kW	149 540 kW	2 x TG50D5U	3P HRSG
GE Power Aero (50/60 Hz)											
LM6000 SAC PC	1997	60 000 kW	59 000 kW	6573 Btu	51.9%	6935 kJ	1.2 inch Hg	45 600 kW	14 400 kW	1 x LM6000	2P non reheat, gearbox
LM6000 SAC PC	1997	120 000 kW	118 000 kW	6555 Btu	52.1%	6916 kJ	1.2 inch Hg	91 200 kW	28 800 kW	2 x LM6000	2P non reheat, gearbox
LM6000 SAC PC Sprint	1998	67 100 kW	66 000 kW	6573 Btu	51.9%	6935 kJ	1.2 inch Hg	51 500 kW	15 600 kW	1 x LM6000	2P non reheat, gearbox
LM6000 SAC PC Sprint	1998	135 300 kW	133 000 kW	6555 Btu	52.1%	6916 kJ	1.2 inch Hg	103 000 kW	32 300 kW	2 x LM6000	2P non reheat, gearbox
LM6000 SAC PG	2009	74 300 kW	73 000 kW	6535 Btu	52.2%	6895 kJ	1.2 inch Hg	55 500 kW	18 800 kW	1 x LM6000	2P non reheat, gearbox
LM6000 SAC PG	2009	148 600 kW	146 000 kW	6516 Btu	52.4%	6874 kJ	1.2 inch Hg	111 000 kW	37 600 kW	2 x LM6000	2P non reheat, gearbox
LM6000 SAC PG Sprint	2009	77 300 kW	76 000 kW	6535 Btu	52.2%	6895 kJ	1.2 inch Hg	58 500 kW	18 800 kW	1 x LM6000	2P non reheat, gearbox
LM6000 SAC PG Sprint	2009	155 700 kW	153 000 kW	6516 Btu	52.4%	6874 kJ	1.2 inch Hg	117 000 kW	38 700 kW	2 x LM6000	2P non reheat, gearbox
LM6000 DLE PF	1997	59 000 kW	58 000 kW	6179 Btu	55.2%	6520 kJ	1.2 inch Hg	44 600 kW	14 400 kW	1 x LM6000	2P non reheat, gearbox
LM6000 DLE PF	1997	119 100 kW	117 000 kW	6161 Btu	55.4%	6500 kJ	1.2 inch Hg	89 200 kW	29 900 kW	2 x LM6000	2P non reheat, gearbox
LM6000 DLE PF Sprint	2006	65 100 kW	64 000 kW	6179 Btu	55.2%	6520 kJ	1.2 inch Hg	49 600 kW	15 500 kW	1 x LM6000	2P non reheat, gearbox
LM6000 DLE PF Sprint	2006	131 200 kW	129 000 kW	6161 Btu	55.4%	6500 kJ	1.2 inch Hg	99 200 kW	32 000 kW	2 x LM6000	2P non reheat, gearbox
LM6000 DLE PF+	2016	71 400 kW	70 000 kW	6105 Btu	55.9%	6441 kJ	1.2 inch Hg	52 000 kW	19 400 kW	1 x LM6000	2P non reheat, gearbox
LM6000 DLE PF+	2016	144 900 kW	142 000 kW	6085 Btu	56.1%	6420 kJ	1.2 inch Hg	104 000 kW	40 900 kW	2 x LM6000	2P non reheat, gearbox
LM6000 DLE PF+ Sprint	2016	78 400 kW	77 000 kW	6105 Btu	55.9%	6441 kJ	1.2 inch Hg	57 800 kW	20 600 kW	1 x LM6000	2P non reheat, gearbox
LM6000 DLE PF+ Sprint	2016	158 000 kW	155 000 kW	6085 Btu	56.1%	6420 kJ	1.2 inch Hg	115 600 kW	42 400 kW	2 x LM6000	2P non reheat, gearbox

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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 Power Aero (50 Hz)											
LM2500	1981	35 000 kW	34 200 kW	6943 Btu	49.1%	7325 kJ	1.2 inch Hg	23 600 kW	11 400 kW	1 x LM2500	2P non reheat
LM2500	1981	70 200 kW	68 600 kW	6916 Btu	49.3%	7297 kJ	1.2 inch Hg	47 200 kW	23 000 kW	2 x LM2000	2P non reheat
LM2500 DLE	1981	33 600 kW	32 800 kW	6533 Btu	52.2%	6892 kJ	1.2 inch Hg	22 100 kW	11 500 kW	1 x LM2500	2P non reheat
LM2500 DLE	1981	67 400 kW	65 800 kW	6507 Btu	52.4%	6865 kJ	1.2 inch Hg	44 200 kW	23 200 kW	2 x LM2000	2P non reheat
LM2500+	1995	42 400 kW	41 500 kW	6931 Btu	49.2%	7312 kJ	1.2 inch Hg	29 700 kW	12 700 kW	1 x LM2500+	2P non reheat
LM2500+	1995	85 000 kW	83 200 kW	6907 Btu	49.4%	7287 kJ	1.2 inch Hg	59 400 kW	25 600 kW	2 x LM2500+	2P non reheat
LM2500+ DLE	1995	45 000 kW	44 000 kW	6384 Btu	53.4%	6736 kJ	1.2 inch Hg	30 800 kW	14 200 kW	1 x LM2500+	2P non reheat
LM2500+ DLE	1995	90 200 kW	88 200 kW	6361 Btu	53.6%	6711 kJ	1.2 inch Hg	61 600 kW	28 600 kW	2 x LM2500+	2P non reheat
LM2500+ G4	2005	49 300 kW	48 200 kW	6884 Btu	49.6%	7263 kJ	1.2 inch Hg	34 200 kW	15 100 kW	1 x LM2500+ G4	2P non reheat
LM2500+ G4	2005	98 900 kW	96 800 kW	6860 Btu	49.7%	7238 kJ	1.2 inch Hg	68 400 kW	30 500 kW	2 x LM2500+ G4	2P non reheat
LM2500+ G4 DLE	2005	48 800 kW	47 700 kW	6343 Btu	53.8%	6693 kJ	1.2 inch Hg	33 100 kW	15 700 kW	1 x LM2500+ G4	2P non reheat
LM2500+ G4 DLE	2005	97 900 kW	95 700 kW	6320 Btu	54.0%	6668 kJ	1.2 inch Hg	66 200 kW	31 700 kW	2 x LM2500+ G4	2P non reheat
LM2500XPRESS	2020	47 800 kW	47 200 kW	6275 Btu	54.4%	6621 kJ	1.2 inch Hg	33 400 kW	14 400 kW	1 x LM2500XPRESS	2P non reheat
LM2500XPRESS	2020	95 800 kW	94 600 kW	6261 Btu	54.5%	6606 kJ	1.2 inch Hg	66 800 kW	29 000 kW	2 x LM2500XPRESS	2P non reheat
TM2500	****	49 200 kW	48 400 kW	6851 Btu	49.8%	7229 kJ	1.2 inch Hg	37 500 kW	11 700 kW	1 x TM2500	2P non reheat
TM2500	****	98 900 kW	97 200 kW	6827 Btu	50.0%	7203 kJ	1.2 inch Hg	74 900 kW	24 000 kW	2 x TM2500	2P non reheat
LM9000 Low NOx	2017	89 700 kW	88 000 kW	6109 Btu	55.9%	6445 kJ	1.2 inch Hg	65 400 kW	24 300 kW	1 x LM9000	2P non reheat
LM9000 Low NOx	2017	179 400 kW	176 000 kW	6089 Btu	56.0%	6424 kJ	1.2 inch Hg	130 800 kW	48 600 kW	2 x LM9000	2P non reheat
LM9000 Sprint	2017	96 700 kW	95 000 kW	6220 Btu	54.9%	6562 kJ	1.2 inch Hg	72 300 kW	24 400 kW	1 x LM9000	2P non reheat
LM9000 Sprint	2017	194 500 kW	191 000 kW	6200 Btu	55.0%	6541 kJ	1.2 inch Hg	144 600 kW	49 900 kW	2 x LM9000	2P non reheat
LMS100 PB	2013	129 300 kW	127 600 kW	6527 Btu	52.3%	6887 kJ	1.2 inch Hg	106 600 kW	23 100 kW	1 x LMS100	2P non reheat
LMS100 PB	2013	260 100 kW	256 700 kW	6490 Btu	52.6%	6847 kJ	1.2 inch Hg	213 200 kW	47 600 kW	2 x LMS100	2P non reheat
LMS100 PA	2005	136 300 kW	134 500 kW	6616 Btu	51.6%	6981 kJ	1.2 inch Hg	113 200 kW	27 400 kW	1 x LMS100	2P non reheat
LMS100 PA	2005	274 000 kW	270 500 kW	6579 Btu	51.9%	6942 kJ	1.2 inch Hg	226 400 kW	54 700 kW	2 x LMS100	2P non reheat
GE Power Aero (60 Hz)											
LM2500	1981	35 800 kW	35 000 kW	6844 Btu	49.9%	7221 kJ	1.2 inch Hg	24 600 kW	11 200 kW	1 x LM2500	2P non reheat
LM2500	1981	71 800 kW	70 200 kW	6819 Btu	50.0%	7195 kJ	1.2 inch Hg	49 200 kW	22 600 kW	2 x LM2500	2P non reheat
LM2500 DLE	1981	34 000 kW	33 200 kW	6456 Btu	52.9%	6811 kJ	1.2 inch Hg	23 000 kW	11 000 kW	1 x LM2500	2P non reheat
LM2500 DLE	1981	68 200 kW	66 600 kW	6431 Btu	53.1%	6785 kJ	1.2 inch Hg	46 000 kW	22 200 kW	2 x LM2500	2P non reheat

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 Power Aero (60 Hz) (cont'd)											
LM2500+	1995	43 900 kW	43 000 kW	6809 Btu	50.1%	7184 kJ	1.2 inch Hg	31 500 kW	12 400 kW	1 x LM2500+	2P non reheat
LM2500+	1995	88 100 kW	86 300 kW	6787 Btu	50.3%	7161 kJ	1.2 inch Hg	63 000 kW	25 100 kW	2 x LM2500+	2P non reheat
LM2500+ DLE	1995	44 800 kW	43 900 kW	6299 Btu	54.2%	6645 kJ	1.2 inch Hg	31 600 kW	13 200 kW	1 x LM2500+	2P non reheat
LM2500+ DLE	1995	90 100 kW	88 200 kW	6277 Btu	54.4%	6622 kJ	1.2 inch Hg	63 200 kW	26 900 kW	2 x LM2500+	2P non reheat
LM2500+ G4	2005	51 300 kW	50 300 kW	6729 Btu	50.7%	7099 kJ	1.2 inch Hg	36 800 kW	14 500 kW	1 x LM2500+ G4	2P non reheat
LM2500+ G4	2005	103 000 kW	100 900 kW	6707 Btu	50.9%	7076 kJ	1.2 inch Hg	73 600 kW	29 400 kW	2 x LM2500+ G4	2P non reheat
LM2500+ G4 DLE	2005	48 700 kW	47 700 kW	6239 Btu	54.7%	6583 kJ	1.2 inch Hg	34 200 kW	14 500 kW	1 x LM2500+ G4	2P non reheat
LM2500+ G4 DLE	2005	97 800 kW	95 700 kW	6218 Btu	54.9%	6560 kJ	1.2 inch Hg	68 400 kW	29 400 kW	2 x LM2500+ G4	2P non reheat
LM2500XPRESS	2020	47 900 kW	47 300 kW	6246 Btu	54.6%	6590 kJ	1.2 inch Hg	33 700 kW	14 200 kW	1 x LM2500XPRESS	2P non reheat
LM2500XPRESS	2020	96 000 kW	94 800 kW	6232 Btu	54.8%	6575 kJ	1.2 inch Hg	67 400 kW	28 600 kW	2 x LM2500XPRESS	2P non reheat
TM2500	****	51 500 kW	50 500 kW	6703 Btu	50.9%	7072 kJ	1.2 inch Hg	36 800 kW	14 700 kW	1 x TM2500	2P non reheat
TM2500	****	103 400 kW	101 300 kW	6681 Btu	51.1%	7049 kJ	1.2 inch Hg	73 600 kW	29 800 kW	2 x TM2500	2P non reheat
LM9000 Low NOx	2017	89 700 kW	88 000 kW	6109 Btu	55.9%	6445 kJ	1.2 inch Hg	65 400 kW	24 300 kW	1 x LM9000	2P non reheat
LM9000 Low NOx	2017	179 400 kW	176 000 kW	6089 Btu	56.0%	6424 kJ	1.2 inch Hg	130 800 kW	48 600 kW	2 x LM9000	2P non reheat
LM9000 Sprint	2017	96 700 kW	95 000 kW	6220 Btu	54.9%	6562 kJ	1.2 inch Hg	72 300 kW	24 400 kW	1 x LM9000	2P non reheat
LM9000 Sprint	2017	194 500 kW	191 000 kW	6200 Btu	55.0%	6541 kJ	1.2 inch Hg	144 600 kW	49 900 kW	2 x LM9000	2P non reheat
LMS100 PB	2013	129 900 kW	128 300 kW	6521 Btu	52.3%	6880 kJ	1.2 inch Hg	107 500 kW	22 400 kW	1 x LMS100 PB	2P non reheat
LMS100 PB	2013	261 400 kW	258 000 kW	6484 Btu	52.6%	6841 kJ	1.2 inch Hg	215 000 kW	46 400 kW	2 x LMS100 PB	2P non reheat
LMS100 PA	2005	139 100 kW	137 300 kW	6543 Btu	52.1%	6903 kJ	1.2 inch Hg	116 400 kW	22 700 kW	1 x LMS100 PA	2P non reheat
LMS100 PA	2005	279 700 kW	276 100 kW	6508 Btu	52.4%	6866 kJ	1.2 inch Hg	232 800 kW	46 900 kW	2 x LMS100 PA	2P non reheat
GE Power Frame (50/60 Hz)											
6B.03	1987	69 250 kW	68 000 kW	6614 Btu	51.6%	6978 kJ	1.2 inch Hg	43 650 kW	25 600 kW	1 x 6B.03	2P non reheat
6B.03	1979	139 700 kW	137 000 kW	6551 Btu	52.1%	6912 kJ	1.2 inch Hg	87 300 kW	52 400 kW	2 x 6B.03	2P non reheat
6F.01	2003	86 350 kW	85 000 kW	5896 Btu	57.9%	6221 kJ	1.2 inch Hg	56 650 kW	29 700 kW	1 x 6F.01	3P non reheat
6F.01	2003	173 700 kW	171 000 kW	5849 Btu	58.3%	6171 kJ	1.2 inch Hg	113 300 kW	60 400 kW	2 x 6F.01	3P non reheat
6F.03	1991	137 000 kW	135 000 kW	5998 Btu	56.9%	6328 kJ	1.2 inch Hg	87 600 kW	49 400 kW	1 x 6F.03	3P non reheat
6F.03	1991	276 100 kW	272 000 kW	5944 Btu	57.4%	6271 kJ	1.2 inch Hg	175 200 kW	100 900 kW	2 x 6F.03	3P non reheat
GE Power Frame (50 Hz)											
9E.03	1979	206 550 kW	204 000 kW	6399 Btu	53.3%	6751 kJ	1.2 inch Hg	131 050 kW	75 500 kW	1 x 9E.03	2P non reheat
9E.03	1979	416 000 kW	410 000 kW	6353 Btu	53.7%	6703 kJ	1.2 inch Hg	262 100 kW	153 900 kW	2 x 9E.03	2P non reheat

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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 Power Frame (50 Hz) (cont'd)											
9E.04	2014	219 500 kW	216 000 kW	6220 Btu	54.9%	6563 kJ	1.2 inch Hg	143 300 kW	76 200 kW	1 x 9E.04	2P non reheat
9E.04	2014	441 700 kW	436 000 kW	6180 Btu	55.2%	6520 kJ	1.2 inch Hg	286 600 kW	155 100 kW	2 x 9E.04	2P non reheat
GT13E2	2012	308 750 kW	305 000 kW	6189 Btu	55.1%	6530 kJ	1.2 inch Hg	207 950 kW	100 800 kW	1 x GT13E2	2P non reheat
GT13E2	2012	620 900 kW	613 000 kW	6153 Btu	55.5%	6492 kJ	1.2 inch Hg	415 900 kW	205 000 kW	2 x GT13E2	2P non reheat
9F.03	1994	417 050 kW	412 000 kW	5778 Btu	59.1%	6096 kJ	1.2 inch Hg	263 650 kW	153 400 kW	1 x 9F.03	3P reheat
9F.03	1994	835 800 kW	825 000 kW	5764 Btu	59.2%	6081 kJ	1.2 inch Hg	527 300 kW	308 500 kW	2 x 9F.03	3P reheat
9F.04	2015	449 200 kW	443 000 kW	5666 Btu	60.2%	5978 kJ	1.2 inch Hg	285 600 kW	163 600 kW	1 x 9F.04	3P reheat
9F.04	2015	900 900 kW	889 000 kW	5649 Btu	60.4%	5960 kJ	1.2 inch Hg	571 200 kW	329 700 kW	2 x 9F.04	3P reheat
9F.05	2002	498 500 kW	493 000 kW	5619 Btu	60.7%	5928 kJ	1.2 inch Hg	****	****	1 x 9F.05	3P reheat
9F.05	2002	1 000 000 kW	989 000 kW	5603 Btu	60.9%	5911 kJ	1.2 inch Hg	625 300 kW	374 700 kW	2 x 9F.05	3P reheat
9HA.01	2011	688 300 kW	680 000 kW	5356 Btu	63.7%	5651 kJ	1.2 inch Hg	****	****	1 x 9HA.01	3P reheat
9HA.01	2011	1 378 800 kW	1 363 000 kW	5345 Btu	63.8%	5639 kJ	1.2 inch Hg	909 700 kW	469 100 kW	2 x 9HA.01	3P reheat
9HA.02	2014	848 000 kW	838 000 kW	5320 Btu	64.1%	5613 kJ	1.2 inch Hg	****	****	1 x 9HA.02	3P reheat
9HA.02	2014	1 700 000 kW	1 680 000 kW	5306 Btu	64.3%	5598 kJ	1.2 inch Hg	1 142 400 kW	557 600 kW	2 x 9HA.02	3P reheat
GE Power Frame (60 Hz)											
7E.03	1977	144 200 kW	142 000 kW	6505 Btu	52.5%	6863 kJ	1.2 inch Hg	90 600 kW	53 600 kW	1 x 7E.03	2P non reheat
7E.03	1979	291 200 kW	287 000 kW	6439 Btu	53.0%	6793 kJ	1.2 inch Hg	181 200 kW	110 000 kW	2 x 7E.03	2P non reheat
7F.04	2009	309 450 kW	305 000 kW	5715 Btu	59.7%	6030 kJ	1.2 inch Hg	196 650 kW	112 800 kW	1 x 7F.04	3P reheat
7F.04	2009	623 100 kW	615 000 kW	5676 Btu	60.1%	5989 kJ	1.2 inch Hg	393 300 kW	229 800 kW	2 x 7F.04	3P reheat
7F.05	2009	388 000 kW	383 000 kW	5692 Btu	60.0%	6005 kJ	1.2 inch Hg	240 300 kW	147 700 kW	1 x 7F.05	3P reheat
7F.05	2009	779 100 kW	769 000 kW	5664 Btu	60.3%	5976 kJ	1.2 inch Hg	480 700 kW	298 400 kW	2 x 7F.05	3P reheat
7HA.01	2012	443 100 kW	438 000 kW	5481 Btu	62.3%	5783 kJ	1.2 inch Hg	294 100 kW	149 000 kW	1 x 7HA.01	3P reheat
7HA.01	2012	890 700 kW	880 000 kW	5453 Btu	62.6%	5753 kJ	1.2 inch Hg	588 200 kW	302 500 kW	2 x 7HA.01	3P reheat
7HA.02	2014	580 100 kW	573 000 kW	5381 Btu	63.4%	5677 kJ	1.2 inch Hg	****	****	1 x 7HA.02	3P reheat
7HA.02	2014	1 162 200 kW	1 148 000 kW	5365 Btu	63.6%	5660 kJ	1.2 inch Hg	765 000 kW	397 200 kW	2 x 7HA.02	3P reheat
7HA.03	2019	650 780 kW	640 000 kW	5342 Btu	63.4%	5677 kJ	1.2 inch Hg	****	****	1 x 7HA.03	3P reheat
7HA.03	2019	1 297 600 kW	1 282 000 kW	5331 Btu	>64.0%	5625 kJ	1.2 inch Hg	860 000 kW	437 600 kW	2 x 7HA.03	3P reheat

IHI Power Systems (50/60 Hz)

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
LM2500PE	1986	32 500 kW	31 790 kW	7093 Btu	48.1%	7484 kJ	****	22 230 kW	10 270 kW	1 x LM2500PE	
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)

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
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	
LM6000PF+	2016	68 470 kW	67 200 kW	6203 Btu	55.0%	6545 kJ	****	50 240 kW	18 230 kW	1 x LM6000PF+	
LM6000PF+	2016	137 680 kW	135 020 kW	6175 Btu	55.3%	6515 kJ	****	100 480 kW	37 200 kW	2 x LM6000PF+	
LM6000PF+ Sprint	2016	72 570 kW	71 230 kW	6337 Btu	53.8%	6686 kJ	****	54 110 kW	18 460 kW	1 x LM6000PF+	
LM6000PF+ Sprint	2016	145 820 kW	143 020 kW	6313 Btu	54.0%	6661 kJ	****	108 220 kW	37 600 kW	2 x LM6000PF+	
LM6000PG	2009	71 310 kW	70 000 kW	6524 Btu	52.3%	6883 kJ	****	53 980 kW	17 330 kW	1 x LM6000PG	
LM6000PG	2009	143 290 kW	140 600 kW	6495 Btu	52.5%	6853 kJ	****	107 960 kW	35 330 kW	2 x LM6000PG	
LM6000PG Sprint	2009	73 670 kW	72 320 kW	6559 Btu	52.0%	6920 kJ	****	55 850 kW	17 820 kW	1 x LM6000PG	
LM6000PG Sprint	2009	148 000 kW	145 230 kW	6532 Btu	52.2%	6892 kJ	****	111 700 kW	36 300 kW	2 x LM6000PG	

Note: All IHI ratings with inlet and exhaust losses

MAN Energy Solutions (50/60 Hz)

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
THM 1304-12N	2004	34 040 kW	****	7720 Btu	44.2%	8150 kJ	2.6 inch Hg	23 040 kW	11 000 kW	2 x THM 1304-12N	2P HRSG

Note: Heat rate and efficiency gross plant performance for MAN

Mapna Group (50Hz)

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
MCC-30 1x1	2016	35 550 kW	34 980 kW	7077 Btu	48.2%	7467 kJ	****	24 600 kW	10 950 kW	1 x MGT-30	2P non reheat
MCC-40 2x1	2017	131 230 kW	128 400 kW	6824 Btu	50.0%	7200 kJ	****	40 470 kW	50 290 kW	2 x MGT-40	2P non reheat
MCC-70(3) 2x1 (1)	2016	546 900 kW	536 590 kW	6405 Btu	53.3%	6758 kJ	****	177 300 kW	192 300 kW	2 x MGT-70(3)	2P non reheat
MCC-70(3) 2x1 (2)	2016	559 490 kW	549 700 kW	6261 Btu	54.5%	6606 kJ	****	177 280 kW	204 930 kW	2 x MGT-70(3)	3P reheat

