Feasibility Study on Solar Process Heat in Jordan Using the Software greenius

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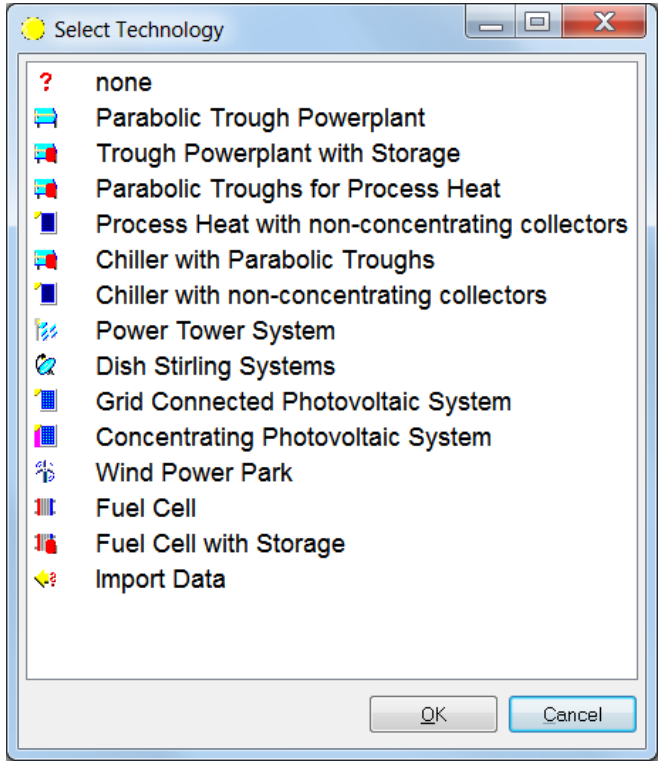
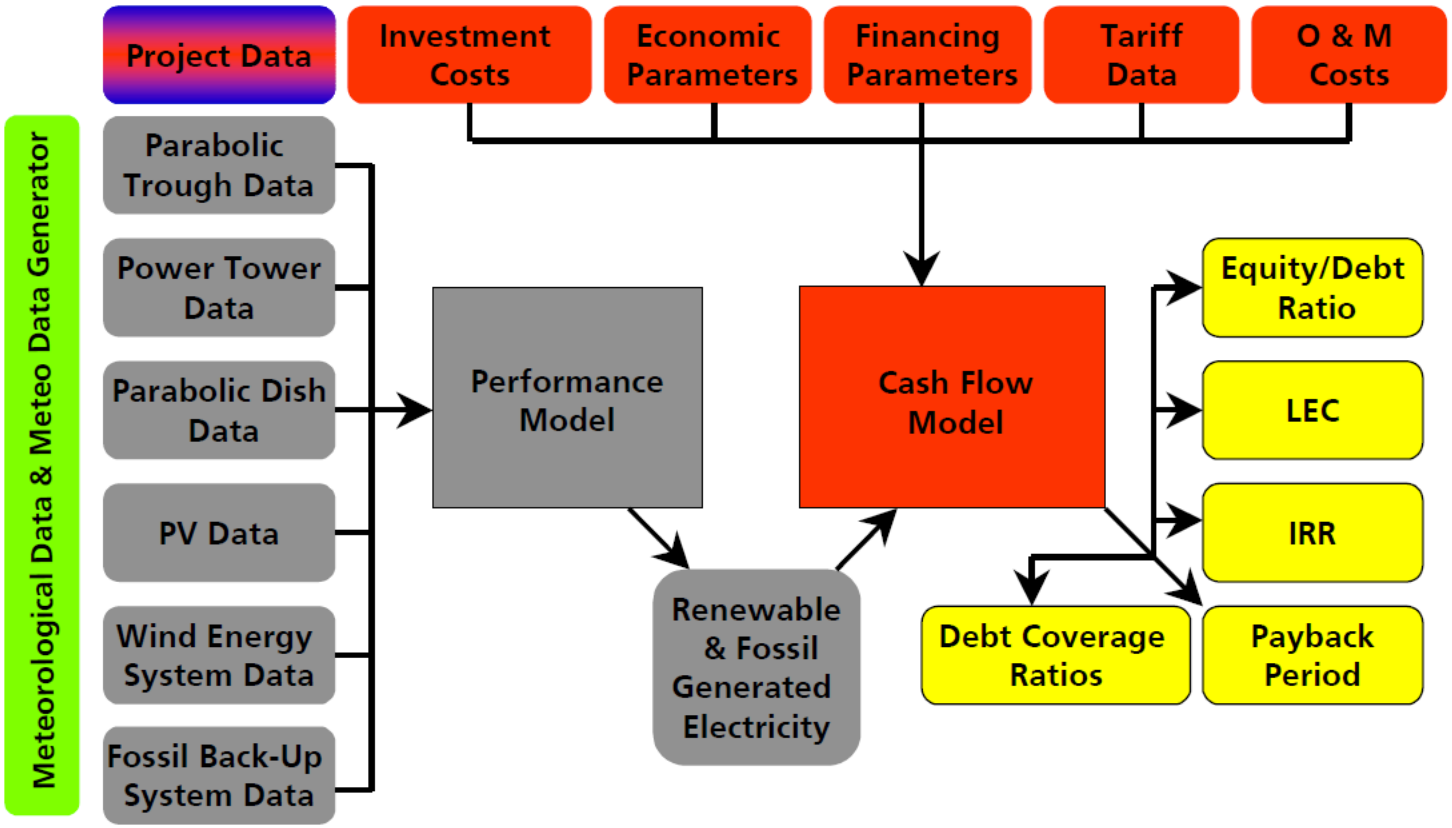
The software tool greenius

