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Techno-economic analysis of solar tower reference plant

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Solar tower plants, alternatively referred to as central receiver plants, offer higher efficiencies and potentially lower costs in comparison with parabolic trough systems. Therefore, the focus of ASTRI has been shifted to these systems.

Plant description

The ASTRI tower reference plant is a typical two tank molten salt solar tower with a gross capacity of 111 MW_e (net capacity of 100 MW_e) and 4 hours of thermal storage which is located in Alice Springs. In order to conduct an in-depth techno-economic analysis, the reference plant was split into three subsystems, namely solar concentrator (SC), thermal receiver (TR), and power block and thermal energy storage (PB). Figure 1 illustrates the schematic of the plant and Table 1 lists its main technical specifications.

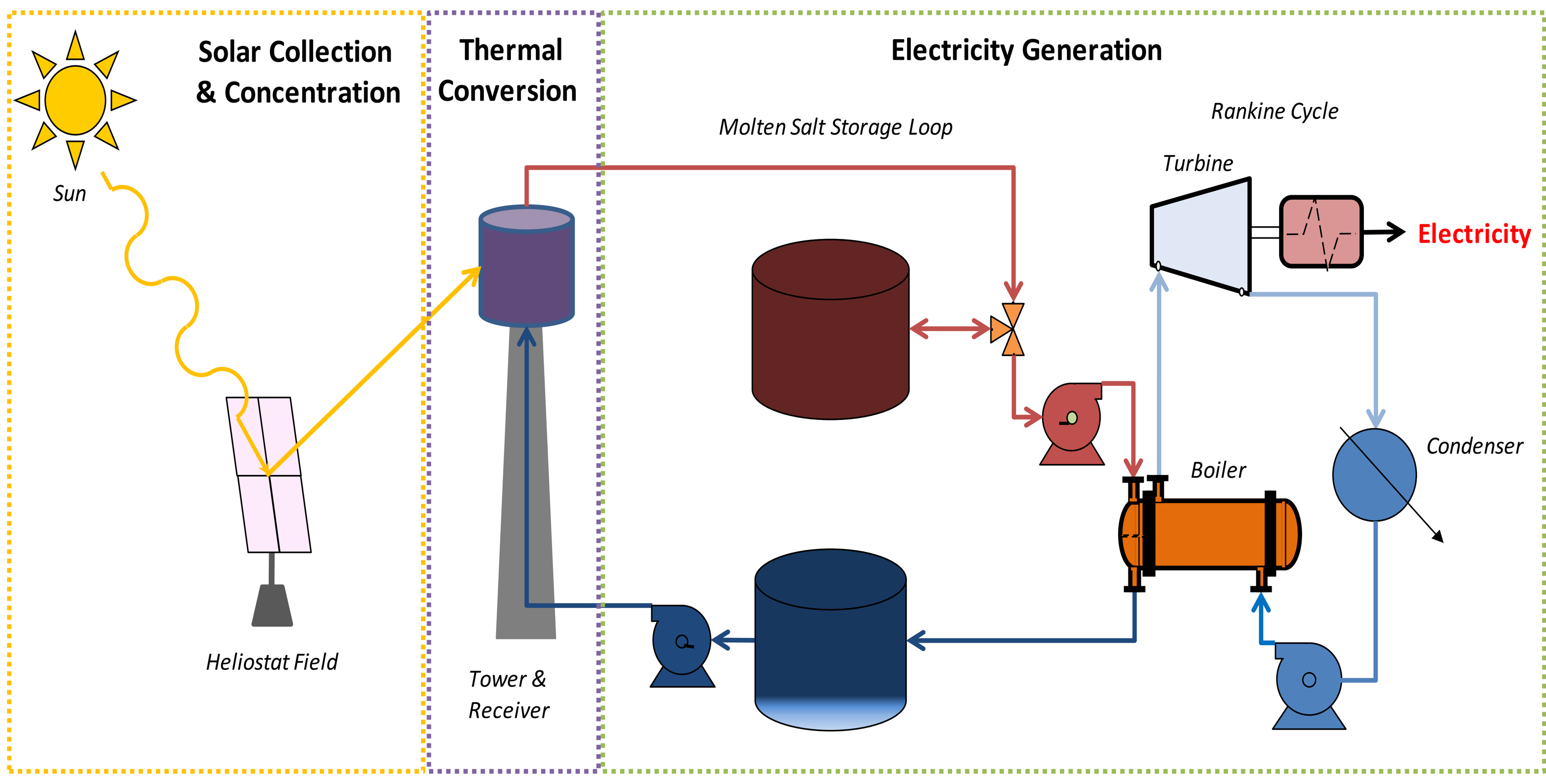

Figure 1: Central receiver reference plant

Table 1: Technical specifications

SUBSYSTEM	ITEM	VALUE
SC	• Heliostat size • Number of heliostats • Mirror reflectance and soiling • Solar multiple	• 12.2 m x 12.2 m • 6377 • 0.9 • 1.8
TR	• Tower height • Receiver type • Receiver height • Receiver diameter • Receiver design thermal power	• 183.33 m • External • 18.67 m • 15 m • 529.412 MWt
PB	• Design turbine gross output • Nameplate capacity • Rated cycle conversion efficiency • Design thermal power • Design heat transfer fluid inlet temperature • Design heat transfer fluid outlet temperature • Condenser type • Storage type • Full load hours of storage	• 111 MWe • 100 MWe • 0.3774 • 294.118 MWt • 574 °C • 290 °C • Air cooled • Two tank molten salt system • 4 hours

Solar data

For the reference plant design, solar data in the form of a representative meteorological year (RMY) file from the US DOE Energy Efficiency and Renewable Energy website (EERE, 2014) was used. Also, the performance variation over 13 real years of solar data (years 1999-2011) was predicted using annual years developed from BOM one-minute solar and half-hourly weather data. Figure 2 shows the annual DNI for the design and real years.