Mitsubishi Hitachi Power Systems (50/60 Hz)

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
MPCP1(H-25)	2008	60 100 kW	****	6319 Btu	54.0%	6667 kJ	1.2 inch Hg	39 600 kW	20 500 kW	1 x H-25	
MPCP2(H-25)	2008	121 400 kW	****	6261 Btu	54.5%	6606 kJ	1.2 inch Hg	79 200 kW	42 200 kW	2 x H-25	

Mitsubishi Hitachi Power Systems (50 Hz)

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
MPCP1(H-100)	2013	171 000 kW	****	5945 Btu	57.4%	6272 kJ	1.2 inch Hg	112 700 kW	58 300 kW	1 x H-100	
MPCP2(H-100)	2013	346 000 kW	****	5884 Btu	58.0%	6207 kJ	1.2 inch Hg	225 400 kW	120 600 kW	2 x H-100	
MPCP1(M701DA)	1981	213 200 kW	212 500 kW	6635 Btu	51.4%	7000 kJ	1.5 inch Hg	142 100 kW	70 400 kW	1 x M701DA	
MPCP2(M701DA)	1981	427 900 kW	426 600 kW	6610 Btu	51.6%	6974 kJ	1.5 inch Hg	284 200 kW	142 400 kW	2 x M701DA	
MPCP3(M701DA)	1981	647 000 kW	645 000 kW	6585 Btu	51.8%	6947 kJ	1.5 inch Hg	426 300 kW	218 700 kW	3 x M701DA	
MPCP1(M701F)	1992	567 700 kW	566 000 kW	5504 Btu	62.0%	5807 kJ	1.5 inch Hg	379 300 kW	186 700 kW	1 x M701F	
MPCP2(M701F)	1992	1 138 500 kW	1 135 000 kW	5486 Btu	62.2%	5788 kJ	1.5 inch Hg	758 600 kW	376 400 kW	2 x M701F	
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	820 400 kW	818 000 kW	5332 Btu	64.0%	5625 kJ	1.5 inch Hg	557 500 kW	260 500 kW	1 x M701JAC	
MPCP1(M701JAC)	2018	651 900 kW	650 000 kW	5332 Btu	64.0%	5625 kJ	1.5 inch Hg	441 700 kW	208 300 kW	1 x M701JAC	

Mitsubishi Hitachi Power Systems (60 Hz)

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
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(M501DA)	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(M501DA)	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(M501DA)	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	615 800 kW	614 000 kW	5332 Btu	64.0%	5625 kJ	1.5 inch Hg	420 300 kW	193 700 kW	1 x M501JAC	
MPCP2(M501JAC)	2015	1 234 700 kW	1 231 000 kW	5315 Btu	64.2%	5608 kJ	1.5 inch Hg	840 600 kW	390 400 kW	2 x M501JAC	

Note: All MHPS ratings on natural gas fuel LHV, at generator terminals, with inlet and exhaust losses

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
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	87 952 kW	86 431 kW	6814 Btu	50.1%	7190 kJ	1.5 inch Hg	70 229 kW	17 723 kW	1 x FT4000	
FT4000 SWIFTPAC 120	2012	177 243 kW	174 178 kW	6762 Btu	50.5%	7135 kJ	1.5 inch Hg	140 823 kW	36 420 kW	2 x FT4000	
Siemens Gas and Power (50/60 Hz)											
SGT-A35 G62 DLE 1x1	1993	****	37 700 kW	6801 Btu	50.2%	7175 kJ	1.5 inch Hg	26 716 kW	12 045 kW	1 x SGT-A35 (Ind RB211)	2P no reheat
SGT-A35 GT62 DLE 1x1	1999	****	39 800 kW	6639 Btu	51.4%	7005 kJ	1.5 inch Hg	28 626 kW	12 205 kW	1 x SGT-A35 (Ind RB211)	2P no reheat
SGT-A35 G61 DLE 1x1	2000	****	42 600 kW	6464 Btu	52.8%	6820 kJ	1.5 inch Hg	31 171 kW	12 593 kW	1 x SGT-A35 (Ind RB211)	2P no reheat
SCC-600 1x1	1981	****	35 900 kW	6843 Btu	49.9%	7220 kJ	1.3 inch Hg	23 880 kW	12 600 kW	1 x SGT-600	2P no reheat
SCC-600 2x1	1981	****	73 280 kW	6702 Btu	50.9%	7071 kJ	1.3 inch Hg	47 780 kW	26 450 kW	2 x SGT-600	2P no reheat
SCC-700 1x1	1999	****	45 160 kW	6517 Btu	52.3%	6876 kJ	1.3 inch Hg	32 300 kW	14 410 kW	1 x SGT-700	2P no reheat
SCC-700 2x1	1999	****	91 620 kW	6424 Btu	53.1%	6778 kJ	1.3 inch Hg	62 600 kW	30 040 kW	2 x SGT-700	2P no reheat
SCC-750 1X1	2012	****	51 550 kW	6407 Btu	53.3%	6760 kJ	1.3 inch Hg	38 650 kW	13 480 kW	1 x SGT-750	2P no reheat
SCC-750 2X1	2012	****	103 740 kW	6367 Btu	53.6%	6718 kJ	1.3 inch Hg	77 300 kW	27 480 kW	2 x SGT-750	2P no reheat
SCC-800 1x1	2010	****	71 200 kW	5969 Btu	57.2%	6298 kJ	1.2 inch Hg	48 800 kW	23 100 kW	1 x SGT-800	3P no reheat
SCC-800 2x1	2010	****	143 900 kW	5908 Btu	57.8%	6233 kJ	1.2 inch Hg	97 500 kW	47 800 kW	2 x SGT-800	3P no reheat
SCC-800 3x1	2010	****	215 700 kW	5903 Btu	57.8%	6228 kJ	1.2 inch Hg	146 300 kW	71 600 kW	3 x SGT-800	3P no reheat
SCC-800 1x1	2010	****	77 300 kW	5993 Btu	56.9%	6323 kJ	1.2 inch Hg	52 800 kW	25 300 kW	1 x SGT-800	3P no reheat
SCC-800 2x1	2010	****	156 300 kW	5931 Btu	57.5%	6257 kJ	1.2 inch Hg	105 700 kW	52 200 kW	2 x SGT-800	3P no reheat
SCC-800 3x1	2010	****	234 300 kW	5934 Btu	57.5%	6261 kJ	1.2 inch Hg	158 500 kW	78 200 kW	3 x SGT-800	3P no reheat
SCC-800 1x1	2010	****	80 700 kW	5896 Btu	57.9%	6221 kJ	1.2 inch Hg	55 800 kW	25 700 kW	1 x SGT-800	3P no reheat
SCC-800 2x1	2010	****	163 100 kW	5837 Btu	58.5%	6158 kJ	1.2 inch Hg	111 600 kW	53 200 kW	2 x SGT-800	3P no reheat
SCC-800 3x1	2010	****	245 000 kW	5833 Btu	58.5%	6154 kJ	1.2 inch Hg	167 400 kW	80 100 kW	3 x SGT-800	3P no reheat
SCC-800 1x1	2019	****	88 000 kW	5782 Btu	59.0%	6100 kJ	1.2 inch Hg	61 200 kW	27 700 kW	1 x SGT-800	3P no reheat
SCC-800 2x1	2019	****	180 000 kW	5687 Btu	60.0%	6000 kJ	1.2 inch Hg	122 400 kW	59 400 kW	2 x SGT-800	3P no reheat
SCC-800 3x1	2019	****	270 000 kW	5687 Btu	60.0%	6000 kJ	1.2 inch Hg	183 800 kW	88 900 kW	3 x SGT-800	3P no reheat
Siemens Gas and Power (50 Hz)											
SGT-A65 DLE 1x1	****	****	73 000 kW	6249 Btu	54.6%	6593 kJ	****	****	****	1 x SGT-A65 (Ind Trent 60)	2P no reheat
SGT-A65 DLE ISI 1x1	****	****	83 000 kW	6301 Btu	54.2%	6648 kJ	****	****	****	1 x SGT-A65 (Ind Trent 60)	2P no reheat
SGT-A65 DLE 2x1	****	****	147 000 kW	6204 Btu	55.0%	6546 kJ	****	****	****	2 x SGT-A65 (Ind Trent 60)	2P no reheat
SGT-A65 DLE ISI 2x1	****	****	166 800 kW	6272 Btu	54.4%	6617 kJ	****	****	****	2 x SGT-A65 (Ind Trent 60)	2P no reheat

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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 Gas and Power (50 Hz) (cont'd)											
SCC5-2000E 1x1	1981	****	275 000 kW	6341 Btu	53.9%	6690 kJ	****	187 000 kW	93 000 kW	1 x SGT5-2000E	2P no reheat
SCC5-2000E 2x1	1981	****	551 000 kW	6341 Btu	53.9%	6690 kJ	****	374 000 kW	186 000 kW	2 x SGT5-2000E	2P no reheat
SCC5-4000F 1S*	1995	****	475 000 kW	5716 Btu	59.7%	6030 kJ	****	****	****	1 x SGT5-4000F	3P reheat
SCC5-4000F 2x1	1995	****	950 000 kW	5716 Btu	59.7%	6030 kJ	****	658 000 kW	320 000 kW	2 x SGT5-4000F	3P reheat
SCC5-8000H 1S*	2009	****	665 000 kW	5583 Btu	61.0%	5890 kJ	****	****	****	1 x SGT5-8000H	3P reheat
SCC5-8000H 2x1	2010	****	1 335 000 kW	5573 Btu	61.0%	5880 kJ	****	900 000 kW	435 000 kW	2 x SGT5-8000H	3P reheat
SCC5-8000HL 1x1 1S*	2017	****	708 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	1 x SGT5-8000HL	3P reheat
SCC5-8000HL 2x1	2017	****	1 416 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	2 x SGT5-8000HL	3P reheat
SCC5-9000HL 1x1 1S*	2017	****	870 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	1 x SGT5-8000HL	3P reheat
SCC5-9000HL 2x1	2017	****	1 740 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	2 x SGT5-8000HL	3P reheat

*Siemens model 1S designates single shaft

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 Gas and Power (60 Hz)											
SGT-A65 DLE 1x1	****	****	73 000 kW	6249 Btu	54.6%	6593 kJ	****	****	****	1 x SGT-A65 (Ind Trent 60)	2P no reheat
SGT-A65 DLE ISI 1x1	****	****	83 000 kW	6301 Btu	54.2%	6648 kJ	****	****	****	1 x SGT-A65 (Ind Trent 60)	2P no reheat
SGT-A65 DLE 2x1	****	****	147 000 kW	6204 Btu	55.0%	6546 kJ	****	****	****	2 x SGT-A65 (Ind Trent 60)	2P unfired
SGT-A65 DLE ISI 2x1	****	****	166 800 kW	6272 Btu	54.4%	6617 kJ	****	****	****	2 x SGT-A65 (Ind 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	2P no reheat
SCC6-2000E 2X1	1989	****	347 000 kW	6541 Btu	52.2%	6901 kJ	****	234 000 kW	119 000 kW	2 x SGT6-2000E	2P no reheat
SCC6-5000F 1X1	1989	****	387 000 kW	5725 Btu	59.6%	6040 kJ	****	260 000 kW	133 000 kW	1 x SGT6-5000F	3P reheat
SCC6-5000F 2X1	1989	****	775 000 kW	5715 Btu	59.7%	6030 kJ	****	520 000 kW	267 000 kW	2 x SGT6-5000F	3P reheat
SCC6-5000F 1X1	1989	****	325 000 kW	5734 Btu	59.5%	6050 kJ	****	215 000 kW	115 000 kW	1 x SGT6-5000F	3P reheat
SCC6-5000F 2X1	1989	****	650 000 kW	5725 Btu	59.6%	6040 kJ	****	430 000 kW	230 000 kW	2 x SGT6-5000F	3P reheat
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	****	****	****	2 x SGT6-8000H	3P reheat
SCC6-9000HL 1x1 1S*	2017	****	595 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	1 x SGT6-9000HL	3P reheat
SCC6-9000HL 2X1	2017	****	1 190 000 kW	<5416 Btu	>63.0%	<5714 kJ	****	****	****	2 x SGT6-9000HL	3P reheat

*Siemens model 1S designates single shaft

Mechanical Drive GTW Design Ratings

Refer to "rule-of-thumb" editorial box on page 63 for adjustment factors that will enable you to estimate mechanical drive design ratings at non-ISO operating and site conditions.

Mechanical Drive Rating Parameters

ISO standard ratings with correction factors to adjust for actual site and operating conditions

GTW Mechanical Drive design ratings provide access to updated OEM gas turbine performance data in a consistent format that enables evaluation and comparison of competitively sized units on an apples-to-apples basis.

Conditions

Performance ratings are quoted for continuous load operation at ISO standard site conditions: 59°F (15°C) ambient air temperature, 14.7 psia (1.015 bar) sea level site elevation and 60% relative humidity conditions.

Unless otherwise stated, ratings are for natural gas fuel and ***gross power*** output excluding deductions for inlet and exhaust losses, and power consumed by auxiliaries.

Net ratings ***include deductions*** for inlet loss typical of high efficiency air filter (~ 4.0 inches H_2O), exhaust loss for stack and silencer (~ 5.0 inches H_2O) and parasitic auxiliary power consumption for packaged units (~ 0.25%).

In either case, ratings are always for a factory "new and clean" gas turbine with less than 200 hours of fired operation.

Format

Gas turbine OEMs appear in alphabetic order, with gas turbine models listed in ascending order by power rating.

For comparative evaluation purposes, the rating parameters are the same for all OEM listings (see column headings):

- **Model**. A number or alphabetic letter ending the model designation denotes an evolutionary upgrade.

- **Intro Year**. When original design series was (or will be) first introduced commercially.

Adjusting ISO ratings to match site and operating conditions

Rule of thumb factors for adjusting ISO-based ratings to estimate actual performance at non-ISO site and operating conditions.

■ **Ambient temperature**. Expect about 0.4% reduction in power output and 0.1% increase in heat rate for each 1°F (0.56°C) rise in ambient temperature above 59°F (15°C).The reverse holds true below 59°F ambient temperature.

■ **Site elevation**. For each 1,000-ft increase in site elevation above sea level, there is about a 3.5% loss in power output. The effect is minimal on heat rate.

■ **Inlet losses**. For each inch H_2O of added inlet pressure drop, figure on about a 0.4% reduction in power output and 0.1% increase in heat rate.

Outlet losses. For each inch H_2O of added outlet or exhaust pressure drop, you can expect a 0.1% reduction in power output and 0.1% increase in heat rate.

■ **Net Rating.** Allow for about 2-3% reduction in power output and an increase of about 1% in heat rate due to packaging losses (e.g., inlet and outlet pressure drops) and power consumed by auxiliaries.

■ **Fuel type**. Figure on around 2-3% less power and 1-2% higher heat rate when burning distillate fuel as compared to natural gas. (Check with OEM on possible derating for out-of-spec fuel.)

- **ISO Continuous.** Design power rating (hp) for full load continuous operation (over 6,000 hours per year) with normal service and maintenance intervals.

- **Heat rate**. Lower heating value (LHV) of natural gas fuel unless otherwise stated (expressed as Btu/hp-hr).

- **Efficiency**. Percentage of energy "out" divided by energy "in" at baseload power output, calculated as 2544.4 divided by LHV heat rate as Btu/hp-hr.

- **Pressure ratio.** Turbine compressor discharge divided by inlet pressure. High pressure ratio is characteristic of high efficiency design.

- **Mass flow**. Compressor output flow plus fuel combustion gas flow at base load output, without water or steam injection unless otherwise stated.

- **Turbine Speed**. Power turbine output coupling speed for direct drive or into gearbox to match driven load speed.

- **Exhaust temperature.** Hot gas flow leaving the gas turbine outlet duct at base load output.

Engineering design ratings are generally confirmed by full-load factory testing before shipment (for small gas turbines) and by field testing (units too large for in-house test facilities).

Factory testing prior to shipment is preferred because it is faster, less expensive and can be performed under controlled conditions. In addition, corrective issues can be more readily addressed.

OEMs typically place a contractual limit on fired hours before verification testing in the field and on calendar time after delivery. If testing is not completed within the specified time limits, it is deemed to have been completed, and contractual requirements met.

Degradation

All gas turbines experience some degradation in power output and efficiency during their operating lifetimes. To some extent most of those losses are recoverable.

Compressor fouling is a common contributor to a fall-off in performance. This may be partially corrected by online water washing at regular intervals, supplemented by various mechanical cleaning methods during shutdowns.

Degradation due to normal wear and tear calls for component repair or replacement during minor and major maintenance outages.

Typically, power and heat rate will degrade by 2-6% during the first 24,000 hours of operation (routine interval for a hot gas path inspection) and then stabilize.

Replacing worn parts normally will restore performance to within 1 to 1.5% points of original factory-new levels.

Many OEMs offer retrofit improvements in gas turbine designs, during overhaul shutdowns with improved technology components that will increase power and efficiency, "beating the degradation curve".

Due diligence

Remember that published design ratings are subject to change as the result of an engineering upgrade or modification, often without OEM notification.

Considering that the specs data has been recently updated, our Handbook ratings are well suited for preliminary planning studies and gas turbine performance evaluation.

But as projects develop, and more detailed studies become necessary, it is imperative to confirm the accuracy of those ratings with the gas turbine OEM involved before making any firm engineering or approval decisions.

This is also the time to inquire about potential near-term upgrades in the works or pending new gas turbine ready for introduction that might better fit project requirements and still meet your project timetable.

Gas turbine OEM sales and marketing engineers are adept at optimizing off-design performance of their machines that can be tailored to satisfy special environmental permit and operating requirements.

Last, please notify the Handbook editor of any ratings that appear questionable. We'll check with the gas turbine OEM and reply to you with an answer plus publish validated corrections.

Special note

Gas turbine units for oil and gas pipeline, offshore platform and petrochemical installations must be specially packaged to operate safely in explosive, flammable and other hostile environments.

This need for compliance with strict international standards mandated by API, ISO and PED specifications (European directive for pressurized equipment) also may compromise published ratings.

The preceding comments pertaining to hazardous installations only emphasize the need to contact OEMs and verify site-defined performance ratings as you narrow down your gas turbine model selections for ongoing project application. ■

2020 GTW Mechanical Drive Specs

Model	Intro Year	ISO Continuous	Heat Rate (Btu/hp-hr)	Efficiency	Pressure Ratio	Mass Flow (lb/sec)	Turbine Speed (rpm)	Exhaust Temp (F)	Approx Weight	Approx LxWxH	Comments
Baker Hughes GE											
NovaLT5-2	2015	7 721 hp	8 233 Btu	30.9%	15.0	43.2 lb	12500 rpm	1031 F	61 729 lb	42 x 8 x 11 ft	DLN <25ppm NOx
NovaLT12	2014	17 499 hp	6 933 Btu	36.7%	19.0	92.8 lb	8900 rpm	929 F	92 594 lb	25 x 8 x 13 ft	DLN 15ppm NOx
NovaLT16	2014	23 422 hp	6 781 Btu	37.5%	19.3	120.4 lb	7800 rpm	923 F	110 230 lb	33 x 12 x 13 ft	DLN 15ppm NOx
PGT25	1981	31 660 hp	6 787 Btu	37.5%	17.9	151.9 lb	6500 rpm	976 F	83 005 lb	30 x 12 x 12 ft	standard combustion
PGT25+	1996	42 962 hp	6 296 Btu	40.4%	21.5	189.1 lb	6100 rpm	932 F	67 790 lb	21 x 12 x 13 ft	standard combustion
PGT25+G4	2005	46 385 hp	6 296 Btu	40.4%	23.2	198.4 lb	6100 rpm	950 F	68 010 lb	21 x 12 x 13 ft	standard combustion
PGT25	1981	31 638 hp	6 823 Btu	37.3%	17.9	151.0 lb	6500 rpm	983 F	83 005 lb	30 x 12 x 12 ft	DLE 25/15 ppm NOx
PGT25+	1996	42 682 hp	6 309 Btu	40.3%	21.8	188.2 lb	6100 rpm	936 F	67 790 lb	21 x 12 x 13 ft	DLE 25/15 ppm
NOx											
PGT25+G4	2005	46 061 hp	6 308 Btu	40.3%	23.0	197.5 lb	6100 rpm	955 F	68 010 lb	21 x 12 x 13 ft	DLE 25 ppm NOx
PGT25+G5	2018	50 825 hp	6 233 Btu	40.8%	24.9	203.9 lb	6100 rpm	1022 F	68 010 lb	21 x 12 x 13 ft	DLE 25/15 ppm NOx
LM6000PC	1997	59 560 hp	5 957 Btu	42.7%	28.8	278.9 lb	3600 rpm	845 F	68 345 lb	31 x 14 x 14 ft	standard combustion
LM6000PF	2006	58 809 hp	5 917 Btu	43.0%	28.0	275.0 lb	3600 rpm	851 F	68 345 lb	31 x 14 x 14 ft	DLE 15 ppm NOx
LM6000PG	2008	70 787 hp	5 890 Btu	43.2%	32.3	311.0 lb	3930 rpm	880 F	68 645 lb	31 x 14 x 14 ft	standard combustion
LM6000PF+	2017	72 812 hp	5 960 Btu	42.7%	32.0	319.0 lb	3930 rpm	890 F	68 645 lb	31 x 14 x 14 ft	DLE 25 ppm NOx
MS5002(C)	2010	38 000 hp	8 698 Btu	29.3%	9.1	270.0 lb	4670 rpm	1004 F	****	****	standard combustion
MS5002(D)	2010	45 569 hp	8 413 Btu	30.2%	10.4	308.0 lb	4670 rpm	1040 F	****	****	standard combustion
MS5002(E)	2003	45 300 hp	6 884 Btu	37.0%	17.4	226.0 lb	5714 rpm	964 F	257 940 lb	56 x 11 x 13 ft	DLN-2 combustion
MS6001(B)	1999	58 380 hp	7 647 Btu	33.3%	12.2	309.0 lb	5111 rpm	1011 F	211 645 lb	52 x 11 x 12 ft	standard combustion
MS7001(EA)	1984	115 630 hp	7 718 Btu	33.0%	12.7	652.5 lb	3600 rpm	995 F	266 760 lb	38 x 11 x 12 ft	standard combustion
M9001(E)	2003	174 520 hp	7 348 Btu	34.6%	12.7	921.0 lb	3000 rpm	1004 F	479 505 lb	73 x 15 x 21 ft	standard combustion
LM9000	2017	89 850 hp	5 919 Btu	43.0%	33.0	395.0 lb	3429 rpm	850 F	81 079 lb	45 x 16 x 15 ft	DLE 15 ppm NOx
LMS100PB+	2016	144 835 hp	5 669 Btu	44.9%	43.2	494.0 lb	3428 rpm	787 F	209 000 lb	59 x 69 x 15 ft	DLE 25 ppm NOx
LMS100PA+	2016	152 430 hp	5 669 Btu	44.9%	42.7	501.6 lb	3428 rpm	775 F	209 000 lb	59 x 69 x 15 ft	standard combustion

