

---

# Medium and Small Scale Concentrating Solar Thermal Power (MSS-CSP)

---

## Chances and Potentials



Dr. Werner Platzer

Fraunhofer-Institut für  
Solare Energiesysteme ISE

SolarPaces Workshop  
Berlin, 16th September 2009



---

## Content

- Introduction
- Demand worldwide
- Collectors for MSS-CSP
- Heat engines
- Case studies
- Outlook



Aerial view of the solar power stations SEGS III to VII (Solar Electric Generating Systems), KJC, Kramer Junction, California, with an installed capacity of 30 MW each.

## Motivation

- Larger power stations using Concentrated Solar thermal Power ( $CSP > 20 \text{ MW}_{el}$ ) is available on the market having levelised electricity costs (LEC) between 0,15 – 0,25 €/kWh (2006) and predicted price reductions of 50% until 2015
- Large power stations require appreciable planning efforts and financial expense
- There is increasingly experience and development in alternative heat engines from ORC turbines to steam piston motors and screw compressors in a lower nominal power range
- Photovoltaics, wind power and biomass projects have shown to be successfully implemented by cooperative public investment projects

---

## Potential disadvantages of smaller projects

- Lower efficiencies  
(lower temperature levels, less complex thermodynamical processes)
- Suitable heat engines not available
- higher specific planning costs
- higher specific investment costs

---

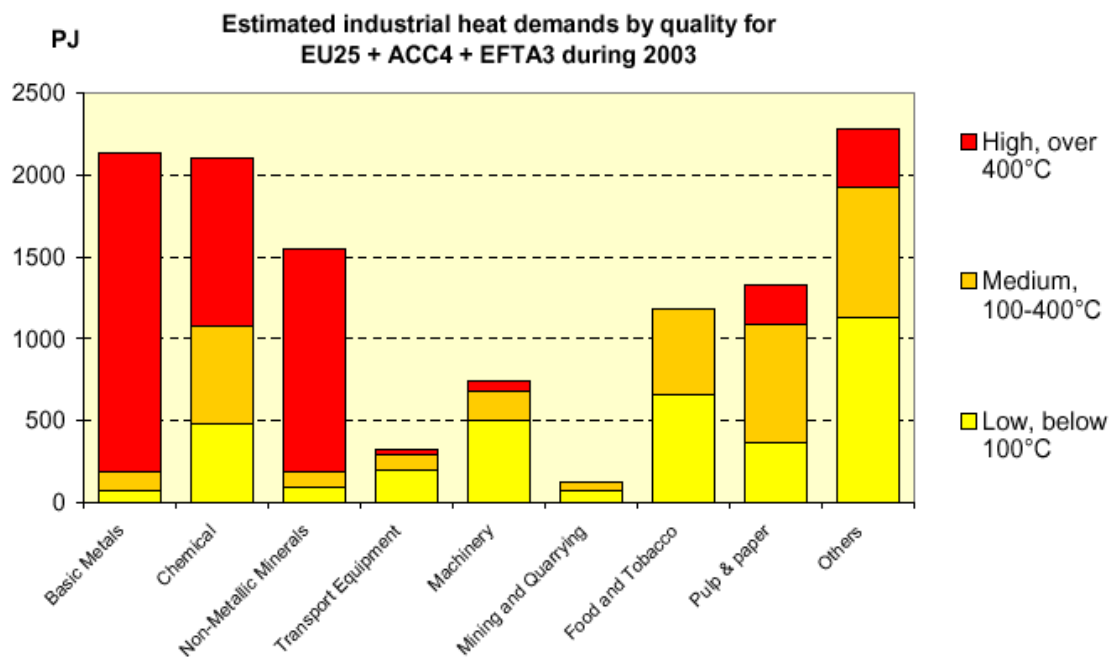
## Potential advantages of smaller projects

- Coupling with heating or cooling consumer loads with matching nominal power possible
- Off-grid systems may replace more expensive solutions using e.g. Diesel engines
- Series production of components -> basis for cost degression
- Less complex operation, lower temperatures -> lower component costs

# Content

- Introduction
- Demand and potentials
- Collectors for MSS-CSP
- Heat engines
- Case studies
- Outlook

