Mathania Solar Power Plant for India

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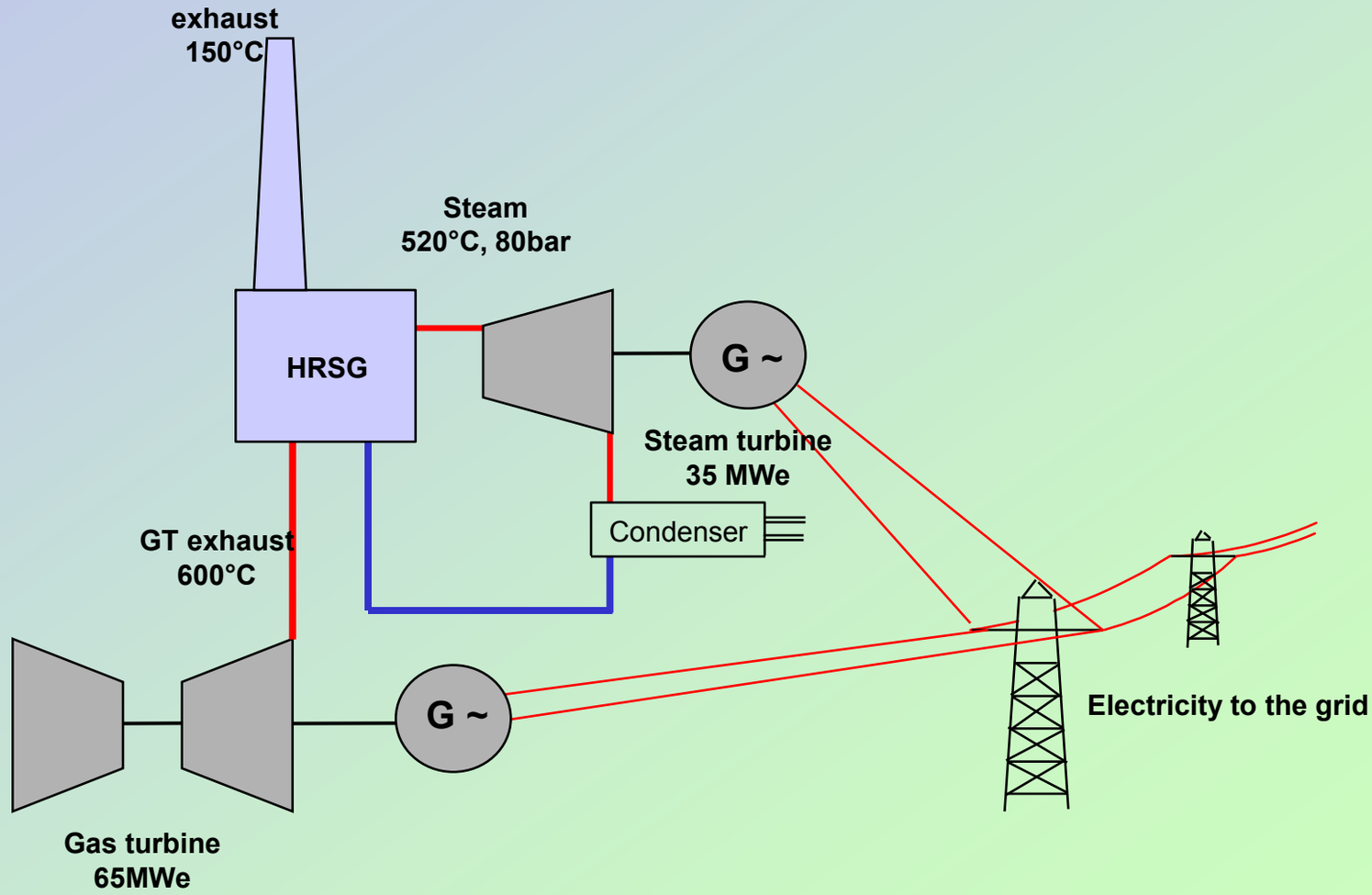
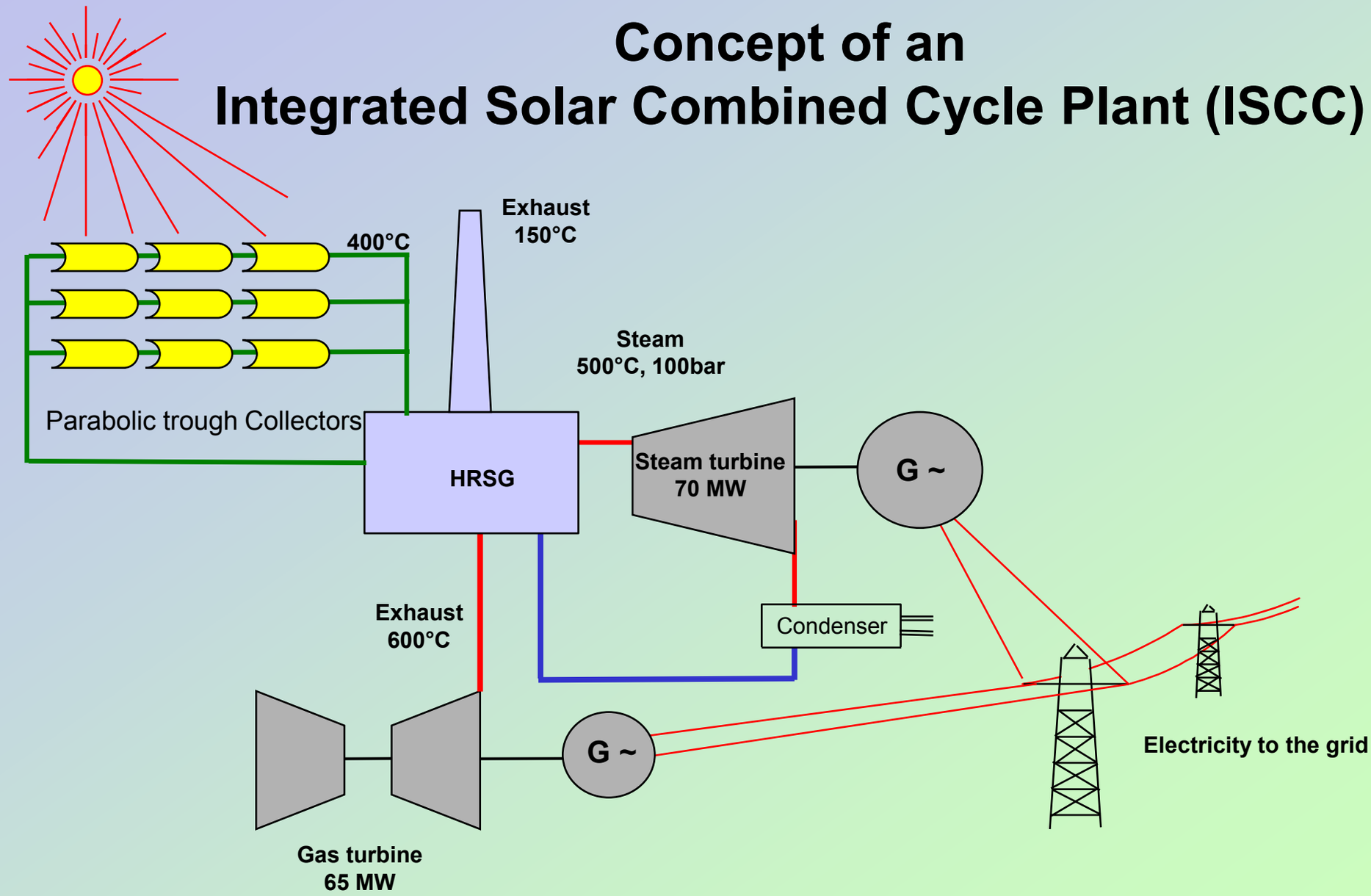
Fichtner Solar GmbH