Note: All weights & sizes without enclosure for BHGE

Model	Intro Year	ISO Continuous	Heat Rate (Btu/hp-hr)	Efficiency	Pressure Ratio	Mass Flow (lb/sec)	Turbine Speed (rpm)	Exhaust Temp (F)	Approx Weight	Approx LxWxH	Comments
Kawasaki Heavy Industries											
L30A	2012	47 660 hp	6 100 Btu	41.7%	25.8	204.1 lb	5600 rpm	936 F	****	****	
Magellan Aerospace											
GT6000	1993	8 717 hp	8 078 Btu	31.5%	14.0	68.3 lb	8200 rpm	806 F	7 716 lb	12 x 4 x 5 ft	
GT10000	2002	14 081 hp	7 068 Btu	36.0%	19.5	79.0 lb	4800/6500	914 F	11 023 lb	13 x 6 x 6 ft	
GT15000	1991	22 395 hp	7 270 Btu	35.0%	20.0	157.0 lb	5200 rpm	788 F	25 574 lb	15 x 7 x 7 ft	
GT25000	1995	35 805 hp	6 971 Btu	36.5%	21.0	194.0 lb	3700/5000	914 F	35 274 lb	21 x 8 x 9 ft	
	Note: weights & size engine only for Magellan										
MAN Energy Solutions											
MGT6000	2012	9 250 hp	7 480 Btu	34.0%	15.0	62.0 lb	12000 rpm	860 F	****	26 x 10 x 13 ft	
MGT6000	2018	11 130 hp	7 270 Btu	35.0%	16.0	66.1 lb	12000 rpm	896 F	****	26 x 10 x 13 ft	
THM1304-10N	1980	14 080 hp	8 370 Btu	30.4%	10.0	102.5 lb	9000 rpm	914 F	71 000 lb	33 x 11 x 15 ft	
THM1304-12N	2004	16 090 hp	8 210 Btu	31.0%	11.0	106.0 lb	9000 rpm	977 F	71 000 lb	33 x 11 x 15 ft	
Mapna Group											
MGT-30MD	2013	33 526 hp	7 048 Btu	36.1%	21.5	194.0 lb	3500/5000/5250	892 F	31 306 lb	21 x 8 x 8 ft	
Mitsubishi Hitachi Power Systems											
H-100	2010	144 350 hp	6 542 Btu	38.9%	18.4	646.0 lb	3600 rpm	993 F	386 000 lb	40 x 15 x 18 ft	
H-100	2013	160 780 hp	6 549 Btu	38.9%	20.1	695.0 lb	3000 rpm	1025 F	476 000 lb	46 x 16 x 20 ft	
PW Power Systems											
FT8	1990	37 940 hp	6 580 Btu	38.7%	20.2	193.4 lb	5500 rpm	857 F	****	****	
Siemens Gas and Power											
SGT-100	2010	7 640 hp	7 656 Btu	33.2%	14.9	43.0 lb	6500/13000/13650	1013 F	59 400 lb	20 x 9 x 16 ft	
SGT-300 (8 MW)	2011	11 216 hp	7 315 Btu	34.8%	13.8	65.5 lb	5750/11500/12075	925 F	67 042 lb	23 x 10 x 14 ft	
SGT-300 (9 MW)	2011	12 257 hp	7 191 Btu	35.4%	14.5	67.3 lb	5750/11500/12075	954 F	67 042 lb	23 x 10 x 14 ft	
SGT-400 (11 MW)	2018	14 470 hp	7 019 Btu	36.2%	16.0	74.5 lb	5750/11500/12075	946 F	67 042 lb	23 x 10 x 14 ft	
SGT-400 (13 MW)	1997	18 000 hp	7 028 Btu	36.2%	16.8	86.8 lb	4750/9500/9975	1031 F	88 000 lb	24 x 10 x 14 ft	
SGT-400 (15 MW)	2010	20 006 hp	6 908 Btu	36.8%	18.9	97.0 lb	4750/9500/9975	1004 F	88 500 lb	24 x 10 x 14 ft	
SGT-600	1981	33 847 hp	7 344 Btu	34.6%	14.0	179.2 lb	3850/7700/8085	1009 F	130 000 lb	38 x 13 x 13 ft	
SGT-700	1999	45 151 hp	6 661 Btu	38.2%	18.7	209.0 lb	3250/6500/6825	991 F	139 000 lb	38 x 13 x 13 ft	
SGT-750 (41 MW)	2012	54 994 hp	6 122 Btu	41.6%	24.3	253.5 lb	3050/6100/6405	875 F	167 551 lb	40 x 14 x 14 ft	
SGT-750 (34 MW)	2012	45 595 hp	6 299 Btu	40.4%	21.9	236.9 lb	3050/6100/6405	822 F	167 551 lb	40 x 14 x 14 ft	

Model	Intro Year	ISO Continuous	Heat Rate (Btu/hp-hr)	Efficiency	Pressure Ratio	Mass Flow (lb/sec)	Turbine Speed (rpm)	Exhaust Temp (F)	Approx Weight	Approx LxWxH	Comments
Siemens Gas and Power (cont'd)											
SGT-A35 (G62) DLE	1993	37 465 hp	6 819 Btu	37.3%	20.6	201.0 lb	3120/4800/5040	934 F	****	****	Industrial RB211 G62 DLE
SGT-A35 (G62)	1993	39 075 hp	6 743 Btu	37.7%	21.3	206.0 lb	3120/4800/5040	934 F	****	****	Industrial RB211 G62 non-DLE
SGT-A35 (GT62) DLE	1999	41 084 hp	6 602 Btu	38.5%	21.7	209.0 lb	3120/4800/5040	938 F	****	****	Industrial RB211 GT62 DLE
SGT-A35 (G62)	1999	41 495 hp	6 599 Btu	38.6%	22.0	212.0 lb	3120/4800/5040	938 F	****	****	Industrial RB211 GT62 non-DLE
SGT-A35 (GT61) DLE	2000	44 230 hp	6 306 Btu	40.3%	21.6	207.0 lb	3153/4850/5093	949 F	****	****	Industrial RB211 GT61 DLE
SGT-A35 (GT61)	2000	45 316 hp	6 299 Btu	40.4%	22.1	209.0 lb	3153/4850/5093	949 F	****	****	Industrial RB211 GT61 non-DLE
SGT-A35 (GT30 34MW) DLE	2015	44 374 hp	6 541 Btu	38.9%	22.3	216.5 lb	2400/3429/3600	933 F	****	****	Industrial RB211 GT30 DLE
SGT-A35 (GT30 34MW)	2015	45 245 hp	6 516 Btu	39.1%	22.8	218.9 lb	2400/3429/3600	934 F	****	****	Industrial RB211 GT30 non-DLE
SGT-A35 (GT30 38MW)	2017	51 092 hp	6 317 Btu	40.3%	25.2	241.8 lb	2400/3429/3600	910 F	****	****	Industrial RB211 GT30 non-DLE
SGT-A65 DLE	2003	79 249 hp	5 731 Btu	44.4%	35.6	357.1 lb	3500 rpm	824 F	****	****	Industrial Trent 60 DLE
SGT-A65 DLE W. ISI	2003	84 385 hp	5 786 Btu	44.0%	36.6	364.9 lb	3500 rpm	831 F	****	****	Industrial Trent 60 DLE
Solar Turbines											
Saturn 20	1960	1 590 hp	10 360 Btu	24.6%	6.7	14.3 lb	22300 rpm	970 F	15 000 lb	15 x 6 x 7 ft	
Centaur 40	1969	4 700 hp	9 100 Btu	27.9%	10.3	41.7 lb	15500 rpm	840 F	33 000 lb	20 x 8 x 9 ft	
Centaur 50	1985	6 130 hp	8 485 Btu	30.0%	10.3	41.4 lb	16500 rpm	960 F	36 000 lb	20 x 8 x 9 ft	
Taurus 60	1990	7 700 hp	7 950 Btu	32.0%	12.2	47.6 lb	14300 rpm	950 F	34 000 lb	20 x 8 x 9 ft	
Taurus 70	1995	11 110 hp	7 190 Btu	35.4%	16.5	59.7 lb	11605 rpm	935 F	54 000 lb	25 x 9 x 11 ft	
Mars 90	1978	13 220 hp	7 655 Btu	33.2%	16.3	88.4 lb	9500 rpm	870 F	74 000 lb	30 x 9 x 11 ft	
Mars 100	1978	15 900 hp	7 395 Btu	34.4%	17.1	92.9 lb	9500 rpm	905 F	74 000 lb	30 x 9 x 11 ft	
Titan 130	1998	23 470 hp	6 800 Btu	37.4%	16.1	110.0 lb	8855 rpm	895 F	85 000 lb	32 x 10 x 10 ft	
Titan 250	2009	31 900 hp	6 360 Btu	40.6%	24.1	150.0 lb	7000 rpm	865 F	110 000 lb	34 x 11 x 13 ft	
UEC-Aviadvigatel											
GTU-10P	1999	13 759 hp	7 831 Btu	32.5%	14.3	96.8 lb	9000 rpm	865 F	30 860 lb	24 x 11 x 11 ft	
GTU-12P	1994	16 629 hp	7 355 Btu	34.6%	15.8	103.6 lb	6500 rpm	878 F	24 250 lb	24 x 11 x 11 ft	
GTU-16P	1996	22 087 hp	6 878 Btu	37.0%	19.6	125.9 lb	5300 rpm	1004 F	30 860 lb	35 x 11 x 11 ft	
GTU-25P	2003	34 330 hp	6 492 Btu	39.2%	27.8	175.5 lb	5000 rpm	910 F	44 090 lb	45 x 8 x 20 ft	

Model	Intro Year	ISO Continuous	Heat Rate (Btu/hp-hr)	Efficiency	Pressure Ratio	Mass Flow (lb/sec)	Turbine Speed (rpm)	Exhaust Temp (F)	Approx Weight	Approx LxWxH	Comments
UEC-Gas Turbines											
GPA-4RM	2003	5 362 hp	7 832 Btu	32.5%	12.1	47.0 lb	10500 rpm	725 F	8 819 lb	30 x 11 x 12 ft	standard combustion
GPA-4RMP	2009	5 362 hp	7 832 Btu	32.5%	12.1	47.0 lb	10500 rpm	725 F	8 819 lb	30 x 11 x 12 ft	standard combustion
GPA-6.3RM	2005	8 445 hp	7 954 Btu	32.0%	13.4	56.0 lb	8200 rpm	896 F	9 921 lb	30 x 11 x 12 ft	standard combustion
GPA-6.3/8RM	2009	10 724 hp	7 713 Btu	33.0%	14.6	66.0 lb	8200 rpm	932 F	10 141 lb	30 x 11 x 12 ft	standard combustion
GPA-10 (GTD-10RM)	2012	13 405 hp	7 954 Btu	32.0%	17.3	72.0 lb	4800 rpm	968 F	12 125 lb	30 x 11 x 12 ft	standard combustion
GPA-10 (PS-90GP1)	2014	13 405 hp	8 211 Btu	31.0%	14.3	97.0 lb	4800 rpm	865 F	13 228 lb	30 x 11 x 12 ft	standard combustion
GPA-16 Arlan (AL-31)	2009	21 448 hp	7 273 Btu	35.0%	18.0	144.0 lb	5300 rpm	914 F	18 739 lb	30 x 15 x 10 ft	standard combustion
GPA-16R (PS-90GP2)	2013	21 448 hp	7 012 Btu	36.3%	19.6	126.0 lb	5300 rpm	1004 F	19 842 lb	30 x 15 x 10 ft	standard combustion
GPA-25	2014	33 512 hp	6 716 Btu	37.9%	27.8	175.0 lb	5000 rpm	910 F	33 070 lb	30 x 15 x 13 ft	standard combustion
Vericor											
VPS3	1978	4 364 hp	9 063 Btu	28.1%	8.8	28.3 lb	16000 rpm	1110 F	45 000 lb	20 x 8 x 23 ft	twin spool
VPS4	1999	4 877 hp	8 511 Btu	29.9%	10.1	30.4 lb	16000 rpm	1076 F	45 000 lb	20 x 8 x 23 ft	twin spool
TF40F	2013	4 000 hp	9 054 Btu	28.1%	8.5	27.7 lb	15400 rpm	1066 F	1 325 lb	4 x 4 x 3 ft	GT only
TF50F	2013	5 100 hp	8 507 Btu	29.9%	10.5	30.4 lb	15400 rpm	1125 F	1 475 lb	4 x 4 x 3 ft	GT only
Zorya-Mashproekt											
UGT 3000	1998	4 500 hp	8 210 Btu	31.0%	13.5	34.2 lb	9700 rpm	824 F	5 070 lb	8 x 6 x 4 ft	
UGT 6000	2018	8 720 hp	8 080 Btu	31.5%	14.0	68.3 lb	8200 rpm	806 F	8 785 lb	11 x 4 x 5 ft	
UGT 8000	2006	11 130 hp	7 665 Btu	33.2%	16.0	72.8 lb	8200 rpm	896 F	10 980 lb	13 x 5 x 5 ft	
UGT 15000	2017	22 400 hp	7 270 Btu	35.0%	19.5	156.5 lb	5200 rpm	788 F	21 750 lb	15 x 6 x 7 ft	
UGT 16000	1991	22 400 hp	7 955 Btu	32.0%	13.0	216.1 lb	5200 rpm	662 F	33 070 lb	19 x 8 x 8 ft	
UGT 25000	2005	35 800 hp	6 975 Btu	36.5%	21.5	196.2 lb	3700/5000	914 F	31 530 lb	21 x 8 x 8 ft	
UGT 32000	2021	43 990 hp	6 695 Btu	38.0%	22.8	231.5 lb	5500 rpm	887 F	36 600 lb	21 x 8 x 8 ft	

Marine Drive GTW Design Ratings

2020 GTW Marine Gas Turbine Specs

Model	Intro Year	Power	SFC (lb/shp-hr)	Efficiency	Pressure Ratio	Mass Flow lb/sec	Power Turbine	Exhaust Temp(F)	Approx Weight	Approx LxWxH	Comments
GE Marine (Division of GE Aviation)											
LM500	1980	6 663 shp	0.436 lb	31.4%	14.4	36.0 lb	7000 rpm	1049 F	1 350 lb	6 x 2 x 2 ft	
LM2500	1969	33 600 shp	0.372 lb	37.4%	19.3	155.0 lb	3600 rpm	1051 F	10 300 lb	13 x 5 x 5 ft	
LM2500+	1998	40 500 shp	0.354 lb	39.3%	22.2	189.0 lb	3600 rpm	965 F	11 545 lb	14 x 5 x 5 ft	
LM2500+G4	2005	49 587 shp	0.350 lb	39.5%	25.4	206.1 lb	3600 rpm	1042 F	11 545 lb	14 x 5 x 5 ft	
LM6000PC	1997	61 850 shp	0.333 lb	42.2%	28.5	273.0 lb	3600 rpm	853 F	18 010 lb	15 x 6 x 6 ft	
LM6000PG	2008	70 655 shp	0.334 lb	41.6%	34.1	306.9 lb	3850 rpm	935 F	16 300 lb	15 x 6 x 6 ft	

Note: GE ratings at 59°F (15°C) sea level, 60% RH, no inlet/exhaust losses, based on 18,400 Btu (LHV) liquid fuel

Model	Intro Year	Power	SFC (lb/shp-hr)	Efficiency	Pressure Ratio	Mass Flow lb/sec	Power Turbine	Exhaust Temp(F)	Approx Weight	Approx LxWxH	Comments
Rolls-Royce											
501-K34	1986	5 300 shp	0.470 lb	29.4%	11.3	34.4 lb	14340 rpm	1028 F	1 545 lb	****	package AG9140 RF
MT7	2010	5 700 shp	0.429 lb	32.2%	16.7	****	15000 rpm	****	1 043 lb	****	
MT5	2004	5 530 shp	0.489 lb	28.3%	12.5	46.1 lb	14600 rpm	959 F	1 690 lb	****	package RR4500
MT55-HE+	2016	6 034 shp	0.459 lb	29.8%	12.8	****	14600 rpm	1018 F	1 690 lb	****	package AG9160 RF
Spey	1987	26 150 shp	0.379 lb	36.5%	21.9	144.7 lb	5500 rpm	914 F	****	****	
WR-21	1997	28 930 shp	0.327 lb	42.3%	14.2	148.6 lb	3600 rpm	640 F	****	****	
MT30	2001	48 275 shp	0.353 lb	39.2%	24.0	254.6 lb	3300/3600	870 F	70 560 lb	****	mech or elec drive
MT30	2008	53 640 shp	0.348 lb	39.8%	25.7	268.4 lb	3418 rpm	892 F	70 560 lb	****	mech drive apps only

Note: ISA Environment: 18400 Btu/lb LHV; MT30 power constant to 100 F air temp; MT30 power retained through life

Model	Intro Year	Power	SFC (lb/shp-hr)	Efficiency	Pressure Ratio	Mass Flow lb/sec	Power Turbine	Exhaust Temp(F)	Approx Weight	Approx LxWxH	Comments
Vericor											
TF40	1976	4 600 shp	0.489 lb	28.3%	8.5	27.8 lb	15400 rpm	1066 F	1 325 lb	4 x 3 x 3 ft	twin unit available
ETF40B	2001	5 035 shp	0.461 lb	30.2%	10.1	30.2 lb	15400 rpm	1112 F	1 425 lb	4 x 3 x 3 ft	twin unit available
TF50B	2015	5 600 shp	0.460 lb	30.2%	10.9	31.4 lb	16000 rpm	1165 F	1 440 lb	5 x 3 x 3 ft	twin unit available
Zorya-Mashproekt											
UGT 3000	1998	4 500 shp	0.447 lb	31.0%	13.5	34.2 lb	9700 rpm	824 F	3 260 lb	8 x 3 x 4 ft	
UGT 3000R	1988	4 500 shp	0.478 lb	29.0%	14.0	35.3 lb	8800 rpm	878 F	3 970 lb	8 x 3 x 5 ft	reversible
UGT 6000	1978	9 860 shp	0.433 lb	32.0%	14.5	70.5 lb	7000 rpm	824 F	5 400 lb	11 x 4 x 5 ft	
UGT 6000R	1988	9 860 shp	0.462 lb	30.0%	15.0	71.6 lb	4750 rpm	878 F	11 130 lb	12 x 6 x 7 ft	reversible
UGT 6000+	2003	11 830 shp	0.420 lb	33.0%	16.0	75.0 lb	7000 rpm	878 F	6 180 lb	10 x 4 x 6 ft	
UGT 6000R+	1988	11 830 shp	0.447 lb	31.0%	16.5	76.1 lb	7300 rpm	932 F	6 660 lb	11 x 5 x 5 ft	reversible
UGT 15000	1988	22 380 shp	0.396 lb	35.0%	20.0	160.9 lb	5300 rpm	806 F	21 350 lb	15 x 6 x 6 ft	
UGT 15000R	1988	19 720 shp	0.420 lb	33.0%	19.0	154.3 lb	4400 rpm	752 F	25 360 lb	17 x 6 x 9 ft	reversible
UGT 15000+	2005	29 100 shp	0.383 lb	36.2%	21.0	174.2 lb	3500 rpm	851 F	29 770 lb	20 x 8 x 9 ft	
UGT 16000	1988	22 190 shp	0.433 lb	32.0%	13.5	215.5 lb	5300 rpm	662 F	28 300 lb	22 x 7 x 12 ft	
UGT 16000R	1982	22 190 shp	0.462 lb	30.0%	13.5	220.5 lb	3600 rpm	716 F	37 920 lb	22 x 7 x 12 ft	reversible
UGT 25000MA	2008	38 500 shp	0.374 lb	37.0%	22.5	207.2 lb	3460 rpm	932 F	32 400 lb	21 x 8 x 8 ft	
UGT 32000	2021	44 250 shp	0.363 lb	38.2%	22.8	233.7 lb	3040/5500	896 F	38 400 lb	21 x 8 x 8 ft	

Section 4

Combined Cycles

Mississippi Co-op selects HL technology to repower old 200MW coal-steam unit

By Harry Jaeger

Price for converting 200 MW coal-fired steam plant into a 573 MW high-efficiency CC plant estimated at $442 million

Cooperative Energy (formerly known as South Mississippi Electric Power Association) is repowering its 400MW coal-fired R.D. Morrow, Sr. Generating Station to create a modern high-efficiency gas-fired combined cycle power plant.

One of the plant's two existing 200MW steam turbine generators will be modernized and applied to match the design parameters of an advanced technology gas turbine generator and unfired HRSG for combined cycle operation. Project highlights:

■ **Engineering**. Repowering project is designed around a Siemens 400MW SGT6-9000HL gas turbine generator, Nooter/Eriksen 3-pressure level heat recovery steam generator and existing General Electric steam turbine in a 1x1 combined cycle configuration.

■ **Site Rating.** New combined cycle plant is design rated at 573MW gross (558MW net) baseload output and ~60% (LHV) net plant efficiency (~5687 Btu/kWh heat rate) at 62°F average ambient temperature and 260-ft elevation site conditions.

■ **Project Cost**. Estimated at $442 million (~ $800/kW installed) including cost of demolition, new plant equipment, steam turbine overhaul, engineering, construction, upgrading high-voltage transmission line and plant substation.

■ **Timetable**. Demolitions now underway preparing for the start of construction early in 2020, subject to final regulatory approval; expect full combined cycle commercial operation in 2023.

■ **Environment**. Looking at significant reduction in regulated emissions (PM, SO2, NOx), over 2.7 million tons per year less CO2, and over 40% reduction in condenser cooling water requirements.

In announcing their new repowering project, Cooperative Energy executives pointed out that the 40 year-old coal-fired Plant Morrow is no longer competitive in the Midcontinent Independent System Operator (MISO) market environment, where capacity is now being dispatched on a day-ahead basis, or in real-time, as needed.

The fact that the old steam units require 36 hours to ramp up from cold-start to full-load makes economical participation in such a dynamic dispatch environment untenable.

The natural gas-fired combined cycle unit will greatly improve generating economics at the plant, says Trey Cannon, Director of Generation Projects, and, he adds, the multiple interstate gas pipelines near the site will lower fuel transportation costs.

It also helps that needed plant repairs and upgrades will be avoided, and that the cost of compliance with environmental regulations will be much lower when operating on gas. Near term, the company says it expects the capacity factor of the repowered unit will be approximately 70 percent.

Preliminary studies

Leading to the decision to repower the Unit 1 steam turbine, the company conducted a variety of power supply studies, including production cost modeling, to identify the most economical solution for the Morrow Station.

Table 1. Repowered combined cycle plant emissions
Morrow gas-fired 557 MW combined cycle emissions reduction compared to the original coal-fired 2 x 200 MW steam plant at full baseload output.

Power Plant Emissions	557 MW CC Plant	400 MW Coal Plant	Emissions Reduction
SO2	12 lb/hr	316 lb/hr	96%
NOx	75 lb/hr	481 lb/hr	84%
PM 10	36 lb/hr	115 lb/hr	69%
CO2	0.5 x10^6 lb/hr	1.1x10^6 lb/hr	56%

Based on a long-term forecast of the needs of its 11 capital Member utilities, many options and changes to the Cooperative Energy generating fleet were considered. Various studies indicate that repowering Plant Morrow Unit 1 is one of the most economical options available, according to Cannon.

