Integrated Solar Combined Cycle Power Plants

in

Egypt and Morocco

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Concept of an ISCC

In a conventional combined cycle power plant the hot exhaust gases of the gas turbine(s) are used in the heat recovery steam generator (HRSG) to produce steam which can be used in the steam turbine. In an ISCC (integrated solar combined cycle power plant) additional steam is used by a parabolic trough solar field. Thus during day time the electricity production is increased.

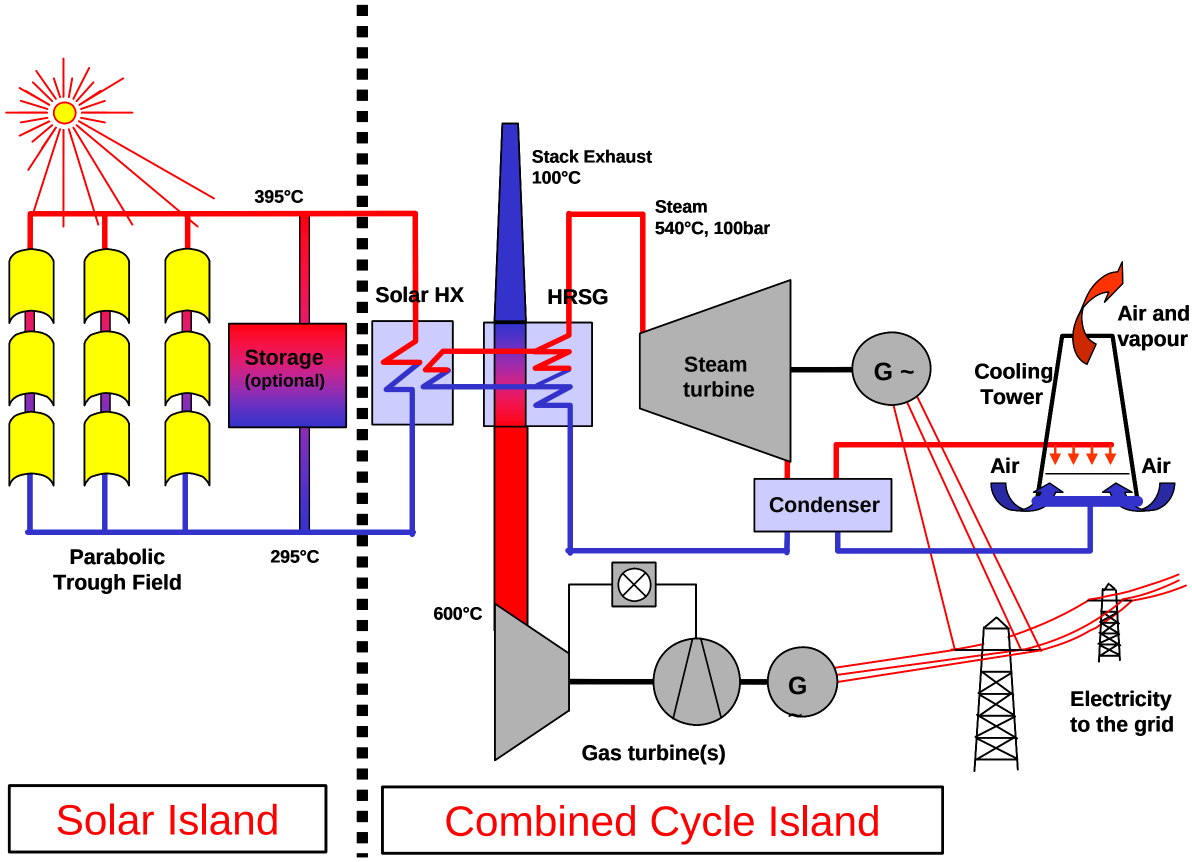


Figure 1 General Concept of an ISCC

Generally in an ISCC, the steam turbine is sized larger than in a corresponding standard combined cycle power plant (with the same gas turbine). Therefore, whenever an ISCC operates in night mode (i.e. without solar heat input) the steam turbine will operate at part load and consequently at a lower efficiency, this is denominated as “Solar Loss”.