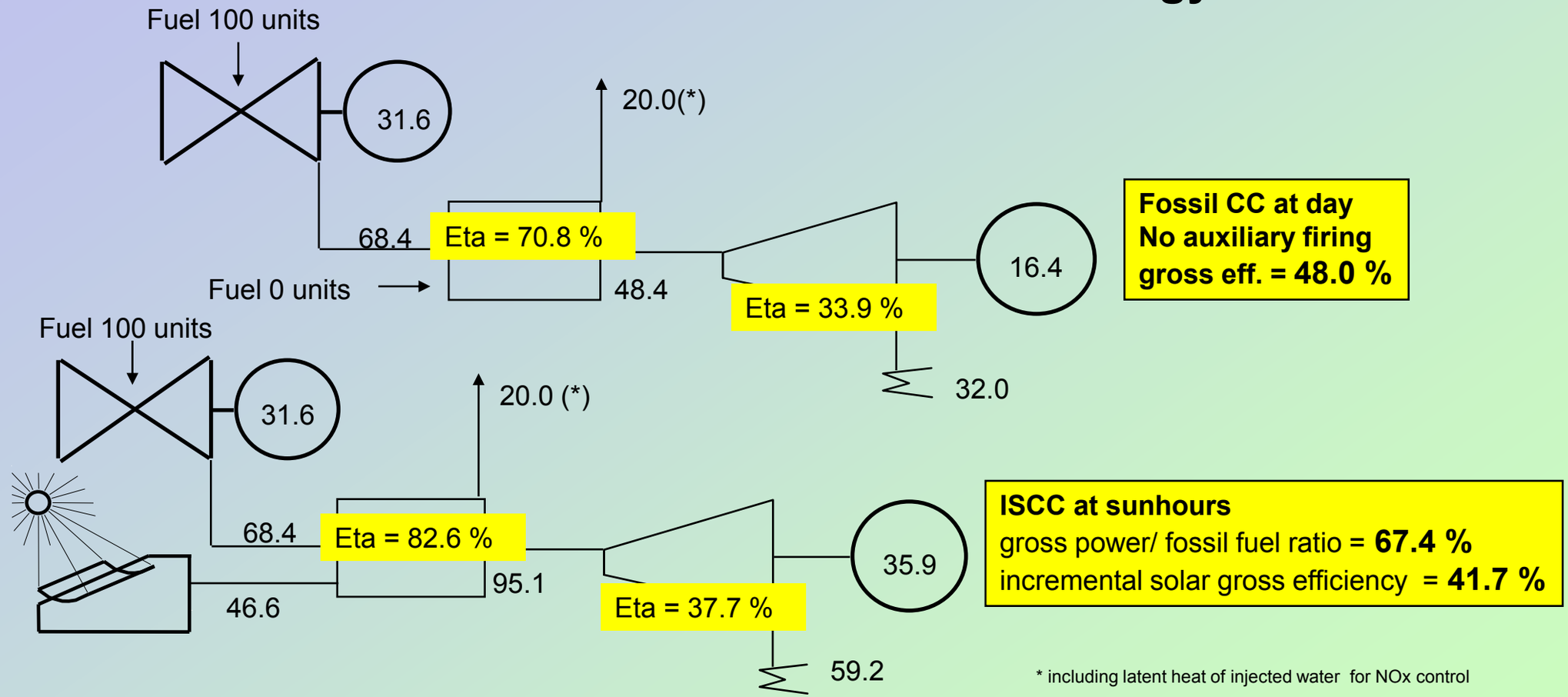
Concept of a combined cycle power plant



Concept of an Integrated Solar Combined Cycle Plant (ISCC)



Efficiency change in a combined cycle plant due to addition of solar thermal energy



