RWE

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Great Yarmouth CCGT Section 36
Technical Information to demonstrate impacts of ambient conditions on gross power generation.

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1. Great Yarmouth CCGT Section 36 – Background

A consent under Section 36 of the Electricity Act 1989 was granted in October 23rd 1997 for Great Yarmouth power station. The original consent stated that the plant gross output was about 350MW, and a variation to increase the capacity to about 400MW was later granted on April 14th, 2001. The term 'about' is not defined within the original consent or in the subsequent variation.

This report was prepared by RWE Generation UK plc ("RWE") in response to additional information requested by BEIS following a meeting on the 11th of October 2022 to discuss how power generation is affected by ambient conditions especially in the winter months in relation to the Great Yarmouth consent.

RWE are asking for confirmation from BEIS that the current Section 36 for the station includes the impacts of variations in ambient conditions and hence clarification that a maximum gross generation of 430MW electrical is consistent with the existing consent.

2. Technical Summary

The combination of low ambient air temperatures and high atmospheric pressure benefit the performance of the gas turbines such as those at Great Yarmouth. These conditions result in a higher electrical output and thermal efficiency at certain times of the year, especially on cold, high atmospheric pressure days when there tends to be reduced output from wind generation due to high pressure resulting in low wind. This is exactly the time when the UK needs all the power possible to meet demand and ensure security of supply.

Furthermore, the air quality assessment has demonstrated that there are no significant impacts on human health or ecological receptors under any scenario where the station operates at 430MWe (gross).

The ability to generate at 430 MWe (gross) is only possible under certain ambient conditions and is also influenced by past maintenance / modest improvements to the station. The ability to generate at this capacity has not been deployed due to RWE's uncertainty in how ambient conditions should be accounted for in the interpretation of the current Section 36 consent. RWE requests confirmation whether the effects of ambient conditions are reflected within the term 'about 400MW' used in the current Great Yarmouth Section 36 consent, authorising the station to operate at 430MWe.

3. Operation of a Gas Turbine (GT)

To demonstrate the impacts of ambient temperatures in gross power generation some of the relevant aspects of a gas turbine operation are outlined below.

A gas turbine has the following major parts:

- Turbine
- Compressor
- Shaft
- Combustion Chamber
- Gear box
- Exhaust

To generate electricity, a gas turbine combusts a mixture of air and fuel at very high temperatures causing the turbine blades to spin, which in turn drives a shaft that is connected to a generator, this converts the energy from the rotating shaft into electricity. Part of the energy produced by the power turbine is used to drive the compressor, and the remainder is used to drive the electrical generator, which is on the same shaft line.

The start of the fuel combustion process in a GT is when air is drawn into the inlet, by the action of the compressor. The compressor then pressurises the air to a high pressure before sending the air into the combustion chamber. The volume of air that is provided to the power turbine is fixed due to the size of the compressor, whilst the mass of air is related to the volume and pressure increase produced by the work of the compressor. The operation of the compressor is one of the key parts of determining the output of a gas turbine and its output is directly related to the ambient conditions.

Figure 1 below shows the process where ambient air is drawn in through a compressor into the power turbine where it is mixed with fuel before being combusted.