- Free & easy
- Simulation of different renewable energy systems for heat or electricity generation
- Main focus on concentrating solar technology
- Customized for fast and simple calculations
- Based on hourly performance simulation of a typical year
- Utilization for e.g. feasibility studies or technology comparisons
- User support by DLR

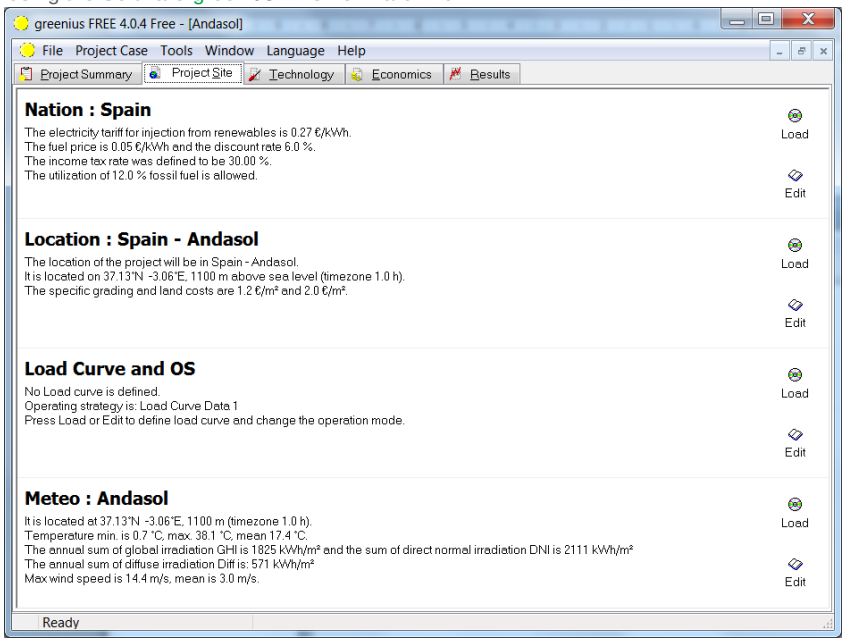


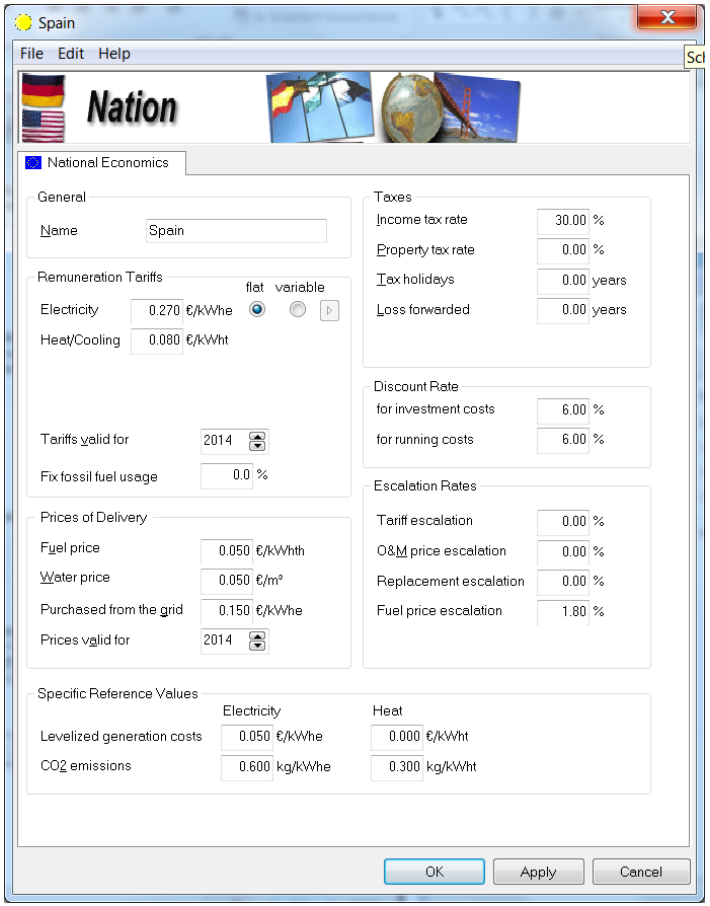
Homepage of **greenius**: http://freegreenius.dlr.de/