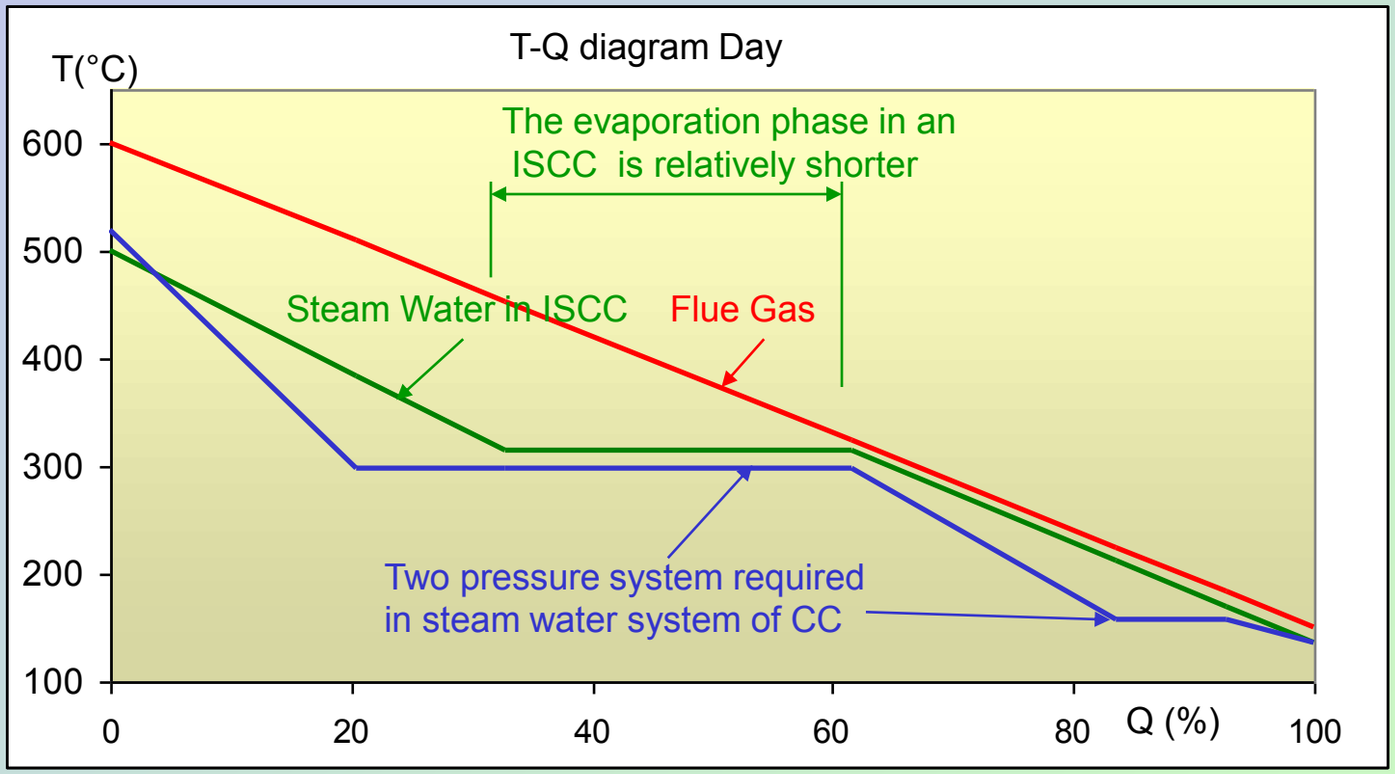
Fossil CC at day
No auxiliary firing
gross eff. = 48.0 %

ISCC at sunhours
gross power/ fossil fuel ratio = **67.4 %**
incremental solar gross efficiency = **41.7 %**

* including latent heat of injected water for NOx control

Due to solar addition the efficiency in the steam water cycle is increased.
The solar thermal energy does not contribute to stack losses.

Solar field increases the efficiency in the steam water cycle



The efficiency in the ISCC is improved due to:

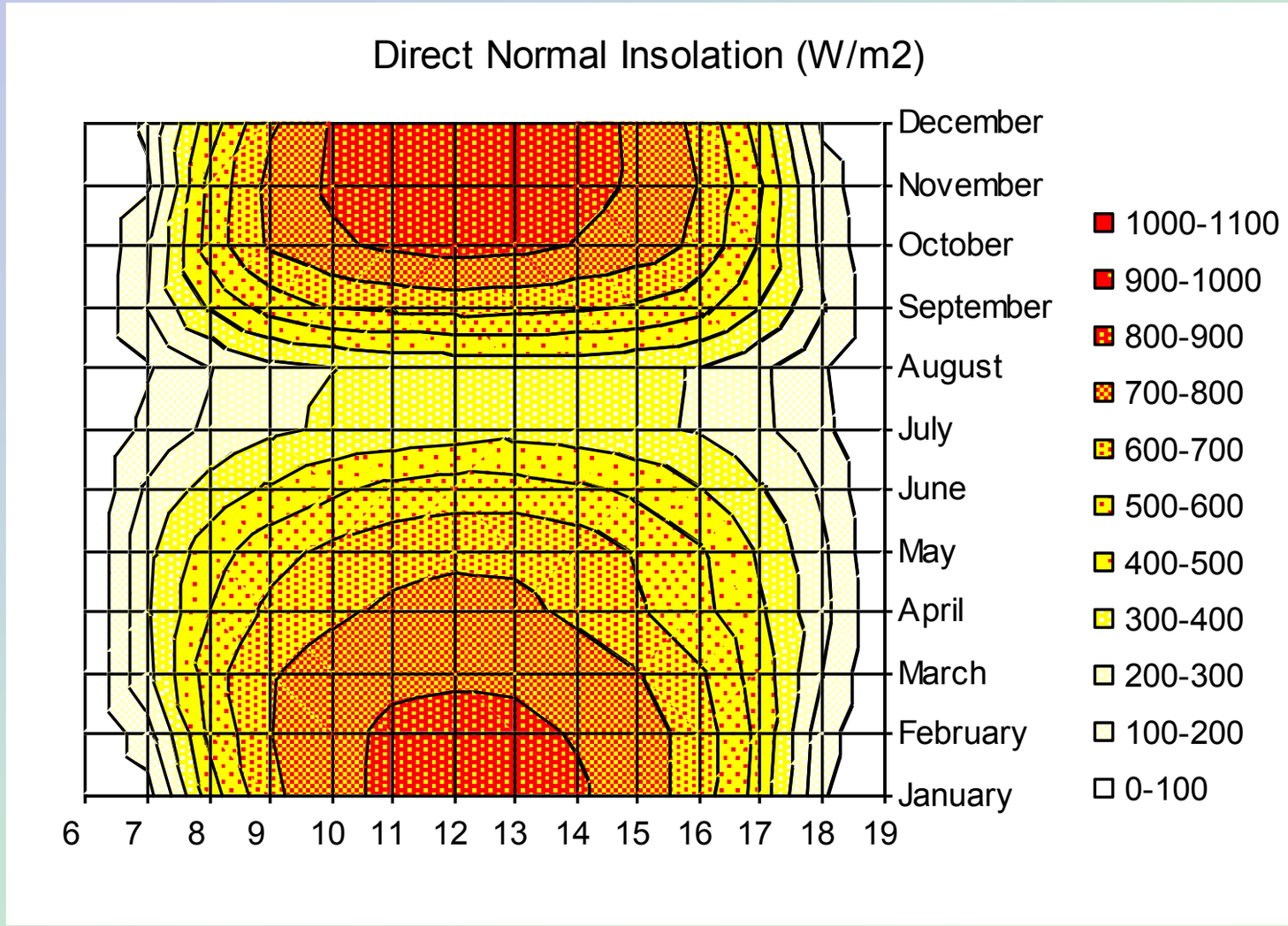
- **Part of the steam generation in the ISCC is by solar, therefore the evaporation portion in the WHRB of the ISCC is shorter and the preheating and superheating curves are flatter. Thereby the steam water curve is closer to the flue gas curve, resulting in less entropy.**
- **The heat transferred from the solar field does not contribute to stack losses**

