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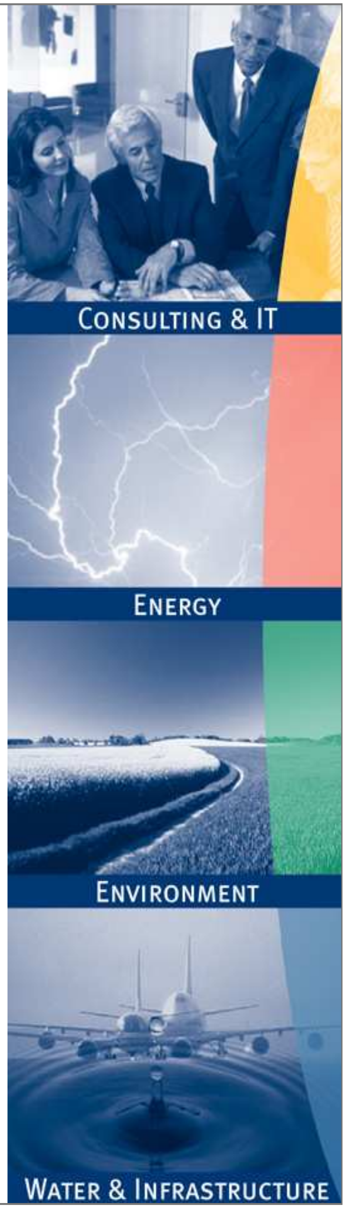
Concentrating Solar Power Plants
- Status and Costs -



