ISCC Kuraymat

Integrated Solar Combined Cycle Power Plant in Egypt

Paper FA4-S7 presented at 13th International Symposium on Concentrating Solar Power and Chemical Energy Technologies, SolarPaces, June 20-23, 2006, Seville, Spain

Georg Brakmann (Presenter) Fichtner Solar GmbH, Sarweystr. 3, D-70191 Stuttgart, Germany, Tel.: +49 711 8995 535, email: brakmann@fichtnersolar.com

Khaled Fekry, New and Renewable Energy Authority (NREA), Egypt

Ayman M. Fayek, New and Renewable Energy Authority (NREA), Egypt

Abstract

The New and Renewable Energy Authority (NREA) of Egypt intends to implement an **I**ntegrated **S**olar **C**ombined **C**ycle Power Plant, ISCC – Kuraymat, to be located about 95 km south of Cairo, on the eastern side of the river Nile, at a northern latitude of 29° 16' and an eastern longitude of 31° 15'. The complete ISCC Project shall be implemented in **three (3) contract lots**:

- One (1) Contract Lot for **Solar Island** as **EPC cum O&M contract** for engineering, procurement, construction, testing, commissioning and five (5) years operation and maintenance; (Two contracts will be used for this Lot (Solar Island), one for EPC and one for the O&M part of the Lot.)
  The Solar Island shall consist of a parabolic trough solar field capable to generate about **110 MW (thermal) of solar heat** at a temperature of 393°C, the related I&C and control room and the heat transfer fluid (HTF) system up to the HTF inlet and outlet flanges of the Solar Heat Exchanger(s).
  The Contractor for Solar Island shall guarantee the supply of solar heat to the Solar Heat Exchanger(s) as a function of normal direct solar irradiation (DNI) and of solar position.
- One (1) Contract for **Combined Cycle Island** as **EPC contract** for engineering, procurement, construction, testing and commissioning and extended two (2) year warranty period.
  The Combined Cycle Island shall consist of one (1) or two (2) **gas turbine(s) with ISO rating of about 80 MWe** (total), one (1) or two (2) heat recovery steam generator(s) (HRSG), one (1) **steam turbine of about 70 MWe**, solar heat exchanger(s) capable to absorb about 110 MW (thermal) of solar heat plus all associated balance of plant equipment.
  The Contractor(s) for Combined Cycle Island shall guarantee the supply of electricity and the heat rate as a function of ambient temperature and as a function of solar heat supply from the Solar Island.
- One (1) Contract for **Combined Cycle Island** as **O&M contract** for five (5) year operation and maintenance.

Concept of the 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.

The scope split (Figure 1) between the **Solar Island** and the **Combined Cycle Island** shall be the HTF inlet and outlet flanges of the Solar Heat Exchanger. The Solar Heat Exchanger shall be part of the Combined Cycle Island.

