B.02.02.05 AN OUTLINE OF THE MAIN ALTERNATIVES CONSIDERED TO THE PROPOSED TECHNOLOGY, TECHNIQUES AND MEASURES

FSU AND REGASIFICATION COMPOUND ALTERNATIVES

Alternative	Comment
Integrated floating storage and regasification unit (FSRU) as an alternative to the FSU	This alternative considers an FSRU where the regasification process would take place on-board of the storage vessel and natural gas would then be transferred to shore. An FSRU could have been supplied either by conversion from existing an LNG carrier, or as is more common by a purpose built vessel for this specific application. Availability of vessel, availability of land, cost and lead-time for completion are factors which influenced the decision between the use of an FSU rather than an FSRU. A principal benefit of the FSRU alternative is that the on-shore plot plan area could be significantly reduced as the majority of the regasification plant is on the vessel. In this instance, extended lead-time for an FSRU acquisition / LNG carrier conversion and the complexity of the ancillary equipment including Boil-Off Gas Compression, Propane Heat Exchange System, Demin. Water / Glycol Heat Exchange System recommended the land based regasification technology in conjunction with the more readily available FSU facility the preferable option.
Conventional LNG Terminal with onshore LNG tanks as alternative to FSU	This solution would store the LNG onshore rather than in a floating unit. The LNG carrier would berth at the jetty and unload its LNG directly to onshore LNG tanks. A much bigger onshore area would have been required for this solution and the time schedule for construction considerably longer. In addition the preliminary QRA rated the use floating storage (FSRU or FSU) the preferable option based on the various safety scenarios
Flexible hose technology as an alternative to a hard arm for BOG transfer.	Flexible hoses will be used for the transfer of BOG from ship to shore and for both LNG and BOG from ship to ship rather than hard arms. Flexible hoses are made of composite durable and flexible material suitable for operation in a marine environment. They are easy to handle and disconnect and they have good flexibility to cater for the relative movement of the LNGC, FSU and jetty. Flexible hoses are more space efficient than the alternative of hard arms and are widely tried and tested in these applications.
Hard arm technology as an alternative to a flexible hose technology LNG ship to shore transfer.	Flexible hoses were also considered for use to transfer LNG to shore. Flexible hoses are made of composite durable and flexible material suitable for operation in a marine environment, and are used in some terminals for ship to shore transfer of LNG between LNG carriers and onshore storage tank. The use of an LNG unloading hose rather than a hard arm would reduce the loads and space requirements on the jetty. However the use of flexible hoses for permanent discharge of LNG at cryogenic temperatures has not been widely tried and tested and thus the more convention hard arm unloading method will be used in this case.

Alternative	Comment
BOG gas re-liquefaction plant as alternative to BOG Compression Package	A BOG re-liquefaction plant would be an alternative to the BOG Compression Package. The BOG would be re-liquefied and stored again in the LNG tanks. This approach would require increased capacity within the Regasification Package, as well as larger plot plan area. Furthermore, as the natural gas demand is expected to be constant and stable throughout the year, thus always providing a demand for NG/BOG as fuel to the power plants, there is no technical justification for "re-liquefaction" of BOG which would then need to be "re-gasified" for use in the power plants.
Vaporizer technology	There are various vaporizer technology alternatives to the proposed one which employs an intermediate fluid vaporizer (IFV). Traditionally Open Rack Vaporizers (ORV) and Submerged Combustion Vaporizers (SCV) have been widely used in big LNG terminals. Ambient Air Vaporizers (AAV) technology is also used for small terminals too. A brief description of these technologies is presented below: • ORV: The LNG vaporization process is carried out via heat exchangers which uses seawater as heat sink. The tubes of the heat exchangers are arranged in panels and are hung from a rack which connects with the inlet and outlet manifolds. Depending on the climate conditions, some ORV could require supplementary heating supply sometimes based on SCV technology especially during winter time. ORVs would require a higher flow rate of seawater comparing to the proposed IFV which would result in higher environmental impact. • SCV: This vaporizer technology makes use of the flue gas as a source of heat. LNG is directed to a coil type heat exchanger submerged in a water bath which is used as heat sink. BOG or other alternative gas is burnt in submerged gas burners and the combustion products are sparged into the water-bath keeping the water warm. This technology would have higher environmental impact than the proposed IFVs as natural gas is burnt to keep the water-bath warm without producing any electrical power, resulting in lower efficiency and higher emissions especially NOx. • AAV: This technology typically consists of air cooled, long, vertical tube heat exchangers which uses air as heat sink. This Air is mechanically entrained routed down-ward the vertical heat exchanger. The tubes are designed for icing and periods of defrosting are required periodically which requires stand-by capacity. For is sometimes created around the vertical heat exchangers as a result of moisture condensation. The environmental impact associated with this technology is small as no seawater is required. However considerably larger plot plan areas are required and some visual impact will be produced by the fog plumes. A higher capital expenditure is expected for this technology.