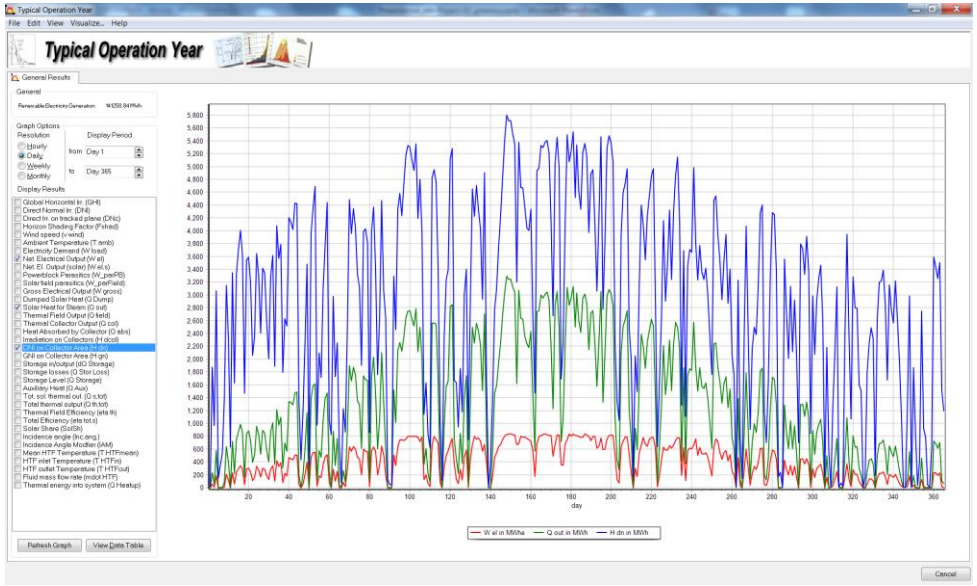
General structure of greenius



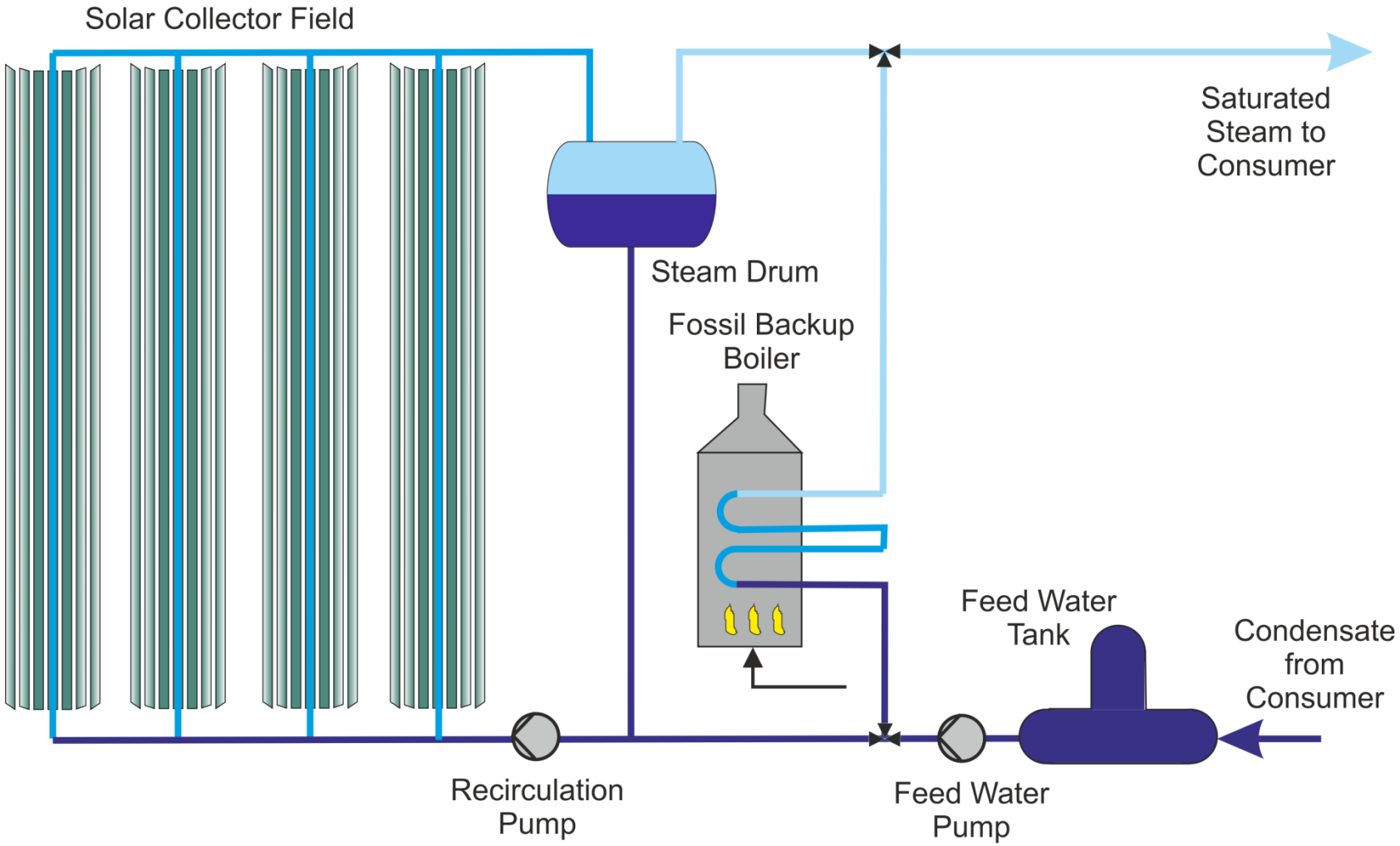
greenius User Interface







Direct Solar Steam Generation with Fresnel Collectors



Feasibility Study – Using Solar Thermal Steam Generation as Fuel Saver

- Solar energy is used to save fossil fuel for steam generation
- Basic solar field parameters:

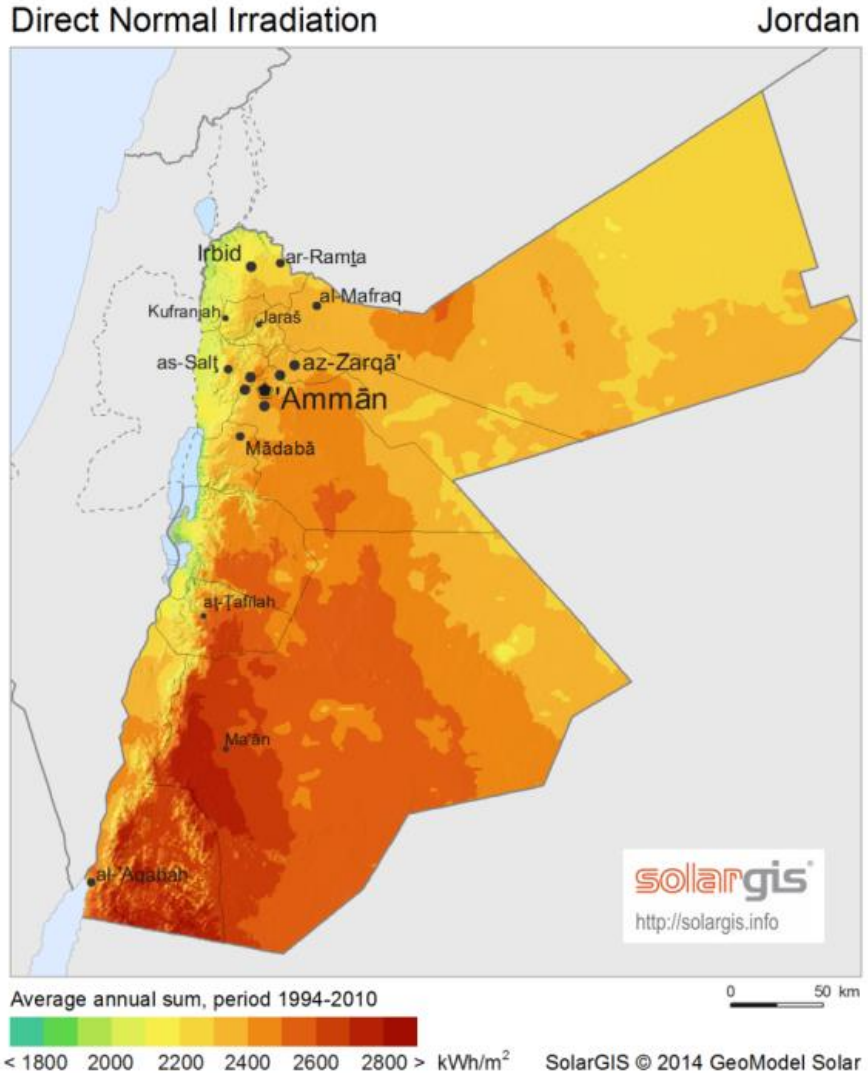
Parameter	Value	Comment
Nominal Steam Production	900kW	1.4 t/h of sat. steam @212°C/20bar
Solar Field Aperture Area	1760 m²	
Required Land Area	3000 m²	e.g. 75m x 40m

Solar Radiation Profile of Jordan

Annual DNI (Direct Normal Irradiation)

- in Ammãn (meteonorm 7):
  2438 kWh/m²
- in Ma'ãn (enerMENA measured data):
  2736 kWh/m² (2011-2015)
- Used for simulation:
  2460 kWh/m²

►very high potential!