The term "**Exergetic Solar Generation**" has been defined to identify the generation of electricity in an ISCC which is a net addition to that in a reference combined cycle power plant at the same location, with identical gas turbine(s) and using the same amount of fossil fuel as the ISCC. Thus the "Exergetic Solar Generation" takes account of the consequences of all modifications (positive = solar gain, as well as negative = solar loss) which are made when converting a combined cycle power plant to ISCC.

The determination of “Exergetic Solar Generation” is to be adapted as required in case of a power grid where combined cycle power plants are generally operated in a load follow mode (e.g. with duct firing).

Status of the Projects in Egypt and in Morocco

Both projects are ISCC plants, sponsored by a GEF grant of about 50 M$. The size of the grant has been calculated in order to cover the net present value of the incremental generation cost of the ISCC against that of a standard combined cycle power plant.

Fichtner Solar has prepared the Conceptual Design and the Bid Documents including Technical Specifications for both projects.

For Morocco (Project Ain Beni Mathar) the bidding is for an EPC contract of the turnkey ISCC.

For Egypt (Project Kuraymat) the bidding is for an EPC contract of the Combined Cycle Island and an EPC cum O&M Contract of the Solar Island.

Both projects are currently in the bidding phase.

For Morocco the technical and financial Bids from competing EPC-Contractors have been received and are under evaluation.

For Egypt the technical Bids for the Solar Island are evaluated and the Bidders have been requested to submit financial bids by the End of January 2007. The technical and financial bids in two different envelopes have been received for the Combined Cycle Island. The technical evaluation is in progress and the financial envelopes remains sealed until completion of the technical evaluation.

The selection criterion for the best ranked bids is the electricity generation cost which will be adjusted for solar merit. After completion of the evaluation, the negotiations will take place with the best ranked bidder.

Order placement for both projects is expected to take place immediately after the “Non-Objection” of the selected Bidder and of the negotiated contract will be received by World Bank.

Site Location

The Kuraymat site (Figure 2 and Figure 3) is located at the northern latitude of 29° 16’ and the eastern longitude of 31° 15’. It is some 95 km south of Cairo and about 2.5 km from the eastern shore of the Nile.