To assist in the planning and design, the company hired Burns & McDonnell as Architect/Engineer for the project.

The decision to use an existing steam turbine generator and much of its related assets, rather than install a new "grass-roots" combined cycle unit, was based on minimizing total project costs while still achieving the target increase in plant efficiency and capacity, plus desired reduction in site emissions.

Table 2. Morrow repowered combined cycle performance
Morrow combined cycle plant ratings are calculated for 62°F average ambient temperature and 260-ft site elevation conditions on natural gas gas fuel.

1 x 1 Configuration Performance Parameter	Morrow Site Rating
Gas turbine output (gross)	402,400 kW
Gas turbine auxiliary loads	533 kW
Net gas turbine output	401,867 kW
Steam turbine output (gross)	171,500 kW
Steam cycle auxiliary loads	15,634 kW
Net steam cycle output	155,866 kW
Net plant output	557,733 kW
Net plant heat rate (LHV)*	~ 5687 Btu/kWh
Net plant efficiency (LHV)*	~ 60%
Part-load turndown (35%)	139,260 kW
NOx emissions (w/o SCR)	25 ppm
CO emissions	10 ppm

*Estimated based on Siemens published data and expected steam turbine power output.

Morrow Generating Station. Coal-fired 400MW (2x200MW) steam power plant. All existing boiler, stack, coal handling and emissions control equipment (behind power house) will be removed and replaced by a Siemens SGT6-9000HL gas turbine and matching Nooter/Eriksen 3-pressure heat recovery steam generator to repower 200MW Unit 1 steam turbine generator. Unit 2 will be mothballed for possible repowering.

Morrow coal plant before repowering

Coal-fired R. D. Morrow, Sr. Generating Station, built around two identical 204 MW steam turbine units, began commercial operation in 1978. Heat rate for the units is approximately 10,200 Btu/kWh or 33.5% HHV efficiency.

Two Riley Stoker "turbo-fired" boilers designed for firing with pulverized eastern Kentucky and western Virginia bituminous coal generated 1,575,000 lbs/hour of superheated steam at 2,620 psig / 1005°F conditions (reheater outlet steam temperature was also set at 1005°F).

The boilers were originally equipped with a Buell hot-side electrostatic precipitator for fly ash removal, and with a 1978-vintage wet limestone scrubber designed by Riley Environeering. The scrubbers were upgraded in 2010/2011 to treat 100% of the flue gas flow at a 98% SO_2 removal efficiency with forced oxidation and Dibasic Acid (DBA) injection.

Prior to demolition, the plant had a single 391 ft. concrete chimney with a separate brick liner, extending 14 ft above the chimney, serving each unit. Continuous emissions monitoring probes are installed in each of the two liners.

Feed water is provided to each steam generator by a Byron Jackson feed water pump system comprising a 5-stage steam driven boiler feed pump, a single-stage booster pump. and a 12-stage motor driven startup boiler feed pump.

The steam turbines and generators were manufactured by General Electric. The gross nameplate rating of the steam turbines is 203,890 kW at 2400 psig steam pressure and 3.0 in. Hg back pressure. The turbines are reheat, double-flow exhaust machines. The generators are hydrogen cooled, 2 pole, 60 Hz, 20 kV, 246 MVA machines with static exciters.

The steam units are controlled by an Invensys (Foxboro) DCS for boiler control; GE Mark V for turbine controls; ABB system for generator voltage controls; and GE Mark VI for main boiler feed pump turbine controls.

Demolition work, which started at the end of 2018, includes removal of all the outdoor coal handling, coal burning and flue gas treatment systems for both units. This includes the railcar coal unloading trestle, the coal and ash conveyors, ash collection and storage systems, flue gas ducting and chimney, boilers and air heaters, wet scrubbers, electrostatic precipitators, and other auxiliary equipment associated with coal-fired operation.

Other coal-operation related equipment located inside the main steam turbine powerhouse, including, primary air fans, coal ball mills, coal crusher-dryers, coal feeders and feedwater heaters, will be demolished in parallel with construction of the new combined-cycle equipment.

The condensate cooling system infrastructure will be retained. The Morrow plant has a pair of Marley induced draft, cross flow cooling towers and three circulating water pumps. The circulating water system will be re-used in the repowering. Makeup water for the circulating water system comes from onsite water wells.

According to Siemens, an optimized all-new single-shaft SCC6-9000HL combined cycle plant is ISO rated at 595 MW net plant output with "over 63%" net plant efficiency on natural gas fuel. (Note: The targeted combined cycle net plant efficiency for HL-class gas turbines is said to be 65% or greater.)

The Morrow plant conversion is described as "heat recovery repowering" whereby the old boiler is replaced by a compatible gas turbine and HRSG combination, while the existing steam turbine generator is retained.

In the first phase of the project, all coal-related equipment and structures will be removed from the site. Only the Unit 1 steam turbine generator will be repowered; the Unit 2 steam turbine generator and condenser will be mothballed for a possible future second repowering, and the existing powerhouse structure will remain in place.

The combined cycle plant will be erected in the same general area where the Unit 1 boiler, precipitator, scrubber and chimney were originally located. The new HRSG addition, complete with SCR and CO catalyst sections, will be erected on the existing boiler foundation mat.

HL-class gas turbine

The simple cycle 60Hz Siemens SGT6-9000HL gas turbine genset, already on order by Cooperative Energy, is ISO rated at 405 MW gross baseload output and 42.6% LHV efficiency on natural gas fuel.

For service in a competitive power market, and to meet dynamic grid demands, the advanced HL gas turbine is said to offer short start-up times and high ramp rates, intended to work in close harmony with intermittent renewables.

The unit features two modes of start-up from cold condition: normal and fast. In normal mode, the machine is ramped up at 15 MW per minute. In fast mode, this is more than doubled, such that a ramp rate of 35 MW/min can be achieved.

This allows full combined cycle plant output to be reached in 30 minutes from a cold-start, according to Siemens product application engineers. Meanwhile, in hot condition, the turbine load can be varied, up and down, at 85 MW/min.

The HL gas turbine's advanced combustor design for high combustion efficiency (ACE) features a pilot burner surrounded by 25 pre-mixed burners. This has enabled the design firing temperature to be increased by around 100°C (180°F), while still maintaining low NOx levels at part load.

Besides contributing to the engine's higher full-load efficiency, the combustor design is a key factor in the HL's improved ramp rate and part-load capabilities. It can be turned down to 35 percent load, to serve grid demands which must balance fluctuating renewable energy sources.

There is also more energy in the gas turbine exhaust for producing steam compared to the earlier design. Rated exhaust mass flow (at ISO site conditions) has increased from 1433 lb/sec in the H-class machine to 1598 lb/sec for the new HL design platform, and exhaust temperature has risen from 1193°F to 1238°F.

Both factors have a positive impact on the bottoming steam cycle, delivering higher combined cycle efficiency.

HRSG/Steam cycle

Adjusting for plant site conditions (62°F / 260 ft.), and the effect of HRSG back pressure on gas turbine performance, the exhaust temperature is expected to be 1250°F, with slightly reduced mass flow rate compared to the ISO rating.

At full combined cycle power, the HRSG will generate ~975,000 lb/hr main throttle steam at 1728 psia and 1,005°F, and also reheat HP/IP crossover steam to 1,005°F, thus matching existing steam turbine design temperatures. In addition, the HRSG will produce supplemental low-pressure steam to increase the LP turbine output.

At these conditions, the Unit 1 steam turbine generator will have an estimated gross output rating of 171,500 kW and net output rating of 155,866 kW after deducting for parasitic power consumption of steam cycle auxiliary equipment.

In modifying the steam cycle for combined cycle operation, the existing boiler feed water heaters are to be removed, and the steam extraction ports on the steam turbine casing will be capped off (see cycle illustration).

In the new cycle configuration, feedwater heating will be handled in the low-temperature end of the HRSG, thereby reducing stack exhaust temperature and increasing cycle efficiency. Otherwise, says Cannon, the existing steam turbine itself will be essentially re-used "as it is". It will be overhauled and returned to the original design to the extent practical, he adds.

Regarding steam control valve changes, the reheat stop/intercept valves will be refurbished with valves capable of throttling, and an LP steam admission valve and stop valve added.

With relatively little change in the steam turbine flow path itself, closing of the feedwater heater extractions and

Repowered plant layout. Conceptual drawing of combined cycle gas turbine and HRSG site arrangement. Open space adjacent to new plant equipment is available for possible repowering of Unit 2. Steam turbine generators will continue to be housed in existing power house (background).

Steam turbine repowering considerations

Both the high/intermediate-pressure (HP/IP) and low-pressure (LP) turbine sections, originally designed for substantially different flow conditions, require close attention.

As for main steam throttle conditions (pressure and temperature), high exhaust temperatures associated with advanced gas turbines (~ 1240F for the HL) allow matching or exceeding the original throttle and reheat steam conditions (typically ~ 2600psia and 1005F/1005F).

Cooperative Energy's decision to maintain the same main throttle and reheat steam temperatures (1005F) signaled that no significant upgrade of the HP and IP steam inlet features are required for repowering Unit 1.

But a thorough row-by-row end-to-end evaluation of the steam turbine flow path for combined cycle integration is mandated due to changes - both ***increases and decreases*** - in steam mass flow rates and volume flow rates (due to substantial pressure changes).

For reasons explained below, the HP throttle flow with Unit 1 Repowering will be reduced by approximately 30 percent, while the inlet pressure level will be reduced by some 34 percent (2605 to 1728 psia).

Conventional steam turbine plant designs are usually based on there being several flow extractions, at various points along the flow path, to deliver steam to condensate and feed water preheaters and deaerator.

Each extraction reduces steam turbine flow, so the flow at the LP exhaust could be only 60% of the HP steam flow at the main throttle valve (see chart, depicting a typical example with five extractions).

With thermodynamic optimization of the combined cycle heat recovery system, condensate and feed water preheating duties are moved to the lower-temperature zone of the HRSG. When this happens, old heaters are taken out of service, and extraction ports capped off, thus increasing the steam flow through the turbine.

Efficient use of lower-grade energy in the HRSG will also produce additional steam for admission into the IP and LP turbine sections, which, when combined with capping off the extraction ports, will cause the flow at the back end of the LP turbine to reach its maximum design value well before the HP inlet steam reaches its original design flow rate.

With the repowering of Unit 1, project engineers opted to reduce the HP throttle flow to about 2/3 of its original value to accommodate the additional LP flow.

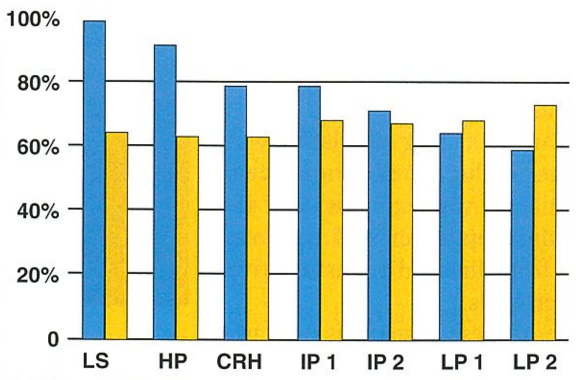
This agrees closely with the typical case depicted in the chart where LP steam induction coupled with existing LP turbine and plant cooling system design limitations results in a 30-40 percent reduction in HP throttle steam flow.

Normally, this would reduce the power generated by the HP turbine and negatively affect the original operating efficiency of that section. However, the lower throttle pressure will restore volume flow rates (and velocities) to match original design conditions.

Note that in the specific situation of Plant Morrow Unit 1, the increased steam flow in the LP turbine brings into play other physical and regulatory site limitations on capacity of the existing steam cooling system (condenser, cooling tower, etc.) and existing permits.

Here, the combined effect of steam flow changes and site limitations will ultimately result in a derating of the 200MW Unit 1 steam turbine generator by some 30MW, so the output rating will be set at 171MW when operating in the combined cycle unit.

Relative steam flow. Typical changes in steam flow as a percent of original HP throttle live steam (LS) flow at various locations before (in blue) and after (in gold) repowering. Five reductions, denoting heater extractions, are shown: one in the HP turbine, one at the Cold Reheater (CRH), one in the IP turbine, and two in the LP turbine. For repowered case (gold bar) steam from HRSG is added to both IP and LP turbines.



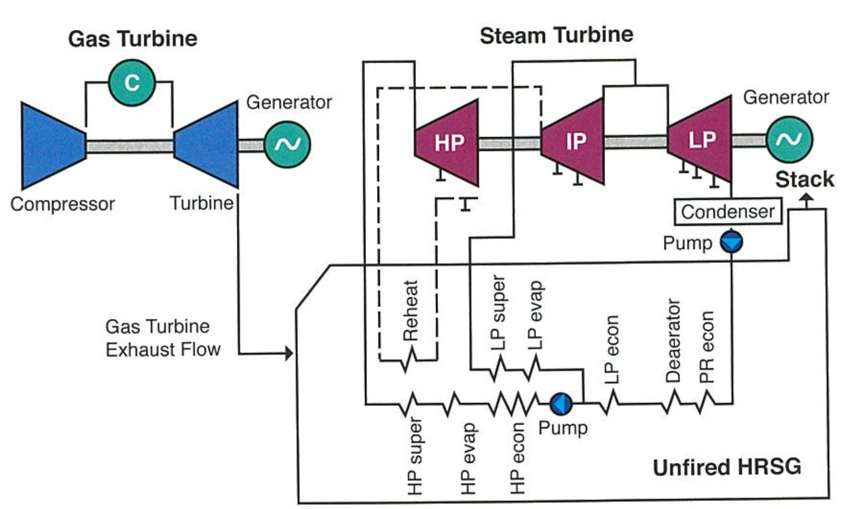
the admission of additional LP steam from the HRSG will cause the LP-end of the steam turbine to reach its maximum design flow at a considerably lower HP throttle-steam flow rate than in the original application.

This, along with other factors, may explain the reduction by some 15% (30MW) in rated steam turbine power output compared with the original design conditions. (See editorial box on steam turbine repowering.)

The new HRSG will be erected on the existing boiler foundation, with its inlet ducting directly connected to the exhaust diffuser of the SGT6-9000HL gas turbine -- and its exhaust stack located close to the existing steam turbine powerhouse building.

There will be no bypass stack to allow for independent gas turbine operation. Rather, the existing Unit 1 surface condenser will be heavily revamped and re-tubed to allow full steam-turbine bypass operation as required during unit startup and shutdown.

Additional changes in the steam cycle include replacing existing steam turbine-driven boiler feed pumps with electric motor driven pumps. And replacing vintage steam plant DCS and GE Mark V turbine controls with a new state-of-art control system platform.



Typical HRSG for Repowering. Typical 3-pressure level HRSG for combined cycle repowering feeds steam to the high pressure (HP), intermediate (IP) and low pressure (LP) sections of the steam turbine. Note that extraction ports from all elements are capped because extraction steam is no longer needed for condensate and feed water heating, cold reheat and deaerator. Those functions are now performed by the HRSG.

Balance of plant and auxiliaries

Auxiliary systems making up the balance of scope for the new combined cycle unit include fuel gas conditioning and heating skids, ammonia storage and supply, additional demineralized water tank, continuous emissions monitoring system and an emergency diesel generator package.

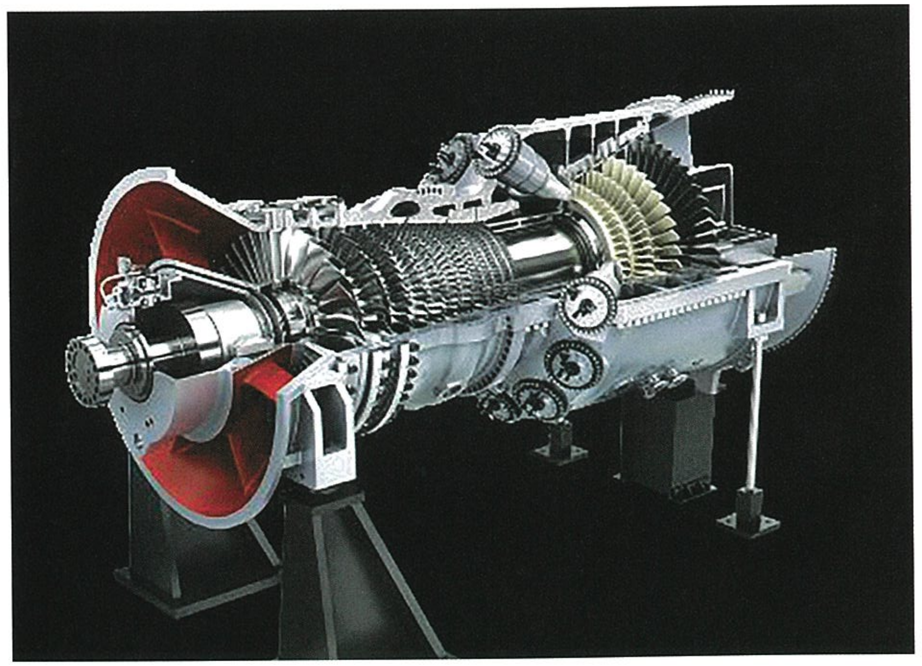
The old powerhouse 4160V switchgear will be also upgraded with a new arc-resistant lineup, and new condensate pumps will be installed in the existing condensate wells.

The plant's existing circulating water system, including cooling towers and circulating water pumps, will be reused. Make-up water will continue to come from the site's existing five deep water wells.

"Reuse of these systems is primarily due to the equipment being in good shape and the associated economics", says Cannon, "but it also simplifies some of the permitting required".

Approximately 4 miles of new natural gas fuel supply line will be constructed, owned and operated by the fuel gas supplier. And work will be done to upgrade high-voltage transmission lines and the plant substation.

The existing 161kV substation will be demolished and rebuilt with increased capacity, and 5 miles of new 161kV transmission lines will be installed. ■



Siemens 400MW-class SGT6-9000HL (60Hz) gas turbine. ISO simple cycle ratings: 405MW gross power, 42.6% efficiency. First engine field verification testing to start in 2020. Inspection intervals extended to 33,000 equivalent base hours (EBH) of operation and to 66,000 EBH for major overhaul.

Keep your iron hot!

S. C. Gülen, Bechtel Fellow, ASME Fellow
Bechtel Infrastructure & Power Corporation

New concept for reducing combined cycle start-up to under 20 minutes to full load can be retrofitted to vintage E and F class plants as well as applied to advanced H and J technology plants.

In response to an age-old search for a better way to shorten power plant starting time, particularly in today's competitive dispatch world of fast-start capacity, a recent US patent (US 10,456,037) filed by Bechtel Infrastructure & Power Corporation discloses a promising new concept.

Bechtel engineers introduced a relatively simple system and method to enable a typical 2x2x1 combined cycle plant to operate more economically in low-load standby, or "parking", mode while awaiting dispatch. This leads to rapid plant restart to full load. Highlights of the patented technology are:

■ **Startup.** Enables multi-unit combined cycle plants to reduce warm restart time from over 90 minutes to ~20 minutes; hot restart time cut by ~30 minutes.

■ **Bypass.** Adds low pressure crossover pipe and valve arrangement between gas turbine exhaust ducts as a bypass to keep idle HRSG warm and ready for re-start.

■ **Cost.** Plant-specific bypass design, control logarithm and material expected to cost much less than the premium cost of an OEM fast start system.

Besides reducing restart times, the proposed system enables 2x2x1 power plants to run economically at only 20% plant load while operating under regulatory requirements for emissions compliance.

What's new? Uniquely, this system calls for running only one gas turbine at its minimum emissions-compliant load (MECL) while the second gas turbine is shut down to idle standby mode, i.e., rotating on turning gear.

How's it done? Conceptually, this is accomplished by adding a bypass, or crossover, pipe and valve arrangement between gas turbine exhaust ducts to feed hot gases into the idle HRSG.

Design Objective

The objective of the proposed fast-start concept is to economically maintain the idle HRSG and the steam turbine at sufficiently elevated temperatures during very low-load operation to enable rapid restart of the full combined cycle plant upon dispatch.

Main features and advantages of the new system:

- Requires little new equipment and controls.
- Does not need extra (high cost) steam bypass piping.
- Enhances readiness for dispatch while operating at MECL.
- Full load available at predictable and rapid ramp rate.
- Minimizes fuel consumption during hot or warm restart.
- Offers excellent retrofit potential to improve competitiveness of older plants.

The new system is intended for multi-unit combined cycle plants built around typical heavy-frame industrial gas turbines. In particular it is an excellent retrofit to existing F-class plants to improve their competitiveness. It can also be incorporated into greenfield advanced H or J class plants.

Simple concept

The proposed concept is depicted in Figure 1 which shows the layout of a typical 2x2x1 combined cycle power plant with two GT-HRSG trains and one steam turbine.

The two heat recovery steam generators (HRSG1 and HRSG2), are connected by a small exhaust-gas bypass duct (or pipe) at their inlet transitions. During normal plant operation, the bypass duct is closed off by a damper valve on both sides.

When the operator selects low-load operation (LLO), the following sequence takes place:

1. GT2 shuts down normally and is placed on turning gear (TG).

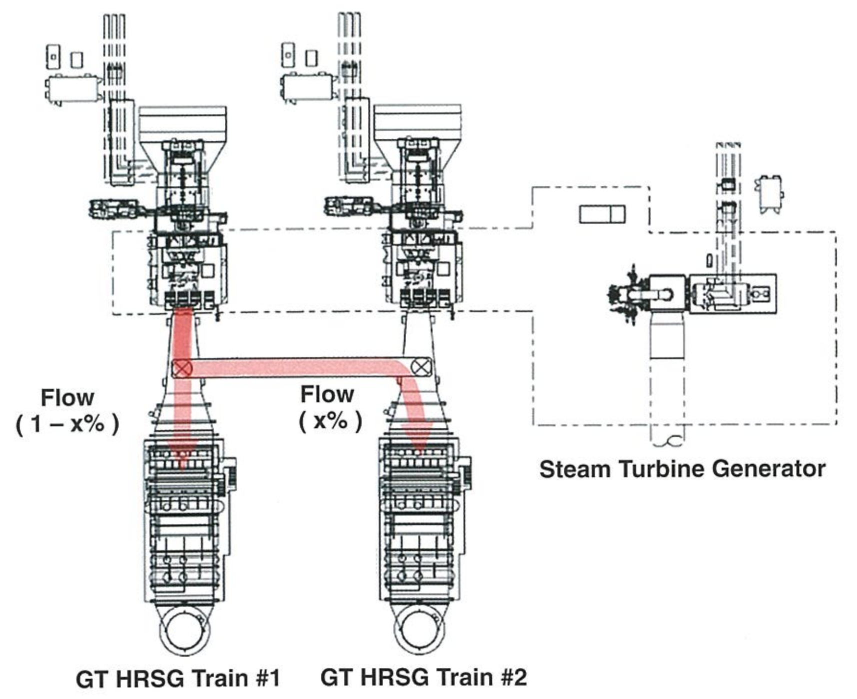
2. GT1 is ramped down to its minimum emissions compliance load (MECL).