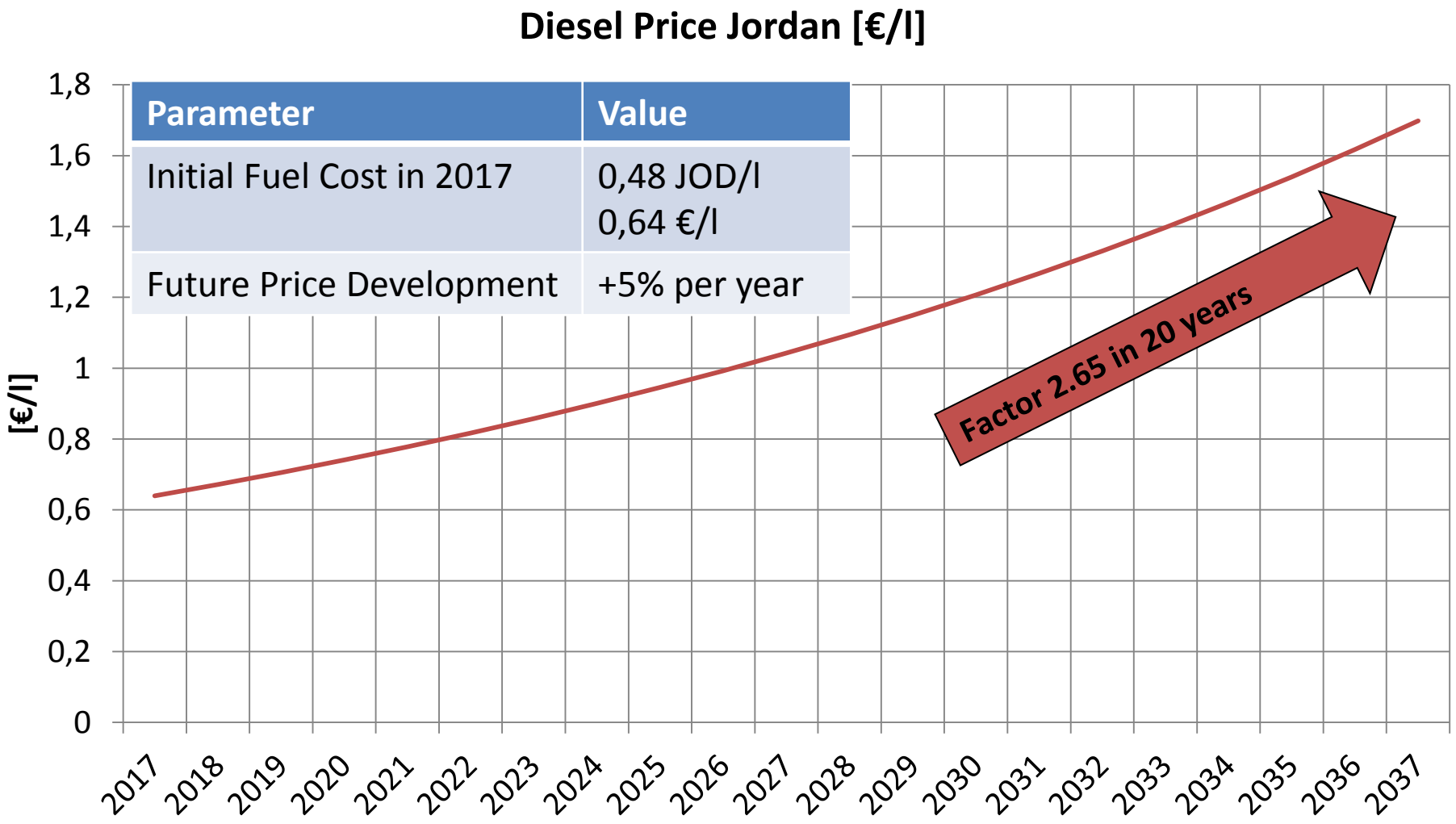


Economic Boundary Conditions

Parameter	Value	Comment
Fossil Steam Generation Cost in 2017	81.7 €/MWh_{th}	Only running cost; boiler efficiency 80%; ex. Rate 0.75 JOD/€
Turn-Key Investment Cost	766 000 €	i.e. 435 €/m² (Industrial Solar costs – 10% incentives)
Running Cost per year	12 000 €	+1% per year
Equity Ratio	20%	
Debt Ratio	80%	
Debt term	10 years	
Debt funding interest rate	4%	

Impact Factor: Future Diesel Price

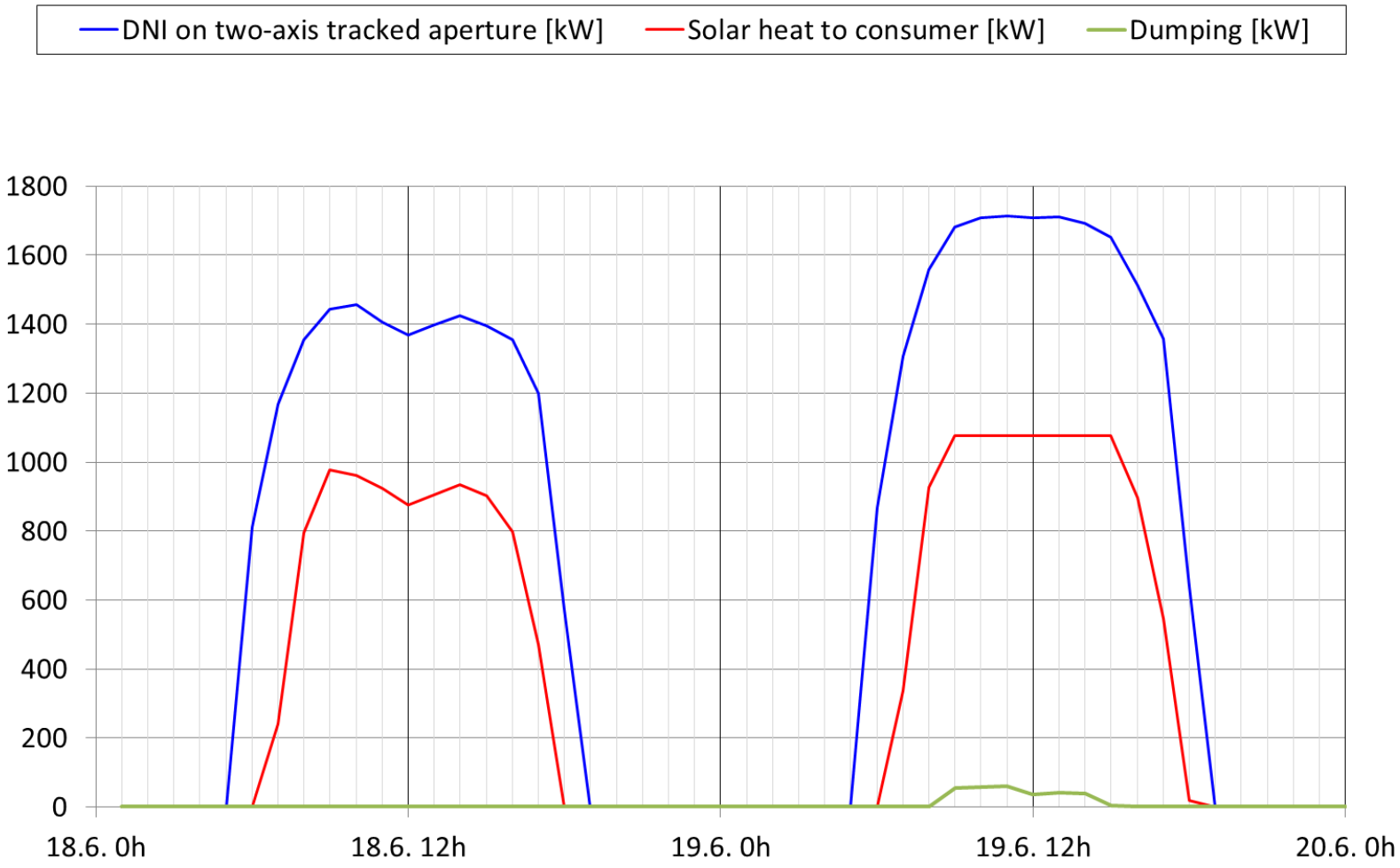
Parameter	Value
Initial Fuel Cost in 2017	0,48 JOD/l 0,64 €/l
Future Price Development	+5% per year