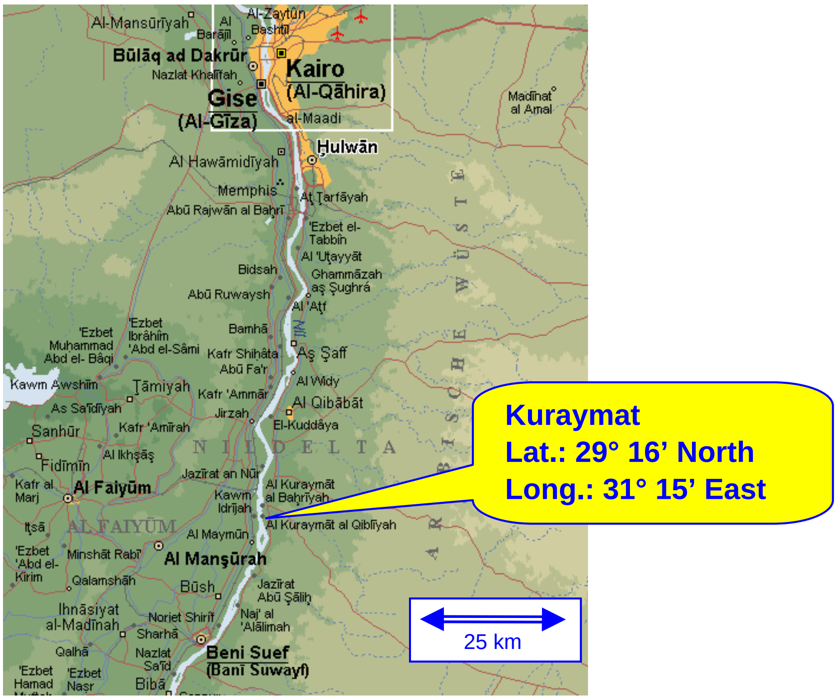


Figure 2 Geographic location of the site

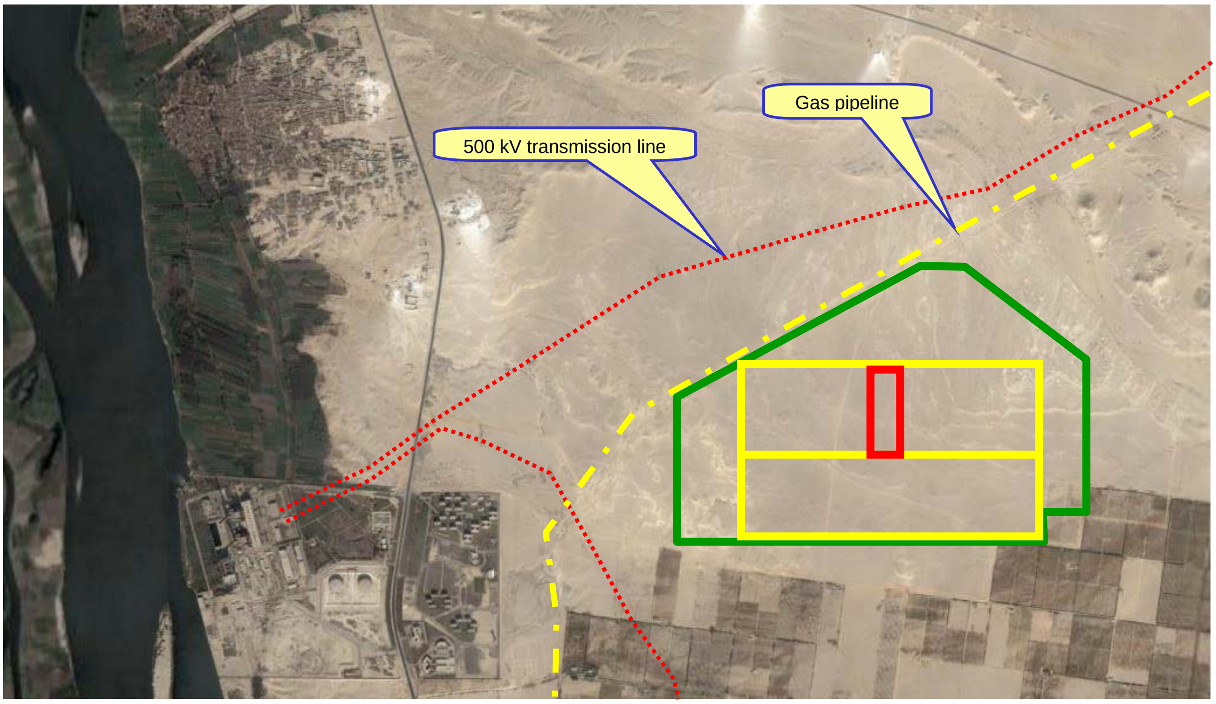


Figure 3 Satellite view of the site

The Ain Beni Mathar site (Figure 4 and Figure 5) is in the eastern part of Morocco, some 88 km south of the city of Oujda, at a northern latitude of 34° 4’ and a western longitude of 2° 6’ and at an elevation of 923 m.

