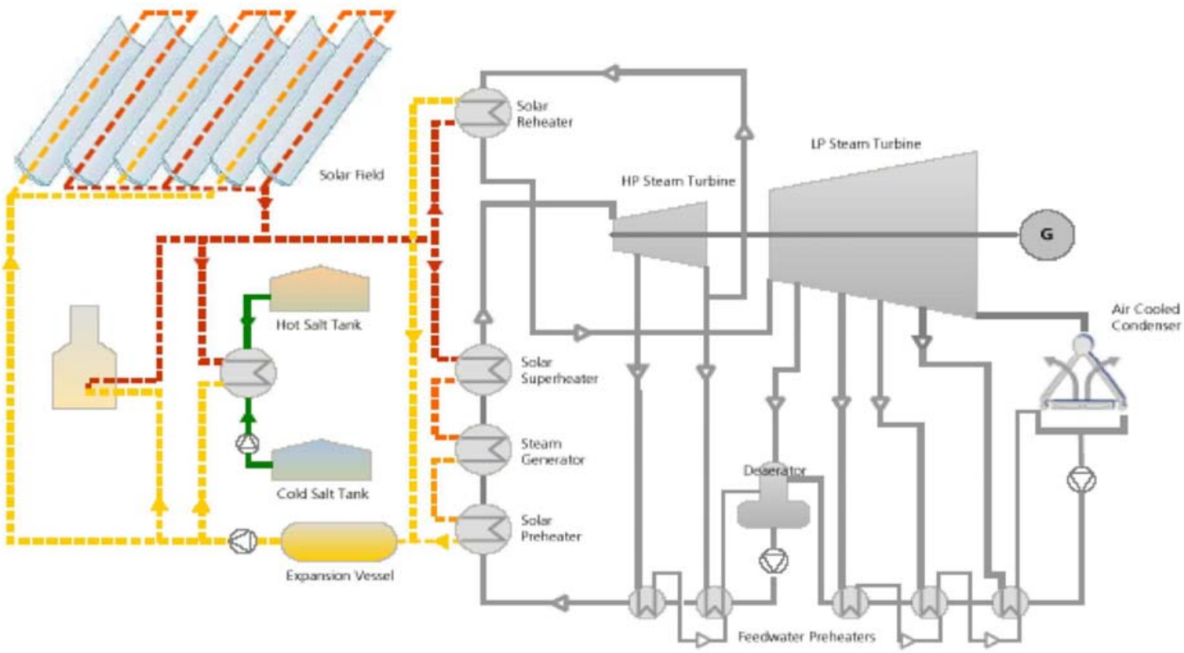
TECHNICAL RISKS AND MITIGATION MEASURES IN DESIGN, CONSTRUCTION, AND OPERATION

A. System configuration

1. The system configuration is composed of 50 megawatt steam turbine capacity with 7 hours molten salt thermal storage having 995 megawatt hour thermal capacity and dry cooling system. It has 621,300 m_2 of solar collector field area with 190 loops. With the system configuration, the project will annually generate more than 197 gigawatt hour non-fluctuating and clean electricity. It is the best configuration design to maximize electricity yield from the solar field and the associated thermal storage system. The system configuration includes natural gas auxiliary heater to prevent heat transfer fluid and thermal energy storage media from freezing during cold winter time. The maximum amount of gas used is limited within 15% of thermal energy production in the solar field.

Figure 1: The Project System Configuration



B. Technical risks factor, potential impact, and mitigation measures

2. Anticipated technical risks are associated with engineering design, site specific condition (such as soil, site slope, wind speed and rose, cold climate, and access to infrastructure), construction and installation, and operation and maintenance (O&M). These technical risk factors, potential impacts on plant performance and safety, and mitigation measures were rigorously assessed and intensively discussed with the executing and implementing agency. All technical risk factor, potential impact, and mitigation measures are detailed in Table 1. All technical risks are manageable, and the owner's engineer and the O&M contractors who support the implementing agency shall ensure implementation of mitigation measures.

Table1: Technical risks factor, potential impact, and mitigation measures

	Risk Factor	Potential Impact	Mitigation Measure
1	Engineering design	Unbalanced definitions over solar field, thermal storage, and power block affects balance of power and the plant performance.	The internationally experienced owner's engineer who carries out design review, procurement support, construction supervision, and test run support shall control design and construction quality, as required in loan covenants.
2	Soil condition	Permanent frozen soil layer (few meters depth from the surface layer) affects the stability of structures.	Geo-technical study in FSR assessed underground soil condition. Foundation should be designed below frozen soil layer. Volume of grounding works is foreseeable and its cost is already incorporated cost estimate.
3	Site slope	Terrain slope or surface alterations create complex foundation and difficult top leveling where solar structures will be anchored. Poorly levelized structures are the cause of steel structure fatigue and uneven heat oil flow rate, which will result in the poor performance of the plant.	The terrain in the project site despite a slight slope from north to south axis is nearly flat (around 3%) having no hills and dried streams inside. Land development work for terracing the area to secure collector installation with less than 1% slope is required.
4	Wind speed and rose	High wind speed damages solar collector element (steel structure, HCE, and mirrors) and affects sun tracking.	Annual wind speed average is 2.2m/s, and maximum hourly wind speed in TMY is 15.1m /s, which is within 15.6 m/s of wind resistance design capacity of typical solar collector element.
		Wind speed rose may create mechanical loads on the collectors directly placed on the wind arrival direction.	Result of wind rose analysis must be reflected in the collector steel and foundation analysis and design. Additional security factors should be incorporated within the first three loops facing wind rose (East and East-North-East) at the site needs to have 30% higher resistance capacity of 15.1 m/s.