CCGT COMPOUND ALTERNATIVES

Alternative	Comment
Reciprocating Gas engine as alternative to CCGT	Reciprocating gas engines are the natural alternative to gas turbines. A different thermodynamic cycle is developed within the engines reaching similar or higher electrical efficiencies than gas turbines operating in open cycle. Reciprocating engines can also operate in combined cycle; however yielding lower net efficiencies than CCGTs as the gas turbines are optimized for combined cycle operation. Higher capital expenditure cost per power generated (€/kwh) is expected for reciprocating engine combine cycle plant at this power rate level.
HRSG with supplementary firing	This is an alternative to the proposed HRSG which doesn't include any supplementary firing. The operation principle of an HRSG with supplementary firing is the same as the non-fired one. The fired HRSG is equipped with a duct burner which is generally fed with a gaseous fuel and increases the temperature and mass flow rate of the flue gases directed from the GTs. Supplementary firing impacts electrical efficiency as the gas used in the gas burners would be more effectively used in the GTs. This Alternative would also cause an increase in emission levels. Applications: Supplementary firing is most often applied in combined-cycle cogeneration plants where the amounts of process steam must be varied independently of the electric power generated. It is also used as a way of enhancing power production during peak electrical demands.
Horizontal HRSG rather than vertical configuration.	Both configurations achieve similar performance and in many cases the preference for one or the other is more a regional preference. In a horizontal HRSG, the heat transfer tubes are vertical suspended from tube supports located throughout the gas path. A benefit of the vertical HRSG arrangement over the horizontal one is that plot plan areas are considerably reduced, which in the case of this compact site was the main reason the vertical configuration was chosen over the horizontal option.
HRSG with three pressure level	An additional low pressure steam evaporator would further increase the energy recovered from the flue gases and would make the power plant more efficient. However this would also add complexity to the system requiring an additional evaporator, drum, auxiliary equipment and instrumentation. Analysis by thermodynamic modelling indicates limited further heat recovery available even if using an additional pressure level, thus in this instance a HRSG with two levels of pressures is the most appropriate solution.
Alternative Condenser cooling water systems	The CCGT condenser and other auxiliaries cooling demands are to be met using once through water cooling using seawater as the heat transfer fluid as detailed in section B020201. Two main alternative cooling systems configurations are widely used in power plants and could have been considered for this plant, these are:

	• Dry air cooling system: This system includes air cooled condensers for main condenser cooling demand and fin-fan coolers for auxiliary cooling. No cooling water is required minimizing environmental impact; however the power output and efficiency of the power plant will decrease due to higher vacuum levels. A considerably larger plan plot area and will be required. The capital expenditure as well as O&M costs will sharply increase with the dry cooling system. • Evaporative cooling: This cooling concept is used in wet or hybrid cooling tower. The water requirement is about 40 to 60 times lower than the amount of water required by once-through cooling system. In some areas, visible plumes can be generated in cooling towers arising visual impact concerns. Plumes can be abated with more sophisticated hybrid cooling towers. A larger plan plot area will be required for cooling tower systems in any case. CAPEX and well as O&M costs are typically higher for this Alternative. However due to the fact that the existing Delimara plant utilises once-through seawater cooling and thus much of the supporting infrastructure for this system already exists and will continue to be operated and maintained plus the space limitations on the site the only really viable solution is the once through sea water option.