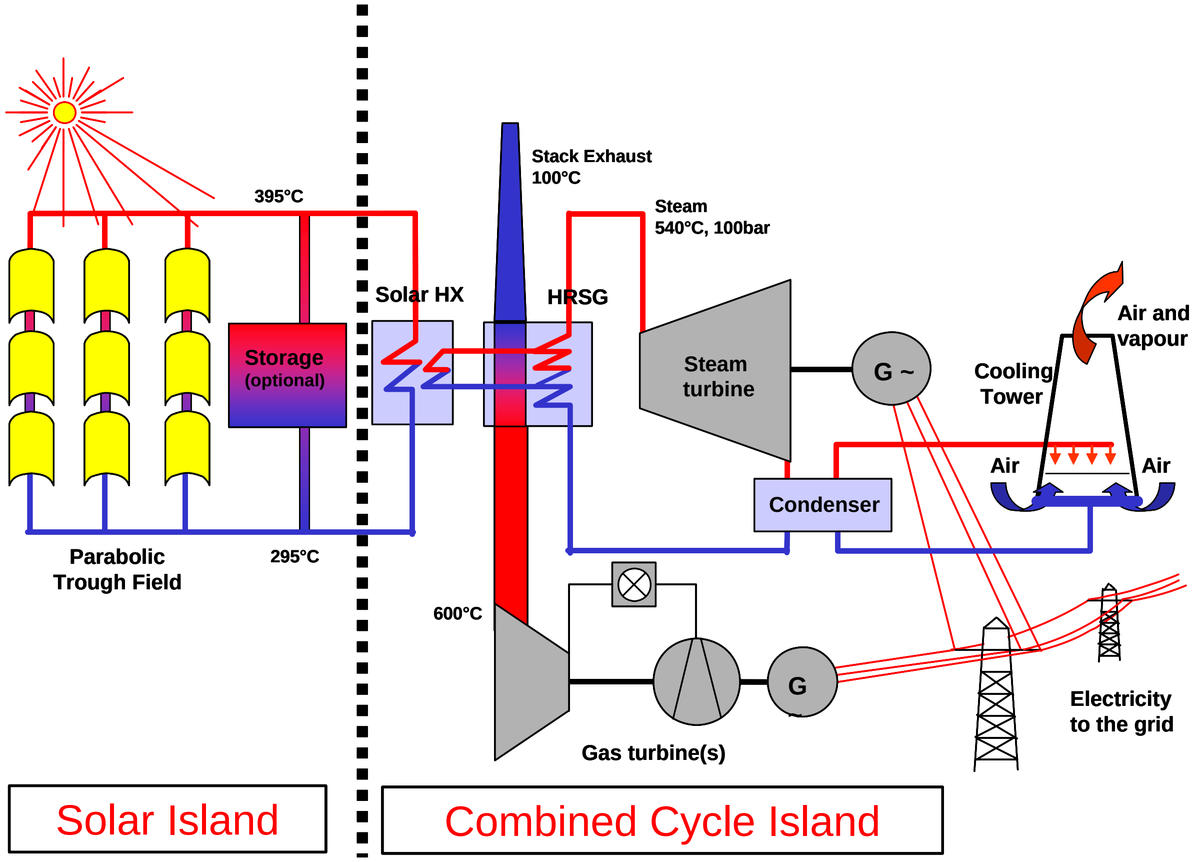


Figure 1 Scope Split and General Concept of an ISCC

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.

Neutralised Summary Technical Parameters of Baseline Design			**ISCC**
Solar field size		1000m2	225
Capacity of gas turbine(s) (at ISO)		MWe	80
Capacity of steam turbine (20°C, design solar heat)	solar	MWe	70
	no solar	MWe	38
Gross capacity of plant (20°C, design solar heat)		MWe	150
Net capacity (20°C, design solar heat)		MWe	**146**
Net electric energy		GWh/a	**980**
Energy of solar heat at baseline DNI		GWh/a	225
Exergetic solar generation		GWh/a	**64,5**

Table 1 Neutralized Summary Technical Parameters of Baseline ISCC Design

Site Location

The 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.