Thermodynamic cycle design for ISCCs

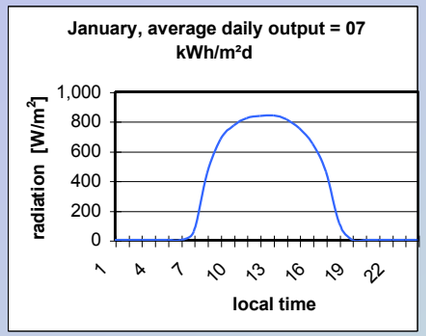
- Integrating a solar portion into a combined cycle plant requires careful tuning of the thermodynamic cycle for all operating conditions. If not done properly, then the solar generated heat will be converted at only a reduced efficiency. Furthermore the losses due to partload operation or auxiliary firing will be larger than necessary.
- Design simplifications can grossly change results and even produce negative solar shares.
- Due to the relatively small solar share in an ISCC (typically less than 10 % on annual basis), **a small percentage error in the efficiency** of both, the base case CC as well as the ISCC, would **drastically change the incremental solar power generation**

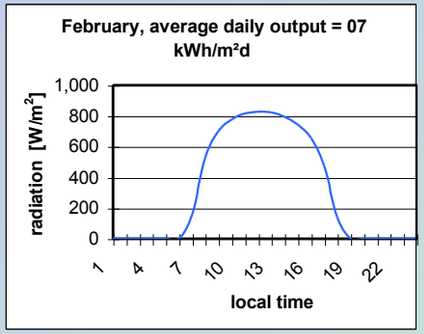
Proper tuning of the thermodynamic cycle for all operating conditions is extremely important and requires sophisticated computer software like Fichtner's own KPRO and SOLPRO programs.

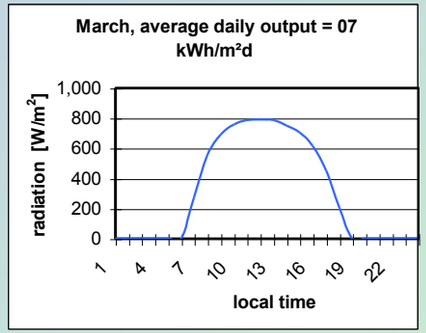
Insolation map for Mathania

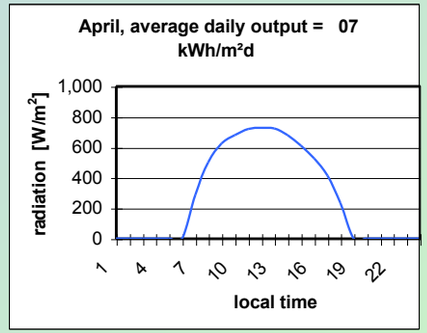


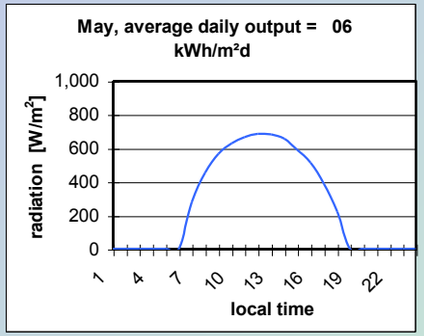
Direct normal insolation for Mathania (W/m²)