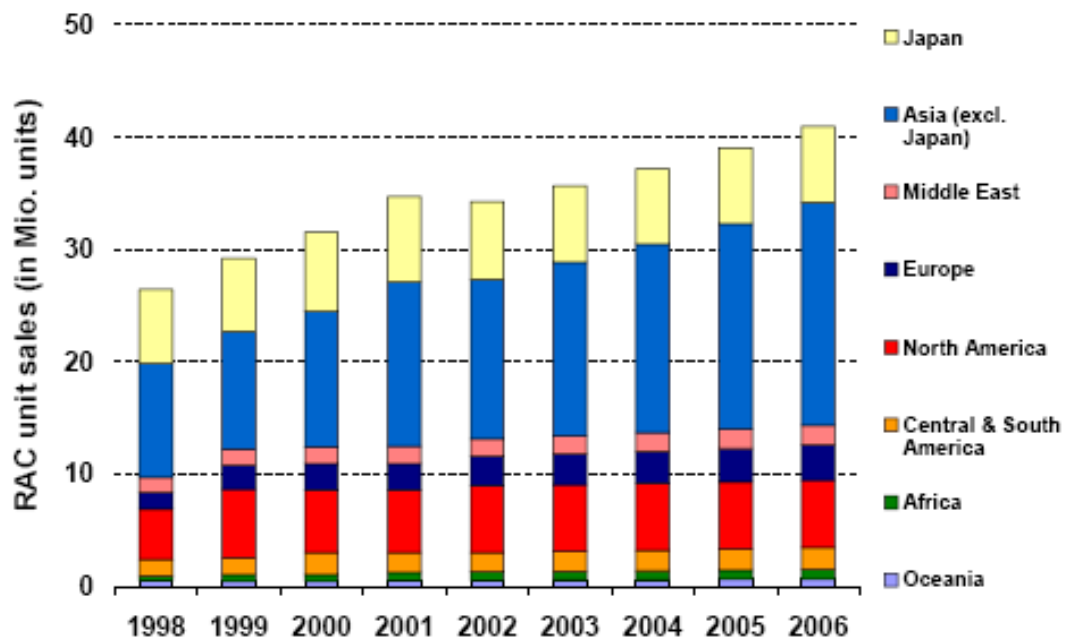
## European Demand for Process Heat



=> about 55% (6500 PJ/a) below 400°C

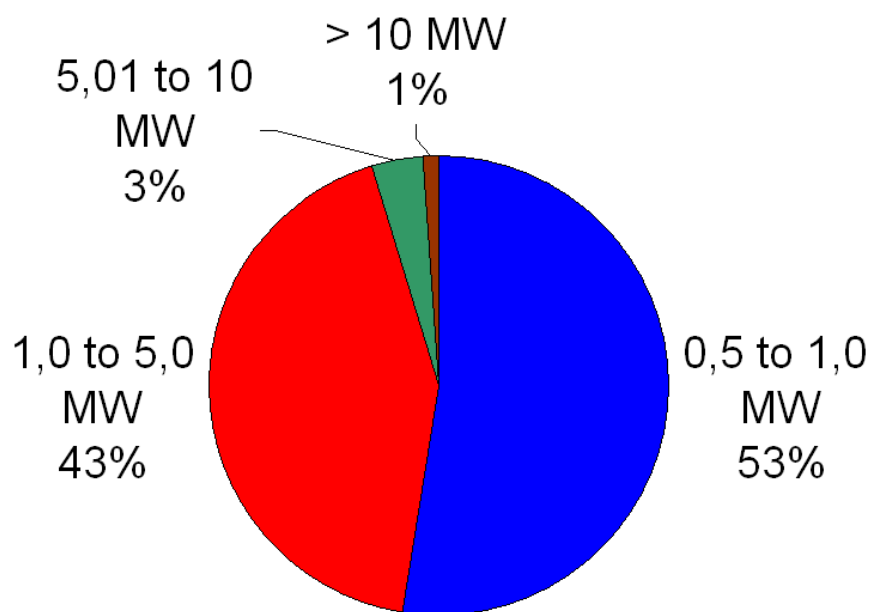
Source: Ecoheatcool.org

# Cooling Demand



9

# Yearly Sales of Diesel Generators for Continuous Operation

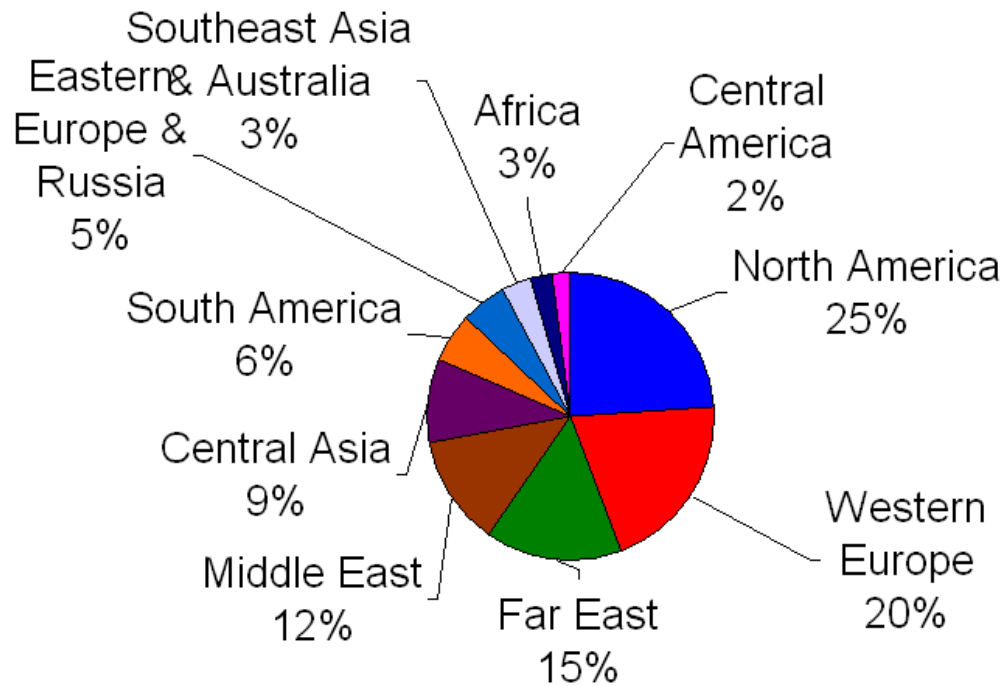


> 9000 Units

<http://www.diesलगasturbine.com>

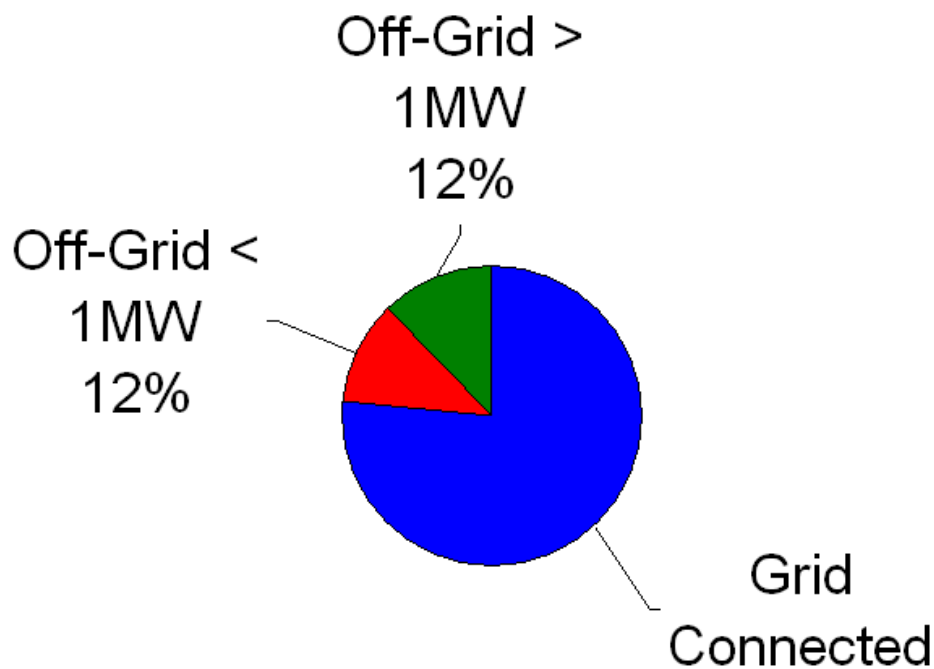
10

## Regional Distribution



11

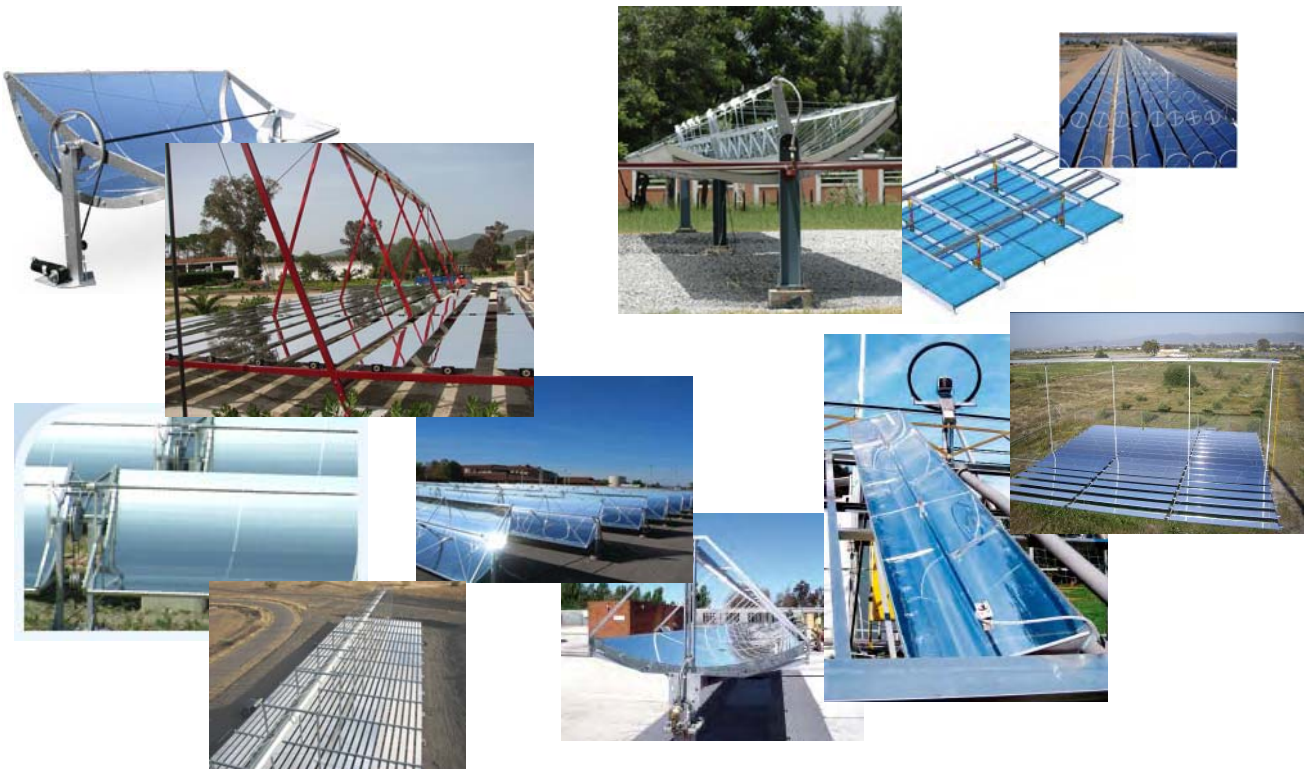
## Example India



12

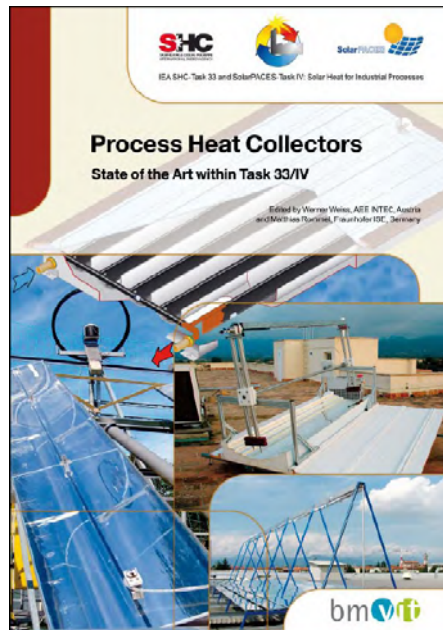
# Content

- Introduction
- Demand worldwide
- Collectors
- Heat engines
- Case studies
- Outlook



# Overview of collector types for process heat

- IEA Task 33
- From improved flat-plate collectors to vacuum tube receivers to concentration collectors
- Performance data partially available
- Cost information missing

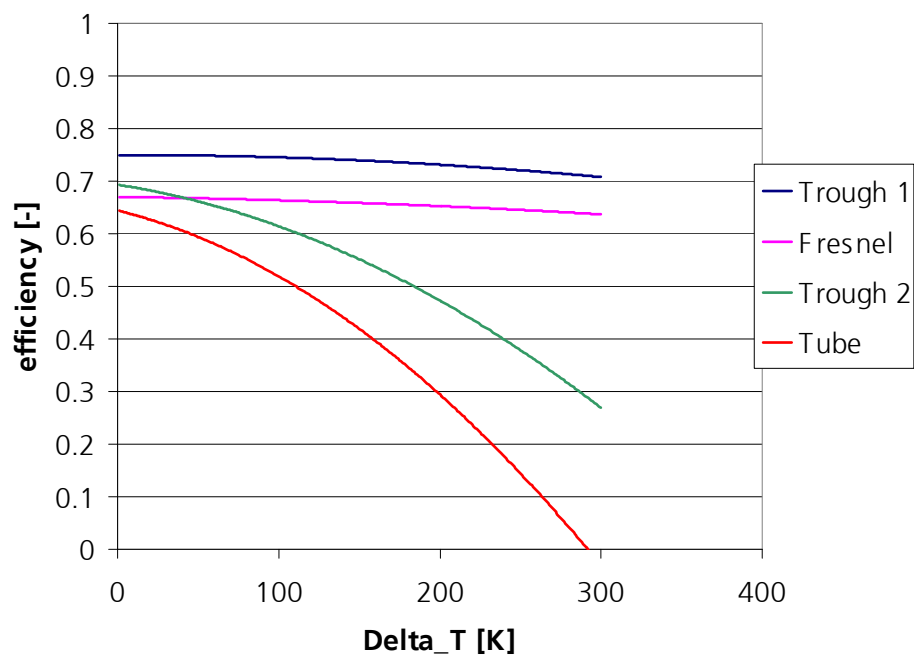


Overview Collector Developments

Collector Type	Operating Temperature [°C]	Heat Transfer Medium	Task 33/IV Contact Person
<b>JAK CPC</b> Collector Type: Evacuated Collector L50 - L50 Water/Glycol			Frank Wallinger JAK Bawin Industriestraße 10, 6 82474 Gerding, Germany
<b>Evacuated Tube Collectors</b>			Task 33/IV Contact Person
<b>Evacuated Tubular Collector</b> E16-10000 E1 - L16 Water/Glycol			Hartmut Rossmann Fraunhofer Institute for Solar Energy Systems Fraunhoferstr. 1 79110 Freiburg, Germany
<b>Parabolic Trough Collectors</b>			Task 33/IV Contact Person
<b>PARASOL</b> Parabolic Trough Collector E16-10000 Water / 90 Bar			Dieter Jöchl AEE INTEC Friedhof 19 8200 Gröden, Austria
<b>SOLTECH PTC 1800</b> Parabolic Trough Collector E16-10000 Water			Klaus Hornschke DLF Institute for Technical Thermodynamics 11179 Berlin, Germany
<b>MSP SOLAR Parabolic Trough 1300</b> Parabolic Trough Collector E16 - L16 Water			Julian Green, Adelaide Hillside New Energy Research Pty Ltd Level 2, 100 St 801 Perth Highway Gardiner Hill, 5012, Australia

26 Process Heat Collectors

## Efficiency curves for generic collectors



---

# Content

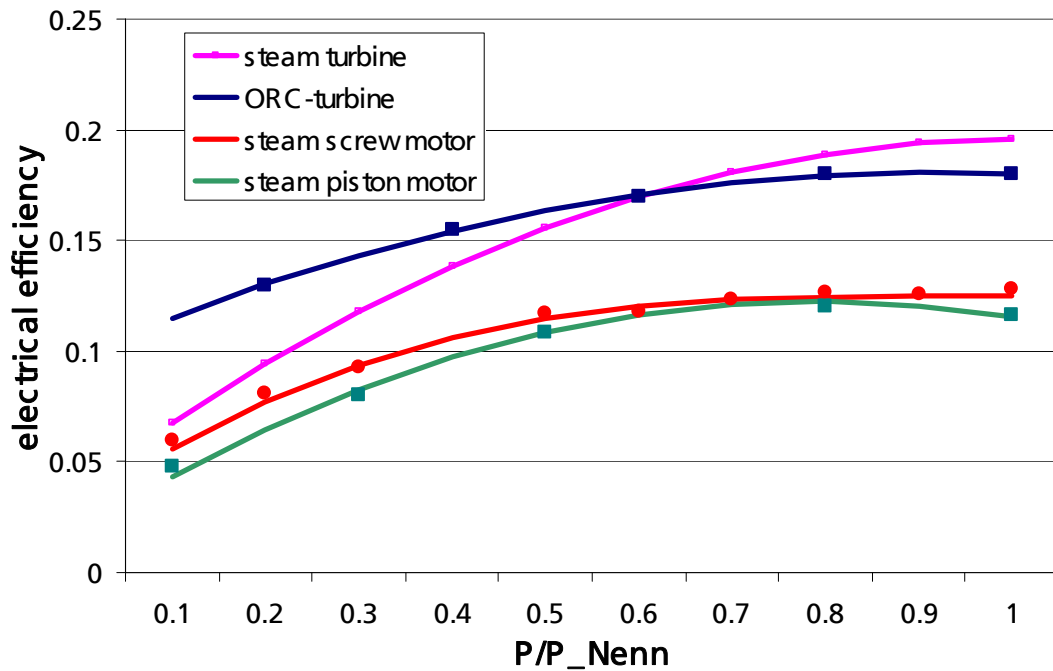
- Introduction
- Demand worldwide
- Collectors
- Heat engines
- Case studies
- Outlook

---

# Characterisation of power block

- Data from manufacturers and publications
- Steam engines
- Smaller engines in prototype stadium
- Cost data for complete power block (pumps, heat exchanger, controls,...)