3. Steam turbine (ST) is throttled down to a load level commensurate with one gas turbine operating at MECL by the ST controller.

4. Damper valves isolating the bypass duct at either end are opened and a portion of the GT1 exhaust gas (x%) is diverted to the HRSG2.

5. Thus HRSG2 and all associated steam pipes and valves are kept warm even though its gas turbine, GT2, is off-line.

Figure 1. Typical 2x2x1 combined cycle powerplant layout with exhaust gas bypass to keep the idle HRSG (on right) warm. GT #1 is running at minimum emissions-compliant load while GT #2 is shut down and rotating on turning gear.



6. The plant runs in this mode until the operator deselects low-load operation to initiate the restart sequence.

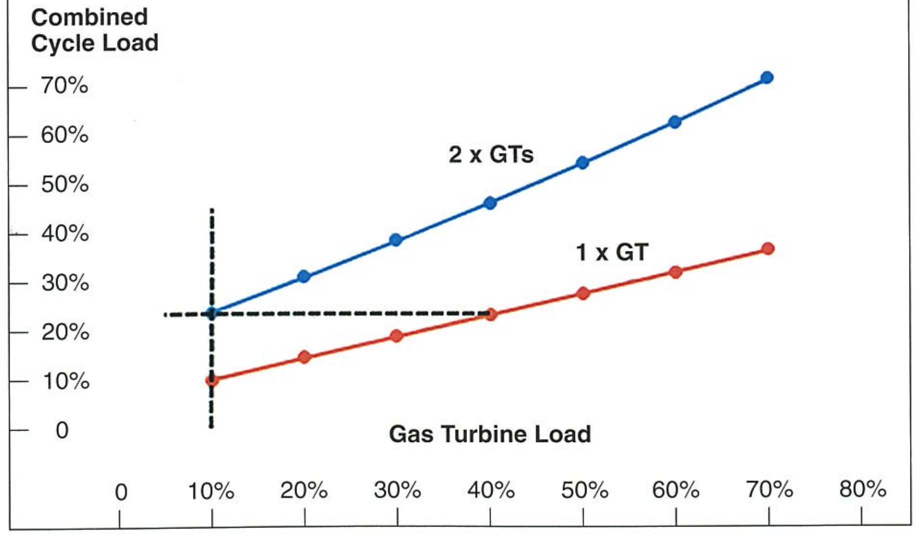
Parking at 20% load

As verified by detailed heat balance simulation, combined cycle plant operation with only one gas turbine running at low-load MECL approximately equals the normal operation of two gas turbines running at a load equal to one-fourth of the MECL load.

For example, as depicted in Figure 2, if the MECL for a gas turbine is 40%, the described operation with only one gas turbine online is equivalent to both gas turbines operating at 10%, which corresponds to slightly above 20% combined cycle load.

Meanwhile, the bottoming cycle is kept warm and in a ready-to-start mode and able to run back to full load at the normal ramp-up rate. Note that the obvious alternative of operating both gas turbines at 10% load to keep the both HRSGs warm is not a viable option because the plant emissions would be non-compliant.

Figure 2. Typical gas turbine and 2x2x1 combined cycle plant loads for operation with one or both gas turbines running.



In the new patented concept, both HRSGs are kept warm with only one gas turbine in operation at its minimum emissions-compliant load.

This is a feasible solution and one that effectively replicates the capability of older sequential combustion units which offer their own advantages for low-load compliant operation.

It also matches the performance of the new generation advanced H and J class gas turbines equipped with dry low NOx (DLN) combustors with axial fuel staging.

Low-cost flexibility

Initial evaluations indicate this approach requires minimal extra capital investment in terms of materials, labor and construction time compared to existing "fast start" technologies which can easily add many millions of dollars to the installed plant price tag.

This is due to their high cost of terminal attemperation equipment, large steam bypass valves and piping required to handle excess steam flow diverted to the condenser, gas and steam turbine control system upgrades, etc.

However, the proposed concept and some older existing fast-start technologies are not mutually exclusive. While the proposed method to be "parked overnight" can replace existing conventional restart protocols (e.g., overnight shutdown and morning "hot" startup"), there is no reason both technologies cannot coexist for ultimate flexibility, at a relatively modest additional cost.

Note, however, that an existing fast or rapid start technology cannot replace the proposed method's spinning reserve ability, i.e., running at low plant load while remaining in emissions compliance -- unless those gas turbines are also equipped with newly emerging combustion technology enabling them to operate at low minimum emissions-compliant load.

The new concept is not limited to a unique gas turbine architecture; it's applied to any combined cycle system

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Fast-Start Combined Cycle Plants - I
The long search for better ways to keep the iron hot

From the earliest days of combined cycle development, engineers have understood that starting a gas turbine combined cycle power plant from standstill requires extreme care to gently warm the enormous amount of cold steel aft of the gas turbine (a reasonably nimble machine itself) before the operator can press the proverbial pedal to the metal.

The conventional approach to dealing with this problem has been to operate the gas turbine at its minimum load. Or to use rather outdated methods such as bypass stacks to achieve gradual HRSG warming and steam production via control of gas turbine exhaust gas flow and temperature.

Steam was then admitted to the steam turbine in a controlled manner to prevent thermal stress and low cycle fatigue damage.

This approach is no longer viable because of strict NOx and CO emission caps set by regulatory bodies on power generators. It is also not a preferred approach when plant operators are called upon to provide a rapid-start response to the dispatcher's call to replace loss of renewable sources.

At the expense of considerable additional piping, valves, and control system software and hardware, the "modern" approach to combined cycle start-up is based on decoupling the gas turbine start-up from the steam turbine startup via "cascaded bypass" and "terminal attemperation".

This enables the so-called "fast" or "rapid" combined cycle start-up, with the gas turbine accelerating quickly from standstill (i.e., low speed turning-gear mode) to full speed, no load (FSNL), followed by synchronization to the grid and then ramping to full speed, full load (FSFL), again at the highest possible rate (in megawatts per minute).

Modern advanced class machines can readily accomplish this in well under 30 minutes (especially with HRSG "purge credit" from proper purging after prior shutdown).

Introduction of exhaust gas energy at its full rated conditions into the HRSG, if not properly controlled, would rapidly generate excessive steam at high temperatures. Therefore, the first control measure is to reroute the excess steam generated in the front-end superheaters via high-pressure/high-temperature bypass piping, first through the reheat superheater (hence "cascaded" bypass) and then "dumped" to the condenser.

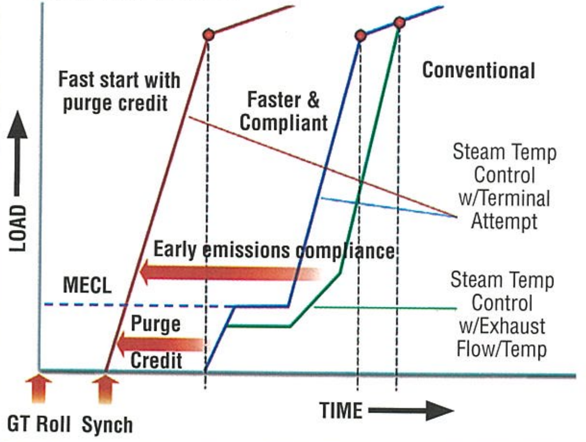
The second control measure is to precisely control the temperature of steam being admitted to the steam turbine. This is accomplished by use of attemperators (also known as desuperheaters) located downstream of the superheater and reheater exits; hence the moniker "terminal attemperators". (Standard attemperators, typically between superheater and reheater tube banks, cannot provide the requisite control accuracy.)

It is noted here that terminal attemperators are rather finicky devices. Although theoretically sound, historically they have been problematic and maintenance intensive. In addition, risk of water induction into the steam turbine must always be considered.

Variations on the theme are possible to reduce the need for attemperation. One example might be a hybrid, akin to the conventional approach mentioned earlier.

Instead of a fast-paced, uninterrupted ramp from FSNL to FSFL, the gas turbine is parked at a sufficiently high load with emissions compliance (known as "minimum emissions-compliant load" or MECL) while the HRSG and steam turbine warm up.

Figure 6. Conventional and fast combined cycle startup load profiles.



with modern gas turbines equipped with DLN systems capable of low minimum emissions-compliant load operation.

Also, note that its low load operating capability is not limited to normal hot and warm start events; it can be selected by the system operator whenever necessary as dictated by grid conditions and/or renewable generation status.

Design challenges

While this novel re-start concept is very simple in theory, the proverbial devil is in the details with implementation. Critical design considerations can be covered under three interrelated requirements.

- prevention of reverse gas flow in the "idle" HRSG (i.e., upstream towards the gas turbine instead of downstream to the stack)
- achieving uniform gas flow and temperature in the idle HRSG's high pressure evaporator cavity housing the Selective Catalytic Reduction (SCR) equipment
- avoidance of temperature excursion on the cold end of the idle HRSG

To address these issues, Nels Consulting Services, Inc. (www.nels.on.ca) was retained to perform both physical scale-model studies and Computational Fluid Dynamics (CFD) analysis to demonstrate the viability of the concept.

It is envisioned that a detailed, focused CFD model study will be performed during future efforts as a part of the feasibility analysis for a specific client and a specific application.

Scale model results

The physical scale-model studies revealed that the hot-gas bypass flow from the running gas turbine exhaust transition, upon entering an idle unit, would flow towards the stack and not back towards the idle gas turbine.

This will happen by the stack's natural draft effect, aided by the flow created by the gas turbine rotating on turning gear, as long as the stack damper in the idle HRSG is cracked open (see Figure 3, flow is from right to left).

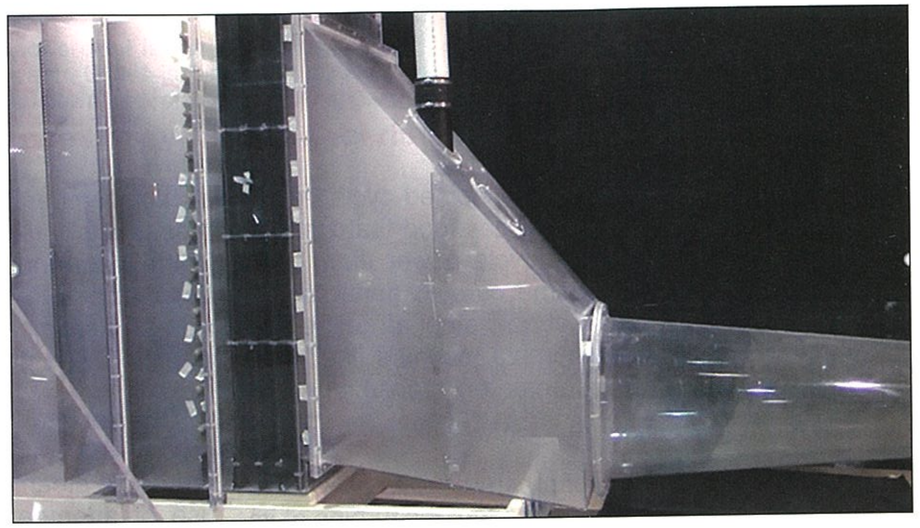


Figure 3. Scale test model of the idle HRSG flow during test run, recorded by video for 38 lb/s simulated airflow induced by the gas turbine turning and 33 lb/s crossover/bleed flow from the active HRSG, with a stack opening of 20 square feet.

CFD study results

Results of the CFD study indicate that a sufficiently high temperature can be maintained in the HP evaporator cavity of the idle HRSG, thus minimizing pressure/temperature decay in the HP system during shutdown (see Figure 4 for sample CFD output).

The study confirmed that target temperatures, on the order of 400+ F, could be achieved by modulating both the exhaust gas bypass and stack dampers. This would allow elimination of the usual warming, or soaking, phase during the restart the HRSG.

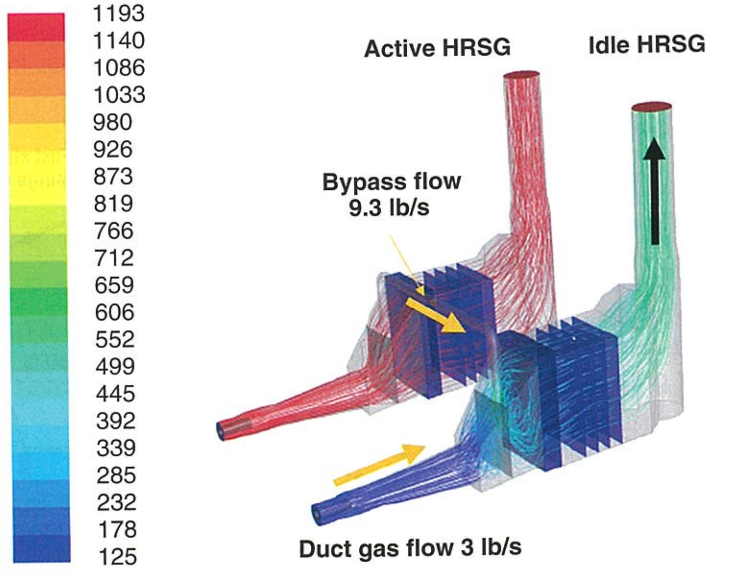
And elevated temperature in the HP evaporator cavity would ensure operability of the SCR system when the need arises with increased plant load.

Control challenges

Both HRSGs would have several strategically placed gas-side thermocouples to facilitate temperature control to maintain temperatures when in idle mode.

After unit shutdown and associated stack damper closure, tempera-

Figure 4. CFD model results of HRSGs with bypass flow temperature profiles in °F – one of nine cases run in the study.



Fast-Start Combined Cycle Plants - II
"Parking" eases thermal stress but invites other issues

A popular way of handling the fast startup stress problem with cold plants has become to eliminate it altogether.

Instead of fully shutting down the plant when not needed, and restarting it slowly when dispatched, run the power plant at a low "parking" load during times of low demand. This means the combined cycle plant runs continuously, in alternating modes of "dispatch" and "spinning reserve".

The challenges with this are as obvious as the simplicity of the solution: excess fuel burn and emissions.

Because spinning reserve and parking modes are only allowed for gas turbines running at minimum emissions-compliant load (MECL), said challenges can be difficult to overcome, especially for vintage E and F class machines.

To illustrate, consider a 2x2x1 combined cycle plant nominally rated at 1,000 MW parked in a low-load (spinning reserve) mode. Typically this would set plant operation at around 40% load, or 400 MW, assuming both gas turbines can turn down to an emissions-compliant load of 35%.

Even this low-load operation is not likely to be economically feasible at a time of low power demand and/or reduced electricity tariff. It is practically equivalent to running a 1x1x1 combined cycle power plant at full load but at greatly reduced efficiency.

A noteworthy exception to this issue is for plants powered by gas turbines featuring reheat or sequential combustion technology, marketed under the phrase "Low Load Operation Capability (LLOC)" made possible by two separately controlled stages of combustion.

The low-load uniqueness of sequential combustion technology stems from the ability to run at reduced power by shutting down the second combustion stage. The first combustor is kept running at its nominal operating condition, i.e., in lean premix mode, which is the normal operating mode for modern dry-low-NOx (DLN) combustion gas turbines.

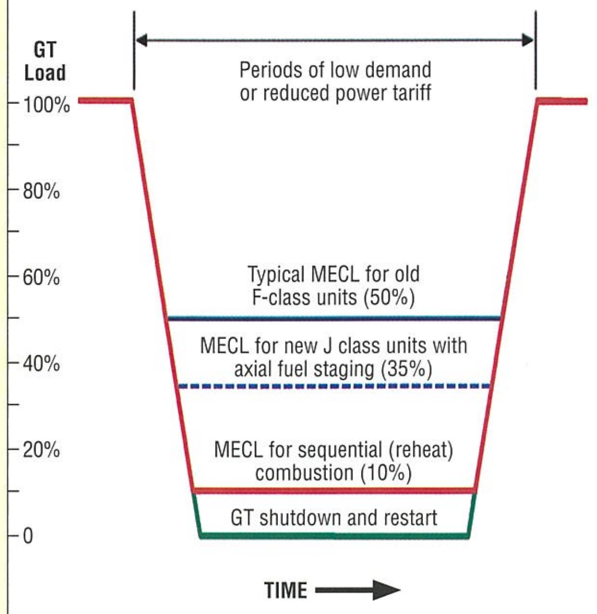
Thus, the gas turbine can be turned down to ultralow loads (~10%) while still being emissions compliant. Since the steam turbine is also in operation, the combined cycle plant can be run economically in a spinning reserve mode, ready to reload to a new dispatch load (as required by the system operator) with normal ramp rates.

It is also worth noting, however, that advanced class (H or J) gas turbines equipped with DLN combustors featuring the latest AFS (Axial Fuel Staging) technology can come close to the low MECL capability of sequential combustion machines and, eventually, may match it.

Current low load "parking" ability of different technologies and operating modes is summarized in Figure 7. As shown there, the typical MECL for vintage F-class units is assumed to be on the order of 50% gas turbine load.

The major gas turbine OEMs are offering retrofit combustion system upgrades to lower this value to be more competitive with newer H and J class units, which nowadays are claiming even lower MECL than the 35% value shown in the chart.

Figure 7. Minimum emissions-compliant load (MECL) for various gas turbine technologies.



tures would be monitored inside of the HRSG ductwork.

When a drop of approximately 25 to 50°F is detected in the critical cavity, both the stack damper and the damper on the bypass duct between HRSGs would open and modulate to bring the temperature inside of the idle unit up to the target value.

Specifically, the sequence of events would be:

1. Upon detection of the temperature drop in the idle HRSG, the bypass damper on the hot jumper will open. Bypass damper on idle HRSG end is in full open position..

2. Simultaneously (or with a short delay) the stack damper in the idle HRSG will open.

3. The opening of the stack damper will initiate a cold turning gear flow + hot gas flow through the idle HRSG toward the stack.

4. At certain (optimal) position of the stack damper target temperature in the SCR cavity can be achieved.

The other critical control issue is maintaining the temperatures in the low-pressure (LP) section of the idle HRSG and its stack. This might require keeping the LP section "alive" with a little steam generation and bypass to the condenser along with LP recirculation.

This will also help during restart by keeping the temperature difference small between the incoming condensate and LP economizer tube metal.

High retrofit potential

Applicability of the proposed concept to retrofit older systems is expected to be very broad. However, it is not apparent that a generic a priori solution will be available as a universal retrofit package.

The wide range of turning gear speeds (from a few rpm to ~120 rpm based on OEM design practices), differences in HRSG geometry and stack construction; and other factors necessitate that each application will require thorough analysis, with the participation of the gas turbine, HRSG, and SCR vendors, and the owner's engineers.

Even though the physical hardware retrofit itself is expected to be minimal, with small case-to-case variation primarily in duct configuration (see Figure 5 for 3-D conceptual drawing showing bypass duct installation), the specific control algorithm is expected to be tailor-made for each case.

Retrofitting vintage F class combined cycle power plants with this technology can make them competitive with more advanced class facilities under certain conditions, which requires a careful cost-benefit evaluation by the owner/operator helped by the technology provider.

Besides retrofit applications, observe that the new fast-start configuration proposed here can be deployed in greenfield projects, which any cost/benefit analysis is expected to support.

Figure 5. Conceptual 3D model of the bypass duct connecting the two HRSGs.

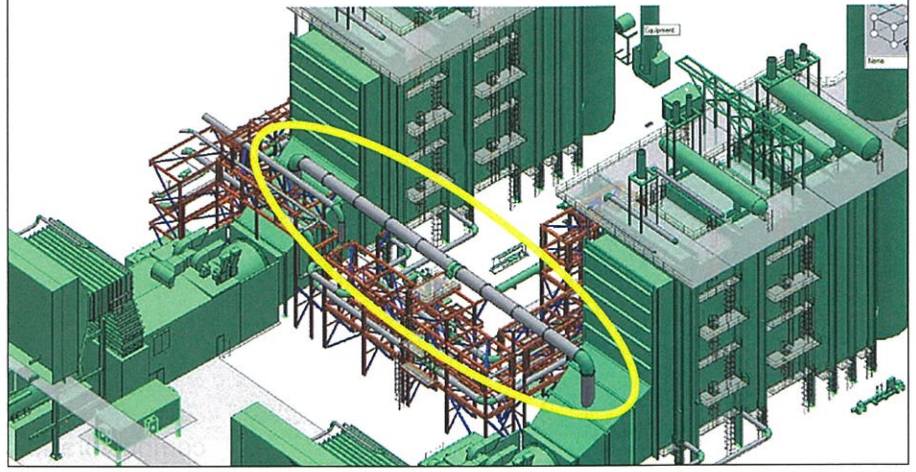


Table 1. Operational and performance benefits of proposed combined cycle start-up technology as a "retrofit" for existing plants and as an "add-on option" for new power plant projects.

Design and Operation	Cost and Performance
Full load is available at a high and very predictable ramp rate	**Maximizes** dispatachable capacity for short term demand. Vital for responding to unpredictable variation in online renewable capacities
Minimizes cost of operating at very low load levels to remain viable for dispatch	**Allows** response to specific opprtunities rather than expending fuel to operate "just in case" or in trying to "time the market"
Faster to reach full load efficiency	**Ability** to minimize time at inefficient low loads directly reducing cost of electricity ($/kWh)
Ducting connections do not require high pressure, heavy wall bypass piping used in competitive fast-start technologies	**Lower** cost of low-pressue piping connections and supports and no hydrostatic testing of major system components
Low pressure ducting penetrations are relatively easy to implement and do not require heavy support structures	**Retrofit lifeline** for existing plants under extreme economic pressure due to inability to rapidly come online to fill short-term needs
Lower thermal cycling of HRSGs exposed to frequent start-stop operation	**Reduced** long term maintenace costs for the HRSGs

Table 2. Operational comparison of alternative technology 2x2x1 combined cycle plants with one or both gas turbines operating at minimum emissions-compliant load (MECL) conditions and with steam turbine load limited to 20% via bypass.

Points of Comparison	Both GT Trains OFF	One GT Train ON	Both GT Trains ON	STG Load 20% Limit	Proposed Concept
Gas Turbine Genset #1	Off	MECL	MECL	MECL	MECL
Gas Turbine Genset #2	Off	Off	MECL	MECL	Off
Steam Turbine Load	Off	> 20%	> 20%	20%	On
Combined Cycle Load	0%	< 20%	> 40%	30%	< 20%
HRSG #2 Restart	Cold	Cold	Warm	Warm	Warm
Purge Credit	Yes	Yes (1)	NA	NA	Yes (1)
Heat Rate Change	NA	130%	115%	165%	130%
Low Load Parking Suitability	NA	Yes	No	Maybe	Yes
Start Technology	Fast	Fast	NA	NA	NA
Hot Restart (to 100% CC load)	53 Min	< 53 Min	< 8 Min	8 Min	18 Min
Warm (to 100% CC load)	88 Min	< 88 Min	< 9 Min	9 Min	20 Min
HRSG Lifetime Impact	Highest	High	Low	Low	Low
CAPEX Adder Impact (2)	High	HIgh	None	None	Low
Benefit-to-Cost Score (3)	Base	Better	Worst	Worse	Best

Footnotes: (NA) not available/necessary; (1) with leak-free certified gas turbine fuel gas valves; (2) over conventional start technology; (3) based on net income during low load operation and restart (electricity sales minus fuel expense) plus maintenance impact.