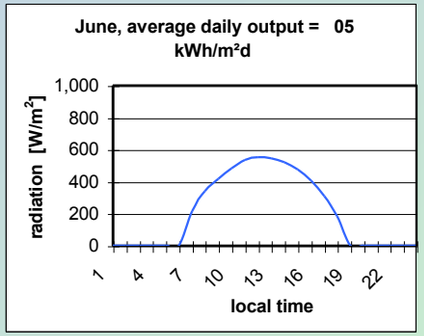


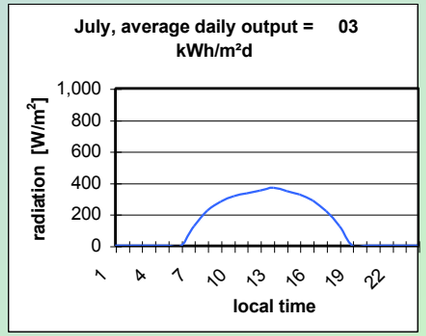


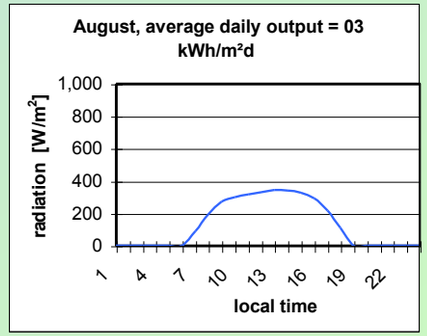


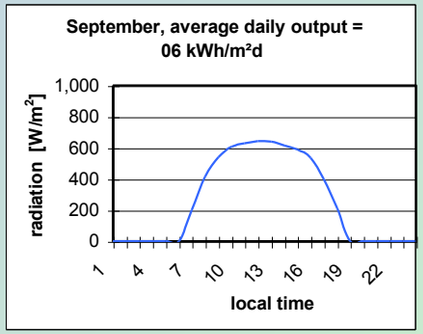


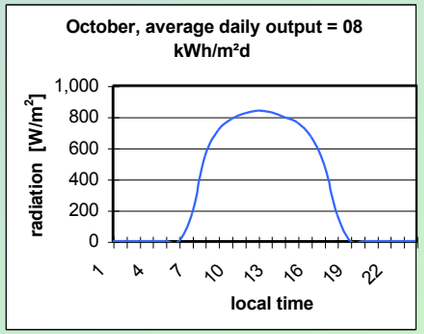


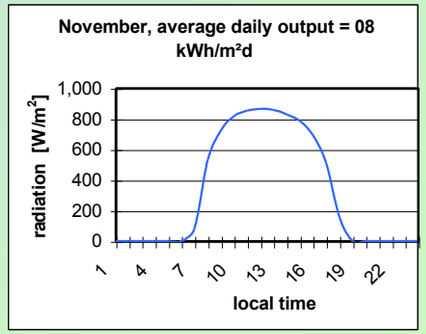


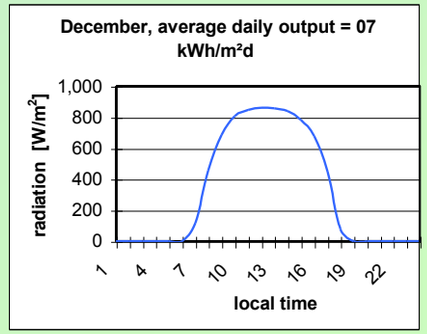




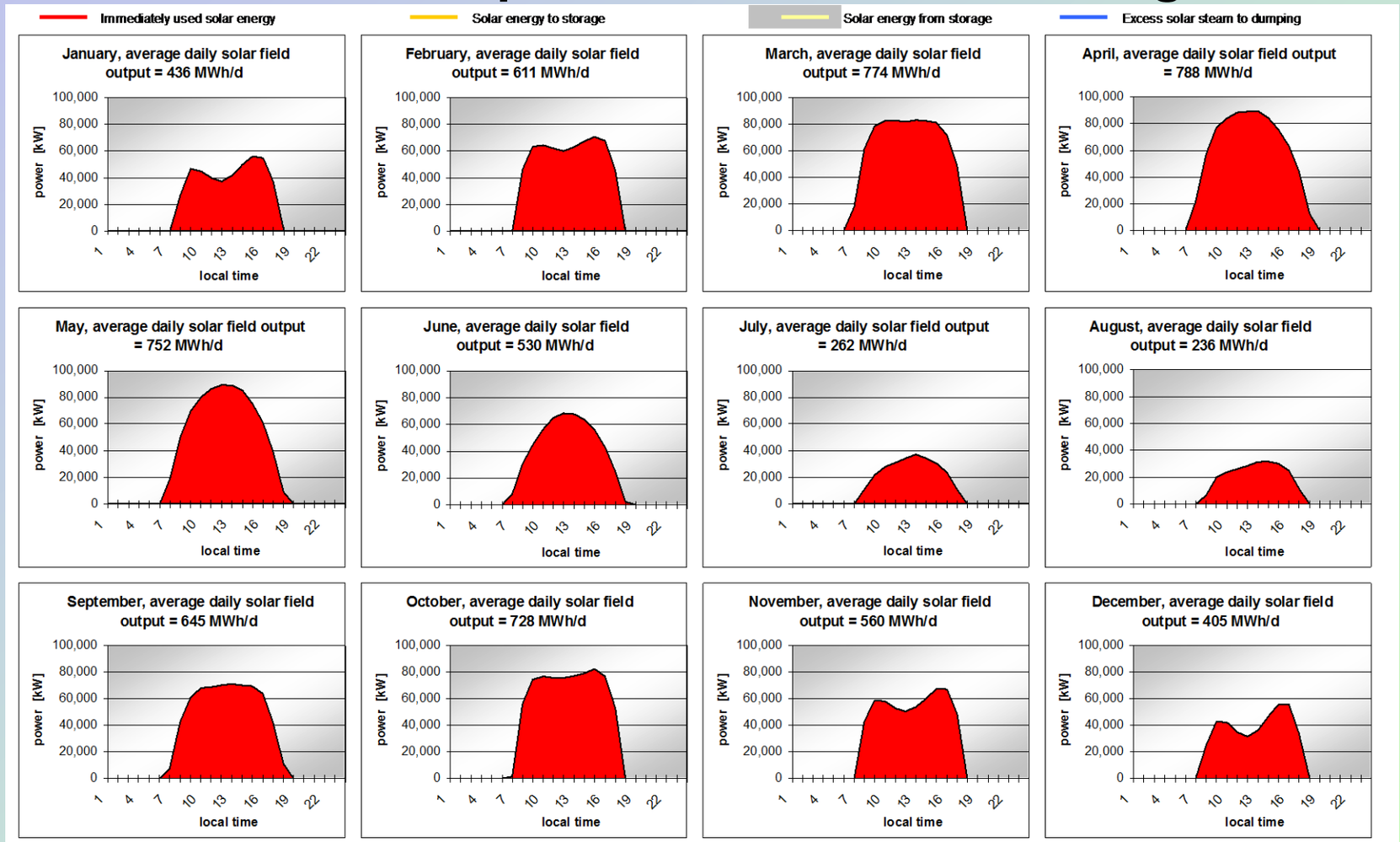








Solar field performance without storage



Storage Capacity	0.0 MWh	Capacity to use thermal power	90.0 MW
Total annual production	204.2 GWh/a	Direct used thermal energy	204.2 GWh/a
Total used	204.2 GWh/a	From storage 99%	0.0 GWh/a
Energy dumped and lost	0.0 GWh/a		