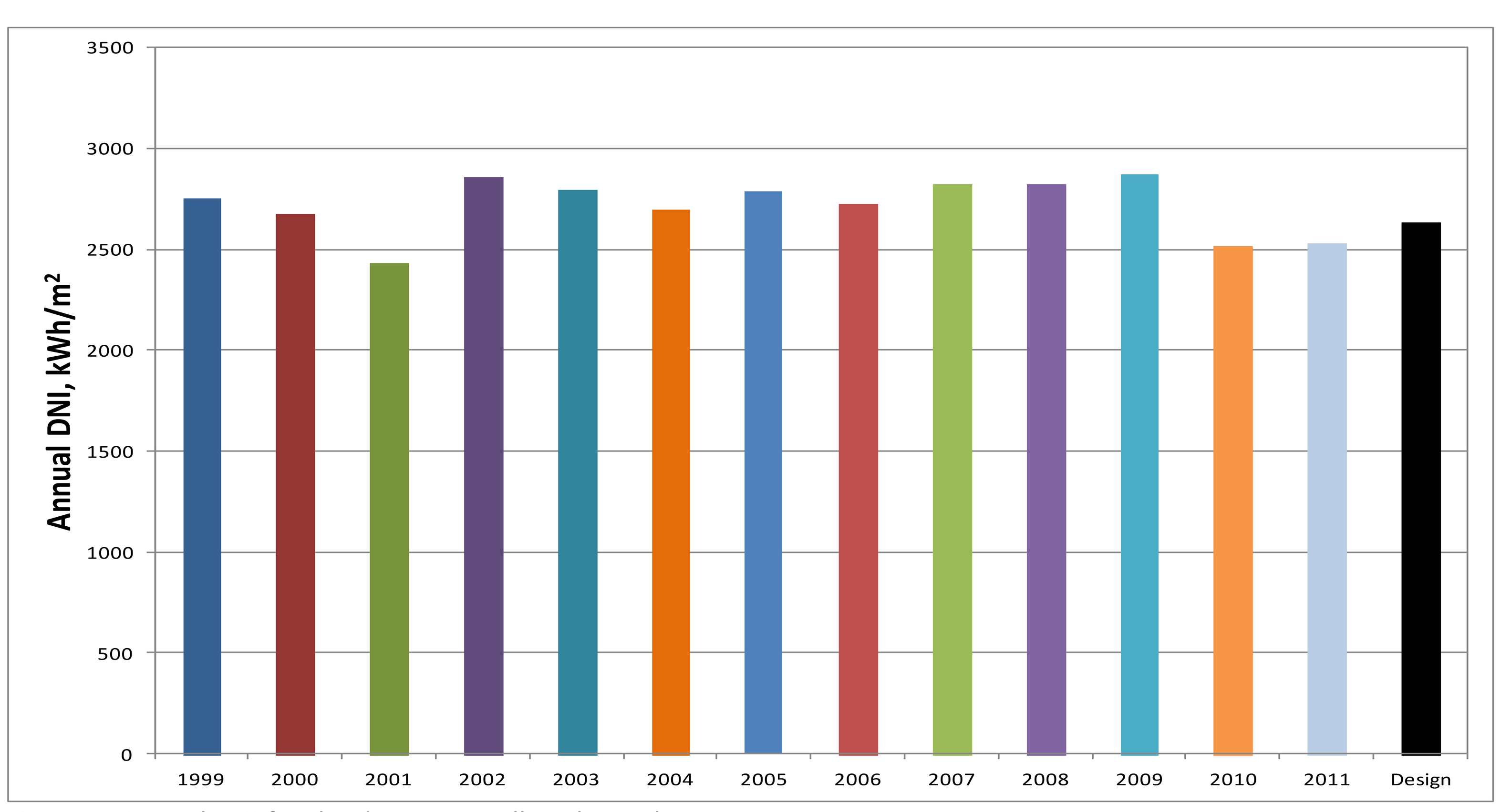

Figure 2: Annual DNI for the design as well as the real years

Costing data

Table 2 shows the plant costing data used in SAM and Figure 3 shows the contribution of cost items to the total installed and O&M costs.

Table 2: SAM costing data

ITEM	VALUE	UNIT
Site improvements	20	$\$/m^2$
Heliostat field	180	$\$/m^2$
Balance of plant	350	$\$/kW_e$
Power block	1000	$\$/kW_e$
Storage	37	$\$/kWh_t$
Fixed tower cost	3,100,000	$
Tower cost scaling exponent	0.0113	-
Receiver reference cost	104,600,000	$
Receiver reference area	1571	m^2
Receiver cost scaling exponent	0.7	-
Contingency	7	%
EPC and owner cost	11% of the direct capital cost	-
Fixed O&M cost by capacity	65	$/kW-yr
Variable O&M cost by generation	4	$/MWh