Figure 4 Geographic location of the site

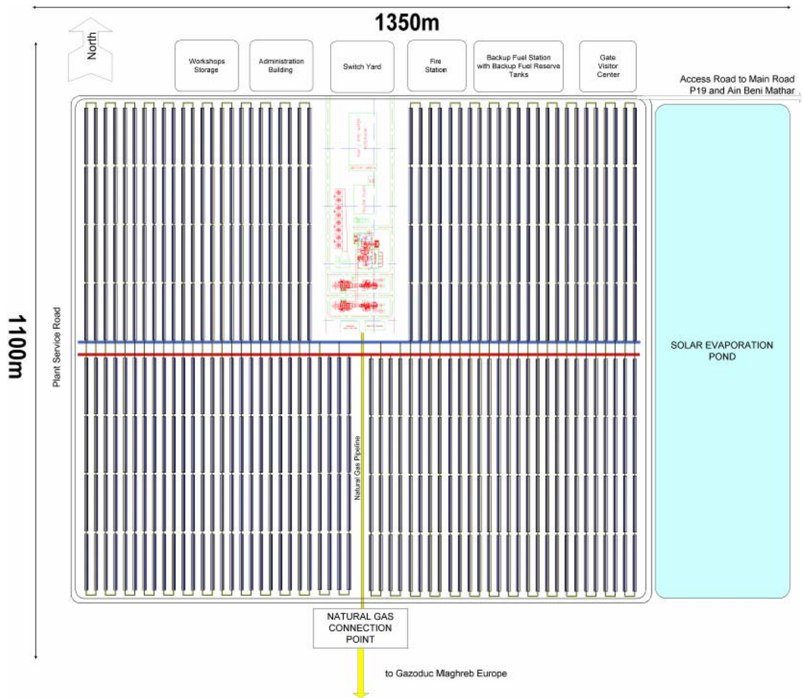


Figure 5 Plant Layout

Technical Design Data

Detailed thermodynamic evaluations had been made by Fichtner Solar GmbH during the conceptual design phase. However the bidders shall not be biased towards a certain gas turbine type, therefore the base line design data (Table 1) have been neutralized and are for information only. The Bidders are requested to provide their own design, in order to best fit the bid evaluation criteria.

			Morocco	Egypt
Solar field size		1000m2	220	225
Capacity of gas turbine(s) (at ISO)		MWe	125	80
Capacity of steam turbine (20°C, design solar heat)	solar	MWe	110	70
	no solar	MWe	78	38
Gross capacity of plant (20°C, design solar heat)		MWe	235	150
Net capacity (20°C, design solar heat)		MWe	**225**	**146**
Net electric energy		GWh/a	**1780**	**980**
Energy of solar heat at baseline DNI		GWh/a	230	225
Exergetic solar generation		GWh/a	**75**	**64,5**

Table 1 Neutralized Summary Technical Parameters of Baseline ISCC Design

The Parameters of the above table show the first design revision. Subsequently the Bidders for Morocco have also been requested to submit alternate bids for a smaller solar field (equivalent to 20 MW solar electric generation) and double gas turbine capacity.

Solar Meteo Data

The design basis DNI (Direct Normal Irradiation) for Kuraymat is **2 431 kWh/m²/a.** The annual distributions of DNI are shown in the following Figure 6.

Solar Irradiations are shown in Figure 7 for a typical 21 December and 21 June. In December there is a large difference between DNI and DII (Direct Incident Irradiation); this is due to the lower solar elevation during winter months. The production of solar heat depends basically on the DII.

The design ambient temperature varies between 2°C and 42°C, with an average of **21.6°C**. The distribution of ambient temperature is shown in Figure 8.