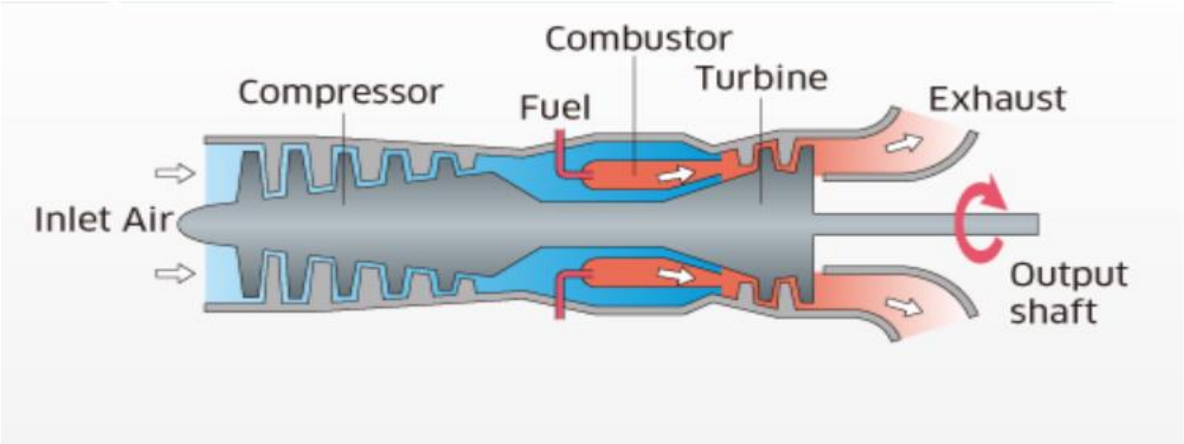

Figure 1 Diagram of simple gas turbine showing air input through the compressor section[1]

[1] https://global.kawasaki.com/en/energy/equipment/gas_turbines/outline.html

4. Impacts of air temperature and air pressure on power generation at Great Yarmouth

Air temperature and pressure have an impact on how much power is produced by a Combined Cycle Gas Turbine (CCGT) power station and the impact varies across the year as ambient conditions vary. There is a relationship between CCGT output and thermal efficiency with ambient temperature and ambient pressure needing to be taken into consideration. If the ambient temperature increases, air density decreases, and the output and efficiency will decrease. If the ambient temperature decreases, then air density increases, and the output and efficiency will increase. Falling ambient pressure means the air is less dense, so output and efficiency will also decrease. These changes are directly related to the mass of air that is drawn through the compressor and is used in the power turbine. The graphs in figure 2 below clearly show the impacts of weather on electrical output which is highest in the cooler months.

It should be noted that power generation does not continue to increase as ambient temperature falls below 1° C. At temperatures below this figure gas turbines operate with an anti-icing air system to prevent ice formation in the air inlet and therefore potential damage to the compressor. The anti-icing air raises the inlet air temperature, so the risk of ice formation is mitigated. The anti-icing air is bled from a higher-pressure stage of the compressor; therefore, the output and efficiency of the unit are reduced.

The times in the year at which Great Yarmouth can generate at 430MW (gross) are not extensive, it would be limited to the time when the ambient temperature is below 5^{0}C and there was a need for the station to operate at full load. (Based upon a review of historic data the ambient temperature in the Great Yarmouth area is less than 5^{0}C for 20% of the year). Figure 2 shows the maximum generation possible taking into consideration the effects of ambient air temperature alone.