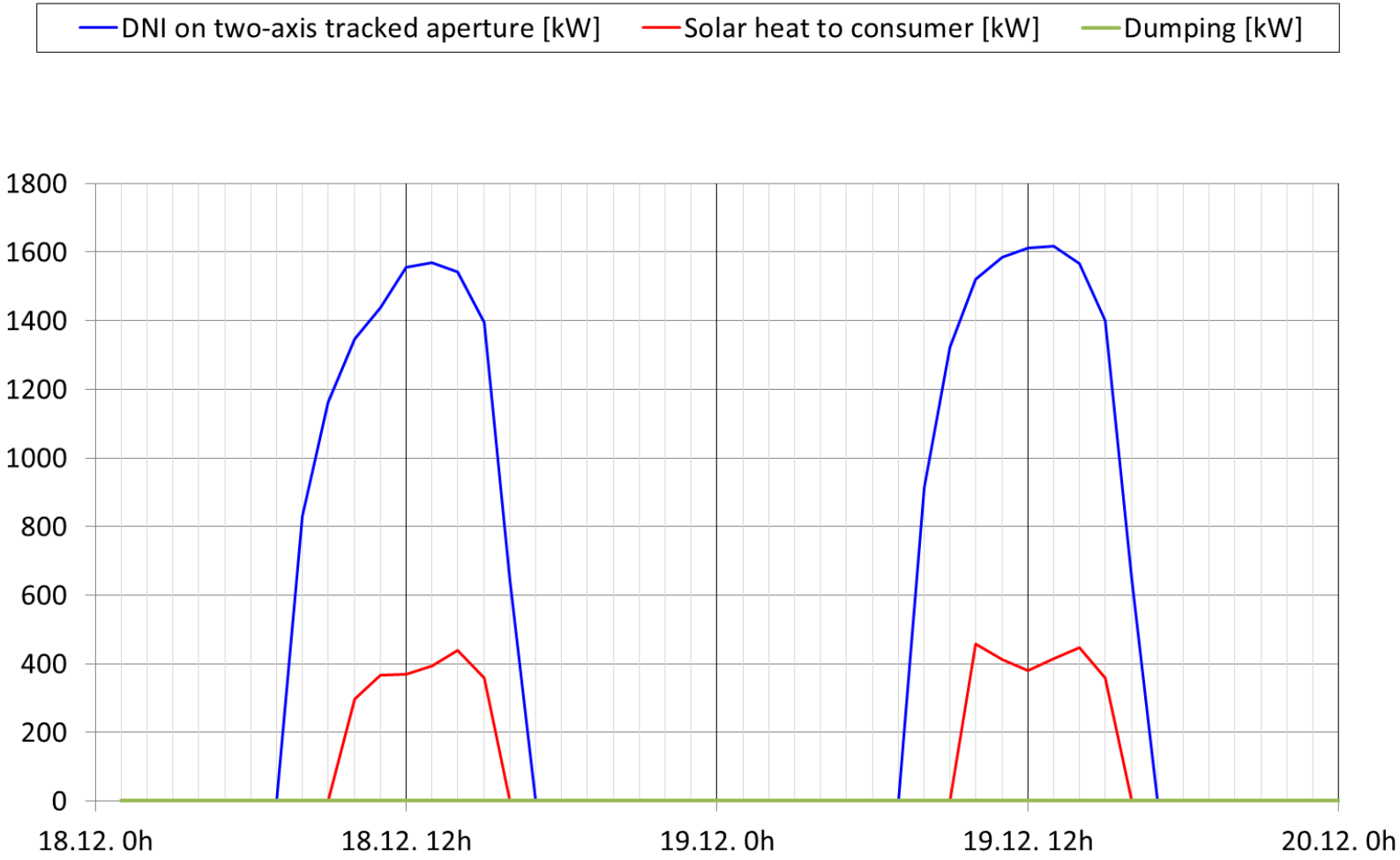
Technical Key Results

Result	Value	Unit
Annual DNI	2460	kWh/m²
Annual Solar Heat Output	1034	kWh/m²
Annual Solar Steam Generation	2765	t
Annual Field Efficiency	42	%