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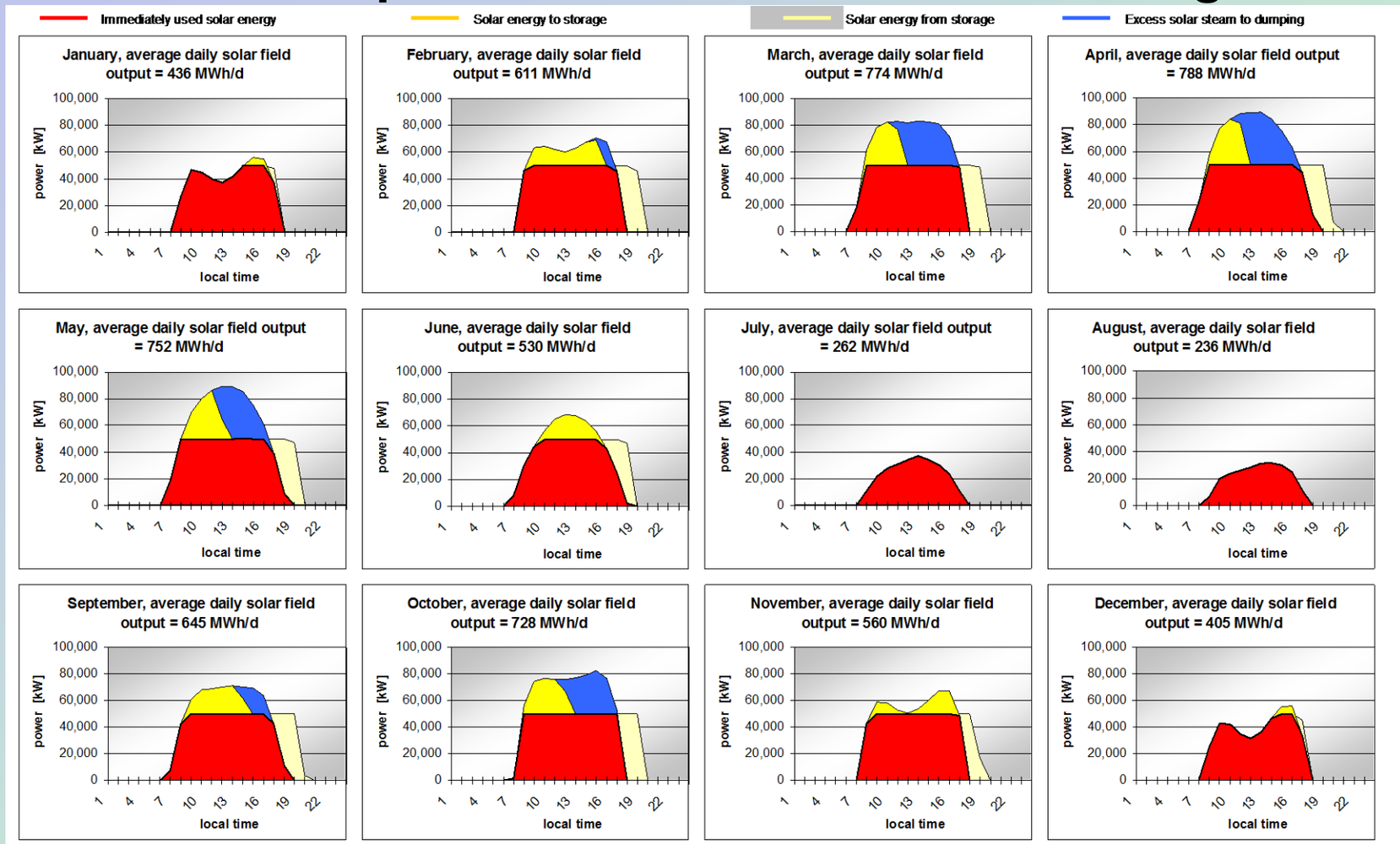
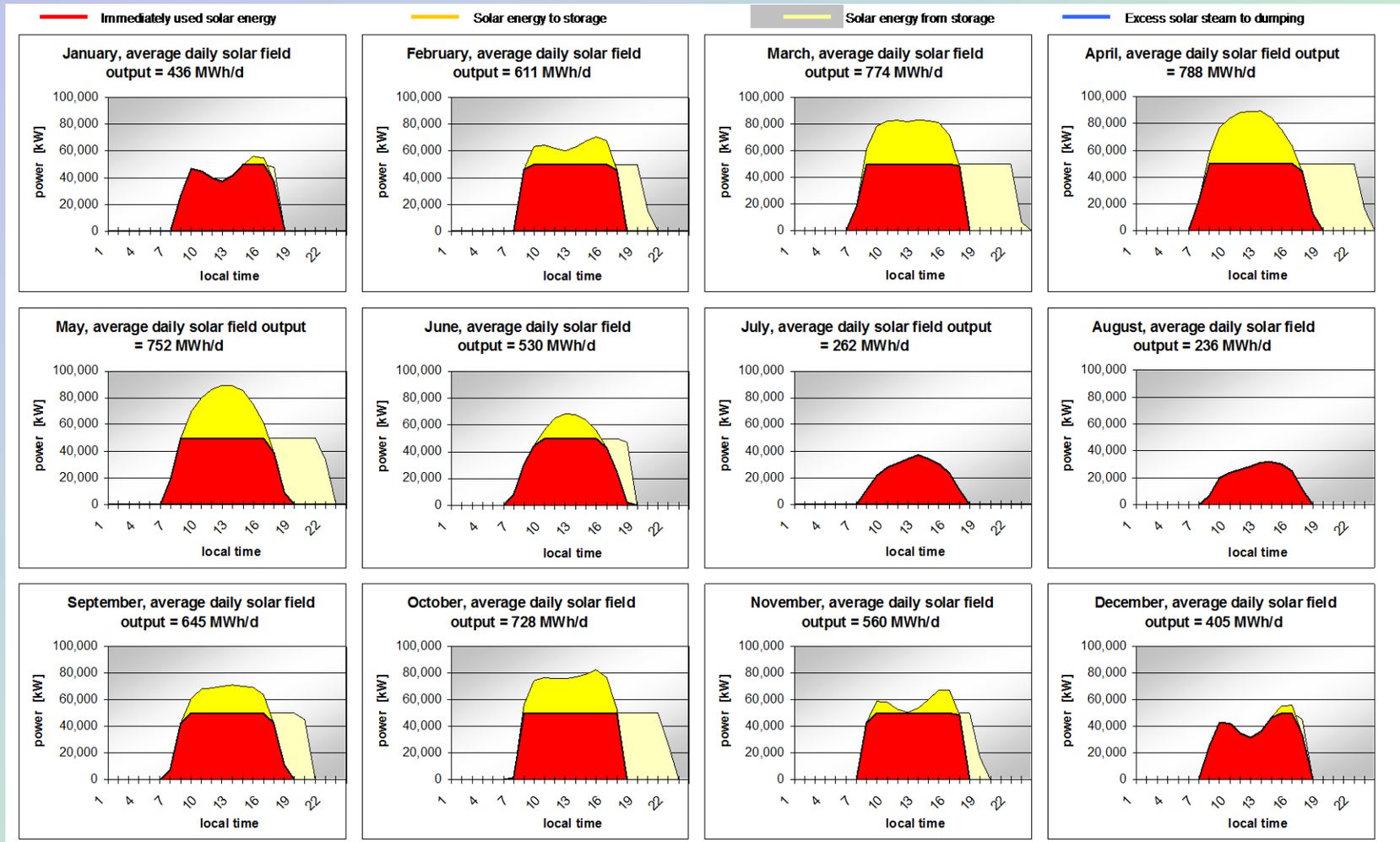
Solar field performance with 100 MWh storage