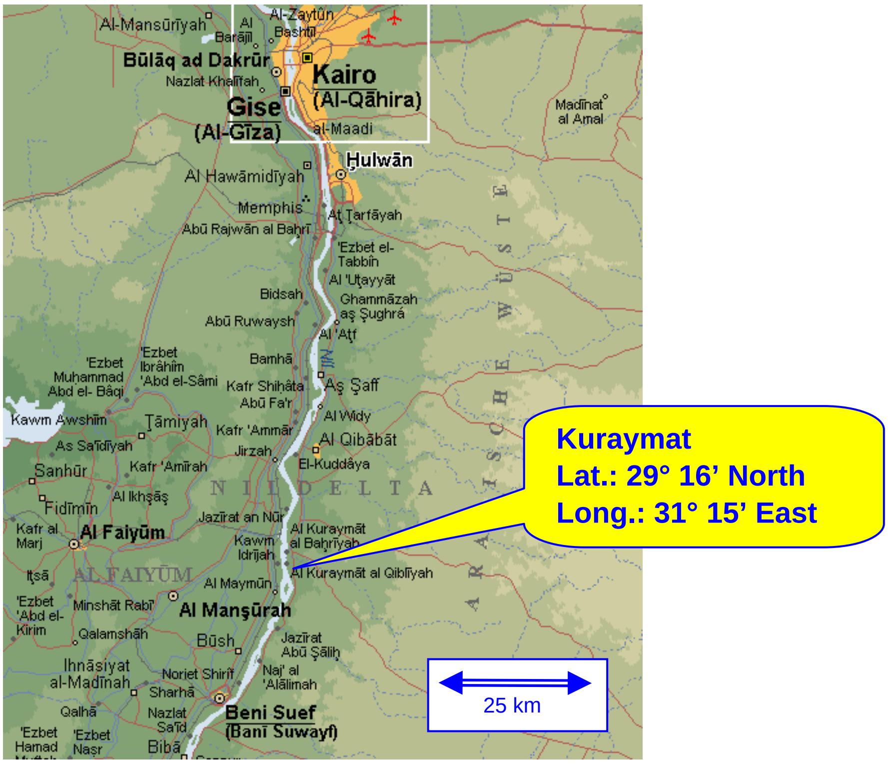


Figure 2 Geographic location of the site

Figure 3 Satellite view of the site

Plant Layout

The area of ISCC Kuraymat consists of solar field areas, power block area, BoP area (Balance of Plant incl. non-plant buildings) and an area for a future test centre. A general plot plan of ISCC Kuraymat is shown in Figure 4.