## Part load behaviour of heat engines



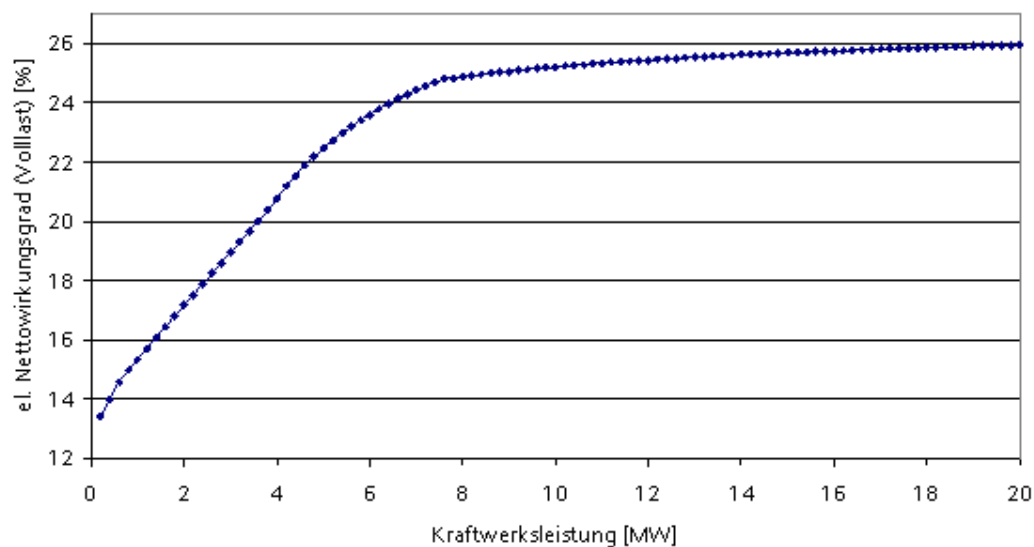
Example:

Nominal power: 1 MW<sub>el</sub>

Field outlet: 300°C

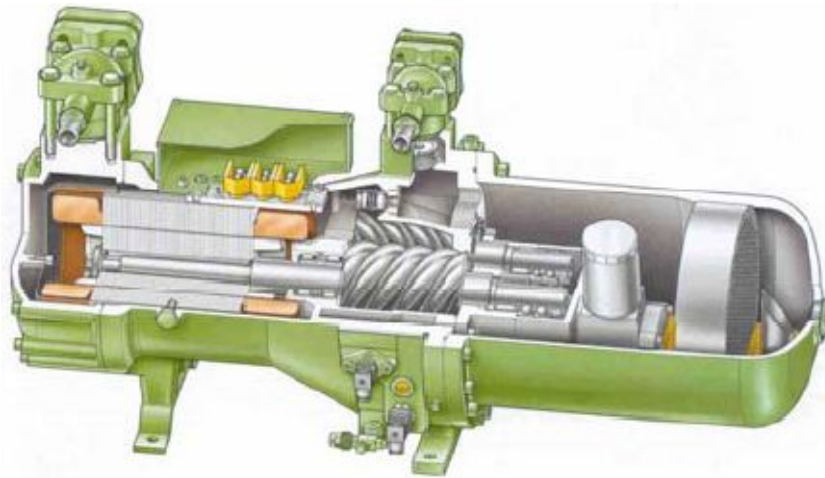
## Turbines: Efficiency is depending on size and mass flow!

Example: Saturated steam at 270 °C and 55 bar

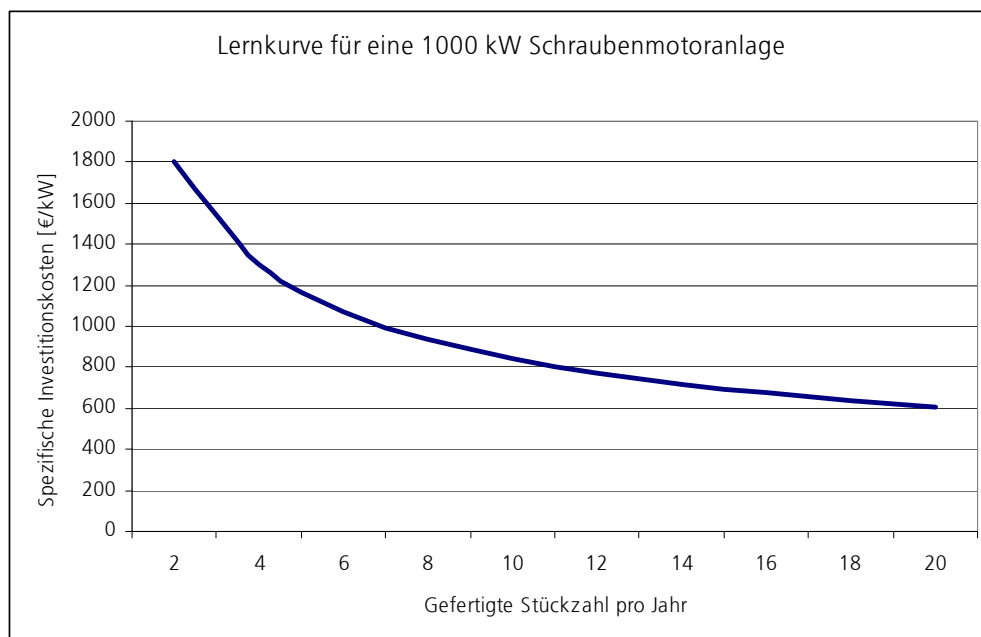


## Screw motor

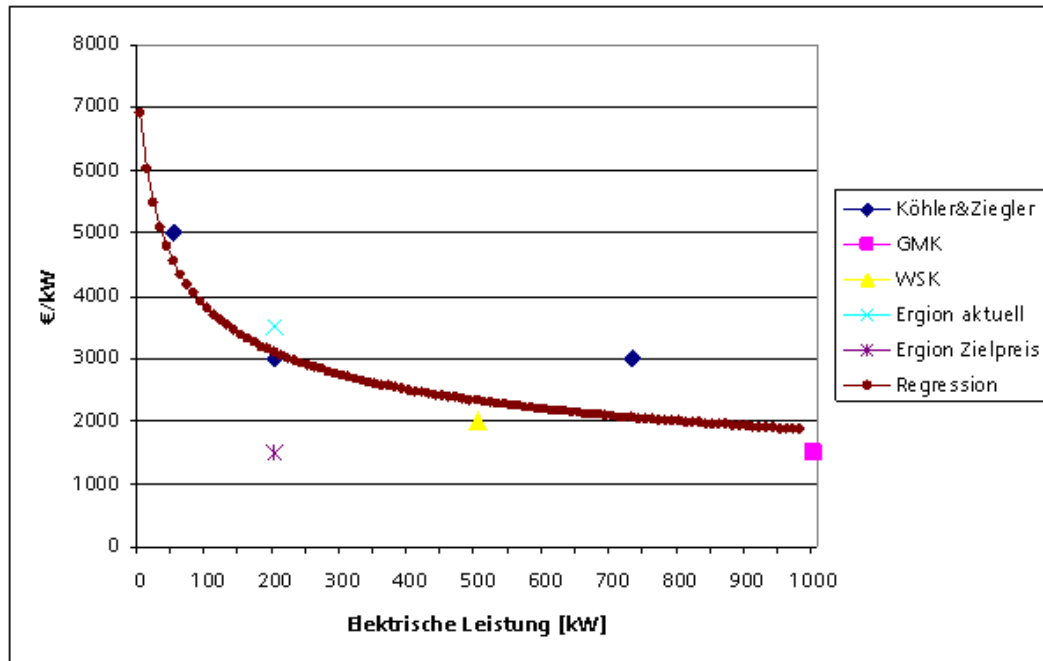
- Screw used in compressors, copes with saturated steam
- Power range 100 – 200 kW<sub>el</sub>, different developments



## Prognostizierte Lernkurve

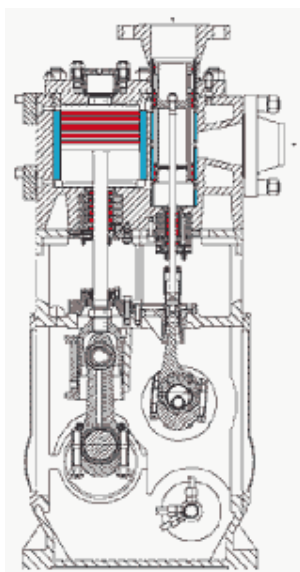


## Spezifische Schraubenmotor-Kosten



23

## Piston motor

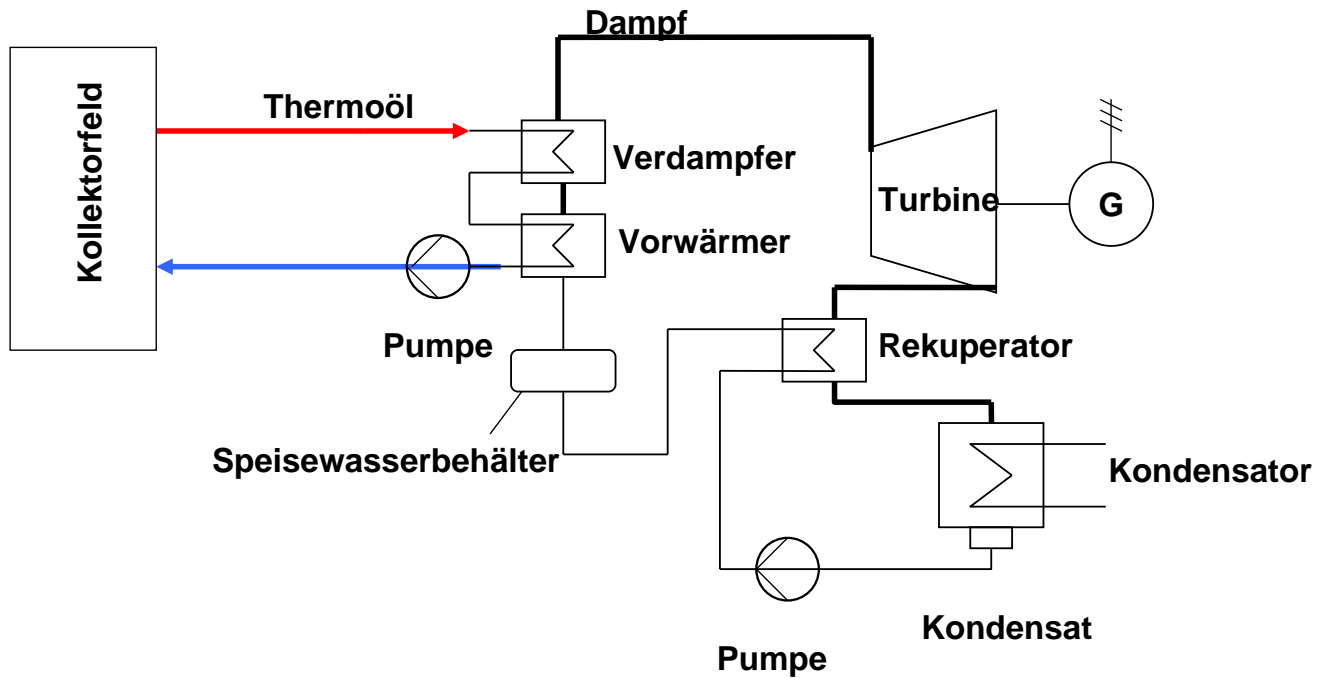


- Power range 25 to 1.500 kW
- Suitable for saturated steam
- Only one manufacturer