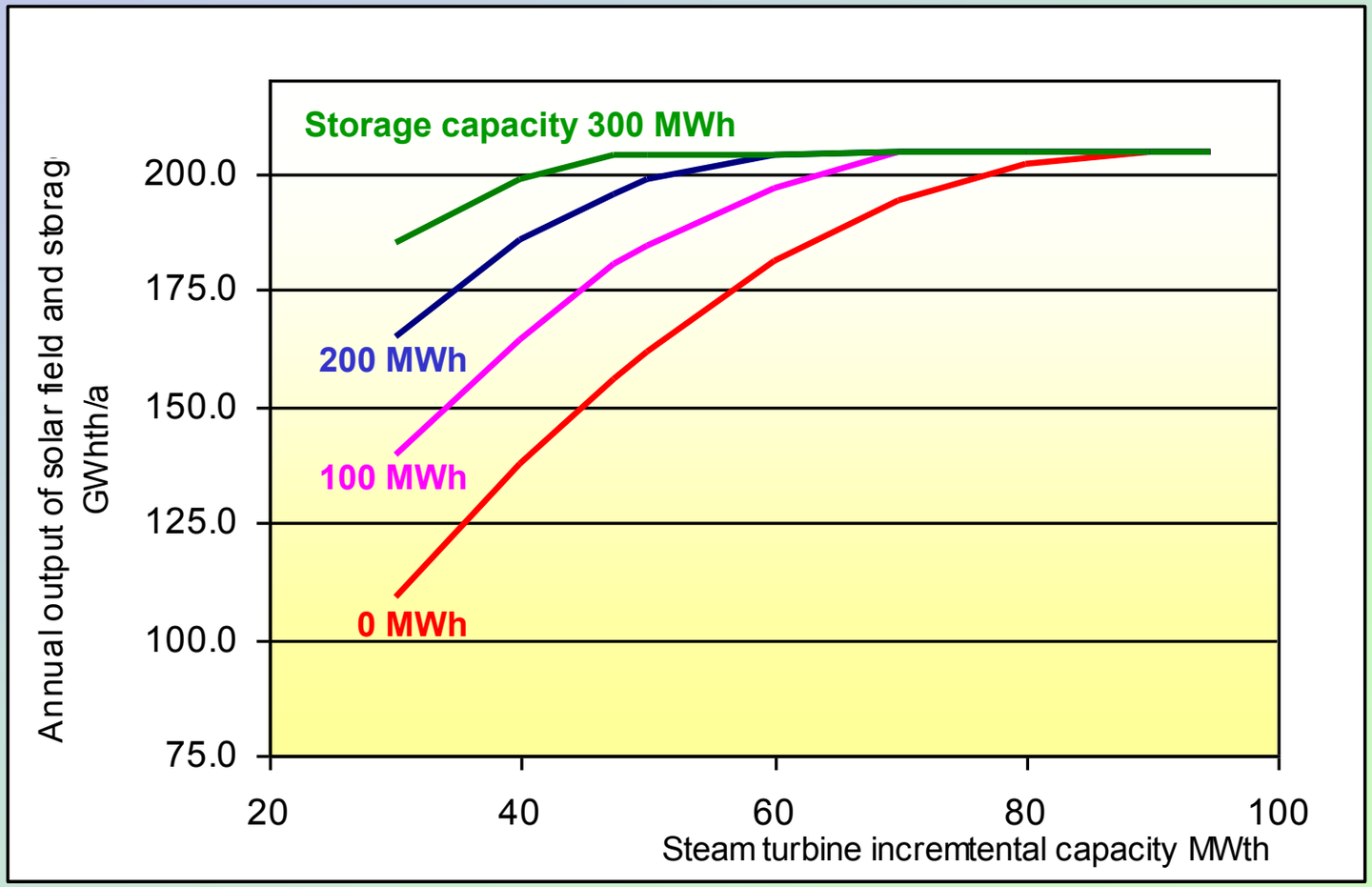
Storage Capacity	100.0 MWh	Capacity to use thermal power	50.0 MW
Total annual production	204.2 GWh/a	Direct used thermal energy	161.5 GWh/a
Total used	184.4 GWh/a	From storage 99%	22.9 GWh/a
Energy dumped and lost	19.8 GWh/a		