Major benefits

There are several major benefits of the proposed combined cycle plant start-up concept described here that tie directly to generation economics, cost of electricity and dispatchability. (These are summarized in Table 1.)

Side-by-side comparison

Benefits of new concept are readily evident via a methodical side-by-side comparison of the with existing alternatives is presented in Table 2. The alternatives are:

1) Both Gas Turbine HRSG trains remain OFF in shutdown condition.

2) One Gas Turbine HRSG train ON at minimum emissions-compliant load and the other OFF; Steam Turbine Generator >20% load

3) Both Gas Turbine HRSG trains ON at MECL; STG at >20%

4) Both Gas Turbine HRSG trains ON at MECL; STG load limited to 20% via bypass

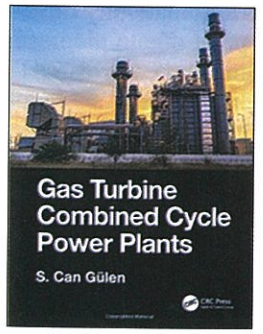
Readers might question the nearly one-hour (53 minute) hot restart time associated with the "fast" start technology in the table.

This is despite major OEMs consistently claiming capability of hot start times of 30 minutes, or even less.

The difference lies in the definition of start-up time or, more precisely, the end point of the start-up period. One definition of the end point, as widely adopted by gas turbine OEMs, is when all steam bypass valves are closed and the gas turbines are at full load (IGVs fully open with normal firing).

Our definition of the end point, as used here, is when the system reaches *fully heat-soaked steady-state operation.*

The difference between the two is determined by the thermal inertia of the bottoming cycle equipment. ■



The author wants to acknowledge the significant contributions of his co-inventors and Bechtel colleagues Ilya Yarinovski and Mark Boulden.

In-depth coverage of gas turbine combined cycle startup and other transients can be found in the recent monograph by the author "Gas Turbine Combined Cycle Power Plants," CRC Press, December 2019 (20 chapters, 500+ pages, 120 figures).

https://www.crcpress.com/Gas-Turbine-Combined-Cycle-Power-Plants/Gulen/p/book/9780367199579
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Combined cycle engineering, design and economic trade-offs

Installed $/kW plant costs can vary by 20 to 30% depending on design factors and comparative costs of engineering options

Scope and boundary limits

Aside from the strong influence of power rating, the cost of a combined cycle plant depends primarily on how one defines scope of supply and plant boundary limits.

Is the cost for equipment only or does it also include Engineering, Procurement and Construction that includes construction labor, materials, site management and supervision?

Are plant startup costs included? Commissioning, testing, spare parts, long-term contract maintenance? How about financing costs and interest on debt before, during and after construction?

Where are the plant boundary limits? Do they include site infrastructure such as connections to the utility grid? Step-up transformers and switchgear? Transmission lines? Natural gas pipeline connection? Land and improvements? Civil works?

Obviously many components go into any project cost estimate and ultimate as-built plant cost. Unless the definitions of supply and boundary limits are clarified, estimates are meaningless.

Turnkey price

For budget estimating purposes, GTW considers the turnkey price for a new combined cycle plant as the "contractor price", an estimate of what an EPC would charge to deliver a turnkey plant on the owner's site.

It is an "overnight price" that excludes escalation and interest during construction. Also excludes all owner's costs such as land, legal, financing, development costs and fees. And it excludes capitalized spares and provisional operating expenses beyond initial startup.

It includes equipment costs plus the EPC's design and detail plant engineering for the installation and procurement of all major standard equipment, materials and labor, construction costs and initial startup.

To set a baseline, it also assumes the plant is built in the US Gulf Coast region with non-union labor. The US Gulf coast has a relatively benign cost and regulatory environment, with an excellent pool of contractors and labor skilled in constructing energy-related infrastructure.

Building a similar plant with union labor in a high-cost state such as California or New York can easily double the cost of labor and add 20% to total plant cost.

Environmental mandates

Site and environmental factors can affect costs by mandating the selection or inclusion of specific equipment.

For instance, where water use is constrained, the design may have to use an air-cooled condenser. This is a lot more expensive than a water-cooled design and also typically reduces steam turbine output.

Plant cost per net kW will likely be around 10% higher than a similar plant with a water-cooled condenser. (Note: a mechanical-draft wet cooling tower is also an optional plant item.)

Emissions reduction is another factor. If selective catalytic reduction for NOx and CO is required, the plant is likely to cost about 5% more per kW than a similar plant without SCR.

Environmental mandates may also require a taller than normal exhaust stack for plume dispersion, waste water treatment before discharge, noise abatement, etc – all of which add cost.

Optional equipment

Add-ons inevitably increase the cost of any bare bones plant. Some common options:

- ***Fuel gas compressor.*** This cost is very plant-specific, will vary considerably depending on pipeline delivery pressure at the fence and gas turbine pressure ratio and fuel flow. The installed cost of two full-capacity compressors (for redundancy) can add around 4-5% to plant cost per kW.

- ***Liquid fuel backup.*** Many plants with natural gas as their primary fuel will add distillate oil fuel as a backup. At the outset, this automatically raises the gas turbine's price due to the need for dual fuel burners and controls.

It also requires the addition of fuel storage tanks, pumps and piping, along with oil heaters and heat tracing to facilitate oil flow in cold environments.

Extra costs associated with inclusion of oil backup fuel depend on site specifics and how much onsite oil storage is required. For a ballpark estimate, figure an extra 2-3% in total plant cost.

- ***Inlet air chilling.*** Many plants operating in a hot ambient add gas turbine inlet-air chilling (with or without onsite water purification and storage) to improve hot day performance.

These systems are very effective at raising plant output during periods of high ambient temperature, when spot prices for power are highest.

Again, the additional costs of these systems vary widely depending on specifics, but will typically increase total plant cost by about 3%-6%.

- ***Bypass stack.*** Many plants have a diverter damper and bypass stack to enable starting and running the gas turbine somewhat autonomously from the HRSG.

Unlike HRSGs, bypass stacks are subject to the full exhaust temperature of the operating gas turbine, well over 1000°F (>538°C). This calls for design application of premium materials and insulation and high-temperature acoustic controls.

The diverter damper and bypass stack, along with the requisite foundations and associated construction costs, can add about 3% to total plant cost.

In some rare instances, this option goes even farther to include a draft fan and fresh-air firing system to the HRSG. This enables HRSG steam production without running its gas turbine, but adds considerable complexity and cost.

- ***HRSG firing.*** Many combined cycles include supplementary firing to increase steam turbine power output. This is especially attractive in power markets where availability of the additional power during peak periods would be highly profitable.

The added costs associated with this feature go well beyond that of the duct burners themselves.

For starters, the HRSG must be designed for higher steam flows, which makes it larger, heavier and more expensive. And the internal lining and insulation for the duct burner must be more resistant to the higher operating temperatures.

In addition, HRSG tubes near the duct burner must be made of higher grade alloys to cope with higher firing temperatures, may also require a tube design with fewer and shorter fins.

This reduction in fin surface area, along with the fact that many heat resistant alloys have lower thermal conductivity, requires more tubes to provide the same thermal performance when the duct burner is off.

Beyond the cost of the HRSG itself, the cost-impact of supplementary firing extends to all related downstream systems. This includes costly high-temperature steam piping, which may need upsizing to accommodate the increase in steam production.

In addition, the steam turbine generator and its related switchgear capacity would have to accommodate the additional steam flow and power production when duct burners are used.

Likewise the condenser and its cooling system would have to be oversized if the steam turbine back-pressure is to be maintained at optimum conditions with duct burners operating at maximum firing.

The total added cost for supplemental firing, and all that it implies, varies widely over the broad range of additional steam production available – from "light" to "heavy" and even "full" firing, where very substantial additional steam turbine power is available. For a ballpark estimate, it can be assumed that heavy duct firing would add 10-15% to a plant's total cost.

However, the increase in steam turbine power output does increase plant maximum rating so the plant cost in $/kW (based on supplementary duct firing) could end up around 5% lower that the unfired design.

Cost vs efficiency trade-off

Numerous technical design parameters can be adjusted to improve plant efficiency. But most of these parametric design tweaks to raise efficiency are subject to a rule of diminishing return.

Trade-off studies are usually performed to identify the optimal values of design parameters i.e., where incremental increase in capital expense (CAPEX) can no longer be justified by gains in efficiency.

Naturally, this depends on the perceived long-term value of fuel savings vs. increased capital cost, and is far from an exact science.

Unfortunately, experience shows it is feasible to design and build a high-cost plant with less than optimal efficiency (i.e., with poor design choices) but generally not feasible to build a low-cost plant with high efficiency.

Bare bones plants

To cope with these uncertainties and wide variations in equipment scope, many preliminary $/kW estimates are based on standard 'bare bones' plants, without options, as adopted by the GTW Handbook.

A "fully loaded" plant could cost upwards of 30% more than the 'bare bones' plant. Even then, the cost would not include the many items that get wrapped into so-called 'owner's costs', and would exclude the all-too-common contractor's "contingency allowance" which usually finds its way into the typical EPC contract. ■

This article is based on a "Combined Cycle Cost Tradeoffs" review by Dr Maher Elmasri, founder and president of Thermoflow Inc.

Converting NOx ppm to mass flow

Approved procedure for converting measured NOx ppmv into lb/hr mass flow for EPA reporting

Simple cycle and combined cycle gas turbine plants are required by law to record NOx emissions on an hourly and annual mass flow basis.

For reporting purposes, the Environmental Protection Agency (EPA) has an approved procedure ("Method 19" Specs) for converting measured NOx ppmvd at 15% oxygen into lb/hr mass flow.

Factors.
Different conversion factors apply depending on type fuel.

EPA conversion factor for **natural gas**: 1 ppm NOx = 0.0036 lb/MMBtu.

For **distillate**: 1 ppm NOx = 0.0040 lb/MMBtu.

To compute NOx flow (lb/hr), multiply the plant's measured exhaust NOx emissions (ppmvd) and fuel consumption (MMBtu/hr) by the appropriate EPA conversion factor.

(Note: To compute MMBtu/hr, multiply the plant's Btu/kWh heat rate by kW output.)

Natural gas example:
Here is how it works for a 400MW combined cycle plant with a 5687 Btu/kWh heat rate (60% efficiency) and 25 ppmvd dry low NOx combustion:

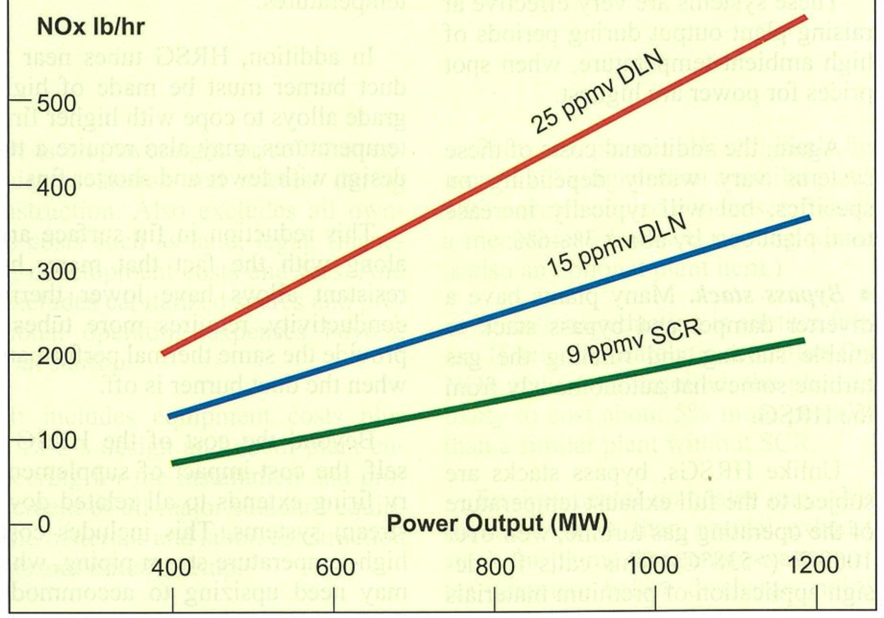
First, compute hourly fuel consumption: (5687) x (400,000) = approximately 2,275 MMBtu/hr. Then convert ppmv to lb/hr: (25) x (0.0036) x (2,275) = 205 lb/hr NOx.

Annual NOx mass flow based on 7500 hours baseload operation per year: (205) x (7500) = 1,537,500 lb/yr (769 tons/yr).

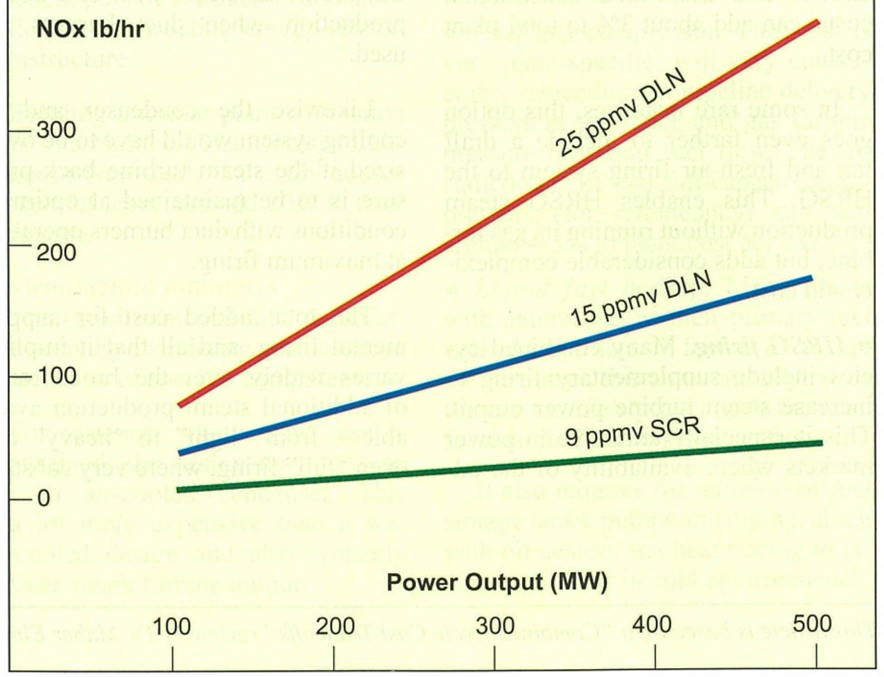
Distillate fuel example:
Same 400MW combined cycle plant operating on distillate fuel: (25) x (0.0040) x (2,275) = approximately 228 lb/hr NOx.

Annual NOx mass flow based on 7500 hours base load operation per year: (228) x (7500) = 1,710,000 lb/yr (855 tons/yr). ■

Combined Cycle. Typical NOx emissions for 5687 Btu/kWh heat rate (60% net efficiency) with dry low NOx combustion and selective catalytic reduction.



Simple Cycle plant. Typical NOx emissions for 8530 Btu/kWh heat rate (40% net efficiency) with dry low NOx combustion and selective catalytic reduction.



LHV vs HHV Fuel Consumption

Understanding difference between fuel LHV and HHV is important when using published gas turbine heat rate values to determine actual fuel consumption.

On the surface, calculating the fuel required to run a gas turbine plant is easy: simply multiply plant heat rate (Btu/kWh) by power rating (kW) and divide by the fuel heating value (Btu/lb or Btu/mcf).

This gives you hourly fuel flow (lb/hr or mcf/hr). Multiply by expected annual usage (hr/year) and end up with total fuel consumption for the year. But not that simple nor straightforward.

Adjust ISO ratings. First you must adjust design ISO ratings to account for non-ISO site conditions and, for combined cycle plants, anticipated operating profile (effective load factor).

Introductions for each of the design performance specifications tables (Section 3) contain "rule of thumb" factors to adjust ISO ratings for site-specific conditions to calculate fuel consumption on a more solid footing.

LHV disconnect. But there is still one more hurdle,. the LHV vs. HHV disconnect. Like apples and oranges, LHV and HHV are not to be mixed when purchasing fuel for a plant.

What's the problem? Published gas turbine heat rates are always based on net or "lower" heating value (LHV) of fuel, whereas fuel supply contracts are based on gross or "higher" heating value (HHV).

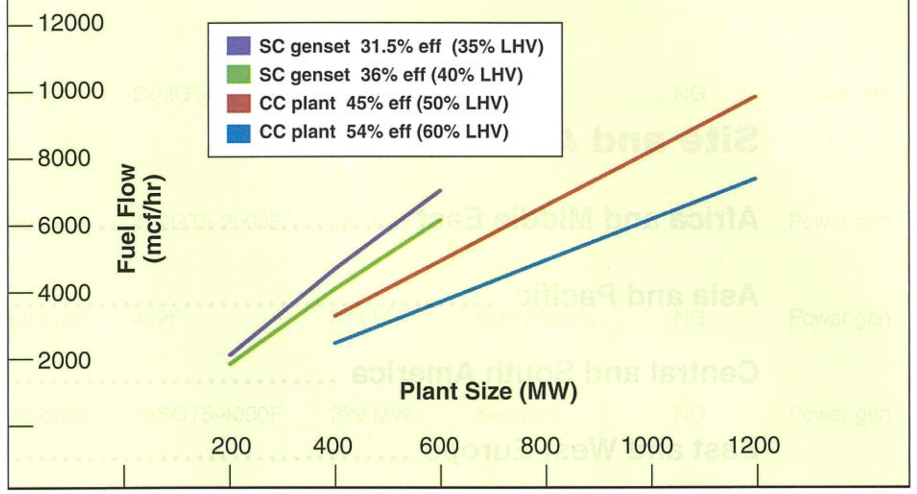
This difference concerns whether the heat of condensation of water vapor formed during combustion is included in calculating energy release when the fuel is burned.

HHV assumes that products of combustion are cooled to 77°F (25°C), below the dew point, where water vapor condenses, so the heat of condensation is included.

Whereas LHV assumes a 302°F (150°C) end point, well above the dew point, and therefore the heat of condensation is excluded.

The more hydrogen in the fuel, the more water vapor is formed during combustion and the greater the difference between LHV and HHV.

NG Fuel Consumption. Curves show calculated fuel flow for two simple cycle gensets with 31.5% and 36% HHV efficiency; two combined cycle plants with 45% and 54% HHV efficiency; natural gas with HHV heating value of 1.035 MMBtu/mcf (multiply HHV by 1.1 for LHV rating).



For natural gas, which is mostly methane (CH4), there is about an 11 percent difference (HHV/LHV ratio = 1.11)

Distillate contains a mix of heavier hydrocarbons which produce less water vapor during combustion, hence the difference only amounts to about 6 percent (HHV/LHV ratio = 1.06).

Since water vapor formed in combustion usually leaves the stack before condensing, the energy associated with water vapor in the HHV heating value is actually lost and not available to the power cycle.

This is why the gas turbine industry uses LHV heating value in specifying power plant performance; it is considered a more accurate measure of useful fuel energy.

Bottom line. The quantity of fuel to be purchased (mcf/hr or lb/hr) for gas turbine plant operation is properly estimated:

- adjust ISO ratings to estimate site-specific power (kW) and LHV heat rate,
- multiply adjusted heat rate by the HHV/LHV ratio for conversion to HHV heat rate (Btu/kWh),
- multiply HHV heat rate by site-adjusted kW to calculate HHV fuel consumption rate (Btu/hr), and then

- • divide HHV fuel consumption by HHV fuel heating value (Btu/lb or Btu/mcf) to obtain fuel flow as lb/hr or mcf/hr.

- Tip: Apply an "average" site ambient temperature to more accurately adjust ISO ratings when estimating gas turbine fuel consumption over an extended period.

Curves. These fuel consumption curves are based on HHV of the fuel so their designated efficiency may appear relatively low for modern technology gas turbine performance.

You can compute the equivalent LHV efficiency by multiplying their HHV value by 1.11 for natural gas fuel.