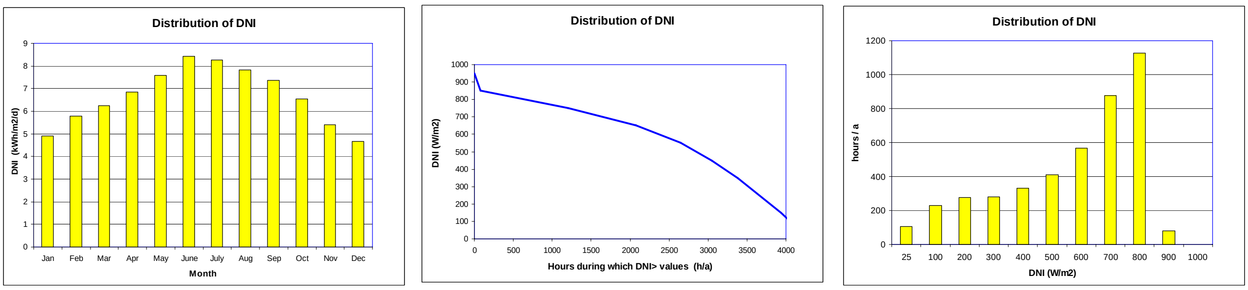


Figure 6 Distribution of DNI

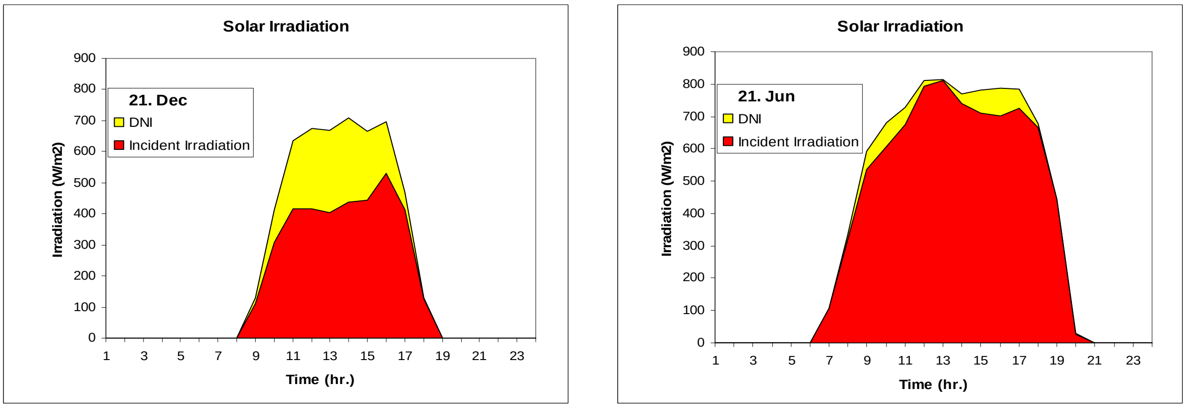


Figure 7 Solar Irradiation (DNI and DII) on typical 21 December and 21 June

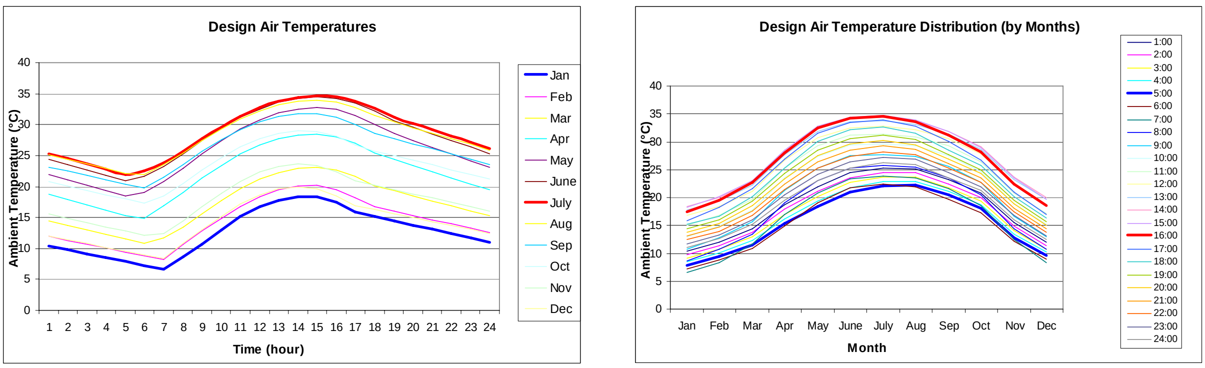
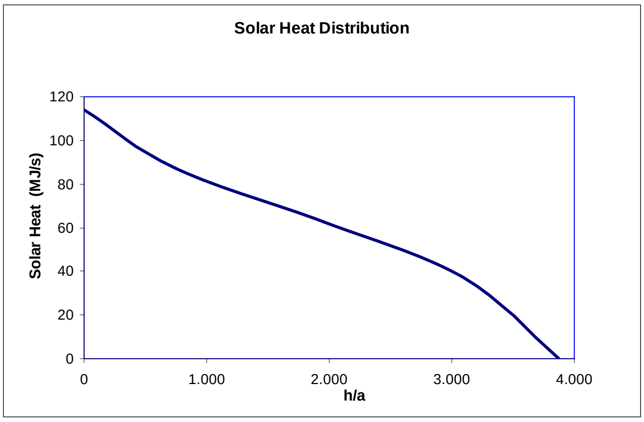