Solar field performance with 300 MWh storage

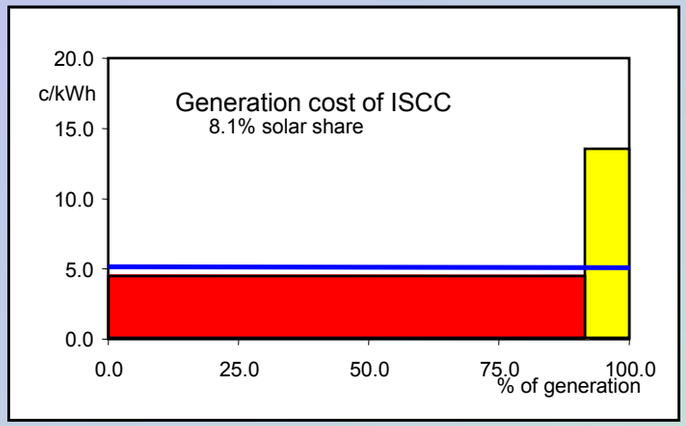


Storage Capacity	300.0 MWh	Capacity to use thermal power	50.0 MW
Total annual production	204.2 GWh/a	Direct used thermal energy	161.5 GWh/a
Total used	203.8 GWh/a	From storage 99%	42.3 GWh/a
Energy dumped and lost	0.4 GWh/a		

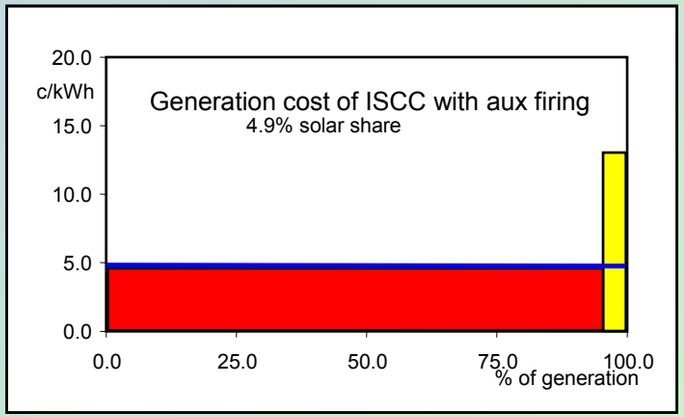
Performance for solar field and thermal storage



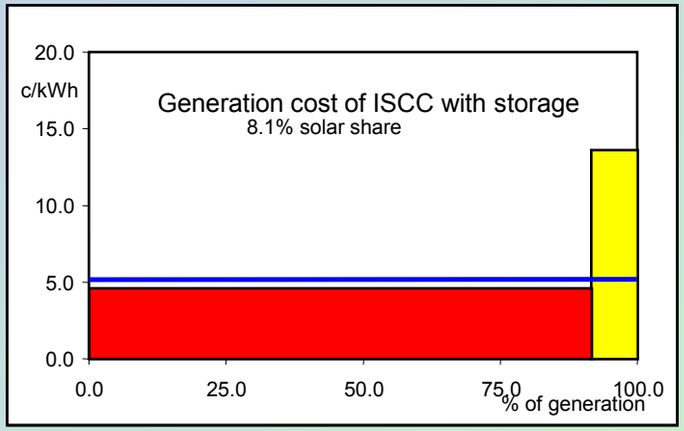
Graph of generation cost



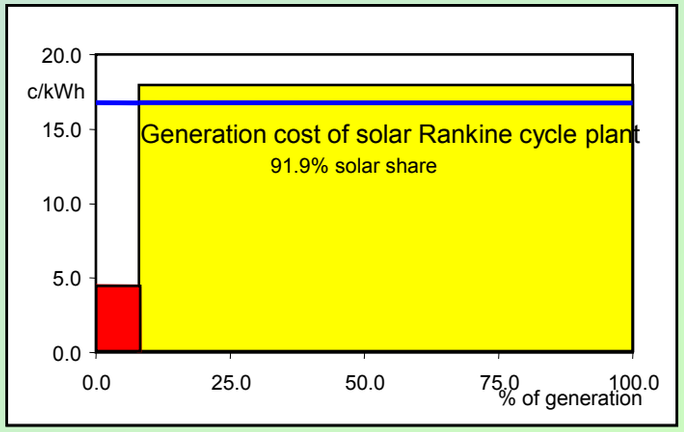
Genrtn cost (c/kWh) 5.7 solar 13.7 Fossil 5.0



Genrtn cost (c/kWh) 5.5 solar 14.4 Fossil 5.0



Genrtn cost (c/kWh) 5.6 solar 12.7 Fossil 5.0



Genrtn cost (c/kWh) 16.4 solar 17.4 Fossil 5.0

Conclusion:

- **Integrating the solar generated thermal energy into the steam turbine of a combined cycle power plant (ISCC) results in lower generation costs for the incremental solar generated electricity.**
- **Potential for conversion of solar thermal into electric energy by parabolic trough technology**
  - **In Rankine cycles: 37.5 % gross efficiency during rated solar operation**
  - **In solar hybrid plants (ISCC): 42 % gross efficiency for incremental solar generation during sunhours**
  - **Net annual solar incremental efficiency** for solar hybrid plants depends on operating mode must be based on annual operation hours. Any **performance losses of the fossil only operation during no-sun hours as well as part load losses are subtracted** from the solar incremental generation :
    - in a typical **Rankine cycle** plant it is **30 %**
    - for a typical **ISCC** it is **31 %**
    - for a typical **ISCC using thermal storage** it is **32 %**