Also, plotting LHV plant heat rate (efficiency) instead of HHV will give you the same set of curves. Consistency is the key. ■

Section 5

Orders and Installations

Site and Application

Africa and Middle East

January 2018 through December 2019

Country, Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
GHANA						
Marinus Energy Atuabo Waste to Power IPP	simple cycle	1xTM2500+G4	37 MW	Gen Electric	Isopentane	Pilot plant
IRAN						
Rashed Torbat-e-Heydarieh Rashed CC Plant, Razavi Khorasan	comb cycle	2xMGT-70	183 MW	MAPNA	NG	Power gen
IRAQ						
Iraq Ministry of Electricity Baiji 1 & 2 Power Plant Rebuild, Northern Iraq	comb cycle	4xSGT5-2000E	187 MW	Siemens	NG	Power gen
Mass Energy Group Holding Phase 3 of Besmaya PP, southeast of Baghdad	comb cycle	4x9F	314 MW	Gen Electric	NG	Power gen
MPC Maisan Power Plant	comb cycle	2xSGT5-4000F	329 MW	Siemens	NG	Power gen
Technical Solutions to Industry Undisclosed dehydration facility, Basra Region	simple cycle	2xC600s	0.6 MW	Capstone	NG	Power gen
Undisclosed Undisclosed oil & gas production site	simple cycle	1xC1000R	1 MW	Capstone	NG	Power gen
ISRAEL						
Israel Electric Orot Rabin Modernization Project, Hadera	comb cycle	1x9HA.01	446 MW	Gen Electric	NG	Power gen
Zomet Energy Ltd. Power Plant, Kiryat Gat	simple cycle	6xFT4000 Swiftpac 60	70.1 MW	PWPS	NG	Power gen
KUWAIT						
Specto International Undisclosed gas processing facility	simple cycle	1xC600S 1xC800S 2xC1000R	0.6 MW 0.8 MW 1 MW	Capstone	NG	Power gen
MOZAMBIQUE						
ExxonMobil Rovuma LNG Project, northern part	mech drive	UndisclosedxH-100	120 MW	MHPS	LNG	Compressor
NIGERIA						
Government of Nigeria Afam 3 Fast Power Plant, Rivers State	simple cycle	8xTM2500	30 MW	Gen Electric	NG	Power gen
OMAN						
Duqm Integrated Power & Water Project Duqm Special Economic Zone	comb cycle	5xSGT-800	57 MW	Siemens	NG	Power gen

Country, Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
SENEGAL						
British Petroleum Greater Tortue Ahmeylm Floating LNG Project	mech drive	4xPGT25+G4	46,385 hp	Baker Hughes	NG	Compressor
SYRIA						
Syrian Public Establishment for Electricity Jandar Power Plant, near Homs	comb cycle	2xMGT-70	162 MW	Mapna	NG	Power gen
TUNISIA						
Societe Tunisienne de l'Electricite et du Gaz Power Plant, Mornaga	simple cycle	2xAE94.3A	325 MW	Ansaldo	NG	Power gen
Societe Tunisienne de l'Electricite et du Gaz Rades C Power Plant, Tunis	comb cycle	1xM701F	243 MW	MHPS	NG	Power gen
UNITED ARAB EMIRATES						
DEWA Unit H, Phase 4, Al Aweer Plant, near Dubai	simple cycle	3xSGT-4000F	329 MW	Siemens	NG	Peaking
Emirates Global Aluminium Smelter, Jebel Ali, Dubai	comb cycle	1xSGT5-9000HL	564 MW	Siemens	NG	Power gen
Sharjah Electricity & Water Authority Sharjah Power Plant, Hamriyah	comb cycle	3x9HA.02	557 MW	Gen Electric	NG	Power gen
Sharjah Electricity & Water Authority Power Plant, Layyah	comb cycle	2xM701F	385 MW	MHPS	NG	Power gen

Asia and Pacific

January 2018 through December 2019

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
AFGHANISTAN						
Bayat Power Bayat Power Phase 1, Jowzjan Province	simple cycle	1xSGT-A45	41 MW	Siemens	NG	Mobile unit
AUSTRALIA						
Optimal Group Undisclosed gas processing plant	simple cycle	1xC1000S	1 MW	Capstone	Butane	Power gen
Australian Navy Hunter class frigate	marine prop	1xMT30	53,640 shp	Rolls-Royce	Dual	CODAG
Optimal Group Undisclosed oil & gas production company	simple cycle	1xC1000S	1 MW	Capstone	NG	Power gen
BANGLADESH						
Summit Meghnaghat Power SMIIPCL Power Plant, Meghnaghat	comb cycle	1x9HA.01	446 MW	Gen Electric	Dual	Power gen
CHINA						
China Datang Group Power Plant, Wanning, Hainan Province	comb cycle	4xAE94.3A	340 MW	Ansaldo	NG	Power gen
China Datang Group Power Plant, Foshan, Guangdong area	comb cycle	4xAE94.3A	340 MW	Ansaldo	NG	Power gen
China Huadian Xiangyang Fancheng Plant Phase One, Hubei Province	simple cycle	2x6F.03	88 MW	Gen Electric	NG	Cogen
China Resources Power Group Standalone Plant, Taixing, Jiangsu Province	comb cycle	2xH-25	41 MW	MHPS	NG	Power gen
EED International Undisclosed utility microgrid project	simple cycle	1xC200	0.2 MW	Capstone	LPNG	CCHP
Guangdong Lee & Man Paper Cogen Plant, Hongmei, Dongguan, Guangdong	simple cycle	2x6F.03	88 MW	Gen Electric	NG	Cogen
Guangzhou Development Group Distributed Energy, Taiping Park, Guangzhou	comb cycle	2xSGT-700	32 MW	Siemens	NG	Distrib gen
Hong Kong Electric Lamma Power Station Unit 12, Hong Kong	comb cycle	1xM701F	385 MW	MHPS	NG	Power gen
Huadian Fuxin Energy CHD Plant, Zengcheng, Guangzhou	comb cycle	2xSGT6-9000HL	386 MW	Siemens	NG	CCHP

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
Lee & Man Paper Manfacturing Factory, Dongguan, Guangdong	simple cycle	2xH-25	41 MW	MHPS	NG	Cogen
Maanshan Iron & Steel Steel plant, Anhui Province	comb cycle	1xM701DA	144 MW	MHPS	BFG	Power gen
Shanghai Electric Power Minhang Power Plant, Minhang, near Shanghai	comb cycle	1xGT36	500 MW	Ansaldo	NG	Power gen
Sichaun Provincial Investment Group Power Plant, Sichaun Province	comb cycle	1xM701J	478 MW	Dongfang	NG	Power gen
State Power Investment Corporation Anci Development Zone, Langfang, Hebei	comb cycle	2x9F.05	314 MW	Gen Electric	NG	Power gen
State Power Investment Corporation Power Plant, Jieyang, Guangdong	comb cycle	2xAE64.3A	80 MW	Ansaldo	NG	Power gen
Zhuhai China Resources Thermal Power Fushan Industrial Park, Zhuhai	comb cycle	2xH-25	41 MW	MHPS	NG	Power gen
INDIA						
Brio Energy Private Undisclosed offshore & gas plant	simple cycle	2xC65	0.065 MW	Capstone	Flare gas	Power gen
Hindustan Petroleum Visakh Refinery Expansion, Visakhapatnam, AP	comb cycle	1x6F.03	60 MW	BHEL	NG	CHP
Hindustan Petroleum Refinery, Visakhapatnam	simple cycle	1x6F.03	87 MW	BHEL Gen Electric	NG	Power gen
INDONESIA						
PT Jawa Satu Power Java 1 Power Plant, Karawang, West Java	comb cycle	3x9HA.02	557 MW	Gen Electric	NG	Power gen
PT PLN Indonesia Power Tambak Lorok Power Plant 3, Java	comb cycle	1x9HA.02	544 MW	Gen Electric	NG	Power gen
PT PLN Persero Muara Karang Power Plant, Western Java	comb cycle	1xM701F	385 MW	MHPS	NG	Power gen
JAPAN						
Japanese Maritime Self Defense Force 30FFM Frigate	marine prop	1xMT30	53,640 shp	Rolls-Royce	Dual	Power gen
Japanese Maritime Self Defense Forces Destroyer JS Asahi	marine prop	2xLM2500+G4	47,370 shp	GE Marine	Dual	CODAG
Japan Maritime Self Defense Force Undisclosed frigate	marine prop	1xMT30	53,640 shp	Rolls-Royce	Dual	Marine prop

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
Kashima South Joint Power Corporation Power Plant, Kamisu, Ibaraki Prefecture	comb cycle	3xL30 A	30.1 MW	Kawasaki	NG	Power gen
KAZAKHSTAN						
TOO Synergy Astana Local oil and gas producer, Western Kazakhstan	simple cycle	1xC1000	1 MW	Capstone	NG	Power gen
TOO Synergy Astana Undisclosed existing pipeline project	simple cycle	2xC800	0.8 MW	Capstone	NG	Power gen
TOO Synergy Astana Western Kazakhstan Pipeline Project Expansion	simple cycle	11xC30	0.03 MW	Capstone	NG	Power gen
KOREA						
GS Power Anyang CHP Plant Unit 2-1, Anyang, Gyeonggi	comb cycle	1x7HA.02	384 MW	Gen Electric	NG	CHP
Korea Zinc LNG Combined Cycle Plant, Onsan, Ulsan	comb cycle	2x6F.03	87 MW	Gen Electric	NG	Power gen
Republic of Korea Navy Final 2 Daegu (FFX-II)-class guided missile frigates	marine prop	2xMT30	53,640 shp	Rolls-Royce	Dual	CODAG
Republic of Korea Navy Patrol Killer Experimental fast attack craft	marine prop	1xLM500	6,000 shp	Gen Electric	Dual	CODAG
Undisclosed Undisclosed luxury residential & commercial	simple cycle	1xC1000S 1xC600S	1 MW 0.6 MW	Capstone	NG	Power gen
Undisclosed customera Power plant, Yeoju,Gyeonggi Province	comb cycle	2xSGT6-9000HL	405 MW	Siemens	LNG	Power gen
MALAYSIA						
Serba Dinamik Numerous undisclosed offshore platforms	simple cycle	6xC65	0.65 MW	Capstone	NG	Power gen
Southern Power Generation Pasir Gudang, Johor	comb cycle	2x9HA.02	557 MW	Gen Electric	NG	Power gen
PAKISTAN						
K-Electric Power Plant, Bin Qasim	comb cycle	Undisclosed	Undisclosed	Siemens	NG	Power gen
K-Electric Bin Qasim Power Station 3, Karachi	comb cycle	2xSGT5-4000F	329 MW	Siemens	NG	Power gen
National Power Parks Management Haveli Bahadur Shah Power Plant, Jhang	comb cycle	2x9HA.02	557 MW	Gen Electric	NG	Power gen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
TAIWAN						
Chiahui Corporation						
Chiahui Power Plant, Chiayi Province	simple cycle	1x7HA.02	384 MW	Gen Electric	NG	Power gen
Taiwan Power						
DaTan 8&9 Power Project, Taoyuan City	comb cycle	4x7HA.02	384 MW	Gen Electric	NG	Power gen
THAILAND						
Global Power Synergy						
Central Utility Plant 4, Rayong	simple cycle	1xSGT-800B5	48 MW	Siemens	NG	Cogen
Nexif Energy						
Rayong Province	comb cycle	1x6FA	57 MW	Gen Electric	NG	IPP, Cogen
Gulf Energy Development						
Power plant, near Bangkok	comb cycle	8xM701JAC	493 MW	MHPS	NG	Power gen
TURKMENISTAN						
Turkmen State Power						
Power Plant, Lebap Province	simple cycle	3xM701DA	144 MW	MHPS	NG	Power gen
VIETNAM						
PTSC Mechanical & Construction						
Sao Vang & Dai Nguyet gas field projects	mech drive	2xMars 90	13 MW	Solar	NG	Compressor

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Central and South America

January 2018 through December 2019

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
BOLIVIA						
Ceramica Guadalquivir						
Undisclosed	simple cycle	1xC600s	0.6 MW	Capstone	NG	CHP
Government of Bolivia						
Termoelectrica de Warnes, near Santa Cruz	comb cycle	4xSGT-800	57 MW	Siemens	NG	Power gen
Government of Bolivia						
Termoelectrica del Sur, Yaguacua	comb cycle	4xSGT-800	57 MW	Siemens	NG	Power gen
Government of Bolivia						
Termoelectrica Entre Rios, 220 km se of La Paz	comb cycle	6xSGT-800	57 MW	Siemens	NG	Power gen
BRAZIL						
BNDES						
Marlim Azul Energia PP, Macae, Rio de Janeiro	comb cycle	1xM501JAC	425 MW	MHPS	NG	Power gen
Braskem						
Petrochemical Complex, Sao Paulo	simple cycle	2xSGT-600	24 MW	Siemens	Residue gas	Cogen
Centrais Electricas de Sergipe						
Porto de Sergipe I Plant, Barra dos Coqueiros, Sergipe	comb cycle	3x7HA.02	384 MW	Gen Electric	NG	Power gen
Gas Natural Acu						
LNG-to-Power Project GNA 1, Port of Acu	comb cycle	3x9000HL	388 MW	Siemens	LNG	Power gen
Luming Inteligencia Energetica						
Undisclosed brewing company	simple cycle	1xC65 1xC200S	0.065 MW 0.2 MW	Capstone	Biogas	Power gen
MODEC						
FPSO Carioca MV30, Sepia Field off Rio de Janeiro	mech drive	4xSGT-A35 RB	51,093 hp	Siemens	NG	Compressor
Vale Azul Energia						
Vale Azul II Project, Rio de Janeiro State	comb cycle	1xM501JAC	400 MW	MHPS	NG	Power gen
COLUMBIA						
Ecopetrol						
Rio Ceibas Field	simple cycle	1xC1000s	1 MW	Capstone	Flare gas	Power gen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
ECUADOR						
Petroecuador Shushufindi Refinery, Sucumbios Province	simple cycle	1xSGT-300	8 MW	Siemens	NG	Repowering
JAMAICA						
Innovative Energy Undisclosed luxury resort	simple cycle	1xC200s	0.2 MW	Capstone	NG	ICHP
Innovative Energy Couples Tower Isle Resort, Ocho Rios	simple cycle	1xC800s	0.8 MW	Capstone	NG	CCHP
PANAMA						
IPP Martano Power plant, near Colon	comb cycle	6xSGT-800	57 MW	Siemens	LNG	Power gen
PERU						
Pluspetrol Peru Block 88, Camisea asset	mech drive	1xSGT-700	45,151 hp	Siemens	NG	Compressor
UNDISCLOSED						
Supernova Energy Services Multiple oil and gas sites	simple cycle	5xC800S 2xC600S	0.8 MW 0.6 MW	Capstone	Gas	Power gen

East and West Europe

January 2018 through December 2019

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
ARMENIA						
ArmPower Yerevan 2 Power Plant, Yerevan	comb cycle	1xSGT5-2000E	187 MW	Siemens	NG	Power gen
FRANCE						
Biogaz Services Undisclosed biogas-to-energy project	simple cycle	1xC400s	0.4 MW	Capstone	Biogas	Power gen
Biogaz Services Undisclosed landfill in northern France	simple cycle	1xC800	0.8 MW	Capstone	Biogas	ICHP
Compagnie Electrique de Bretagne Power plant, Landivisiau	comb cycle	1xSGT5-4000F	329 MW	Siemens	NG	Power gen
Microturbine Power Undisclosed flare gas pilot project	simple cycle	6xC65	0.065 MW	Capstone	Flare gas	Power gen
GERMANY						
BASF Schwarzheide Industrial plant modernization, Schwarzheide	comb cycle	1xSGT-800	57 MW	Siemens	NG	Power gen
E-Quad Power Systems GmbH 4 undisclosed locations	simple cycle	6xC65	0.065 MW	Capstone	NG	CHP
E-Quad Power Systems GmbH 4 undisclosed facilities	simple cycle	2xC65 1xC200R	0.065 MW 0.2 MW	Capstone	NG	CHP
E-Quad Power Systems Undisclosed in Western Germany	simple cycle	2xC200	0.2 MW	Capstone	NG	CCHP
Evonik Industries Power Plant, North Rhine-Westphalia	simple cycle	2xUndisclosed	90 MW	Siemens	Dual	CHP
STEAG GuD Herne GmbH Herne 6 Plant, Herne, North Rhine-Westphalia	comb cycle	1xSGT5-80000H	450 MW	Siemens	NG	CHP
Uniper Irsching 6 Plant, Irsching	simple cycle	1xAE94.3A	340 MW	Ansaldo	NG	Power gen
Uniper Power Plant, Scholven/Gelsenkirchen	comb cycle	2xUndisclosed	Undisclosed	Undisclosed	NG	CHP
Volkswagen Heizkraftwerk West Plant, Wolfsburg	comb cycle	2xH-100	116.4 MW	MHPS	NG	Cogen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
GREECE						
Mytilineos Agios Nikolaos Plant, Voiotia Region	comb cycle	1x9HA.02	571 MW	Gen Electric	NG	Power gen
ITALY						
Edison Marghera Levante Plant, Venice	comb cycle	1xGT36-S5	583 MW	Ansaldo	NG	Power gen
Edison Edison Presenzano Plant, Caserta Province	comb cycle	1xGT36-S5	538 MW	Ansaldo	NG	Power gen
Furlotti & C. Sri Food manufacturer, Medesano	simple cycle	1xC600S	0.6 MW	Capstone	NG	CHP
IBT Group 3 undisclosed wastewater treatment facilities	simple cycle	4xC65 1xC200R	0.065 MW 0.2 MW	Capstone	Biogas	CHP
IBT Group Undisclosed chemical manufacturer	simple cycle	2xC200s	0.2 MW	Capstone	NG	CHP
Italian Navy FREMM frigate Federico Martinengo	simple cycle	1xLM2500+G4	35.3 MW	GE Marine	Dual	CODAG
NETHERLANDS						
Spirit Energy Markham J6A offshore platform	simple cycle	1xOP16-3B	1.8 MW	OPRA	Dual	Power gen
NORWAY						
Statoil Petroleum FPSO in Johan Castberg field, Barents Sea	mech drive	1xSGT-750	41 MW	Siemens	NG	Compressor
Statoil Petroleum FPSO in Johan Castberg field, Barents Sea	simple cycle	2xLM2500+G4 DLE	33.4 MW	Baker Hughes	Dual	Power gen
POLAND						
Micropower Europe Undisclosed textile mill	simple cycle	1xC600S	0.6 MW	Capstone	NG	CHP
RUSSIA						
BMTec Undisclosed housing & communal services	simple cycle	Undisclosed	Undisclosed	Capstone	NG	Power gen
Electrosystems Industrial Park, western Russia	simple cycle	13xC65	0.065 MW	Capstone	NG	CHP
Electrosystems Undisclosed technology manufacturer	simple cycle	Undisclosed	Undisclosed	Capstone	NG	Power gen
JSC Inter RAO - Elektrogeneratslya Verkhny Tagil TPP, Sverlovsk Region	comb cycle	1xSGT5-4000F	329 MW	Siemens	NG	Power gen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
PJSC Kazanorgsintez Tatarstan	comb cycle	1xSGT5-2000E	187 MW	Siemens	Syngas	Power gen
RUE Vitebskenergo Lukomiskaya Peaking power plant, Belarus	simple cycle	3xSGT-800	57 MW	Siemens	NG	Peaking
RUE Vitebskenergo Novopolotskaya Peaking Power Plant, Belarus	simple cycle	2xSGT-800	57 MW	Siemens	NG	Peaking
SERBIA						
Gazprom Energoholding TE-TO Pancevo power plant, Pancevo	comb cycle	2xAE64.3A	90 MW	Ansaldo	NG	CHP
UNITED KINGDOM						
Belfast Power Belfast Station, Belfast, Northern Ireland	comb cycle	Undisclosed	Undisclosed	Siemens	NG	Power gen
Fores Engineering Undisclosed unmanned platform, N Sea	simple cycle	1xC200	0.2 MW	Capstone	NG	Power gen
Pure World Energy Commercial facility	simple cycle	1xC200S	0.2 MW	Capstone	NG	ICHP
Pure World Energy Undisclosed commercial & industrial sector	simple cycle	1xC1000S 2xC200	1 MW 0.02 MW	Capstone	NG	Power gen
SSE plc Keadby 2 power station, Lincolnshire, England	comb cycle	1xSGT-9000HL	564 MW	Siemens	NG	Power gen
UK Royal Navy 3 Type 26 Gobal Combat Ships	marine prop	3xMT30	53,640 shp	Rolls-Royce	Dual	CODAG

North America

January 2018 through December 2019

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
CANADA						
City of Medicine Hat Unit 16, Medicine Hat, Alberta	simple cycle	1xLM6000	44 MW	Gen Electric	NG	Backup powe
Encana Pipestone Processing, Grand Prairie, AB	mech drive	1xSGT-750	55,000 hp	Siemens	NG	Compressor
Inter Pipeline Heartland Petrochemical, near Ft. Sask, AB	simple cycle	2xSGT-800	54 MW	Siemens	NG	Power gen
Macro Enterprises Saturn Station, near Dawson Creek, BC	mech drive	1xSolarT130 DLE	23,470 hp	Solar	NG	Compressor
Nova Gas Transmission Winchell Lake Compressor Station, AB	mech drive	1xSGT-A35	36.6 MW	Siemens	NG	Compressor
Suncor Energy Oil Sands Base Plant, near Fort McMurray, AB	comb cycle	2xM501JAC	425 MW	MHPS	NG	Cogen
Undisclosed EPC contractor Grand Prairie, northeast of Edmunton, AB	simple cycle	2xSGT-300	79 MW	Siemens	NG	Power gen, Compressor
Undisclosed hospital Eastern Canada	simple cycle	4xC65	0.065 MW	Capstone	NG	ICHP
MEXICO						
DTC Ecoenergia Various industrial facilities	simple cycle	3xC1000S 2xC30	1 MW 0.03 MW	Capstone	NG	CHP/CCHP
DTC Ecoenergia Undisclosed manufacturing, near Guadalajara	simple cycle	1xC1000S	1 MW	Capstone	NG	Power gen
DTC Soluciones Inmobiliarias Undisclosed pet food manufacturer	simple cycle	2xC200	0.2 MW	Capstone	NG	CHP
DTC Soluciones Inmobiliarias Undisclosed latex glove manufacturer	simple cycle	2xC200	0.2 MW	Capstone	NG	CHP
DTC Soluciones Inmobiliarias Undisclosed energy drink manufacturer	simple cycle	2xC200	0.2 MW	Capstone	NG	CHP
DTC Soluciones Inmobiliarias Undisclosed produce packager	simple cycle	2xC65	0.065 MW	Capstone	NG	CHP
MODEC FPSO Vessel, 6 miles off the coast	simple cycle	3xSGT-A35	34 MW	Siemens	NG	Power gen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
UNITED STATES						
Advanced Power South Field, Wellsville, Columbiana County, Ohio	comb cycle	2x7HA.02	384 MW	Gen Electric	NG	Power gen
247Solar Undisclosed	simple cycle	2xC200s	0.2 MW	Capstone	NG	Power gen
ARG Precision Undisclosed locations, Puerto Rico	simple cycle	3xFT8 MobilePAC	30 MW	PWPS	Dual	Power gen
Astoria Generating 2 SeaFloat Barges, Brooklyn, New York	simple cycle	8xSGT-A65	76 MW	Siemens	NG	Power gen
Benz Research & Development Manufacturing plant, Sarasota, Florida	simple cycle	1xC200S	0.2 MW	Capstone	NG	CCHP
Caithness Energy Guernsey Power Station, Guernsey, Ohio	comb cycle	3x7HA.02	384 MW	Gen Electric	NG	Power gen
Cal Microturbine Undisclosed pharmaceutical, California	simple cycle	1xC600s	0.6 MW	Capstone	NG	CHP
Cal Microturbine Undisclosed location, California	simple cycle	1xC800s	0.8 MW	Capstone	Flare gas	Power gen
Cal Microturbine Undisclosed oil facility, southern California	simple cycle	2xC800S	0.8 MW	Capstone	Gas	Power gen
Cheniere Energy 3rd liquefaction train, Corpus Christi, Texas	simple cycle	6xPGT25+G4 DLE	34 MW	Baker Hughes	NG	Power gen
China Energy Brooke County Plant, Colliers, West Virginia	comb cycle	2xF7.HA.01	290 MW	Gen Electric	NG	Power gen
Cooperative Energy Morrow Gen Station, Purvis Miss	comb cycle	1xSGT6-9000HL	338 MW	Siemens	NG	Repowering
Danskammer Energy Newburgh, New York	comb cycle	1xM501JAC	425 MW	MHPS	NG	Power gen
E-Finity Distributed Generation Station for Utica Shale pipeline, undisclosed	simple cycle	1xC600S	0.6 MW	Capstone	NG	Power gen
E-Finity Distributed Generation Undisclosed Mid-Atlantic area	simple cycle	1xC600s	0.6 MW	Capstone	NG	Pipeline expa
E-Finity Distributed Generation Undisclosed stations, Mid-Atlantic	mech drive	1xC1000s	1 MW	Capstone	NG	CHP
E-Finity Distributed Generation Undisclosed chemical manufacturer, mid-Atlantic area	simple cycle	1xC1000S	1 MW	Capstone	NG	CHP