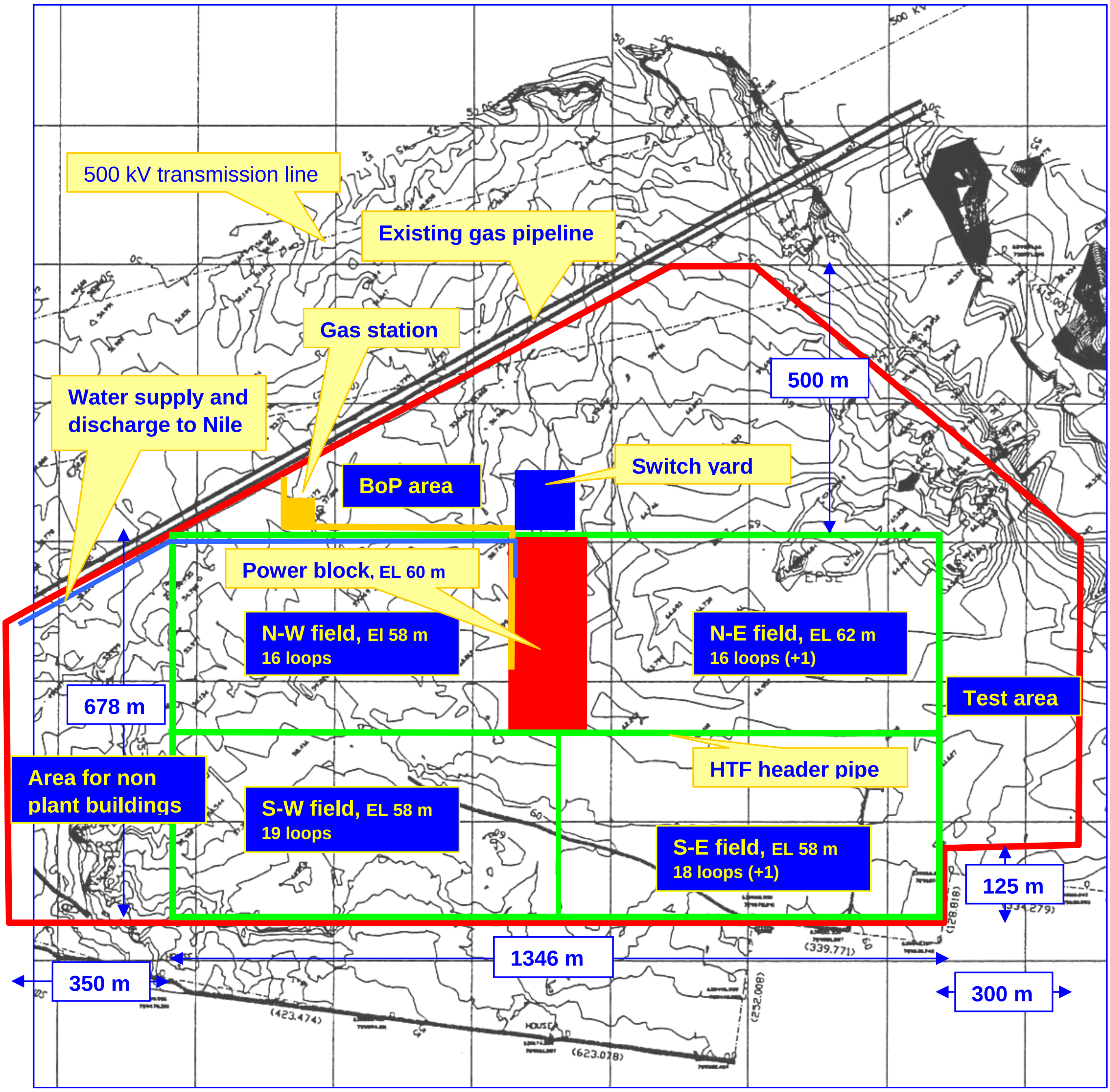


Figure 4 General Plot Plan and Location of ISCC Kuraymat

Solar Meteo Data

The design basis DNI (Direct Normal Irradiation) for Kuraymat is **2 431 kWh/m^2/a.** The annual distributions of DNI are shown in the following Figure 5.

Solar Irradiations are shown in Figure 6 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 7.