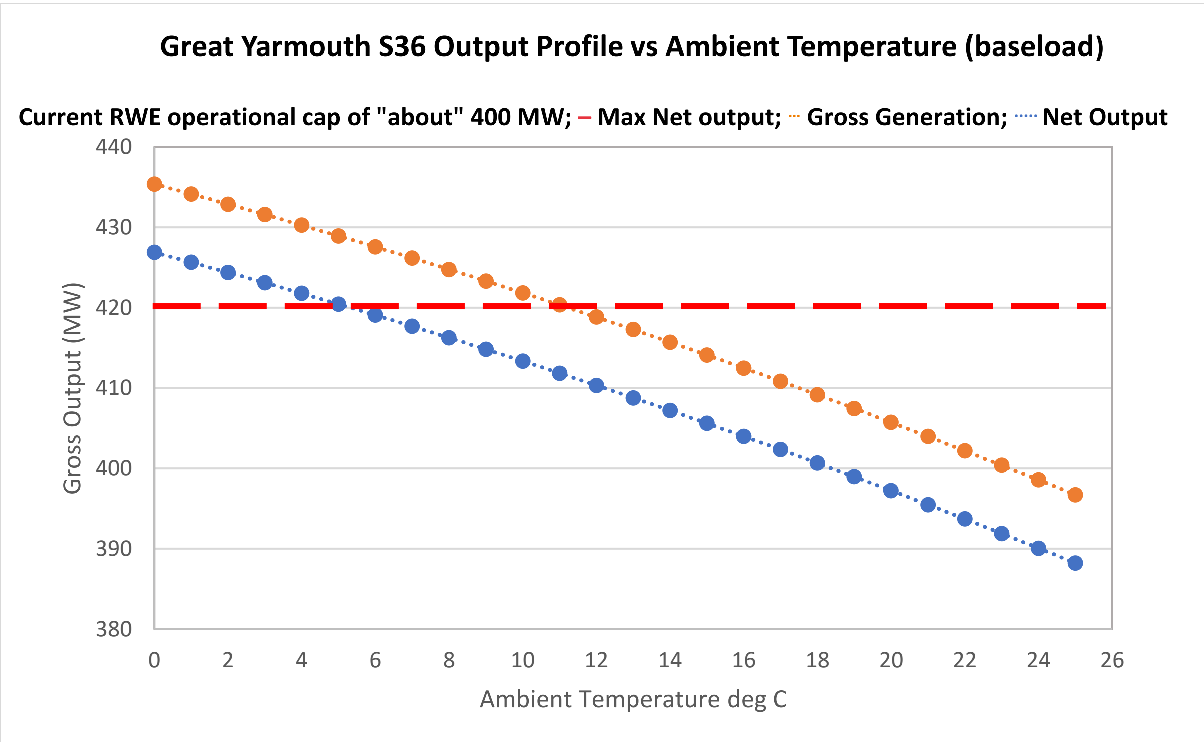

Figure 2 Great Yarmouth Output Profile vs Ambient Temperature (baseload)

Figure 3 below shows the relationship between air pressure alone and gross electrical output.

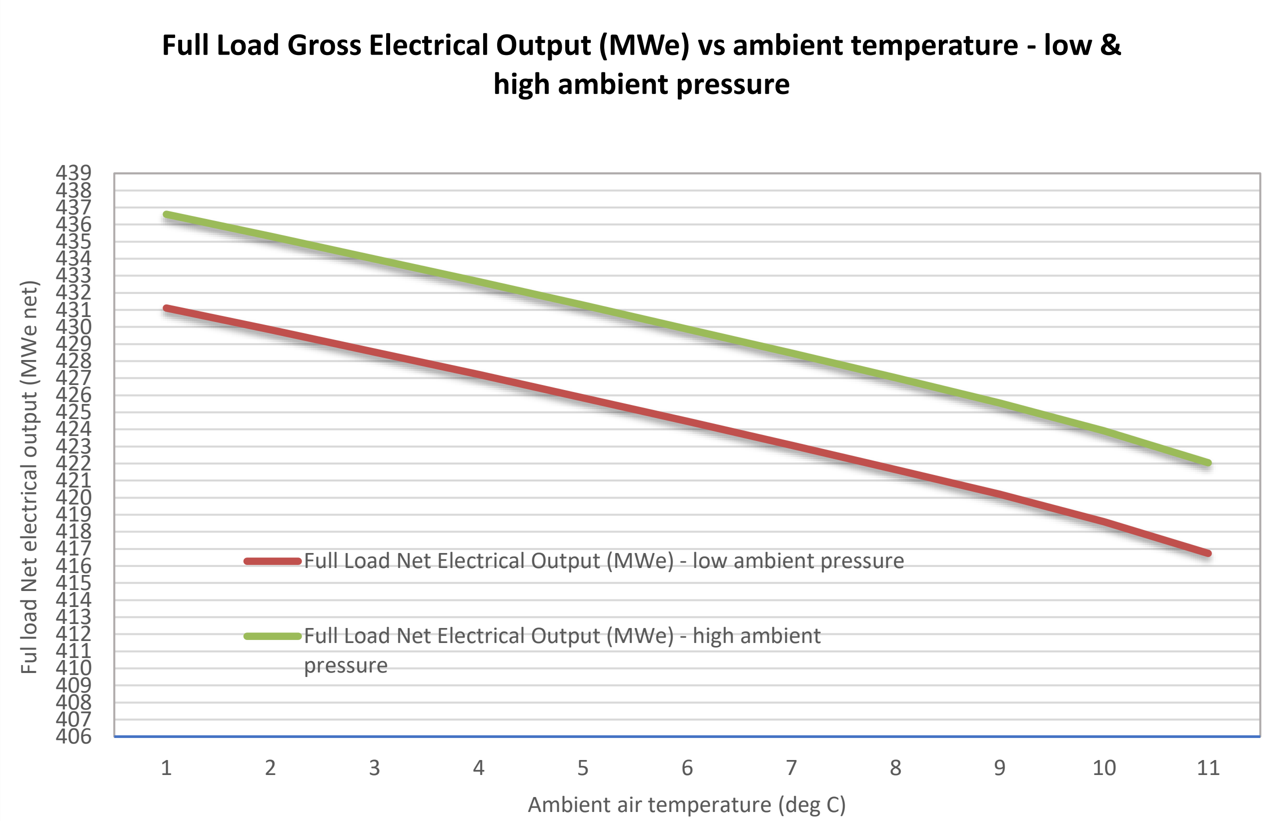

Figure 3 Full Load Gross Electrical Output (MWe) vs ambient temperature - low & high ambient pressure