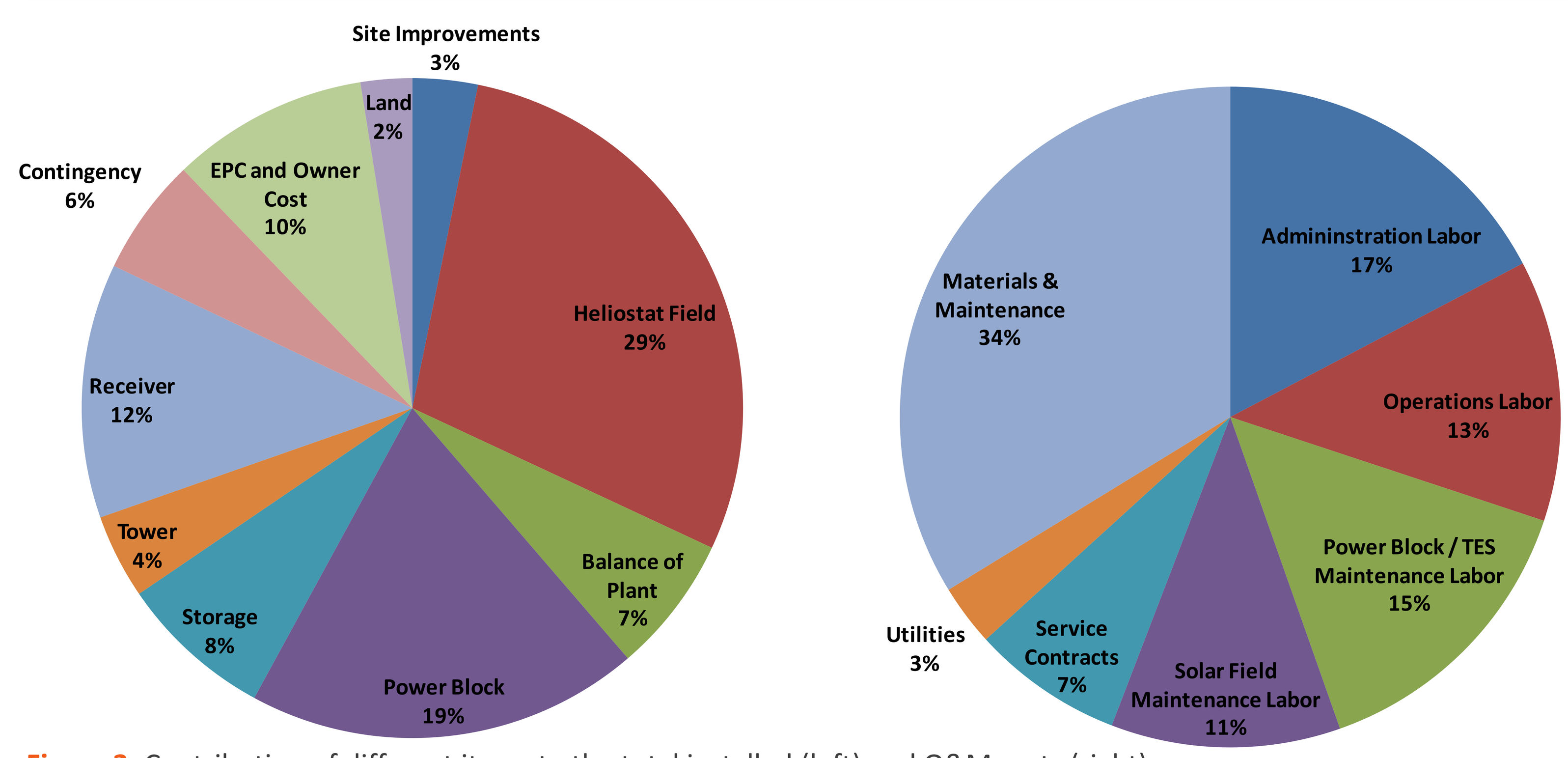

Figure 3: Contribution of different items to the total installed (left) and O&M costs (right)

Exergy and levelized cost of exergy

Figure 4 shows exergy and figure 5 shows levelized cost of exergy (LCOEx) for the three subsystems and for the typical as well as real years.