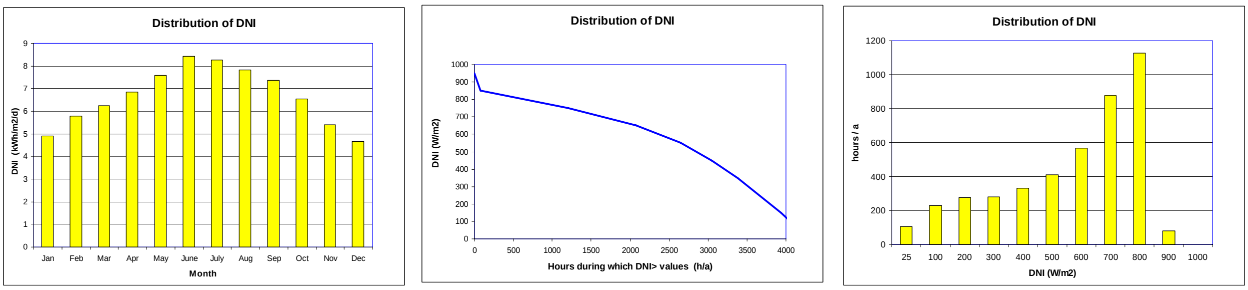


Figure 5 Distribution of DNI

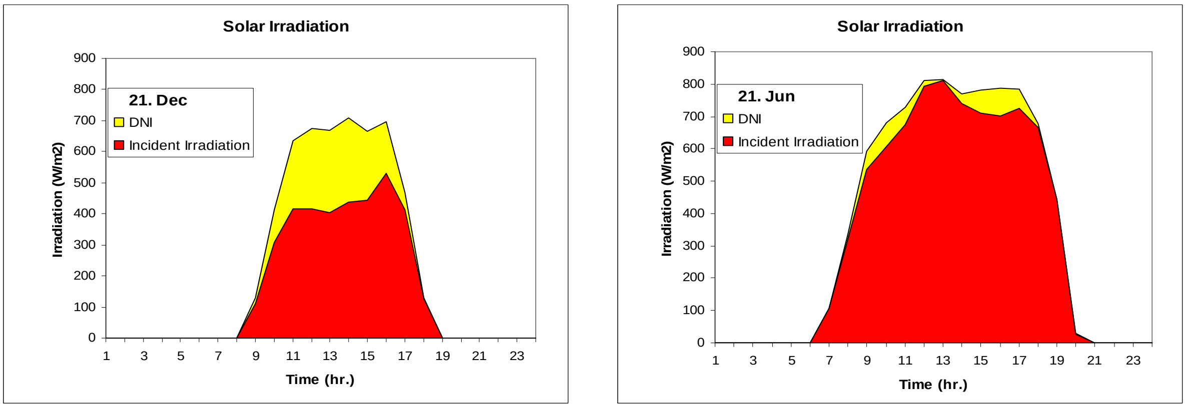


Figure 6 Solar Irradiation (DNI and DII) on typical 21 December and 21 June

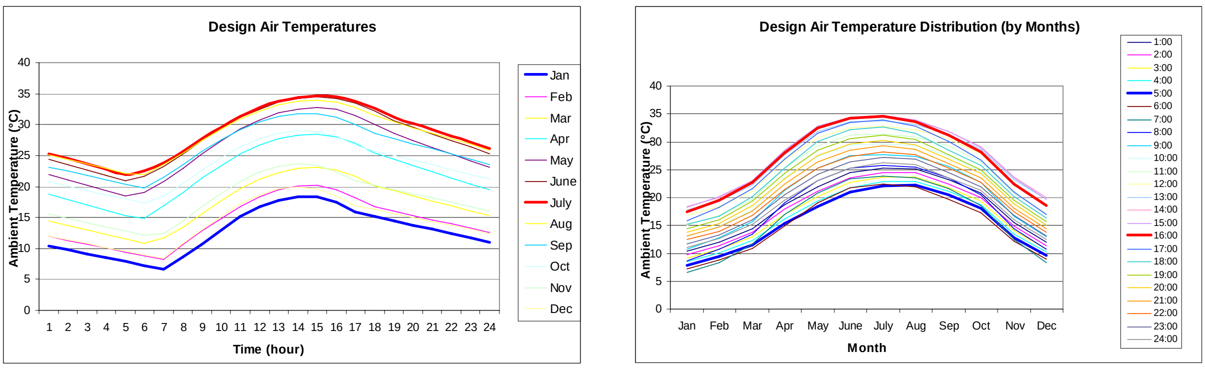


Figure 7 Ambient air temperature

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 8.

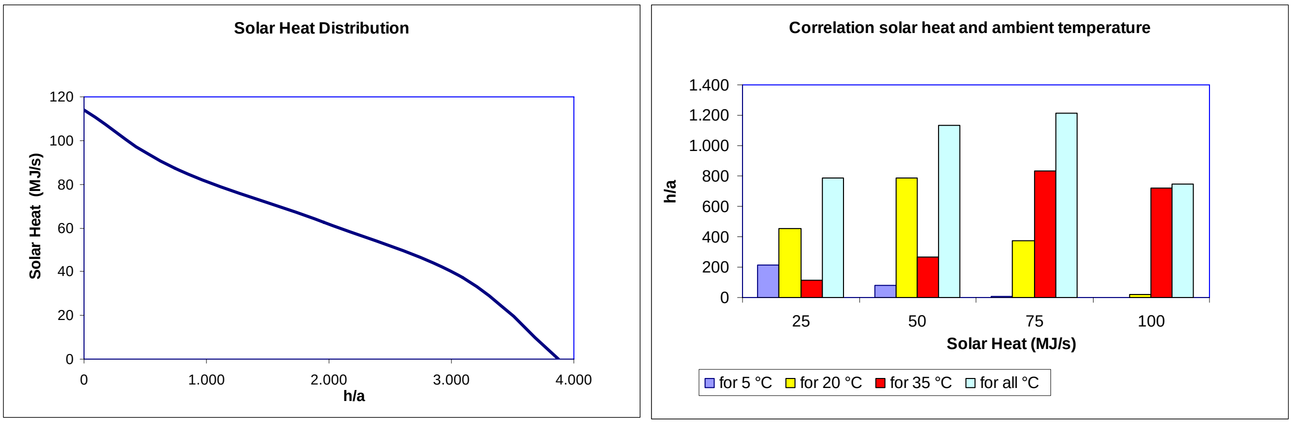


Figure 8 Distribution of Solar Heat and correlation with ambient temperature

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.

