CC-1: Additional information supporting the response to ExQ1.2.1

This document provides additional information referenced in the response to ExQ1.2.1. It has been prepared by Statera Energy, the parent company of the applicant Thurrock Power Ltd.

Hydrogen Combustion in Reciprocating Engines

Statera Energy has constructed three 50MW peaking plants; one at Creyke Beck in Yorkshire and two at Saltholme in Middlesborough and is proposing to construct a number of additional plants in 2022 and 2023. The reciprocating engines used in the existing plants are fuelled by natural gas, however with the transition to net zero it is Statera's intent that future engines are able to be fuelled by an increasing percentage of hydrogen to reduce the carbon emissions of the engines. These smaller facilities are not required to be carbon capture ready (CCR), whereas the Thurrock Plant is CCR. Notwithstanding this, it is possible that Thurrock FGP will be considered for hydrogen utilisation alongside or as a replacement for natural gas. Hydrogen combustion has no carbon dioxide emissions, the product of combustion being water (vapour).

The purpose of this note is to identify the changes to the plant and equipment needed to firstly allow the plant to operate on a blend of 20% hydrogen and 80% natural gas (by volume), and secondly to allow the plant to operate on 100% hydrogen.

There are several engineering challenges, which are first discussed, then the likely approach to adaptation of Statera Energy's plant to meet those challenges. The note concludes that combustion of a 20% hydrogen blend would be straightforward, with minimal modifications to the gas engine technology used by Statera Energy. Combustion of 100% hydrogen is considered to be feasible, subject to availability and cost of hydrogen, but would require greater modifications to the engines and the balance of plant.

Challenges

There are a number of challenges relating to the differing chemical, physical and availability properties of hydrogen that require changes to a combustion plant. These are:

Variable supply (20% H_2)

The likely variability in the supplied ratios of hydrogen to natural gas. Until a delivery mechanism is in place that allows a predictable ratio of gases, as is the case with the natural gas currently supplied via the NTS, it is likely that an engine will have to be able to operate on a 20% blend of hydrogen or 100% natural gas, or potentially other composition blends in between. This will require the combustion process to be adapted to accommodate a potential range in the blends of gas that may be delivered.

Speed of combustion (20% H_2 and 100% H_2)

Hydrogen burns at a faster combustion rate than natural gas. As such, changes are required to injection timing and cylinder design to accommodate this.

Hydrogen diffusion (20% H_2 and 100% H_2)

Due to the small molecular size of hydrogen it can diffuse through many materials. This impacts the selection of materials for pipework, valves, gaskets and seals amongst others.

Hydrogen embrittlement (100% H_2)

Hydrogen embrittlement occurs when metals become brittle as a result of the introduction and diffusion of hydrogen into the material leading to cracks and in the worst cases, leakage. The severity of hydrogen embrittlement is a function of temperature: most metals are relatively immune to hydrogen embrittlement, above approximately 150°C. The pipework usually deployed in the transport of natural gas, as well as the materials used in valves and other fittings are likely to be at risk of hydrogen embrittlement above a certain percentage by volume of hydrogen if introduced to the mixture. Because embrittlement occurs at lower temperatures and higher volumes of hydrogen, this is likely to become an issue as the hydrogen blend moves closer to 100%. However, this will be more of an issue for the hydrogen supply equipment rather than the engine itself, as temperatures in the engine are likely to be higher than 150 degrees C at the interface between hydrogen and metal.

Modifications Required

Presented with these challenges, there will need to be a number of changes to both the engine and the balance of plant. These are summarised below:

Engine Modifications

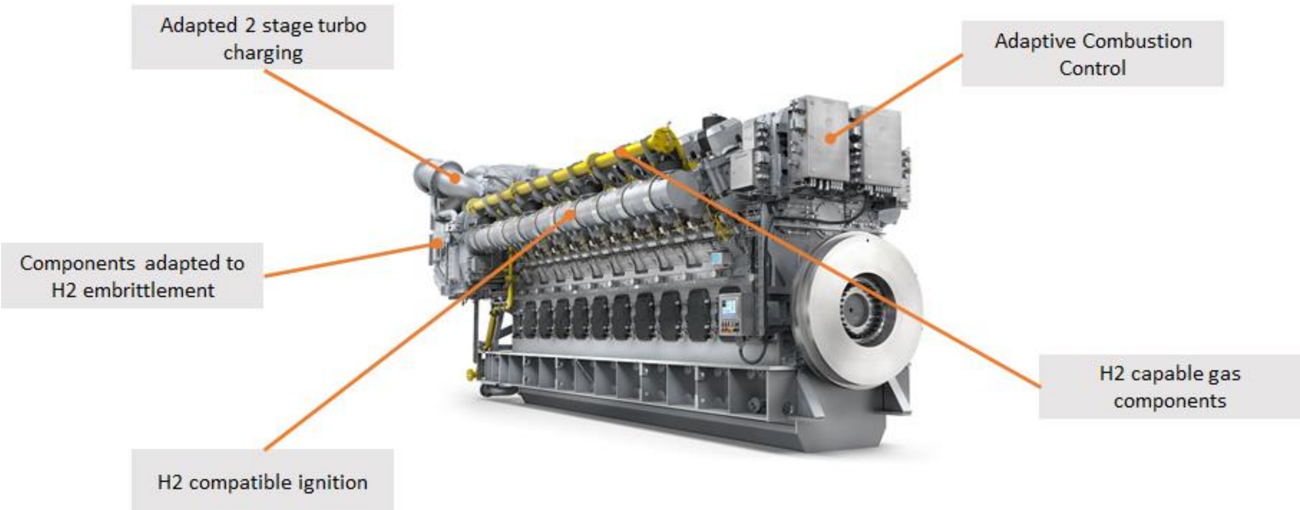
The table below summarises the changes to the engine needed to run on both a 20% blend of hydrogen and 100% hydrogen. It can be seen that the 20% blend is achievable today, whereas 100% hydrogen would require modification to the engines with technologies that are under development.

Item	**20% Hydrogen**	**100% Hydrogen**
Adaptive combustion control	Available	Available
Adapted two stage turbo charging	Available	Available
Components adapted to H_2 embrittlement	Not required	Under development
H_2 compatible ignition	Available	Under development
H_2 capable gas components	Not required	Under development

Adaptive combustion control is required to accommodate the varying combustion characteristics of blends of hydrogen between 0% and 20%. Similarly, the turbo charging of the engine needs to be adapted to accommodate differing exhaust gas characteristics.

For the 100% hydrogen case materials need to be adapted to deal with hydrogen embrittlement, and injectors and other items need to be upgraded to materials that do not suffer from hydrogen diffusion.

Finally, at 20% hydrogen, combustion can be managed using the current injection and ignition systems deployed on the engines, but at 100% hydrogen this is not possible due to the faster combustion reaction rate, so the injection system and potentially the engine cylinder liners will need to be replaced and upgraded to be better tuned for 100% hydrogen operation. An image illustrating these changes can be seen below:



STATERA ENERGY

Balance of Plant Modifications

To accommodate 20% and 100% hydrogen blends, a number of changes will be required to the balance of plant around the engine. This includes the items listed in the table below:

Item	**20% Hydrogen**	**100% Hydrogen**
Piping	No change	Materials selected to account for H_2 embrittlement and increased in size due to lower energy density of hydrogen
ATEX rating of equipment	Review of equipment to be carried out	Will most likely require upgrading to a higher zone
Gas alarm system	Upgraded to detect H_2 as well as CH_4	H_2 detection required in place of CH_4
Firefighting system	Flame detectors may be required to be upgraded to account for clear H_2 flame	Flame detectors will need to be upgraded to account for clear H_2 flame
Ventilation	Upgraded to account for higher air throughput that may be required for H_2 safety concept	Upgraded to account for higher air throughput that may be required for H_2 safety concept
Gas metering	May need to be updated if H_2 is fed from the NTS pipeline	Will need to be updated to account for H_2

Conclusion

Noting the engineering challenges which have been identified, combustion of a 20% hydrogen blend would be relatively straightforward, with minimal modifications to the gas engine technology. Combustion of 100% hydrogen is considered to be technically feasible, subject to availability and cost of hydrogen, but would require greater modifications to the engines and the balance of plant. The introduction of hydrogen would have a consequent impact on the need to utilise carbon capture plant.