24

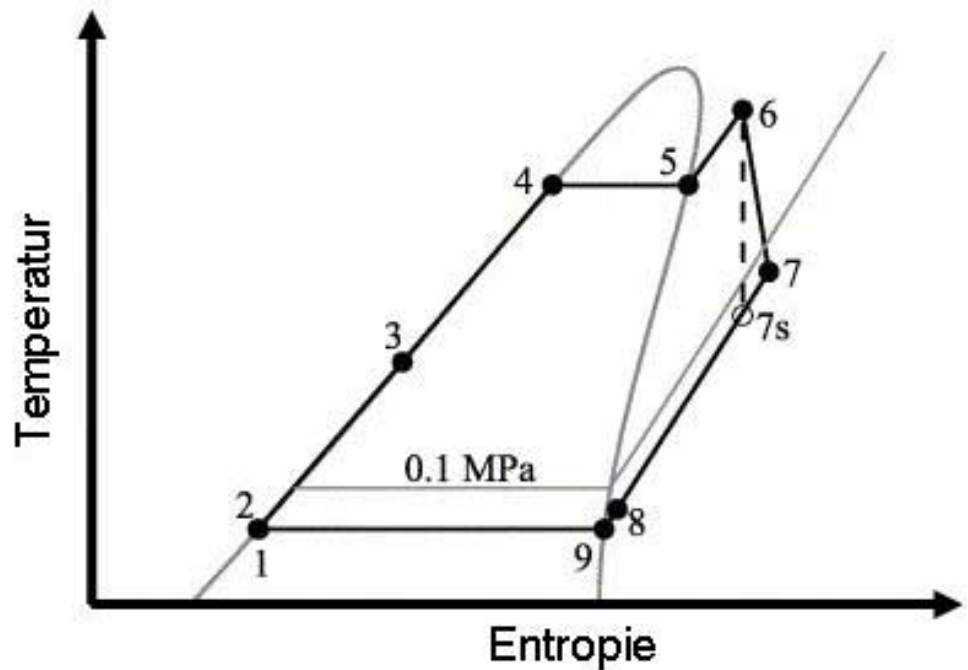
# Organic Rankine Prozess (ORC)



25

# ORC – Organic Rankine cycle

No condensation during expansion!



26

---

## Range of ORC-Turbines

• Adoratec	315 - 1500 kW <sub>el</sub>	270 – 320 °C	18%
• GMK mbH	100 - 1500 kW <sub>el</sub>	275 °C	20%
• Turboden S.r.l	200 - 2000 kW <sub>el</sub>	265 °C	18%
• Barber Nichols	10 - 2700 kW <sub>el</sub>	265 °C	18%
• UTC Power	225 kW <sub>el</sub>	75 °C	8%
• Adaturb GmbH	30-60 kW <sub>el</sub>	270 °C	18%

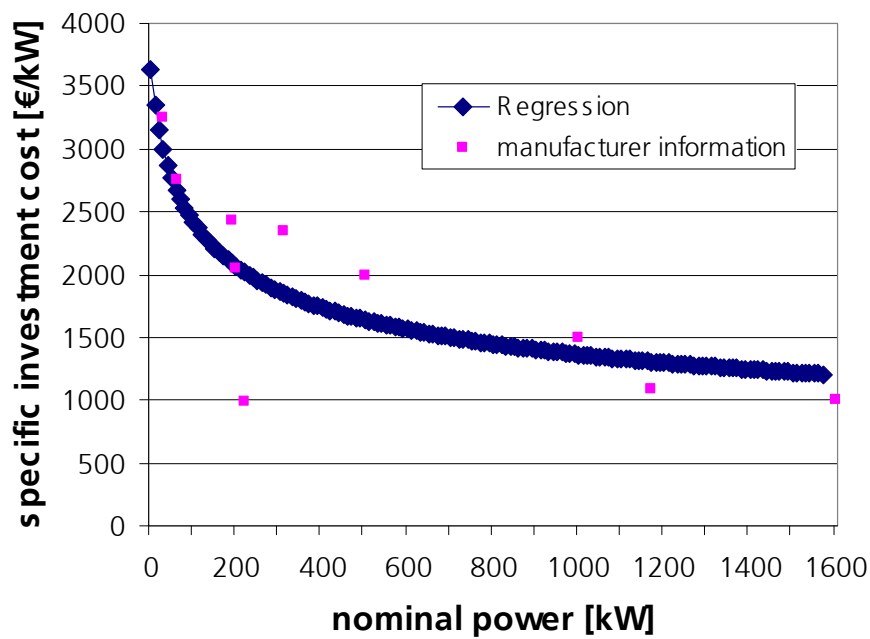
---

## Ausblick

- Leistungsspezifische Kosten (700 kW<sub>el</sub>) uneinheitlich:

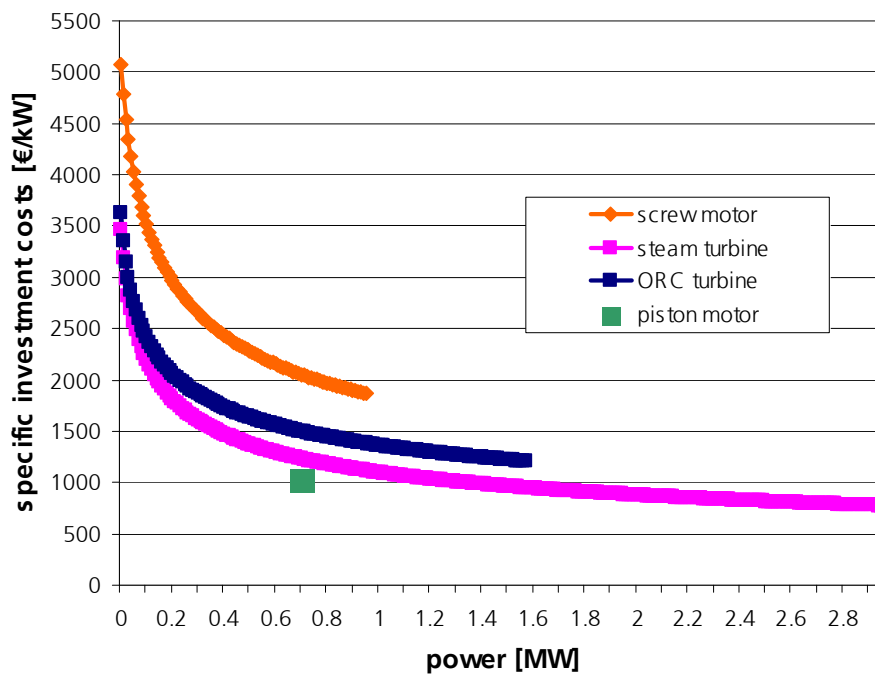
Turbinen	1250 €/kW	19%
Dampfschraube	2100 €/kW	13%
Dampfmotor	1000 €/kW	12%
Zentrifugalkompressor	700 €/kW	
ORC-Turbine	1500 €/kW	18%

## Cost function for ORC turbines



29

## Cost functions of heat engines



30

## Cost situation not clear

- Efficiency losses for smaller engines have technical and economical reasons (e.g. gap losses for turbines)
- Specific costs (200 kW<sub>e,l</sub>) very vague:

turbines	700 – 2000 €/kW
steam screw projection	3000 – 3500 €/kW
steam piston motor	900 – 1100 €/kW
ORC-Turbine	1500 – 3000 €/kW

## Absorption Cooling

**single-effect absorption** many products > 100 kW;  
few products <100 kW;  
water/LiBr,  $T_{\text{drive}} \approx 75^{\circ}\text{C} \dots 110^{\circ}\text{C}$   
ammonia/water,  $T_{\text{drive}} > 160^{\circ}\text{C}$   
COP $\approx$ 0.7;



**double-effect absorption** several manufacturers;  
often direct fired;  
no products <100 kW;  
in most cases water/LiBr;  
COP $\approx$ 1.1;  $T_{\text{drive}} \approx 140^{\circ}\text{C} \dots 180^{\circ}\text{C}$



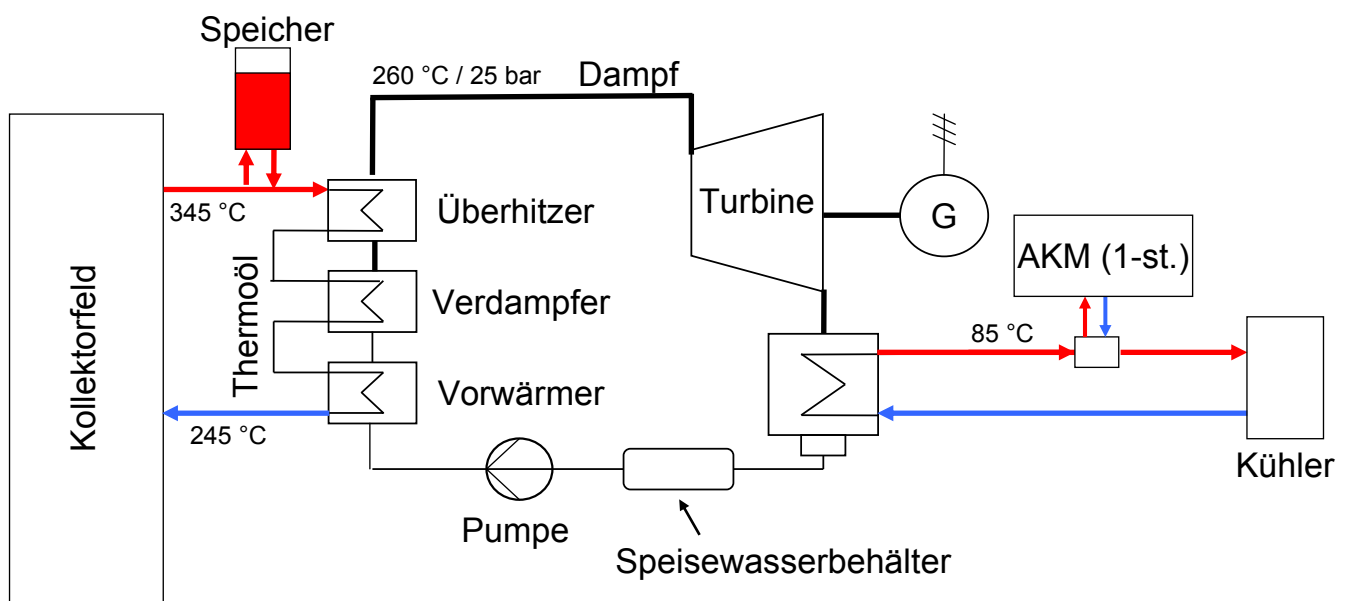
Source: Henning, Fraunhofer ISE

# Content

- Introduction
- Demand worldwide
- Collectors for MSS-CSP
- Heat engines
- Case studies
- Outlook