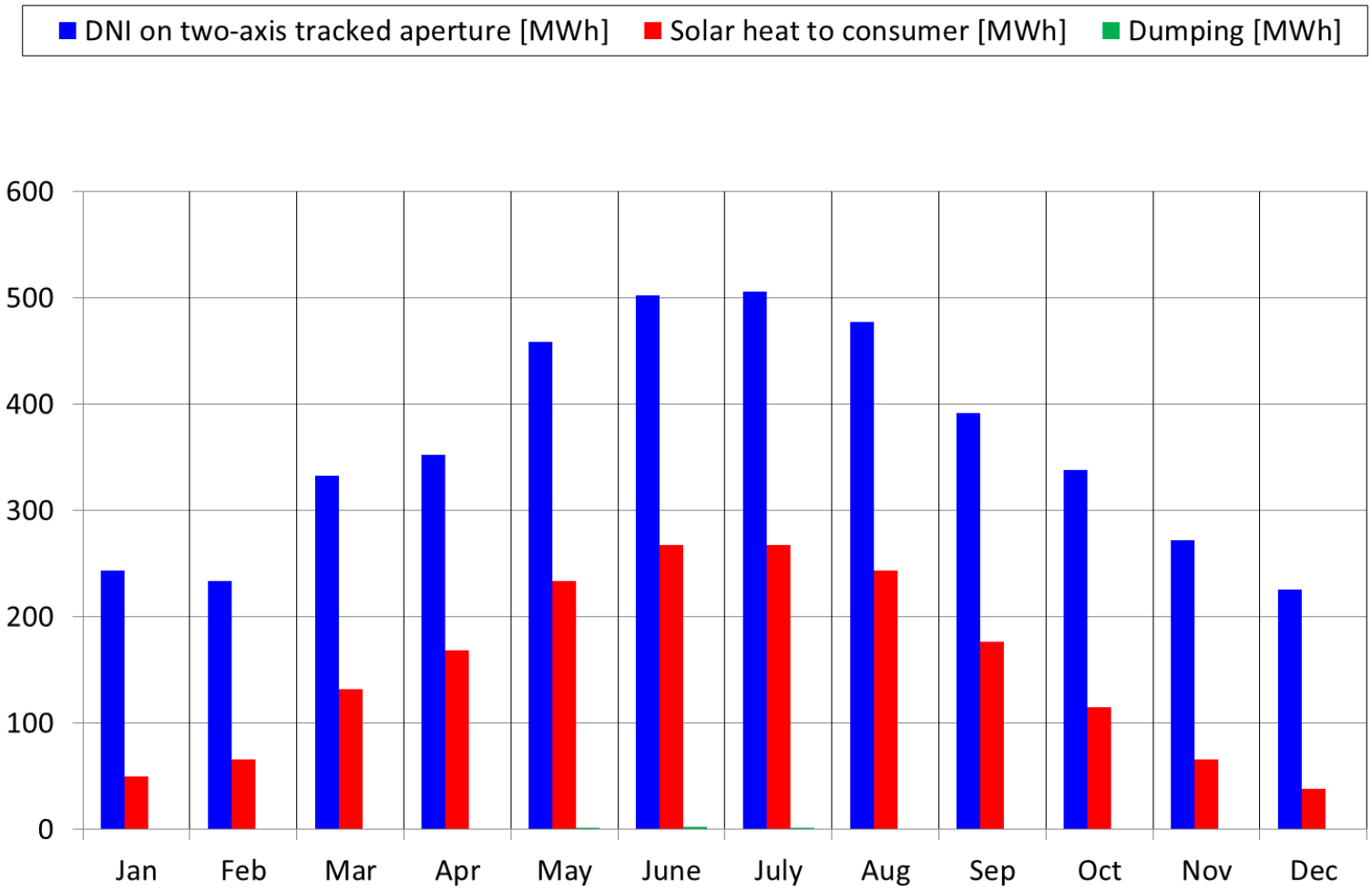
Typical Steam Production Summer



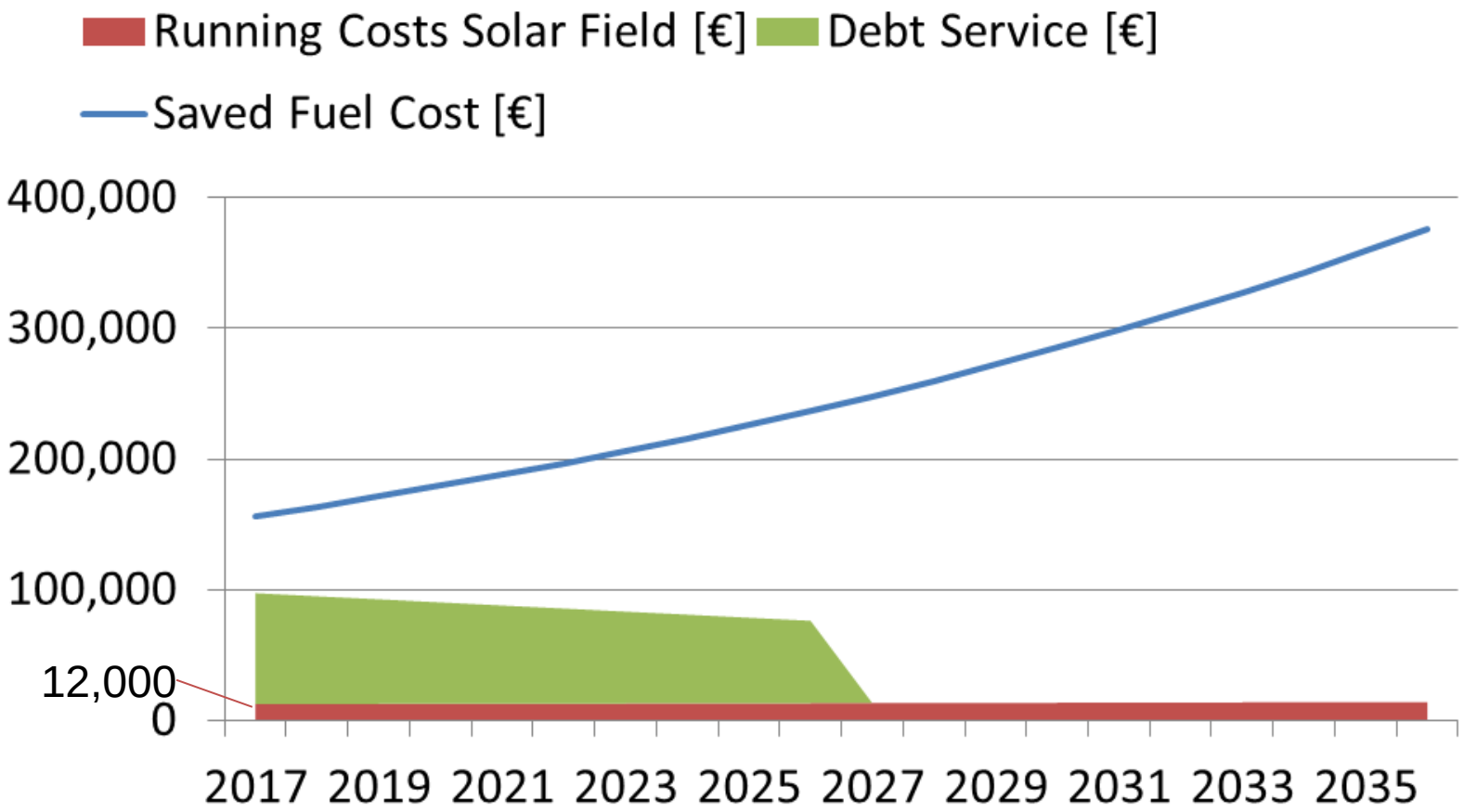
Typical Steam Production Winter



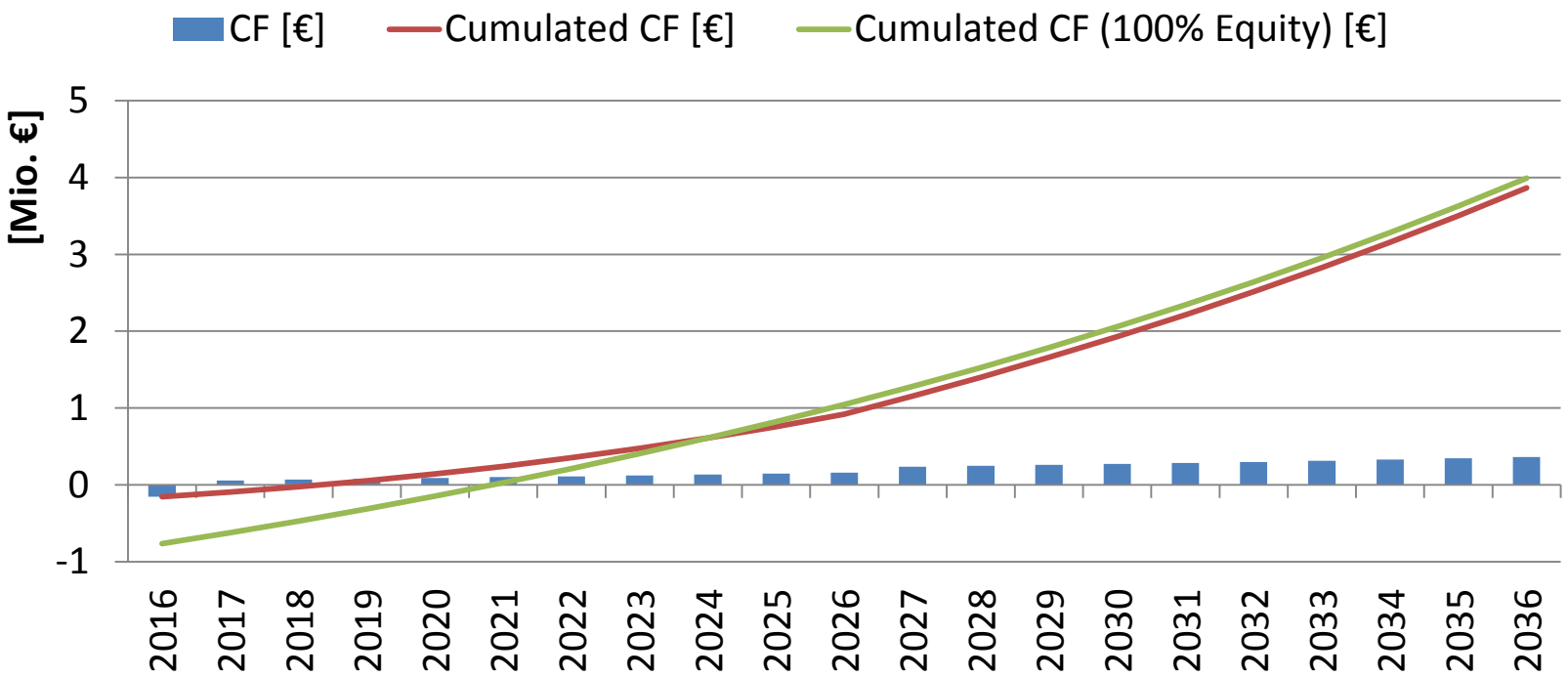
Annual Steam Production Profile



Expected Life Time Savings and Costs of Solar Field



Economic Key Results and Cumulated Cash Flow



Economic Key Results	Base Case	6% Interest	100% Equity	
Payback Time	2.3	2.7	4.8	Years
Internal Rate of Return (IRR)	52	47	23	%
Levelized Heat Cost	41.4	41.4	41.4	€/MWh$_{th}$

Summary

- Jordan has very attractive solar irradiation conditions
- First solar field has already been built
- Technology
  - Direct steam generation (DSG) in Fresnel collectors is efficient and reliable
  - Steam generation varies significantly between summer and winter
  - Turn-Key collector field costs about 435 $/m² (depend on field size)
  - Field efficiency reaches 42%
- Economics
  - Solar collectors produce steam much cheaper (41€/MWh) than Diesel boilers (81€/MWh only fuel costs)
  - Comparison depends significantly on fossil fuel costs
  - Payback time for investments in solar collectors is 2-3 years (20% Equity)
    - Even with constant fossil fuel prices payback time is below 3 years