It is not just the variation in ambient air temperature and pressure that impacts generation, Great Yarmouth draws cooling water direct from the River Yare. Changes in ambient temperature also effect the temperature of cooling water which in turn impacts efficiency. Figure 4 below shows the average variation in output across the year taking into consideration the effects of ambient air temperature and cooling water temperature.

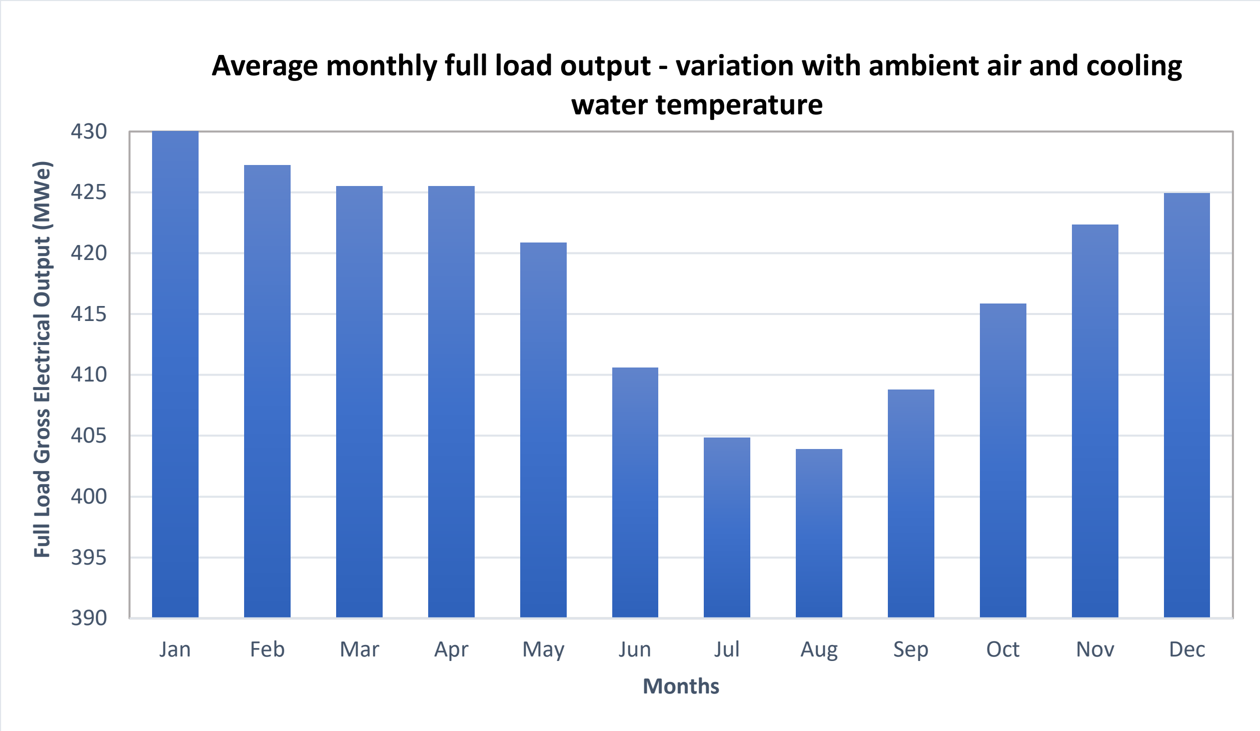

Figure 4 Average monthly full load output variation due to ambient air and cooling water temperature

1.1. Is there a change in efficiency due to ambient conditions?

Figure 5 below represents the change in thermal efficiency as the gross generation increases. This shows that there is a slight increase in thermal efficiency with the change in ambient temperature, which is due to the increased inlet air density, and higher air mass flow through the compressor.