33

## Case Study 1: Combined Cooling Grid-connected

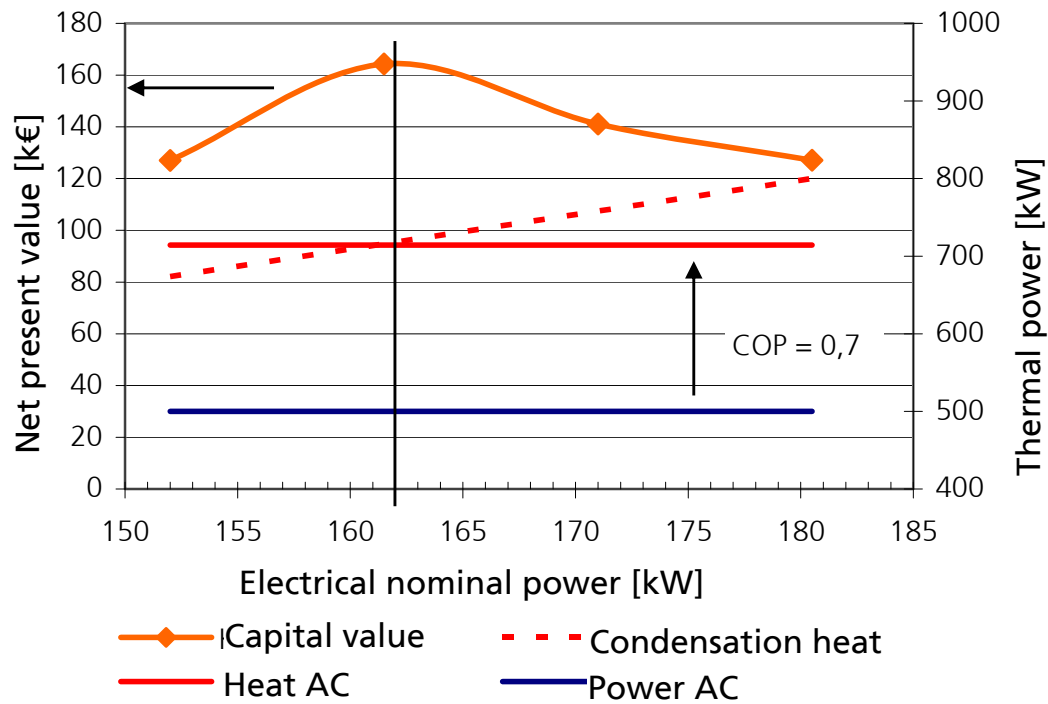


Location Faro, Portugal with Feed-in tariff 27 Cent/kWh

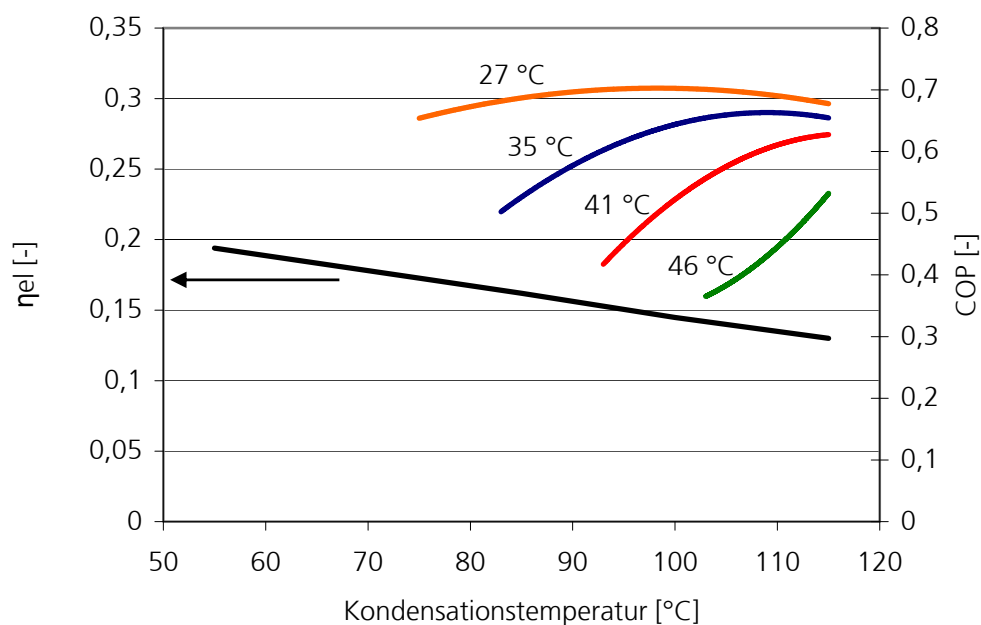
Cooling demand 500 kW at 6°C 24h -> 4,4 GWh/a