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5	Access to infrastructure	Poor transportation access affects material and equipment delivery to the site as scheduled. No access to water and natural gas results in the stranded plant.	The site is the alongside national road No. 315 and have easy access to Delinha railway station nearby. Water and natural gas access points are already in place. Waste water will be treated at on-site treatment facility. The plant will have two back-up water ponds to allow plant operation for 5-6 days in case of municipal water supply failure.
6	Grid connection	Weak or poorly planned evacuation grid due to long distance and limited capacity will restrict plant operation capacity if grid line fails during plant operation hours.	The project plans to be connected directly to a 110 kV substation that is 8.5 km away in the west of the site, which avoids potential grid blockage or failures.
7	Cold climate	The site locates in cold climate condition where mid-winter minimum temperature during night time would be minus 27° C which are far below 50° C of the designed safety temperature of HTF. Any cold spots due to HTF freezing cause serious damage on closed loop piping system in solar collector field. The cold climate also affects molten salt a heat storage media which is frozen below 221°C. Molten salt freezing cause serious damage on thermal storage tanks.	The freezing protection measures should include: (i) mineral wool insulation and cold-bridge stoppers along all the HTF circuit; (ii) a gas-boiler supplement system to deliver warm up energy for the complete HTF circuit; (iii) an appropriate recirculation control and pump system to force HTF circulation in pipes all the time. The thermal storage tanks will be fully insulated with mineral wool and electric trace heating. Bottom of thermal storage tanks needs to be specifically insulated with glass fibers. Oil-to-salt heat exchanger is connected to natural gas auxiliary heater.
8	Sand	The site is in a semi-arid area. Grains of sand could affect function of motors which drive loops. Sand grains get into ball joints	All motors exposed to the external environment shall be strapped with sand protection cover. Ball joint is also strapped with gasket for sand protection.

	Risk Factor	Potential Impact	Mitigation Measure
		which connect loops and affects heat transfer fluid quality.	
9	HTF leakage	HTF leakage in solar field or in HTF expansion, pump, and ullage area could cause fire. HTF spilled over the ground could also contaminate soils. Reported HTF leakage accident is only 1% of the CSP power plants in operation. Lesson learned of HTF leakage in CSP plant in operation has happened at ball joints part connecting the loops during the first 1 to 4 months at test run stage.	HTF system will be equipped with concrete surfaced trench to avoid soil contamination. Ball joints part should be rigorously supervised by the owner's engineer and monitored during installation and O&M stage. A fire protection circuit with automatic water sprinklers will be installed along the HTF main system area (expansion, ullage, pumping, heat exchangers). In case of fire accident, fire suppression system (sprinkler or deluge) and fire suppression vehicle protect the solar field and HTF system. Almost all cases, leaked HTF becomes vapor instantly and some spills over the ground. Spilled HTF shall be immediately removed to bio waste treatment pool inside the plant area. Automatically controlled shut off valves at loop entrance and exits should be in place to ensure that loop is immediately isolated from the field in case of oil pressure drop which suggests some leakage.
10	SCE alignment	The poor alignment of SCE will cause less accurate sun beam interception: DNI is not precisely reflected by the mirror to focus on HCE, which will result in solar thermal energy production loss.	The owner's engineer supervises and checks the alignments of SCE during the installation stage. It shall also be monitored during O&M stage.
11	HCE heat loss, mirror reflectance, and	Vacuum lost due to a crack of annulus or glass of HCE	Preventive maintenance to maintain adequate HCE vacuum

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mirror breakage	leads to heat loss, and results in thermal energy production loss.	and timely replacement of damaged HCE should be implemented as part of the O&M plan to be developed by the O&M contractor.
	A decline of mirror reflectance due to less effective mirror washing practice impacts on heat production in HCE directly.	Mirror cleaning procedure should be in place to avoid reflectivity to drop by more than 3 %.
	Mirror breakage will cause further damage on HCE glass breakage, and other mirror's breakage, which has an impact on the O&M costs and thermal energy production	The Owner's Engineer and the O&M contractor will develop a consistent spare parts list and a replacement strategy.

CSP = concentrated solar thermal power, DNI = direct normal irradiation, m/s = meter per second, km = kilometer, kV = kilovolt, HCE = Heat Collector Element, FSR = Feasibility Study Report, HTF = Heat Transfer Fluid, O&M = Operation and Maintenance, SCE = Solar Collector Element, TMY = Typical Meteorological Yield