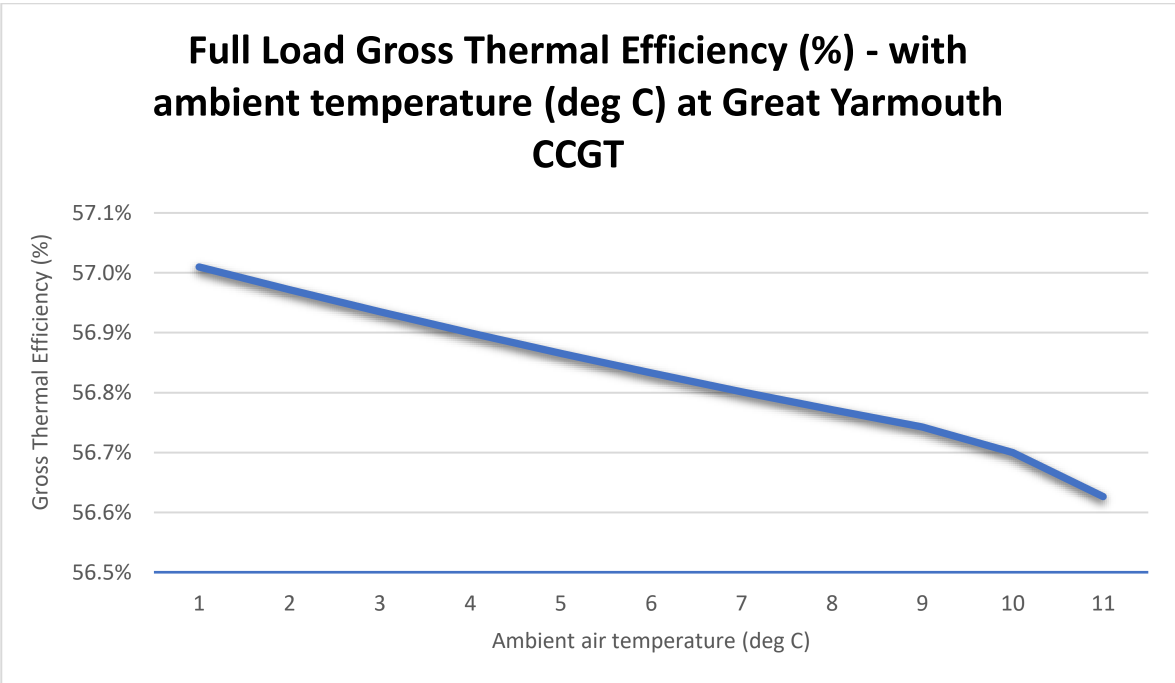

Figure 5 Full Load Gross Thermal Efficiency (%)

1.2. Is there a significant difference in fuel burn between gross output 420Mwe(gross) and 430Mwe (gross)?

Figure 6 below shows the difference in fuel consumption and the corresponding increase in generation. The increase in total fuel consumption between 420MW and 430MW is 44 MJ which is an increase of just over 1.6%, though the overall thermal efficiency is higher at the higher output.