34

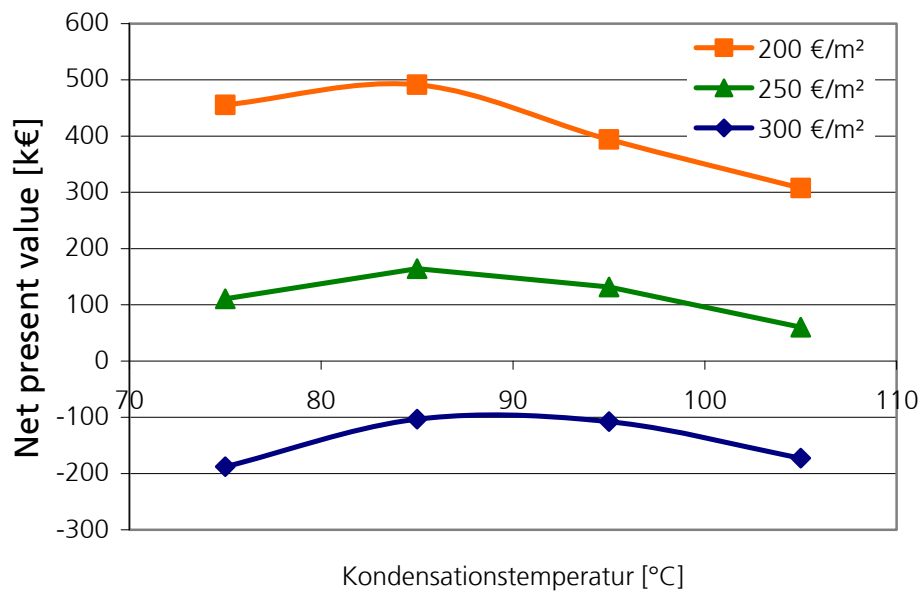
## Optimal Nominal Power



## Efficiency power block and COP Absorption Cooler

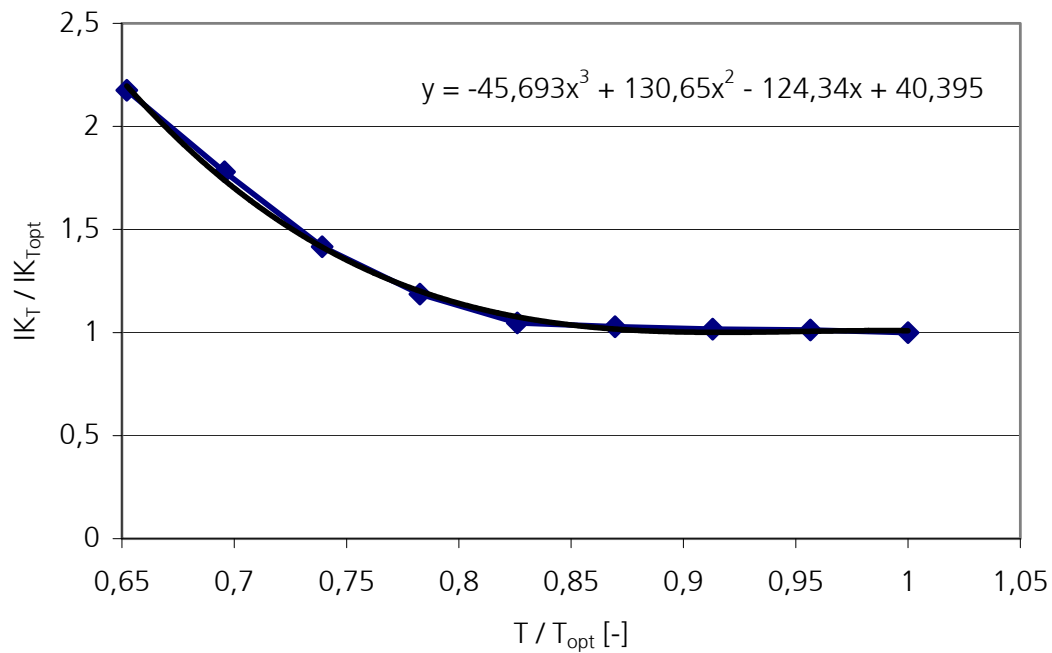


# Optimization Condensation Temperature



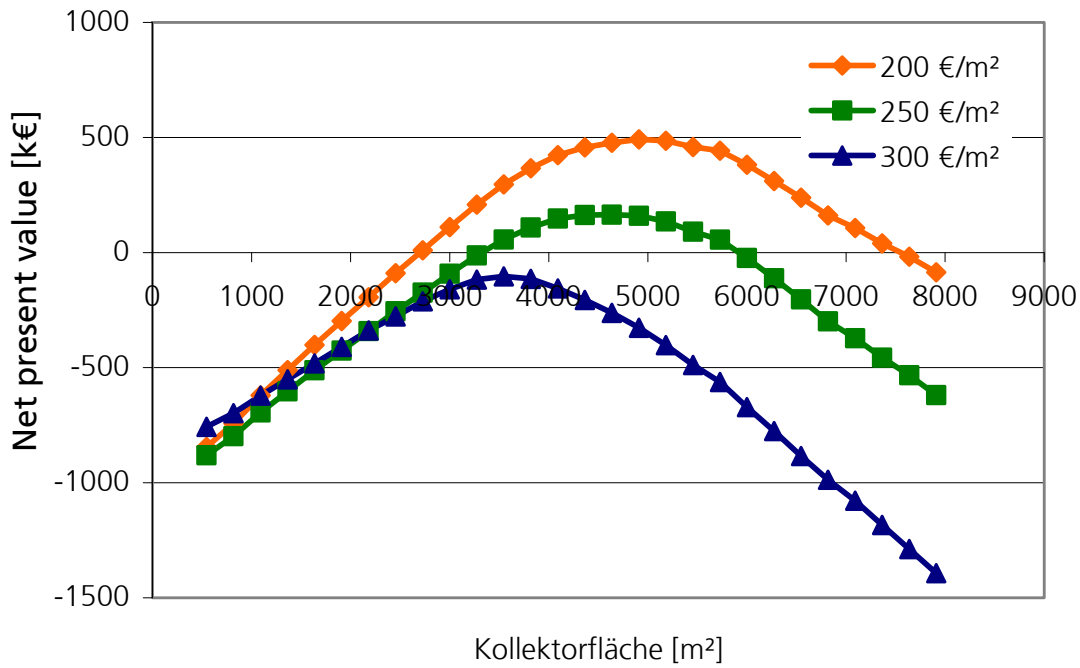
37

# Investment Cost for Absorption Cooling

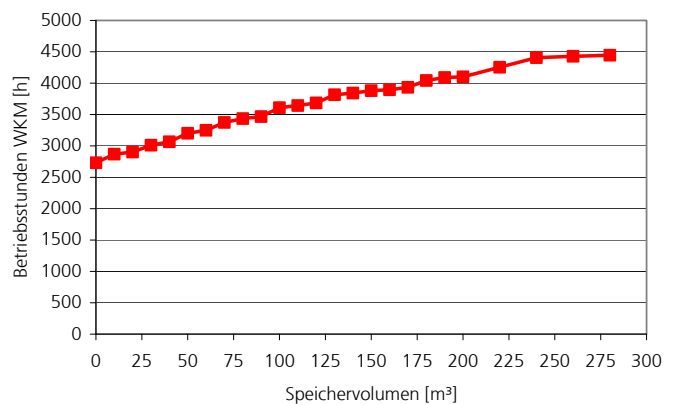
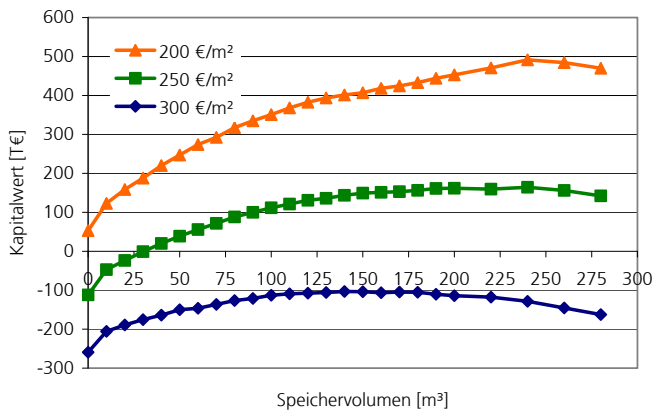


38

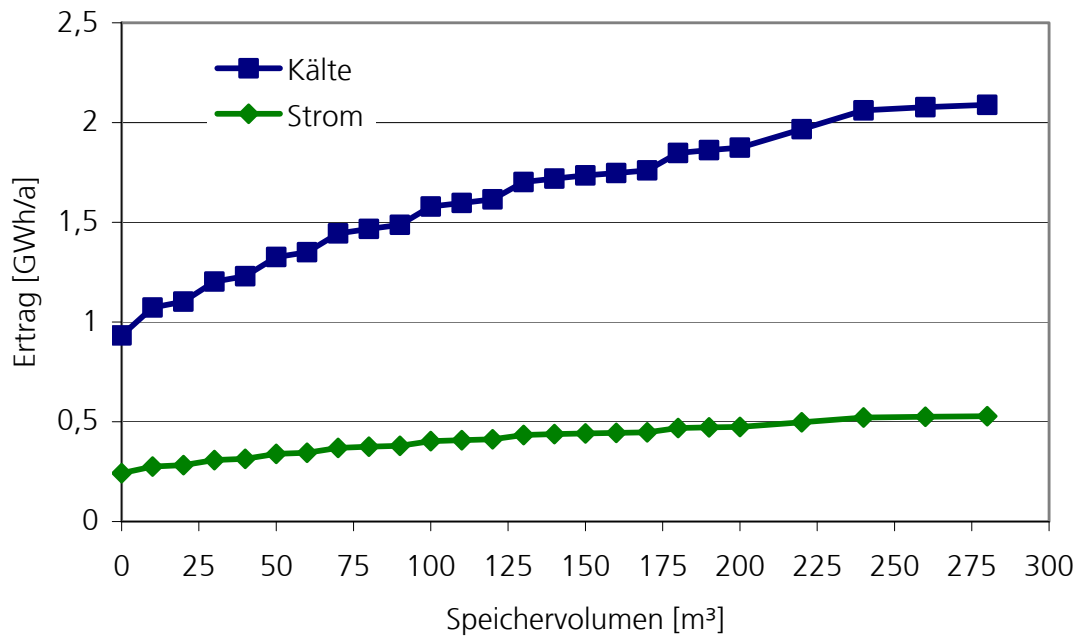
# Optimization of Solar Field Area



# Optimization of Storage Size



# Optimization of Storage Size



41

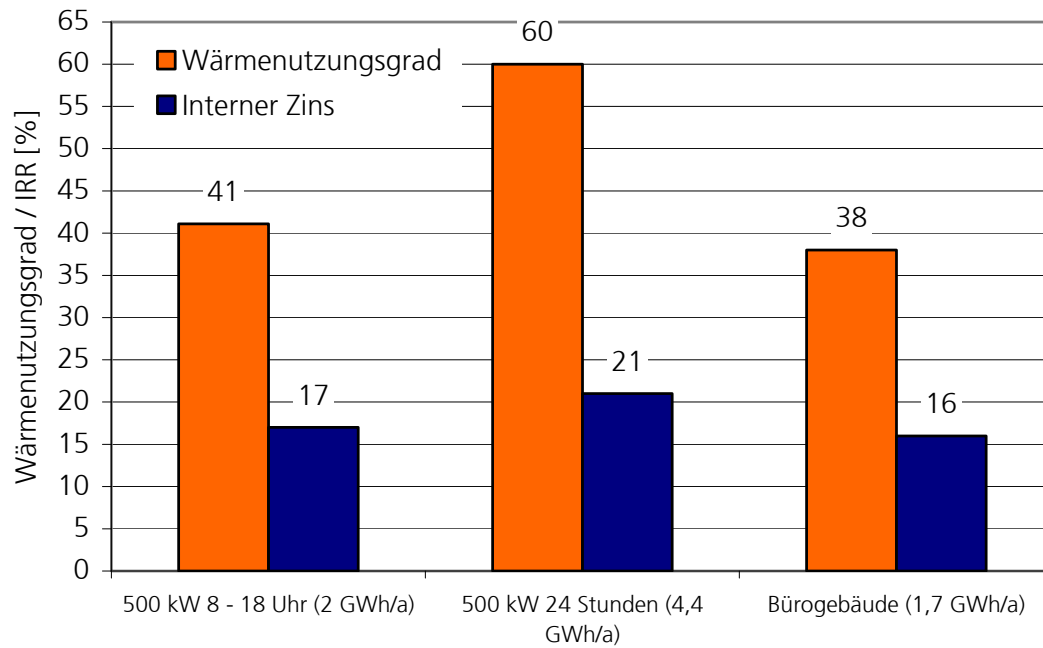
## Example: Results for 2 different collector costs

	200 €/m <sup>2</sup>	300 €/m <sup>2</sup>
Electricity yield [MWh/a]	540	420
Cooling yield [MWh/a]	2130	1640
Solar fraction cooling [%]	49	37
Collector area [m <sup>2</sup> ]	4900	3500
Storage size [m <sup>3</sup> ]	240	140
Investment sum [k€]	1700	1600
Capital value [k€]	492	- 103

Load profiles for cooling important ->large load beneficial, if storage is included

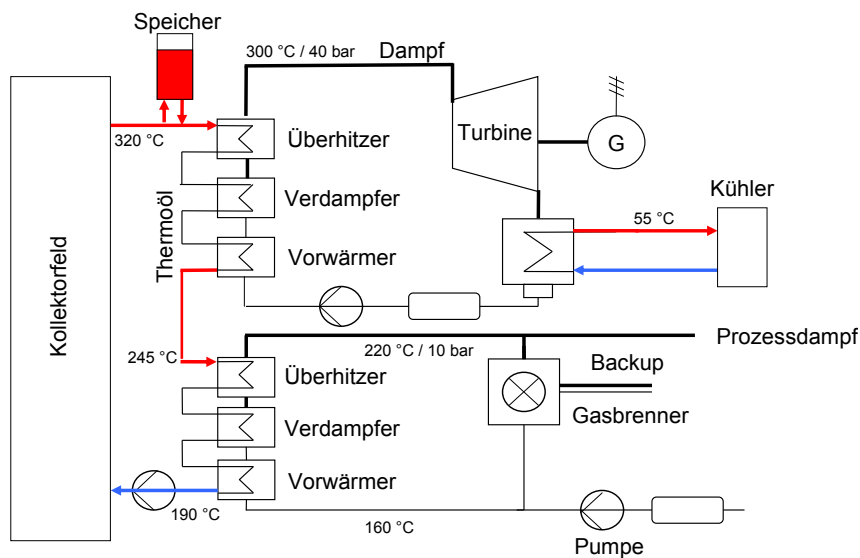
42

# Influence of load profiles for cooling



43

# Case Study 2: Combined Process Steam Generation



44

# Variations for grid-connected systems

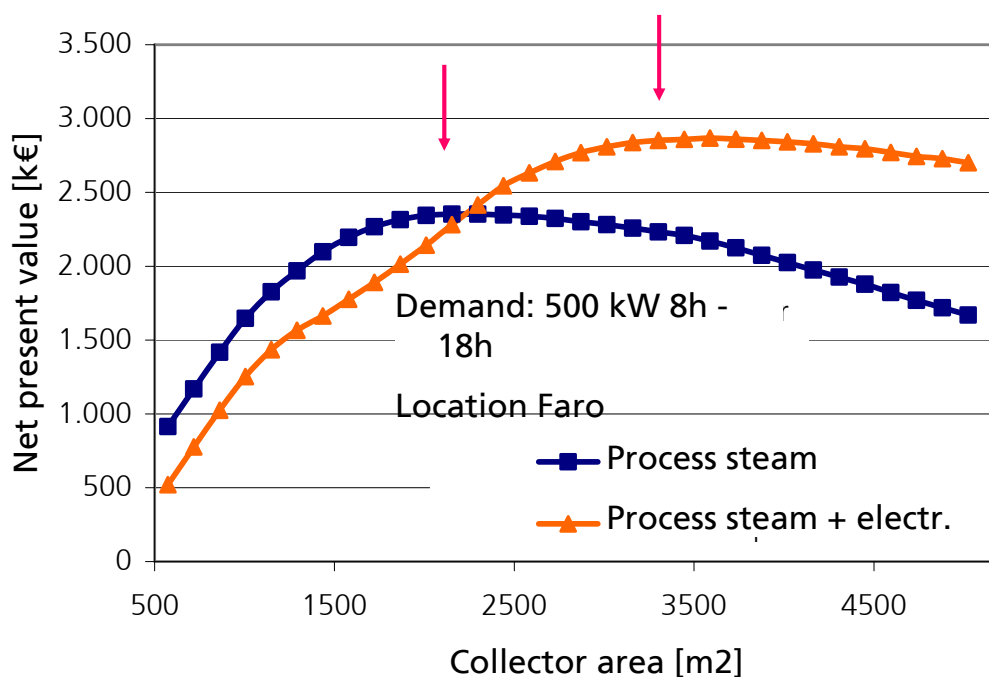
Two locations with different feed-in tariff:

- Faro, Portugal, DNI = 2197 kWh/(m<sup>2</sup>a)  
Feed-in tariff 27 Cent/kWh
- Ajaccio, Korsika, DNI = 1780 kWh/(m<sup>2</sup>a)  
Feed-in tariff 40 Cent/kWh

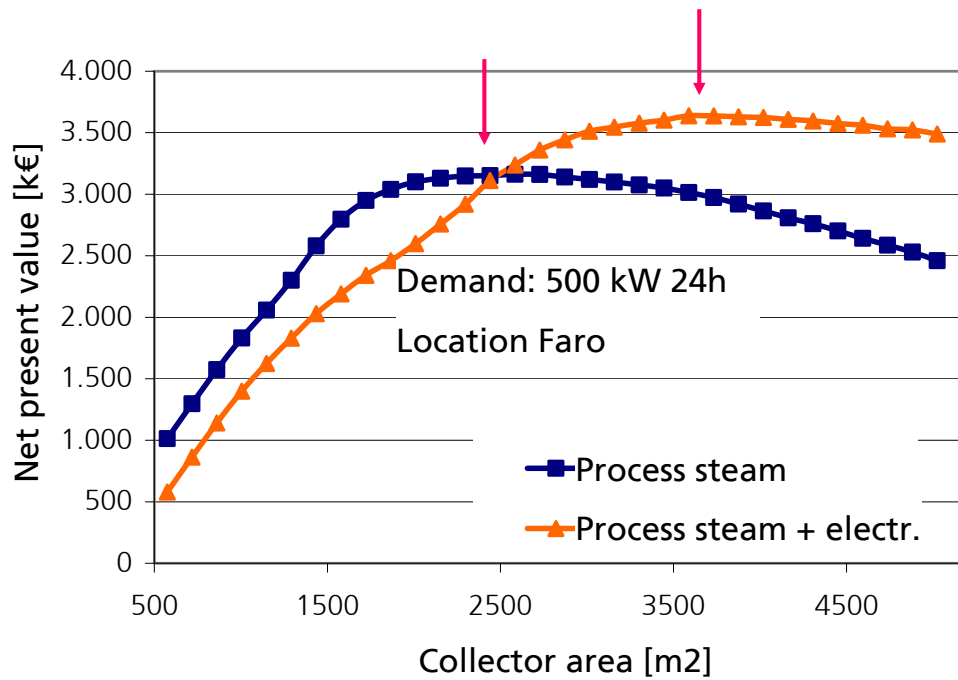
Profiles for process heat demand:

- 500 kW from 9h to 18h
- 500 kW over 24 hours

# Results grid-connection

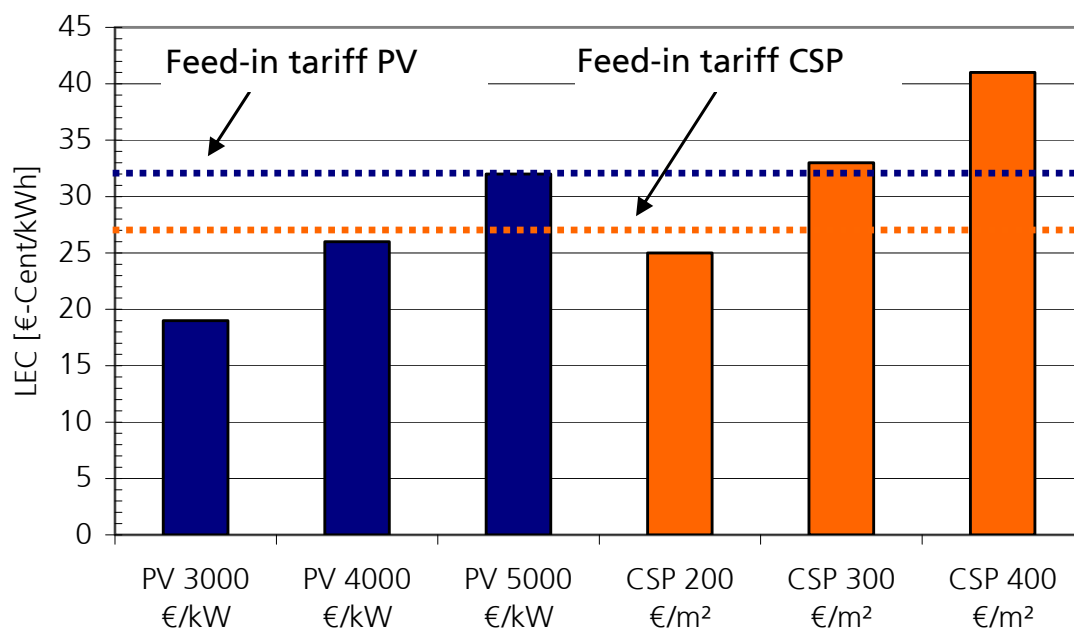


## Results grid-connection



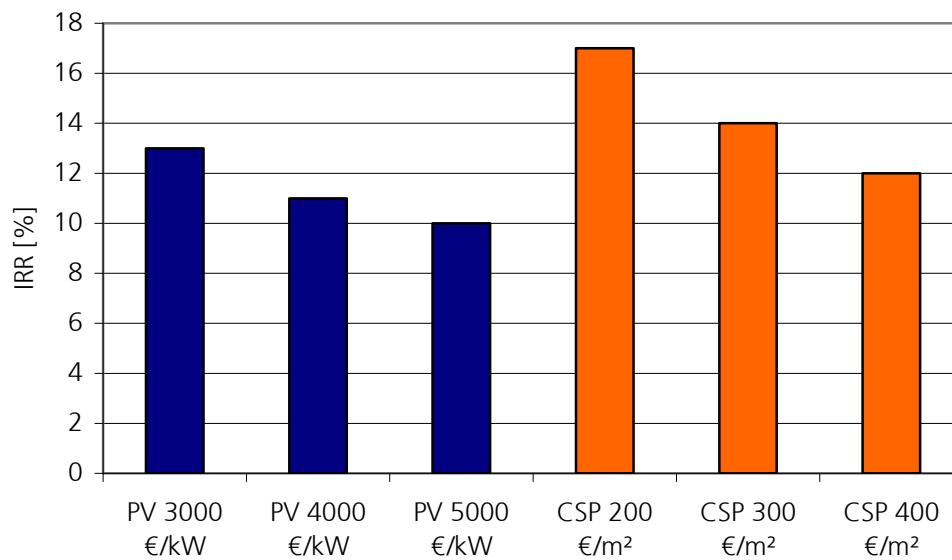
47

## Case Study 3: Comparison CSP with PV grid-connection with feed-in tariff

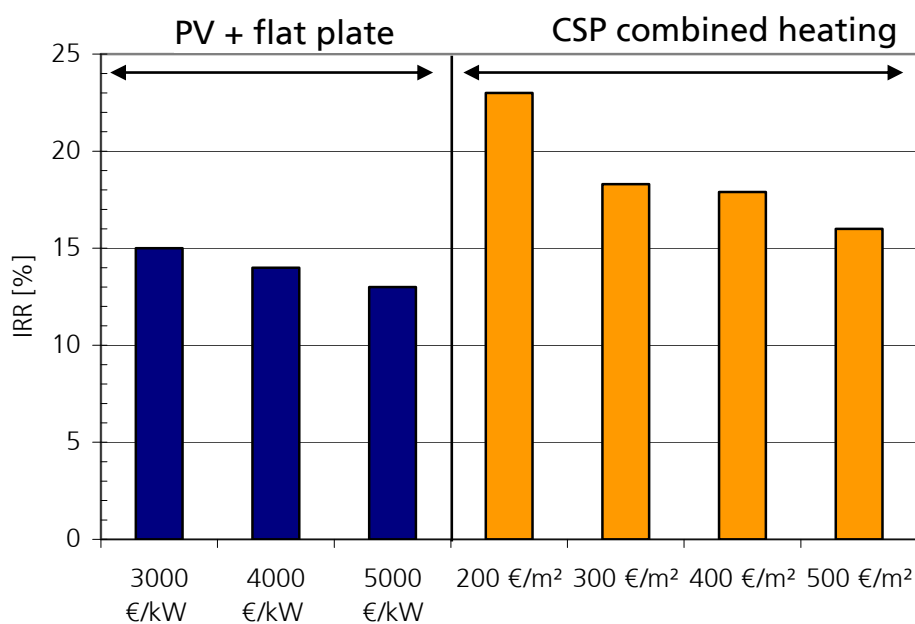


48

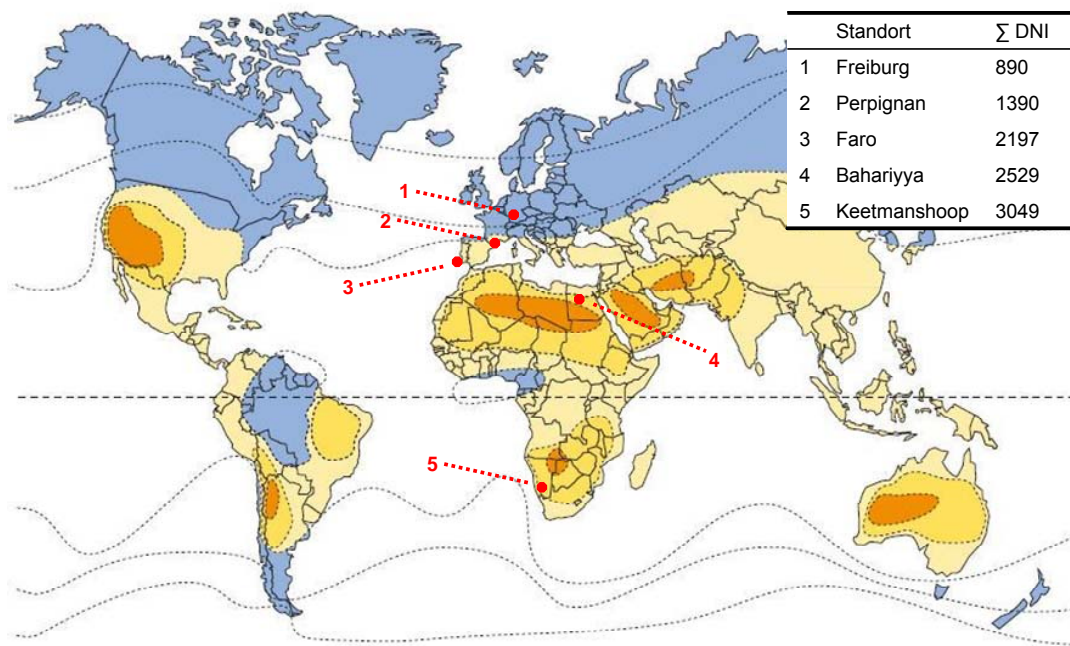
## Case Study 3: Comparison CSP with PV off-grid system