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
E-Finity Distributed Generation Undisclosed university, mid-Atlantic area	simple cycle	1xC1000S	1 MW	Capstone	NG	CCHP
Entergy Louisiana Lake Charles Power Station, Lake Charles, Louisiana	comb cycle	2xM501GAC	283 MW	MHPS	NG	Power gen
Entergy Texas Montgomery Station, Willis, Texas	comb cycle	2xM501GAC	283 MW	MHPS	NG	Power gen
ESC Harrison County Power Harrison County, WV	comb cycle	1x7HA.02	384 MW	Gen Electric	NG	Power gen
ExxonMobil & Qatar Petroleum Golden Pass LNG Export Facility, Sabine, Texas	mech drive	6xMS7001EA	85.4 MW	Baker Hughes	LNG	Compressor
Florida Gas Trasmission Compressor Station, Santa Rosa County, Florida	mech drive	1xTitan 130	23,500 hp	Solar	NG	Compressor
Florida Power & Light Dania Beach Clean Energy, Florida	comb cycle	1x7HA.03	430 MW	Gen Electric	NG	Power gen
Fortress Transportation & Infrastructure Investors Long Ridge Energy Project, Hannibal, Ohio	comb cycle	1x7HA.02	384 MW	Gen Electric	NG	Power gen
Hill Top Energy Hill Top Energy Center, Nemacolin, Pennsylvania	comb cycle	1x7HA.02	384 MW	Gen Electric	NG	Power gen
Horizon Power Systems Undisclosed unmanned station, Wyoming	simple cycle	1xC800s	0.8 MW	Capstone	NG	Power gen
Horizon Power Systems Undisclosed gas compression station, Midwest	mech drive	1xC1000S	1 MW	Capstone	NG	Compressor
Horizon Power Systems Undisclosed gas processing, southern Texas	simple cycle	1xC1000S	1 MW	Capstone	NG	Power gen
Horizon Power Systems Undisclosed unmanned station, Wyoming	simple cycle	1xC600s	0.6 MW	Capstone	HPNG	Power gen
Horizon Power Systems Undisclosed	simple cycle	2xC200S	0.2 MW	Capstone	NG	CHP
Indeck Energy Services Indeck Niles Energy Center, Niles, Michigan	comb cycle	2x7HA.02	384 MW	Gen Electric	NG	Power gen
J-Power USA Development Jackson Generation Project, Elwood, Illinois	comb cycle	2xM501JAC	425 MW	MHPS	NG	Power gen

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
Lansing Board of Water & Light Lansing Power Plant, Lansing, Michigan	comb cycle simple cycle	3xSGT-800	57 MW	Siemens	NG	Power gen
Lone Star Power Solutions Undisclosed Eagle Ford Oil & Gas producer, Texas	simple cycle	1xC800s	0.8 MW	Capstone	NG	Power gen
Lone Star Power Solutions Undisclosed Private High School, Arizona	simple cycle	1xC200S	0.2MW	Capstone	NG	CHP
Lone Star Power Solutions Undisclosed Permian Basin oil & gas producer	simple cycle	unknownxC800	0.8 MW	Capstone	NG	Rental
Lone Star Power Solutions Undisclosed Permian Basin oil & gas producer	simple cycle	2xC800	0.8 MW	Capstone	NG	Power gen
Lone Star Power Solutions 9 undisclosed campus locations, Texas	simple cycle	9xC65	0.065 MW	Capstone	NG	ICHP
Mr. Natural Production Undisclosed indoor grow operation, California	simple cycle	3xC65	0.065 MW	Capstone	NG	Power gen
National Fuel Gas Midstream Undisclosed dehydration site	simple cycle	1xGT333S	0.3 MW	FlexEnergy	NG	Power gen
NTE Energy Reidsville Energy, Rockingham, North Carolina	comb cycle	1xM501GAC	283 MW	MHPS	NG	Power gen
NTE Energy Killingly Energy Center, Killingly, Connecticut	comb cycle	1xM501 JAC	425 MW	MHPS	Dual	Power gen
NOVI Energy Charles City CC Plant, Charles City County, Virginia	comb cycle	2x7HA.02	384 MW	Gen Electric	NG	Power gen
PowerSouth Lowman Energy Center, Leroy, Alabama	comb cycle	1xM501JAC	425 MW	MHPS	NG	Power gen
PowerSouth McWilliams Power Plant, Covington, Georgia	simple cycle	1xSGT6-2000E	117 MW	Siemens	NG	Power gen
RSP Systems Manhattan Wests SE Tower, NYC	simple cycle	1xC1000	1 MW	Capstone	NG	CHP
RSP Systems Undisclosed Hotel, NYC	simple cycle	4xC65	0.065 MW	Capstone	NG	CHP
RSP Systems Undisclosed university, Connecticut	simple cycle	1xC1000S	1 MW	Capstone	NG	CHP
Stanton Energy Reliability Center Under contruction, Los Angeles, California	simple cycle	2xLM6000	59 MW	Gen Electric	NG	Hybrid Electric Gas Turbine

Country Developer and Site	Type	Gas Turbine No. & Model	Unit ISO Rating	Gas Turbine Builder	Fuel	Remarks
Tampa Electric Big Bend Power Station, Hillsborough County, Florida	comb cycle	2x7HA.02	384 MW	Gen Electric	NG	Repowering
U.S. Well Services Fracturing fleets	simple cycle	unknownxFT8 Mobilepa	30 MW	PWPS	NG	Power gen
United States Navy 10 Arleigh Burke-class destroyers DDG 51	marine prop	40xLM2500	47,370 shp	GE Marine	Dual	Power gen
United States Navy DDG 126 & 127 Arleigh Burke-class destroyers	marine prop	unknown xLM2500+G4	47,370 shp	Gen Electric	Dual	CODAG
United States Navy Littoral Combat Ship USS Cincinnati	marine prop	2xLM2500	29,500 hp	GE Marine	Dual	Power gen
United States Navy Undisclosed ship	marine prop	1xLM2500+	40,500 shp	Gen Electric	Dual	Propulsion
United States Navy Undisclosed Littoral Combat Ships	propulsion	Undisclosed xLM2500	40,500 shp	GE Marine	Dual	CODAG
Undisclosed Hospital Western United States	simple cycle	10xC65	0.065 MW	Capstone	NG	ICHP
Undisclosed Manufacturer Undisclosed, California	simple cycle	1xGT333S, 3xGT1300s	0.3 MW, 1.3	FlexEnergy	NG	CHP
Undisclosed Midwest Utility Undisclosed	simple cycle	1x SmartERM501GAC	275 MW	MHPS	NG	Power gen
Undisclosed Oil & Gas Production Facility Los Angeles, California	simple cycle	1xC1000S	1 MW	Capstone	Flare gas	Power gen
Undisclosed Portable Power Oil & Gas project Undisclosed	simple cycle	4xC1000S	1 MW	Capstone	NG	Power gen
Undisclosed Religious Facilities x 2 Undisclosed	simple cycle	2xGT333S	0.33 MW	Flexenergy	NG	CHP
Undisclosed Microgrid, Sonoma County, California	simple cycle	1xC65	0.065 MW	Capstone	NG	ICHP

Section 6

2019 Editorial Abstracts GTW Magazine Issues

Editorial Abstracts 2019 Gas Turbine World

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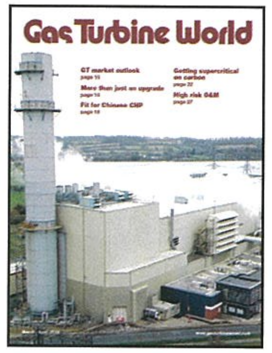

Gas turbine market outlook 2019
Near-term EPU and O&G sector outlook is for the gas turbine market to total 90 to 120 GW of new capacity and approximately 1500 Unit orders over the next three years, with a combined value of $33 billion (units 1 MW and larger).
By Tony Brough, pp 10-12

GT26 upgrade for renewables backup
The growth of renewable energy has led to demand for flexibility of gas turbine operation. The higher the proportion of electricity generated by variable renewable sources, such as wind and solar, the more flexibility that needs to be built into the grid network to balance variable supply and variable demand. This has led GE to develop the GT26 HE upgrade.
By David Flin, pp 14-17

MGT packages commissioned in China
A mechanical efficiency of 34.5% coupled with extremely low emissions makes the MGT 6000 gas turbine among the most modern designs in the 6 MW category. Combined heat and power plants equipped with this turbine achieve efficiency of up to 90%.
By David Appleyard, pp 18-21

La Porte demos carbon capture
NET Power has successfully achieved first fire of its supercritical CO2 demonstration power plant and test facility in La Porte, Texas, USA. This included firing of the 50 MW Toshiba commercial scale combustor, which involved integrated operation of the full NET Power process. NET Power said that it is targeting global deployment of 300 MW commercial scale plants beginning in 2022. GTW gets an update on the key developments that have been made.
By David Flin, pp 22-25

Plant O&M under high risk conditions
Power demand is not restricted to safe and stable locations. Power plants also operate in locations where there is a high risk, be it man-made or natural hazards. Carrying out operation and maintenance on large, static power plants under such circumstances can be challenging, and dealing with these challenges requires planning and preparation one wouldn't consider in secure locations. How does one deal with such challenges? GTW has been examining the issue.
By David Flin, pp 27-30

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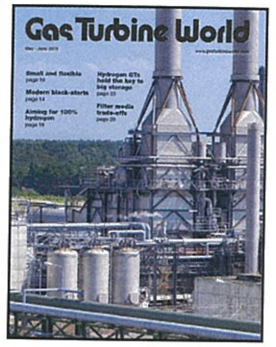

Future for small gas turbines
There is increasing interest in small turbine units to provide power in many different settings to ensure reliable power supply in the absence of a grid. GTW speaks to Mark Schnepel, President and CEO of FlexEnergy, about the issues.
By David Flin, pp 10-12

Modernization for instant power
In addition to supplying a new SGT-800 industrial gas turbine, Siemens will install a battery storage system for black-start. GTW discusses the gas turbine replacement and the technical and economic advantages of the start-up system. *By David Flin, pp 14-17*

Hitting 100% hydrogen
The idea of using hydrogen as a medium for storing excess renewable energy is gathering momentum but to deliver, a number of technological advances are required. Now, a new technology partnership aims to do just that.
By David Appleyard, pp 18-21

Hydrogen turbines for energy storage
As part of a 1 GW project billed as the world's largest energy storage project to date, a gas turbine running on 100% renewable energy-produced hydrogen may hold the key to our clean energy future. It's going to be built in Utah.
By David Appleyard, pp 22-26

Filtration design trade-offs
One of the cost-drivers in gas fired power production is the condition of inlet air. Filters can differ substantially from one another, and each design comes with associated cost trade-offs.
By Mike Roesner, Donaldson Company, pp 28-30

Jul-Aug 2019 Performance Specs, 35th Edition
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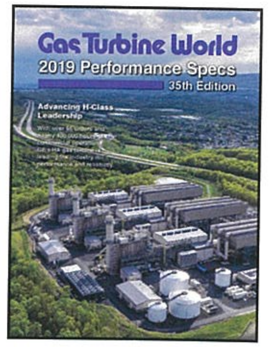

Simple Cycle Gensets
Design ratings for more than 260 gas turbine gensets available for 50/60-Hz power generation, industrial cogeneration and utility combined heat and power projects.
Annual update by GTW staff, pp 4 to 20

Combined Cycle Plants
Design ratings for 1x1 and 2x1 combined cycle configurations operating without supplementary fired HRSGs and without selective catalytic reduction for emissions abatement.
Annual update by GTW staff, pp 22 to 36

Mechanical Drive Power
Design ratings for aeroderivative and industrial frame gas turbines available for offshore platform and land based oil and gas, petrochemical and LNG projects.
Annual update by GTW staff, pp 37 to 43

Marine Drive Gas Turbines
Design ratings for marine gas turbines available for military and commercial ship propulsion, shipboard electric power generation and offshore platform power projects.
Annual update by GTW staff, pp 44 to 47

Sep-Oct 2019
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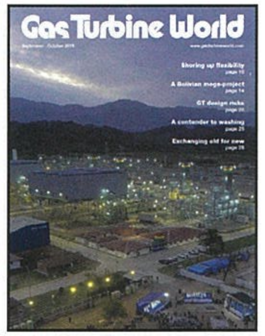

Drax opts for HE upgrade at Shoreham
In its latest move to support the UK's decarbonisation effort, Drax will use GE's GT26 HE (high efficiency) upgrade to boost efficiency, output and operating flexibility at one of its recently acquired gas fired plants. It marks GE's second GT26 HE upgrade since its introduction earlier this year. *By Junior Isles, pp 10-12*

CCGTs power Bolivia's energy vision
The third of three power combined cycle plants was recently inaugurated in Bolivia, marking a major milestone on the road to achieving the country's 2025 energy vision. Inauguration of the projects represents the successful completion of what proved to be a huge logistical undertaking. *By Junior Isles, pp 14-18*

GT design to complement renewables
Major heavy duty gas turbine manufacturers have introduced upgrade versions of turbines that are designed to provide power for balancing renewable energy fluctuations. These upgraded engine designs are influenced by ideas and innovations from aero engines but it is an approach that raises issues around inlet-air filtration and the secondary cooling-air system, thus raising the risk of more frequent forced outages.
By Dr. Vinod Kallianpur and Yosun Shin, Samsung C&T, pp 20-22

An alternative to compressor washing
Compressor washing has its drawbacks and limitations. A new coating process known as Anti Foul Treatment (AFT) could be a good alternative when it comes to maintaining turbine efficiency, reliability and cutting greenhouse gas emissions.
By Peter Asplund, United Sevices Sweden, pp 25-27

Reset the clock to zero
Exchanging an aging gas turbine for a completely new unit that includes the very latest production technology can be an effective solution when it comes to keeping a plant operational and competitive. Greg Perona, Market Development Manager Gas Turbines, North America Region for Siemens, explains to GTW what is involved in such an engine exchange.
By David Flin, pp 28-30

Nov-Dec 2019
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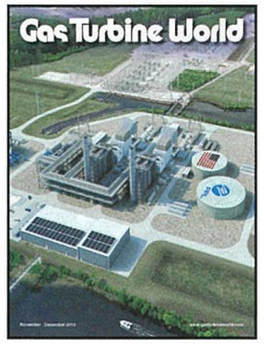
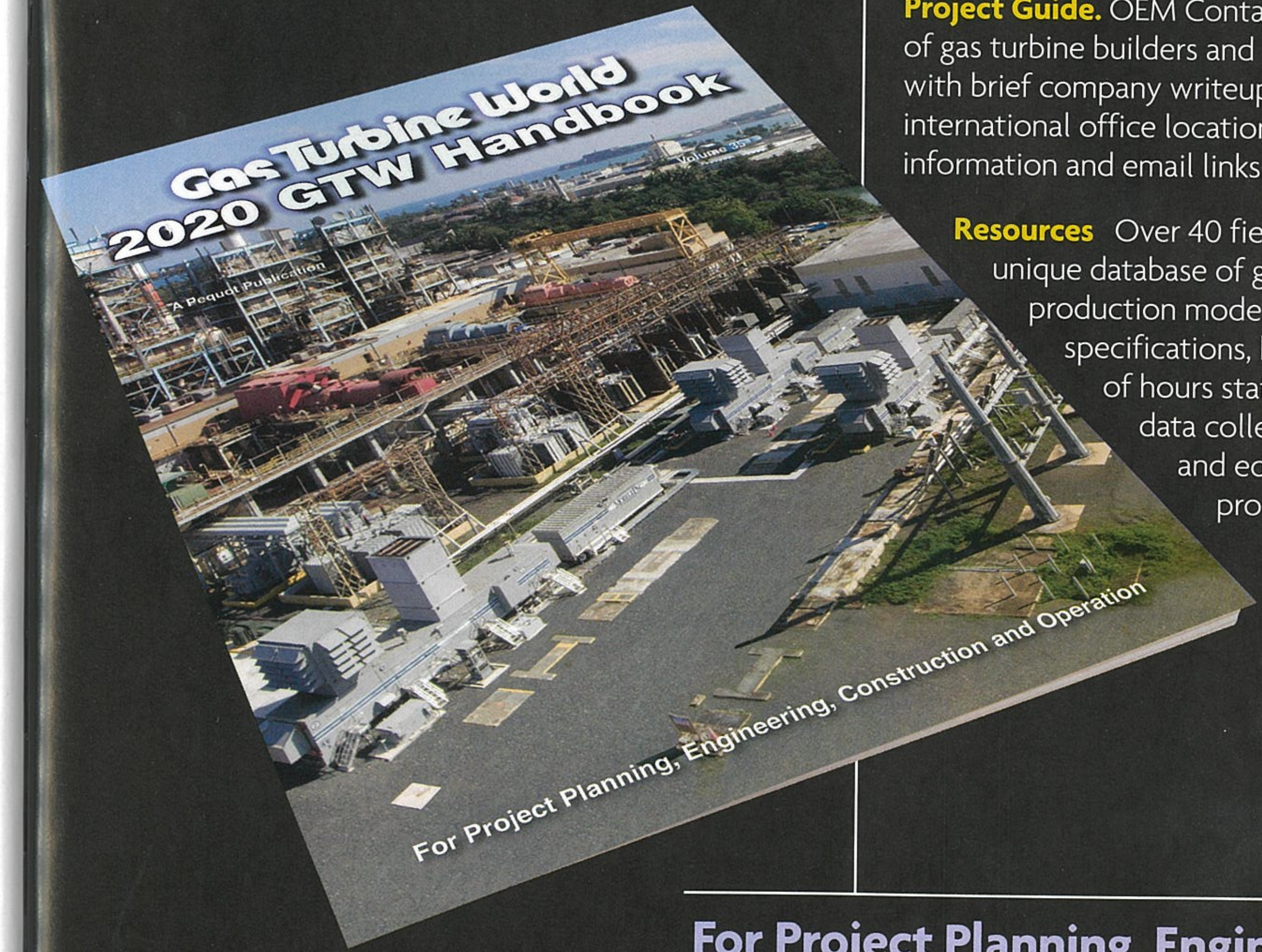


Working towards 100% hydrogen
Siemens has committed to gradually increasing the hydrogen capability of its gas turbines to at least 20% by 2020, and 100% by 2030. The first goal has already been achieved, with projects in place including a 60% hydrogen project involving two SGT-600 turbines at Braskem in Brazil.
By David Flin, pp 10-13

7HA.03 GTs exceed 64% efficiency
Florida Power & Light is building a nominally rated 1280MW combined cycle plant for mid-2022 startup to be powered by GE's latest 7HA.03 gas turbine
By Victor deBiasi, pp 14-20

Keeping up with the cyber threat
In the past five years, digitalization has transformed the utility industry. The rapid adoption of connected power generation, transmission, distribution, and end-use assets are enabling utilities to move away from centralized power generation technologies, and towards distributed energy. But it is a shift that opens utilities to cyber-attacks. GTW looks at a report by Siemens and Ponemon Institute, which assesses the vulnerabilities and preparedness of the industry. *By Junior Isles, pp 22-26*

Gas breathes life into aging coal plants
TransAlta is converting its Sundance and Keephills coal fired plants to natural gas, with Emerson leading the design, procurement, installation and commissioning in the replacement of the full automation system for the converted projects. The conversions are part of a strategy that will see TransAlta transition to clean energy by 2025.
By David Appleyard, pp 28-32



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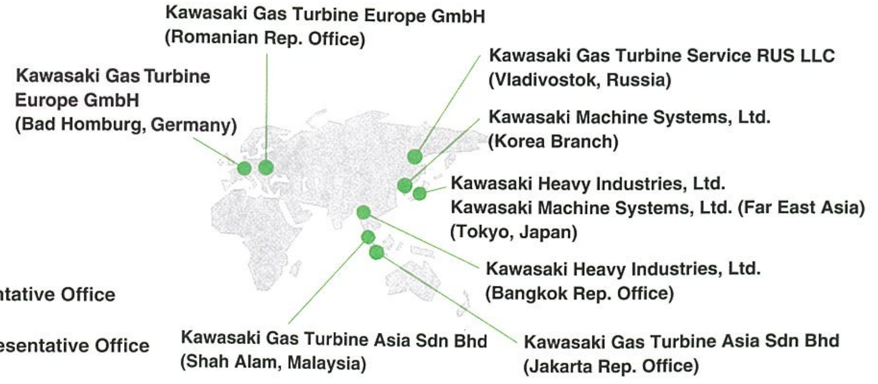

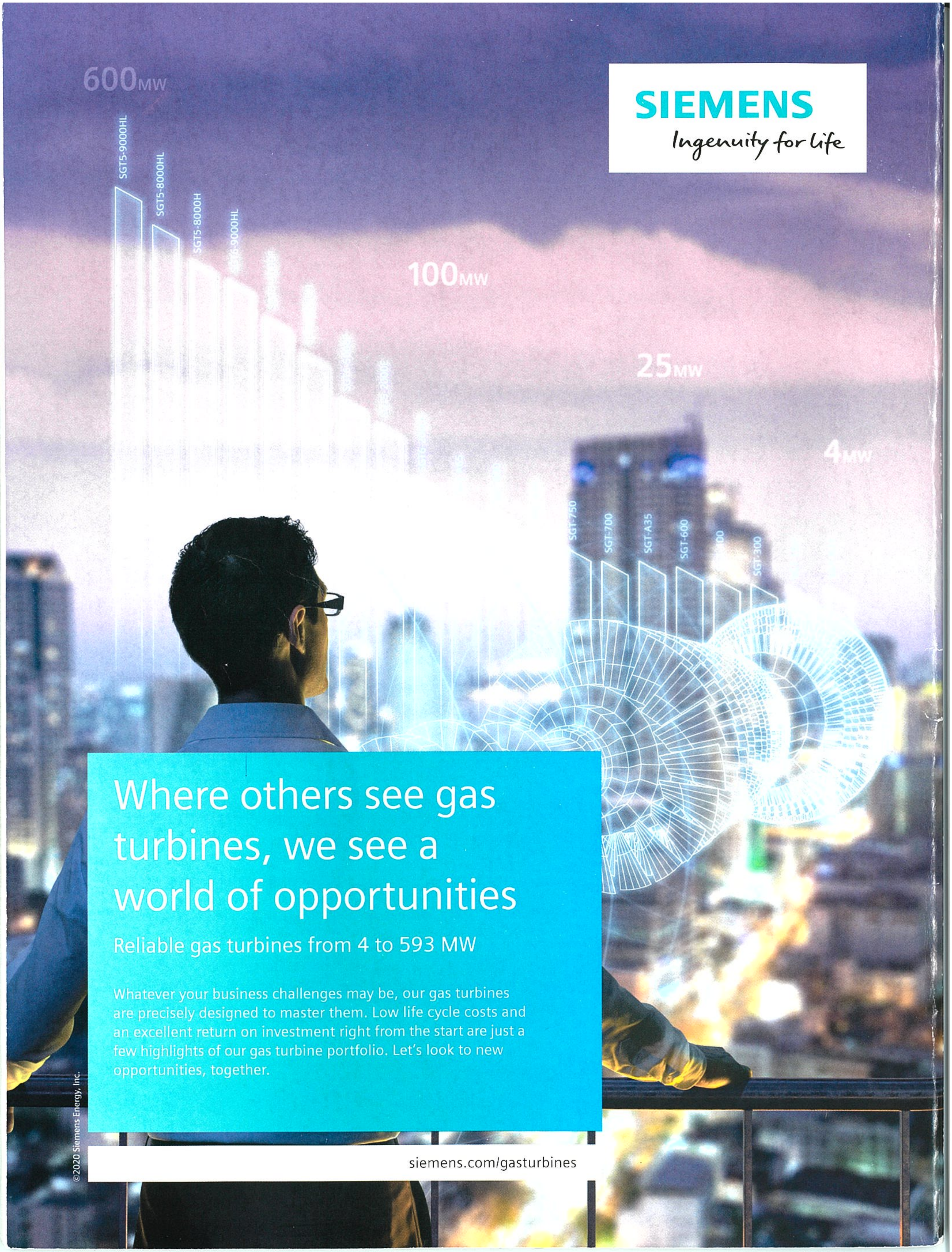
600MW
SGT5-9000HL
SGT5-8000HL
SGT5-8000H
SGT6-9000HL
100MW
25MW
4MW
SGT-750
SGT-700
SGT-A35
SGT-600
SGT-300