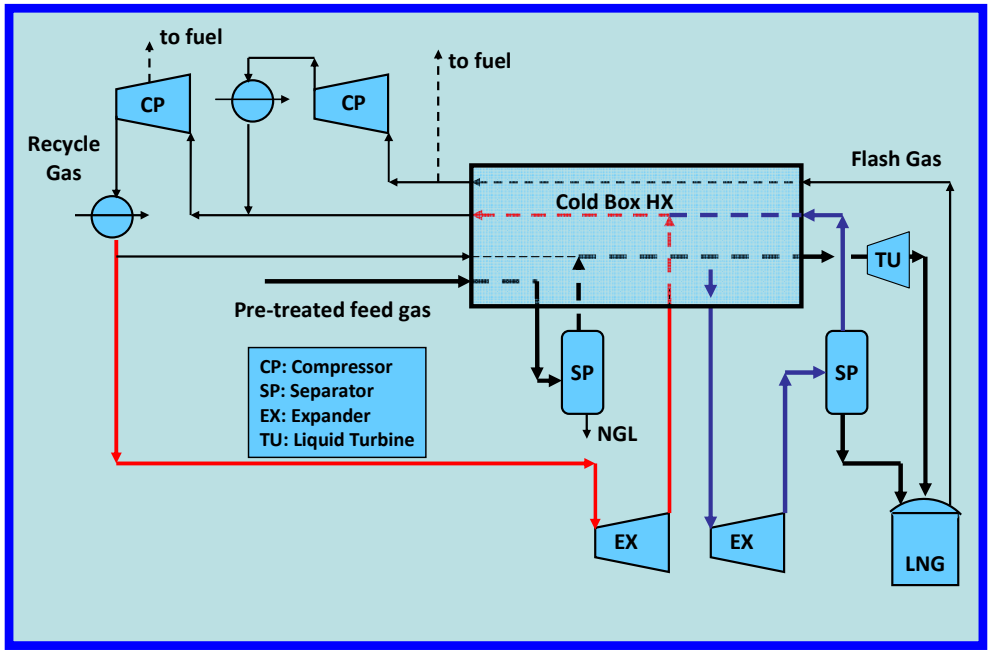
ZR-LNG™ Natural Gas Liquefaction Process for FLNG

The patented ZR-LNG™ process operates on the full spectrum of feed gases including lean feeds with insufficient C2+ for production of a hydrocarbon refrigerant. Single train capacities up to 2 million tonnes/y are feasible. The flowsheet has two expanders operating on the feed gas, requiring no external refrigerants such as propane, mixed hydrocarbons or nitrogen. Liquefaction power consumption is significantly better than dual nitrogen expander or SMR processes; typically 280-320 kWh/tonne of LNG; only marginally inferior to base load plants. ZR-LNG™ achieves its high efficiency without the complexity and cost of feed gas pre-cooling. The lower power consumption allows higher LNG production from the selected compressor driver; significantly enhancing project returns relative to competing mid-scale technologies. These returns may be further enhanced by utilising deck space required by competing processes for the production, storage and transfer of external refrigerants.



The schematic shows one variant of ZR-LNG™. Refrigeration occurs in 2 methane expander circuits indicated in red/blue. Approximately 35% of the compression power is recovered through these expanders. Further power reduction is provided by a cryogenic turbine on the LNG product run down.

Data relevant to ZR-LNG™ is provided in the tabulations below. Estimated 2013 capex for 1 million tonne/y using prefabricated liquefaction modules for FLNG application on an EPIC basis is $150 million. A 2 million tonne/y plant is estimated at $260 million. Excludes gas pre-treatment, NGL fractionation, flare, LNG/NGL storage and utilities.

PARAMETER	BASIS OF DESIGN		PARAMETER	OPERATING DATA 1 MM MTPA
Molar Gas Composition	CH_4 95%; C_2H_6 4%; C_3H_8 1%		Online factor	345 days per year
Gas Pressure at Liquefaction Inlet	60 bar g		Capacity/Flow rate	1 million tonne/y/121 tph
Sea Water Temperature	13 deg C		Recycle compressor power demand	54.7 MWe
Approach temp Sea Water/Circ Water	3 deg C		Flash gas compressor power demand	3.4 MWe
Process Streams cooled to	20 deg C		Total power	58.1 MWe
Minimum cryogenic approach temp	3 deg C		Expander power recovered	21.4 MWe
Recycle compressor polytropic efficiency	85%		Net power	36.7 MWe
Expander adiabatic efficiency	87%		kWh/tonne of product	304

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4 x Nominal 1 million tonnes/y FLNG	ZR-LNG™	SMR	Dual Nitrogen
Field Development $ millions	1500	1500	1500
Hull + Topsides $ millions	2400	2400	2400
Base Capex $ millions	3900	3900	3900
Nominal kWh/tonne	304	350	400
Tonnes/y from 4 x LM6000 at 37MW	4,032,000	3,452,000	3,060,000
Field Life - Years	10.8	12.7	14.3

FLNG facilities are typically space and weight constrained. The ZR-LNG™ process encapsulates simplicity. A nominal 1 million tonne/y train comprises only 2 compressor packages and 8 major equipment items. All flows in the heat exchange equipment are single phase making the process resilient to ship's motion. The specific power consumption of 304kWh/tonne without feed gas pre-cooling compares with 350 and 400 kWh/tonne for the SMR and dual nitrogen expander designs respectively. Installed compression power is the intrinsically limiting production capacity constraint for an FLNG scheme. For an LM6000 gas turbine driver the liquefaction capacities of ZR-LNG™ and the SMR and nitrogen systems are shown in the inset table, together with the estimated capital cost. The assessed on-line availability is 345 days/y. The expander processes are anticipated to have a higher on-line factor because of their relative lack of complexity and faster start-up time than SMR units (6 hours vs 24 hours); though this factor has been ignored in respect of the financial calculations below. The data relates to the Basis of Design data on page 1 and assumes development of a 2 TCF field using a single gas processing train and 4 liquefaction trains to match the maximum output of LM6000s rated at prevailing ambient conditions. The calculations assume exhaustion of the gas reserve on a constant output basis and assume the financial parameters indicated. The inset chart shows the cumulative NPVs of the candidate technologies clearly demonstrating that ZR-LNG™ secures superior returns in a shorter time period. This facilitates redeployment of the plant to another stranded field at an earlier date, further increasing the relative benefit of deploying ZR-LNG™.

- overall capex inc field development $3.9bn
- a debt:equity ratio 70:30
- loan interest rate 8%
- discount rate 15%
- loan repayment period 7 years
- depreciation rate 5%
- tax rate 30%
- gas sales price of $10/million BTU (EU basis)
- shipping cost to market $2/million BTU
- interest during construction capitalised
- O&M costs $1/million BTU