## Case Study 3: Comparison with PV+ flat-plate collector CSP combined heating and generation



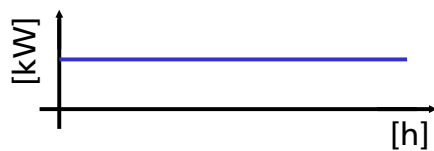
## Case Study 4: Variation in DNI



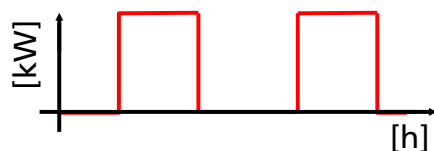
51

## Case Study 4: Variation in DNI

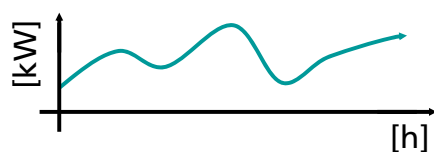
### ■ Off-Grid Systems



■ Cooling 500 kW (24h)



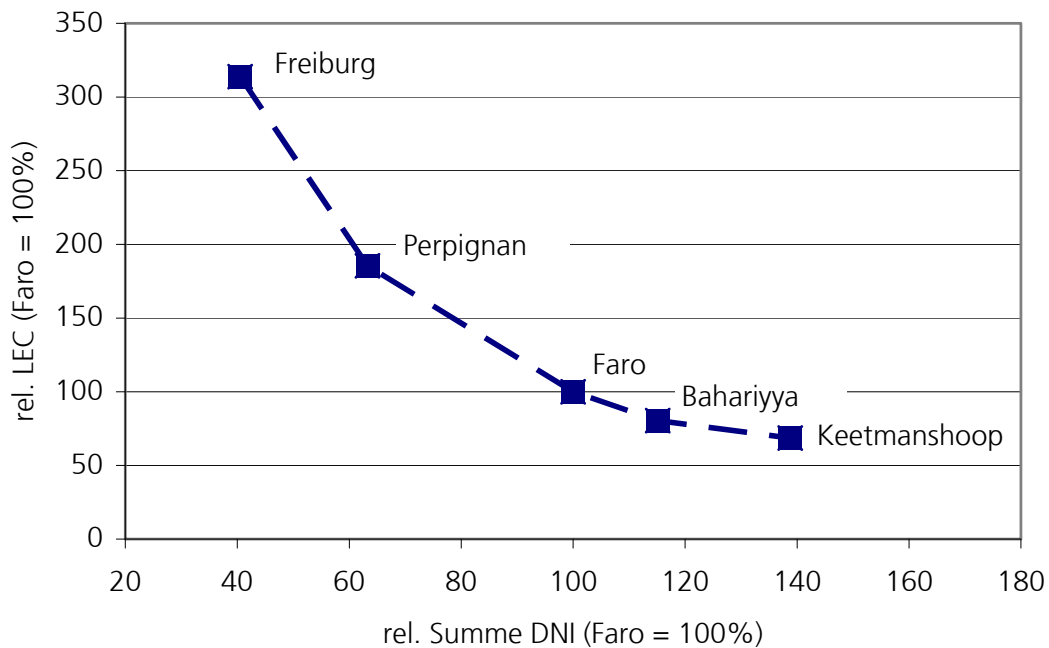
■ Process steam 800 kW (8h – 18h)



■ Electricity profile max. 400kW from literature

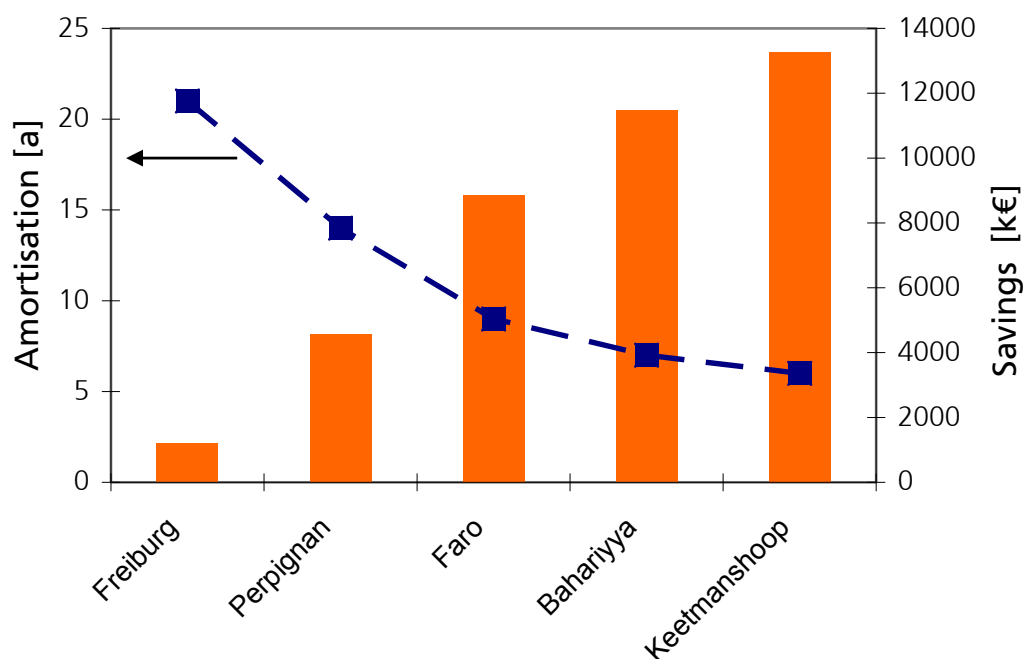
52

## Case Study 4: Solar Electricity



53

## Case Study 4: Solar Combined Heating and Cooling



54

---

# Content

- Introduction
- Demand worldwide
- Collectors for MSS-CSP
- Heat engines
- Case studies
- Outlook

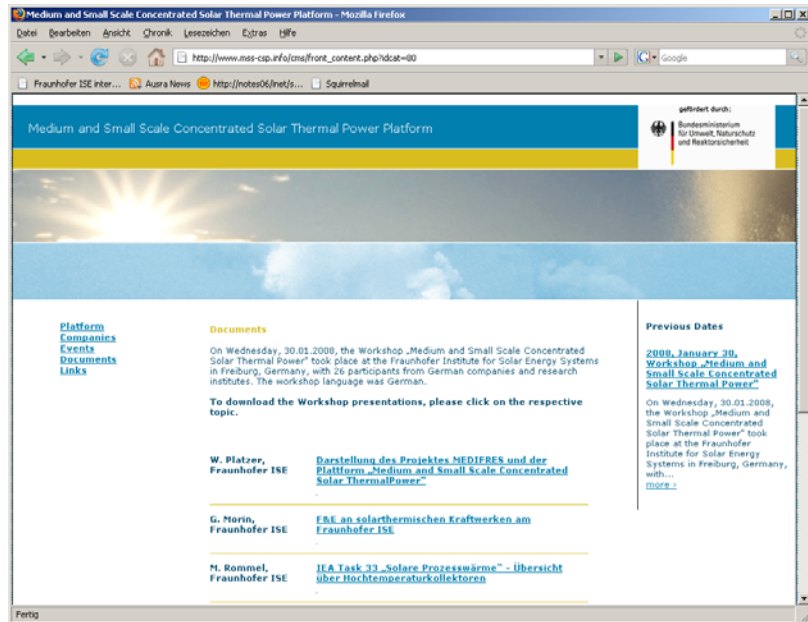
---

# Conclusions and outlook

- Small scale grid-connected electricity production with CSP is certainly still further away from market competitiveness than large scale CSP!
- Replacement of off-grid diesel generator applications might be interesting in some cases, even in comparison to photovoltaic stand-alone systems
- Combined heating and/or cooling enhances economics substantially
- Development of alternative small power blocks (screw, ORC) are under way, demonstration and adaptation to dynamical solar field conditions necessary!
- We need more experience and demonstration worldwide!
- Large potential markets (e.g. India) exist

# Internet-Plattform (englisch)

- Kontakte
- Termine
- Informationen
- Studien



57

# Internet-Plattform - Firmendarstellung

- Kostenfreies Angebot
- Einfache Eintragung über Internet-Formular

	<b>Alanod Aluminium Veredlung GmbH &amp; Co. KG</b> Germany	<a href="http://www.mirosolar.com">www.mirosolar.com</a>
	<b>ENERGIA SINFIN S.L.</b> ESPAÑA	<a href="http://www.energasinfin.es">www.energasinfin.es</a>
	<b>Fraunhofer Institute for Solar Energy Systems</b> Germany	<a href="http://www.ise.fraunhofer.de">www.ise.fraunhofer.de</a>
	<b>LTI ADATURB GmbH</b> Germany	<a href="http://adaturb.lt-i.com/">http://adaturb.lt-i.com/</a>
	<b>NEP Solar Pty Ltd</b> Australia	<a href="http://www.nep-solar.com">www.nep-solar.com</a>
	<b>PSE AG</b> Germany	<a href="http://www.pse.de">www.pse.de</a>
	<b>SOLITEM GmbH</b> Germany	<a href="http://www.solitem.de">www.solitem.de</a>
	<b>Sustainable Heat &amp; Power Europe GmbH</b> Germany	<a href="http://www.shp-europe.com">www.shp-europe.com</a>

<b>LTI ADATURB GmbH</b> Emil-Figge Str. 76 44227 Dortmund	
<b>Contactperson:</b> Klaus-Peter Priebe Managing director	<b>Send E-Mail</b> +49 02319742865 +49 2319742868
<b>Main field of activities:</b> Our firm, the LTI ADATURB Ltd, is specialised in the development of ORC-systems. These systems use exhaust and motor heat of cogeneration units to generate electrical power. While large ORC-systems in the range of performance of several MW run successfully since a long time, we develop small ORC-systems to give operating authorities of small power generation plants the chance to make their installation much more profitable.	
<b>Description of products and services related to Solar Thermal Power:</b> Our ORC-systems offer the possibility to extract from one exhaust gas heat of for example 175 or 350 kW once again 30 respectively 60 kW net for the additional power generation. Furthermore we work on the development of an all-in-one power station for energy supply in rural regions.	
<b>Realized projects and references:</b>	
In the middle of august, our first pilot installation, located in Wildshausen (near Arnberg) will be put into operation. This TG 30 ORC-system is connected to a cogeneration unit, which receives its combustible from the process of wood gasification. The cogeneration unit has an electrical performance of 247 kW. The turbo-generator of the TG 30 is expected to generate further 40 kW. Dates for visiting our pilot installation are possible from the end of august on. Besides the TG 30 the LTI ADATURB Ltd offers a TG 60 with a power generation of 60 kW. The series production of our ORC-systems is	

58

---

Thank you for listening!

[www.mss-csp.info](http://www.mss-csp.info)

[www.ise.fraunhofer.de](http://www.ise.fraunhofer.de)