Figure 8 Ambient air temperature

Solar Heat and Generation of Electricity

The distribution of solar heat being produced by the Solar Island and the correlation with ambient temperature is shown in Figure 9.



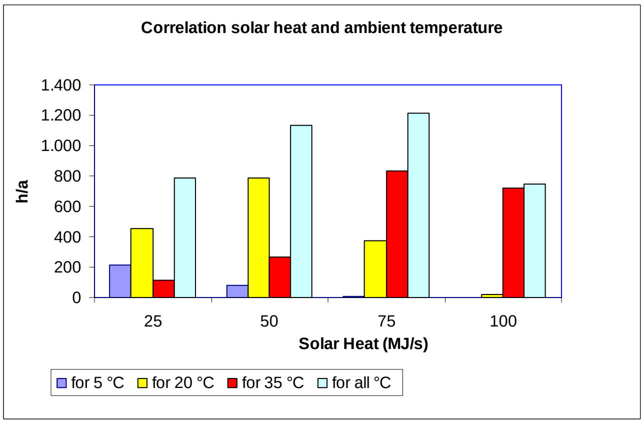


Figure 9   Distribution of Solar Heat and correlation with ambient temperature

There is a higher frequency of occurrence of solar heat in the upper ranges when the ambient air temperature is higher. On the other hand higher ambient temperature causes a decrease in gas turbine power and in exhaust heat to the HRSG (heat recovery steam generator). Thus the steam turbine can accommodate a larger amount of solar heat whenever the ambient air temperature is high. Nevertheless on high solar irradiation days the heat from the HRSG (while the gas turbine is on full power) plus the solar heat can be larger than what can be accommodated by the steam turbine. For such cases there are three solutions:

Increasing the size of the steam turbine

The steam turbine size can be increased. A larger design of a steam turbine would result in higher cost and larger part load losses of the steam turbine during most of the year, whenever the solar heat is not close to its maximum.

Throttling of the gas turbine

During the peaking of solar irradiation the gas turbine can be throttled, resulting in less exhaust heat to the HRSG; thereby the steam turbine can use all of the solar heat. This results in somewhat reduced output, but a better overall efficiency and hence a better use of the fossil fuel.