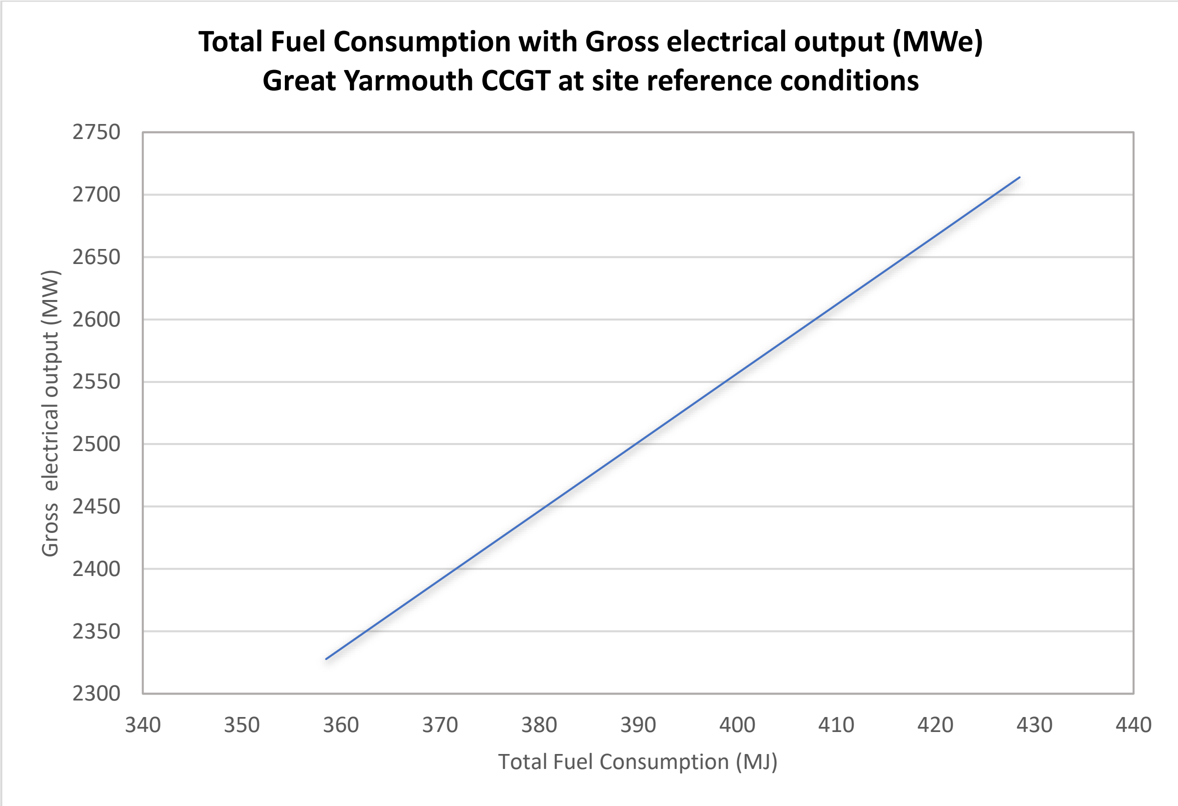

Figure 6 Fuel consumption

5. Environmental Impacts

RWE commissioned AECOM to carry out an air quality impact assessment of any change in emissions from the Great Yarmouth power station operating at 430MWe including variations in the ambient conditions as explained in the sections above. The full assessment can be found in Appendix 1 .

This assessment considers three scenarios, which are detailed below:

- Scenario 1 – Current baseline; operating all year per RWE's strict application of the term about, i.e., 420 MWe (gross);
- Scenario 2 – Worst Case; impacts if the power station were to operate at 430 MWe (gross) all year; and
- Scenario 3 – Realistic Case: The power station operates at 420 MWe (gross) for the majority of the year except when the ambient temperature is favourable, i.e. less than 5°C, at which time the Facility would operate at 430 MWe. (gross).

The conclusion of this assessment is there will be no significant impact arising from Great Yarmouth on both human health and ecological receptors when operating at 430MWe (gross) when compared to the current operation. Furthermore, given that Great Yarmouth would only operate at the increased output when ambient temperature is below 5 ° C or less, this results in no perceivable effects on local air quality in comparison with the current operation.

6. Conclusion

The combination of low air temperatures and high atmospheric pressure benefit the performance of the gas turbine such as those at Great Yarmouth. These benefits occur on cold, high atmospheric pressure day when the UK tends to see reduced output from wind generation due to the high pressure resulting in less wind. This is exactly the time when the UK needs all the power possible to meet demand and maintain security of supply as well as a safe operating energy margin.

The air quality impact assessment in Appendix 1 has shown that there are no significant impacts on human health or ecological receptors in terms of air quality because of operating the station to its full capability and on different ambient conditions. The times in the year at which Great Yarmouth can generate at 430MWe (gross) are not extensive, it would be likely to be limited to the time when the ambient temperature is below 5^{0}C and there was a need for the station to operate at full load (based upon a review of historic data, the ambient temperature in the Great Yarmouth area is less than 5^{0}C for about 20% of the year).

Confirmation that the impacts of ambient temperature and pressure are included within the interpretation of the current Section 36 consent would reflect the actual capability of the power station at certain ambient conditions. Considering that, RWE asks for confirmation that variations on ambient temperature and other factors as explained in this report are inherent to the scope of the Great Yarmouth Section 36 consent. Consequently, allowing a maximum generation of 430MWe (gross).