Combustion Engine vs Gas Turbine: Ambient Temperature

The increasing need for flexible power across the world, often in harsh climates, makes power plant performance under varying conditions an important consideration in technology selection. As combustion engines are less sensible to temperature and humidity, Wärtsilä power plants outperform gas turbines in hot conditions.

Depending on the technology and site conditions, a power plant's actual electrical output, efficiency, and fuel consumption can be quite different than its performance at design conditions. Ambient conditions can vary dramatically with geographic location and by season. For example, summer temperatures in the Middle East and northern Africa frequently exceed 40°C (104°F), while large seasonal temperature swings of over 38°C (100°F) occur in some locations. As surging temperatures usually correspond to peak electrical demand, reduction in power output at high ambient temperatures can be problematic. Gas turbines in particular can experience significant performance derating in hot, humid conditions.

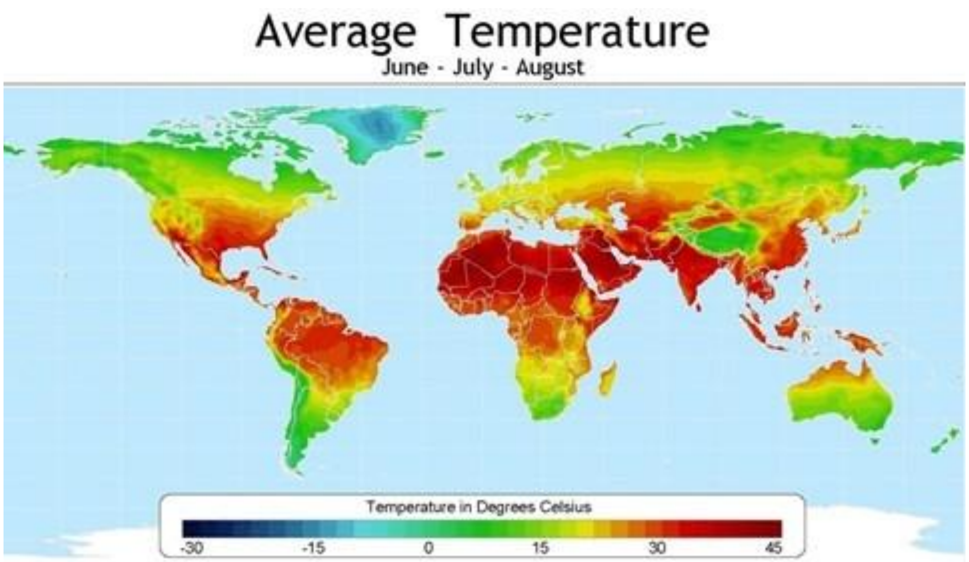

Image credit: Maps of the World

How do ambient conditions affect power plant output and efficiency?
Ambient temperature, altitude and humidity affect the density of air. Hot and humid air is less dense than dry, cooler air. In gas turbines, power output is dependent on the mass flow through the compressor. As the density of air decreases, more power is required to compress the same mass of air. This reduces the output of the gas turbine and decreases efficiency. Studies have found that gas turbine efficiency deteriorates by one percent for every 10 degree rise in temperature above ISO conditions[1]. This translates into a power output reduction of 5 to 10 percent, depending on the type of gas turbine. Gas turbine manufacturers use various techniques to cool inlet air and boost turbine output, including evaporative coolers and mechanical chillers. However, inlet air cooling requires additional power consumption, and the efficacy of cooling systems is highly dependent on the ambient humidity. Combustion engines are less sensitive to temperature and humidity, retaining their rated efficiency and power output over a broader range of ambient conditions.

The performance of simple cycle gas turbines, combined cycle gas turbines (CCGT) and Wärtsilä combustion engines at varying ambient conditions was assessed using data from GT PRO. Popular model heavy frame industrial gas turbines were compared with similarly sized Wärtsilä engines, with capacities of 200 – 275 MW in simple cycle, and approximately 300 MW in combined cycle (see fact box at end of article for full load output of the specific models compared). For combined cycle operation, a 1x1 CCGT configuration was assumed with air-cooled condensers and a bypass stack to isolate the steam generating portion of the plant from the gas turbine. Figure 1 presents the net power plant output at varying ambient temperatures ranging from 10°C to 40°C (50°F to 104°F) for gas turbines and Wärtsilä combustion engines operating in combined cycle. CCGT output decreases by 15 to 18 percent at 40°C compared to ISO reference conditions, while the Wärtsilä Flexicycle™ plant output decreases by only 8 percent compared to reference conditions.