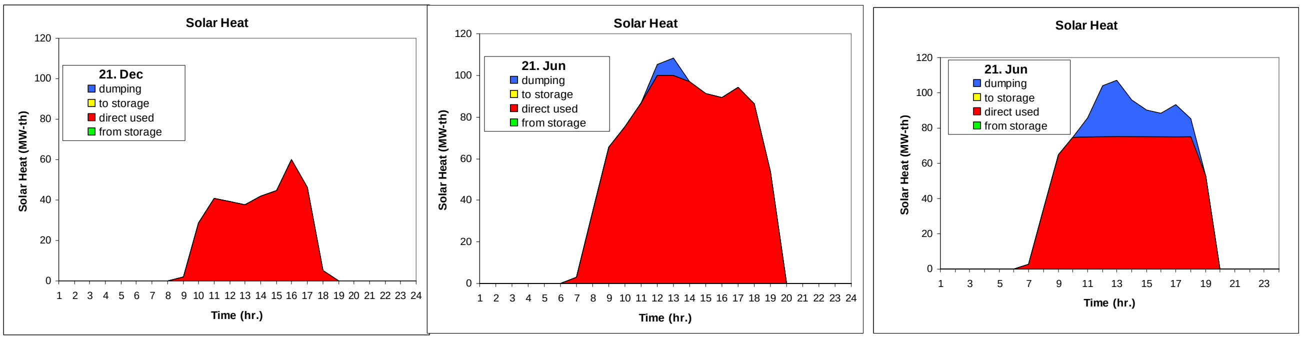
Dumping of excess solar heat

If a larger generation is desired during peaking of solar irradiation, then it is possible not to apply the throttling of the gas turbine, but to dump the excess solar heat by defocusing some collectors. This allows operating both the gas turbine and the steam turbine at full load. The power is maximised at the expense of efficiency.

Figure 10 and Figure 11 show respectively the Solar Heat and the Electricity Generation.

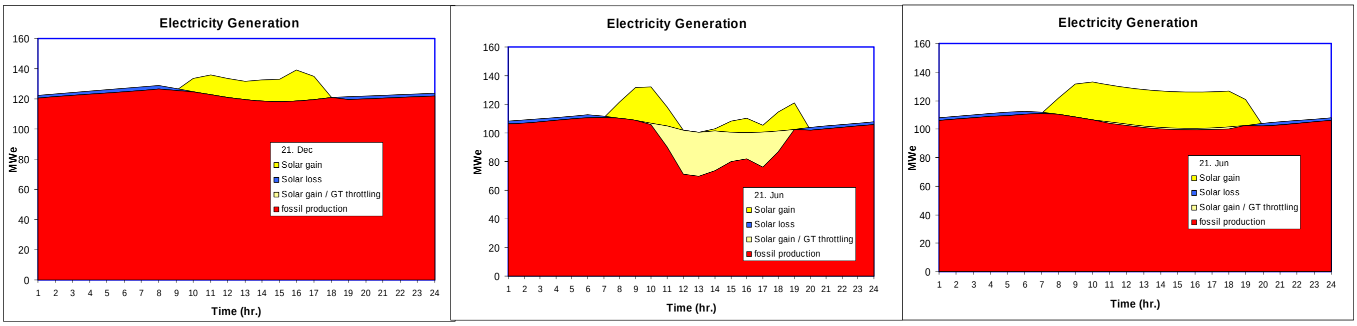
On 21 December the direct incident irradiation and the ambient temperature are low. This results in less solar heat (see Figure 10a), but in more fossil generation (see Figure 11a). There is sufficient capacity in the steam turbine to absorb the entire solar heat.

On 21 June the direct incident irradiation and the ambient temperature are high. This results in more solar heat, but in less fossil generation. Figure 11b shows the case when the gas turbine is throttled and most of the solar heat is used in the steam turbine. In Figure 11c the gas turbine is not throttled and consequently a larger quantity of the solar heat must be dumped.



(a) on 21 December (b) when throttling GT (c) when dumping excess heat

Figure 10 Solar Heat



(a) on 21 December (b) when throttling GT (c) when dumping excess heat

Figure 11 Electricity generation

Generally in an ISCC, the steam turbine is sized larger than in a corresponding standard combined cycle power plant (with the same gas turbine). Therefore, whenever an ISCC operates without solar heat input (e.g. at night), the steam turbine will operate at part load and consequently at a lower efficiency, this is denominated as "**Solar loss**" in Figure 11.

The evaluation criteria in the Bid Documents have been established so that an overall optimization will be obtained, considering the cost of production of electricity from fossil fuel as well as the integration of solar heat into the Combined Cycle Island and the cost of "**Exergetic Solar Generation**".