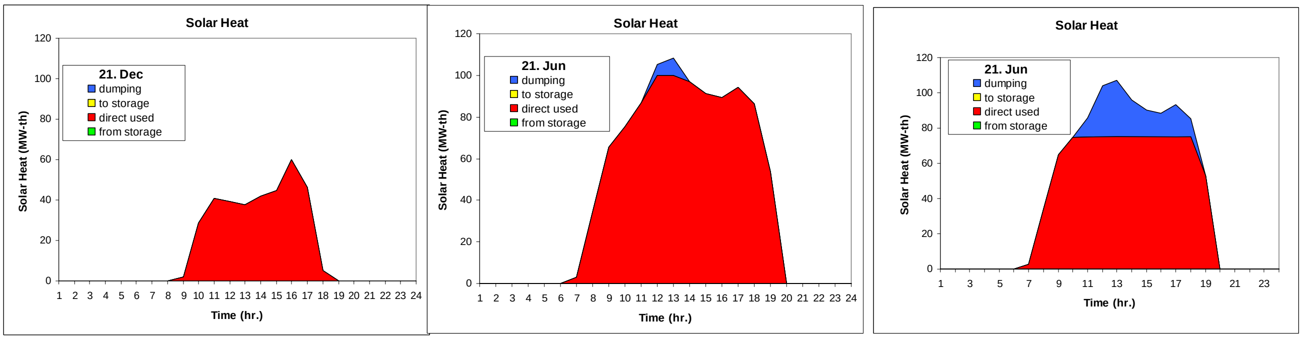
Dumping of excess solar heat

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

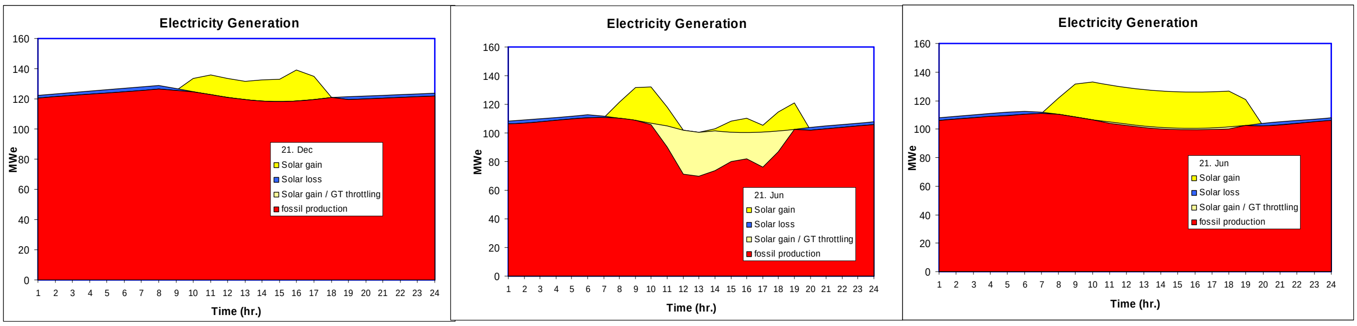
On 21 December the direct incident irradiation and the ambient temperature are low. This results in less solar heat (see Figure 9a), but in more fossil generation (see Figure 10a). There is sufficient capacity in the steam turbine to absorb the entire solar heat.

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 10b shows the case when the gas turbine is throttled and most of the solar heat is used in the steam turbine. In Figure 10c 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 9 Solar Heat



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

Figure 10 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 10.

The evaluation criteria in the Bid Document for the Combined Cycle Island Contractor have been established so that an overall optimisation will be obtained, considering the sizing of the steam turbine in relation to the size of the Solar Island and the integration of solar heat into the Combined Cycle Island.