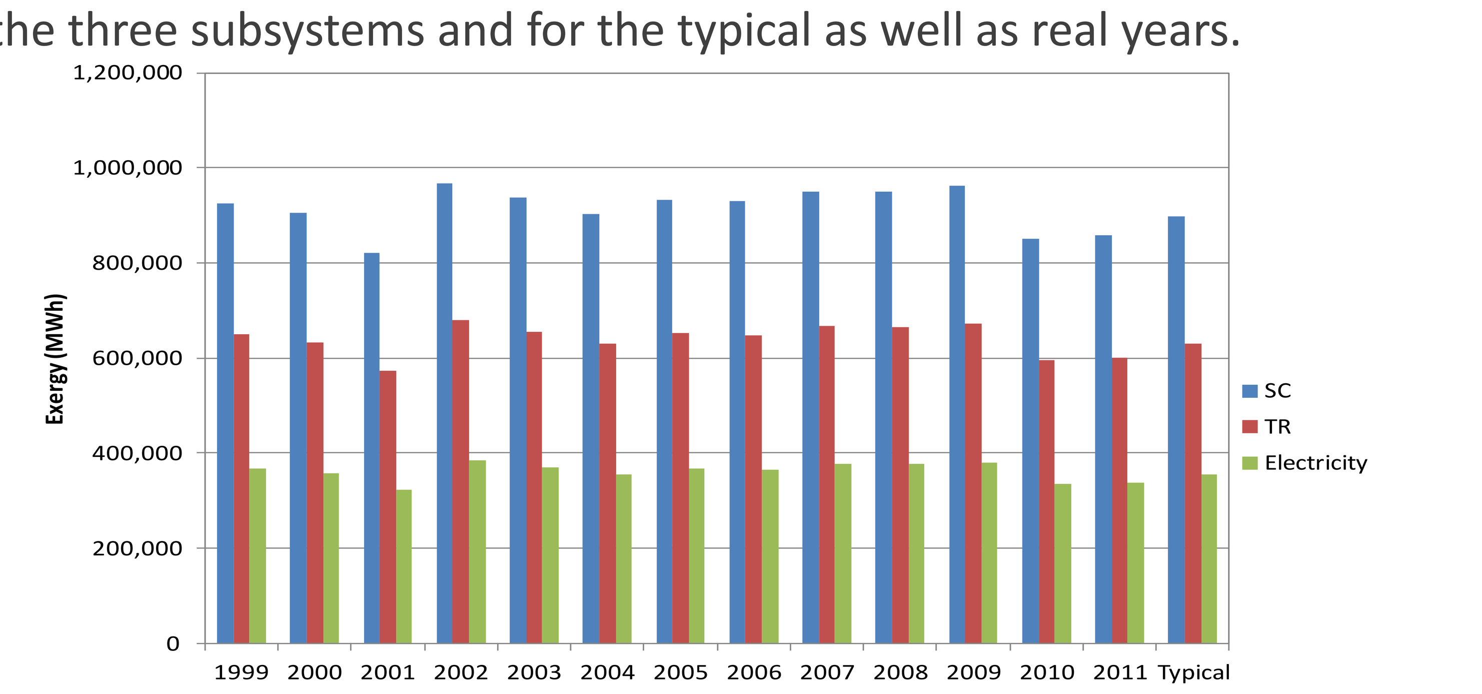

Figure 4: Exergy of subsystems for the typical and real years

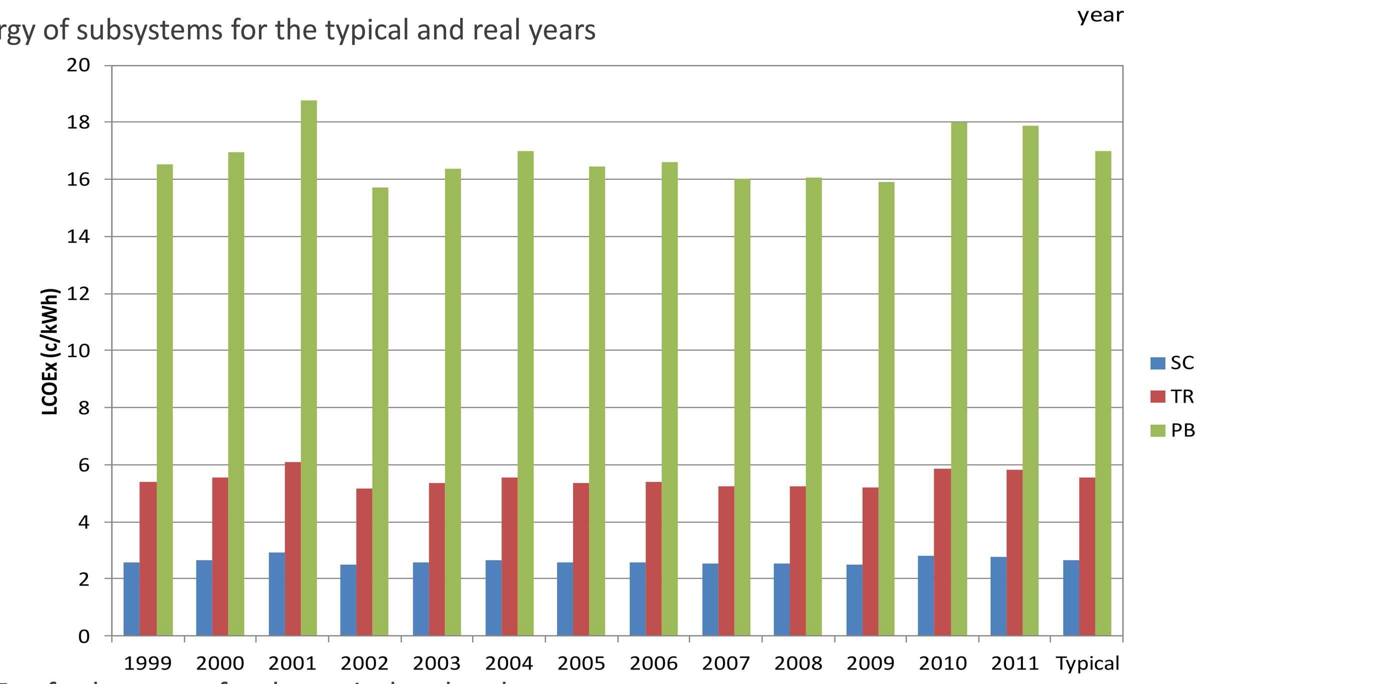

Figure 5: LCOEx of subsystems for the typical and real years

Summary

The reference plant provides a set of standard equipment costs for use in ASTRI and a means of investigating the variability in LCOE arising from changes in costs and solar conditions.

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