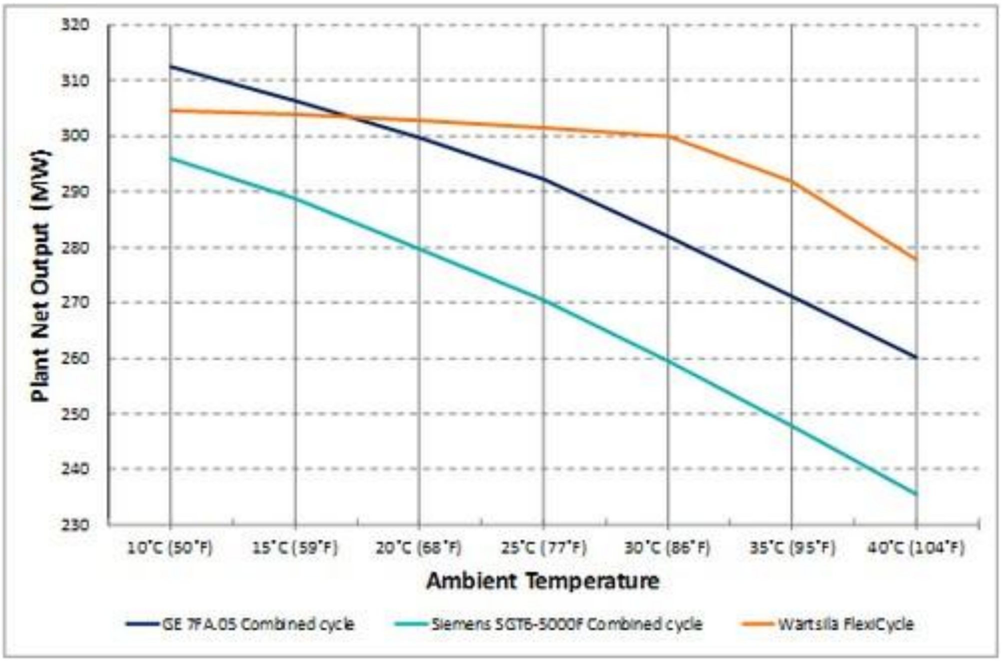

Figure 1: Impact of ambient temperature on Wärtsilä Flexicycle™ and CCGT power output.

The impact on plant efficiency is shown in Figure 2 for both combined cycle and simple cycle operation. At an ambient temperature of 40°C, CCGT efficiency decreases by 3.5 percent compared to ISO conditions. In a Flexicycle™ power plant using combustion engines, efficiency only drops by 1.1 percent at 40°C. All values represent net efficiency at the high-voltage grid side at sea level pressure. In simple cycle operation, Wärtsilä power plants demonstrate significant efficiency advantages over gas turbines. While simple cycle efficiency of a gas turbine is approximately 35 percent at 40°C, Wärtsilä efficiency is over 45 percent. The impact of ambient temperature on efficiency becomes even more pronounced when the plant is operating at part load. As a result, Wärtsilä power plants offer a wide range of operational flexibility and reliable performance, even in harsh ambient conditions.

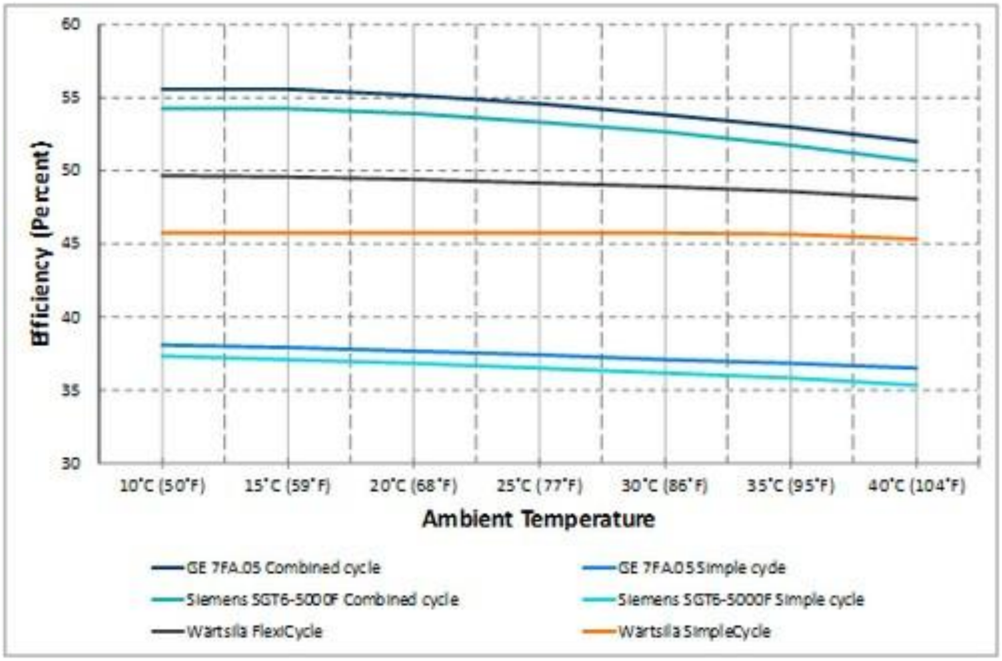

Figure 2: Efficiency of Wärtsilä engines compared with gas turbines at varying ambient temperatures.

Fact Box: Plant Net Output at Varying Ambient Temperatures

	GE 7FA.05		Siemens SGT6-5000F		Wärtsilä	
	Combined cycle	Simple cycle	Combined cycle	Simple cycle	FlexiCycle	SimpleCycle
10°C (50°F)	312	214	296	204	305	276
15°C (59°F)	306	209	289	198	304	276
20°C (68°F)	300	205	280	191	303	276
25°C (77°F)	292	200	270	185	301	276
30°C (86°F)	282	194	259	178	300	276
35°C (95°F)	271	188	248	172	292	269
40°C (104°F)	260	182	235	164	278	257

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[1] The standard reference conditions (prescribed by the International Organization for Standardization, or ISO) are the temperature and pressure conditions under which manufacturers evaluate generating capacity and efficiency. These ISO reference conditions differ depending on the technology. Standard reference conditions for gas turbines (ISO 3977) are 15°C (59°F) and 101.3 kPa (14.7 psia) while for combustion engines (ISO 3046) reference conditions are 25°C (77°F) and 99 kPa (14.4 psia).