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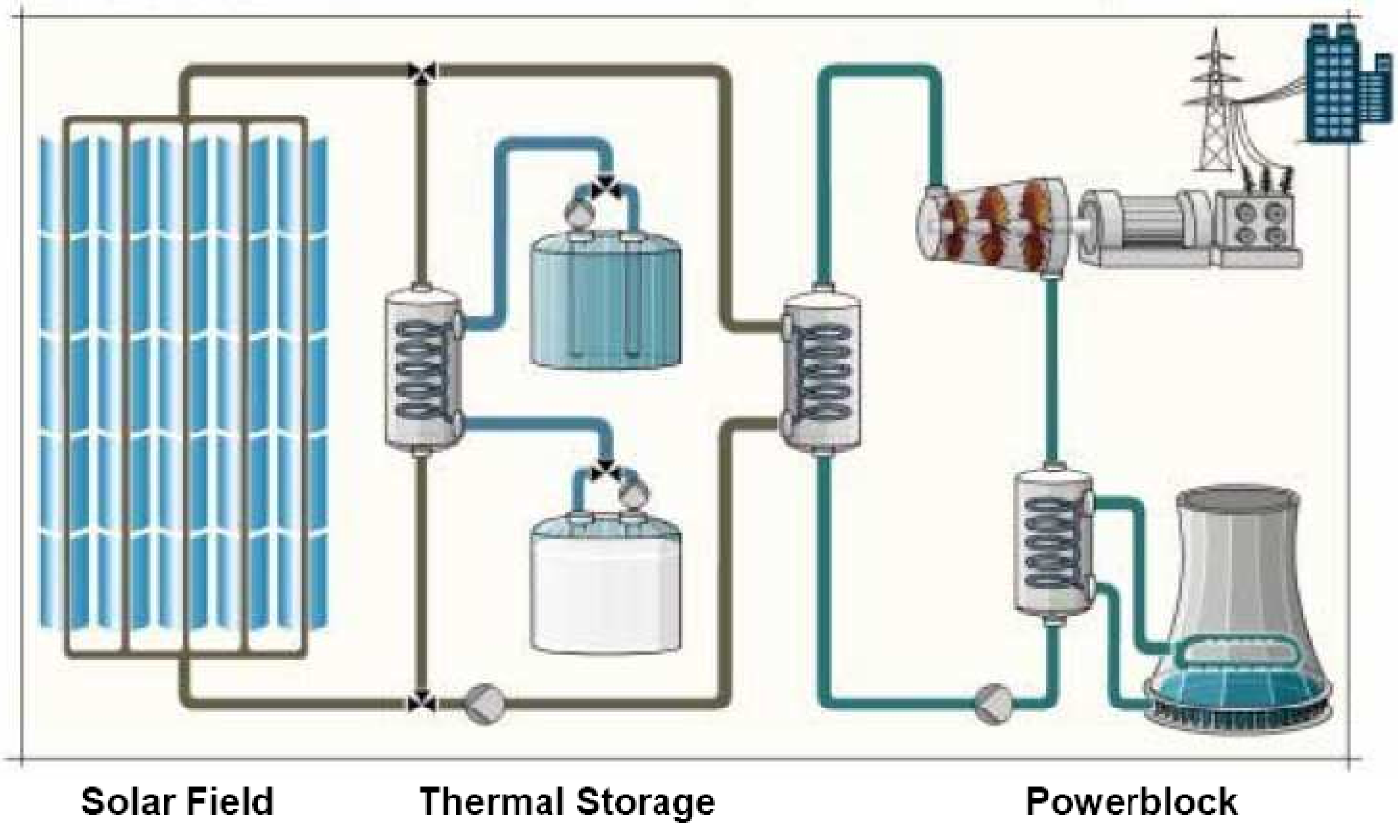
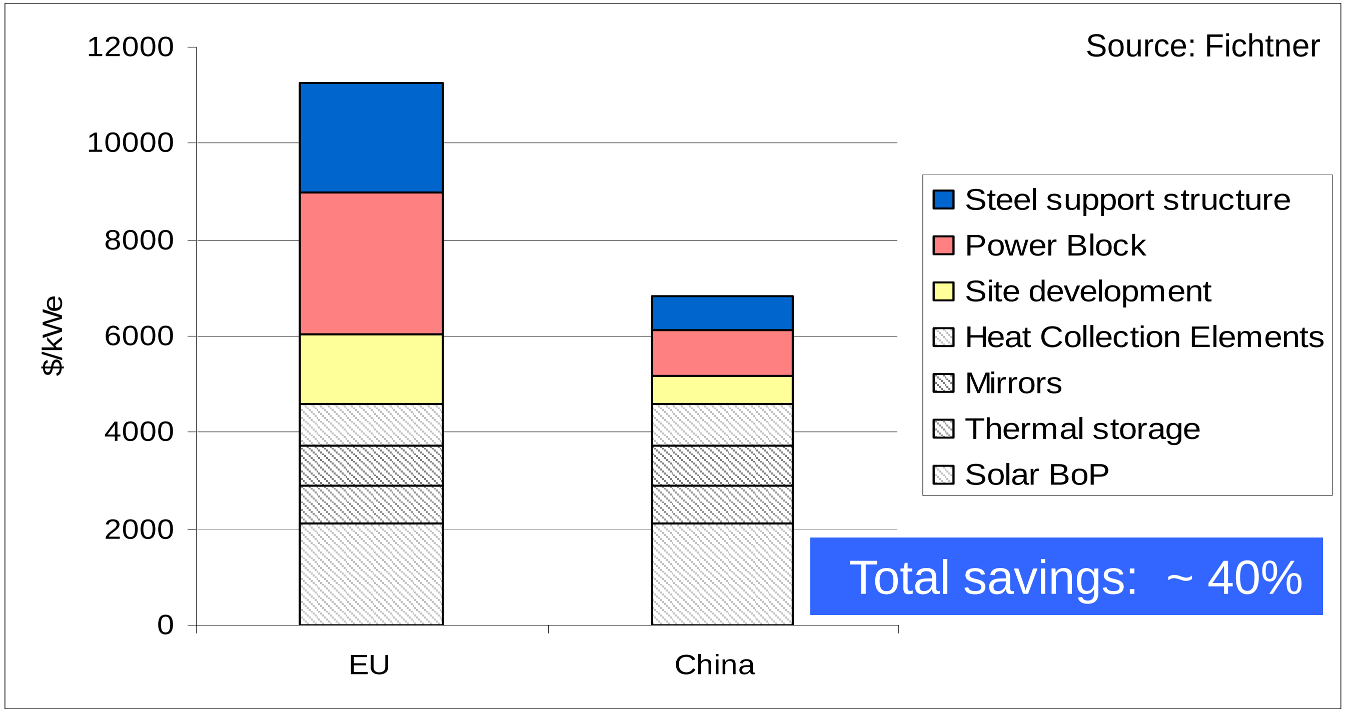
Concentrated Solar Thermal Power



Cost reduction potential – through Chinese manufacturing

- Using services, labor and plant components from domestic Chinese market
  → **significant cost reduction relative to EU**

- Example: Parabolic trough example-plant with storage: 41 MW_e

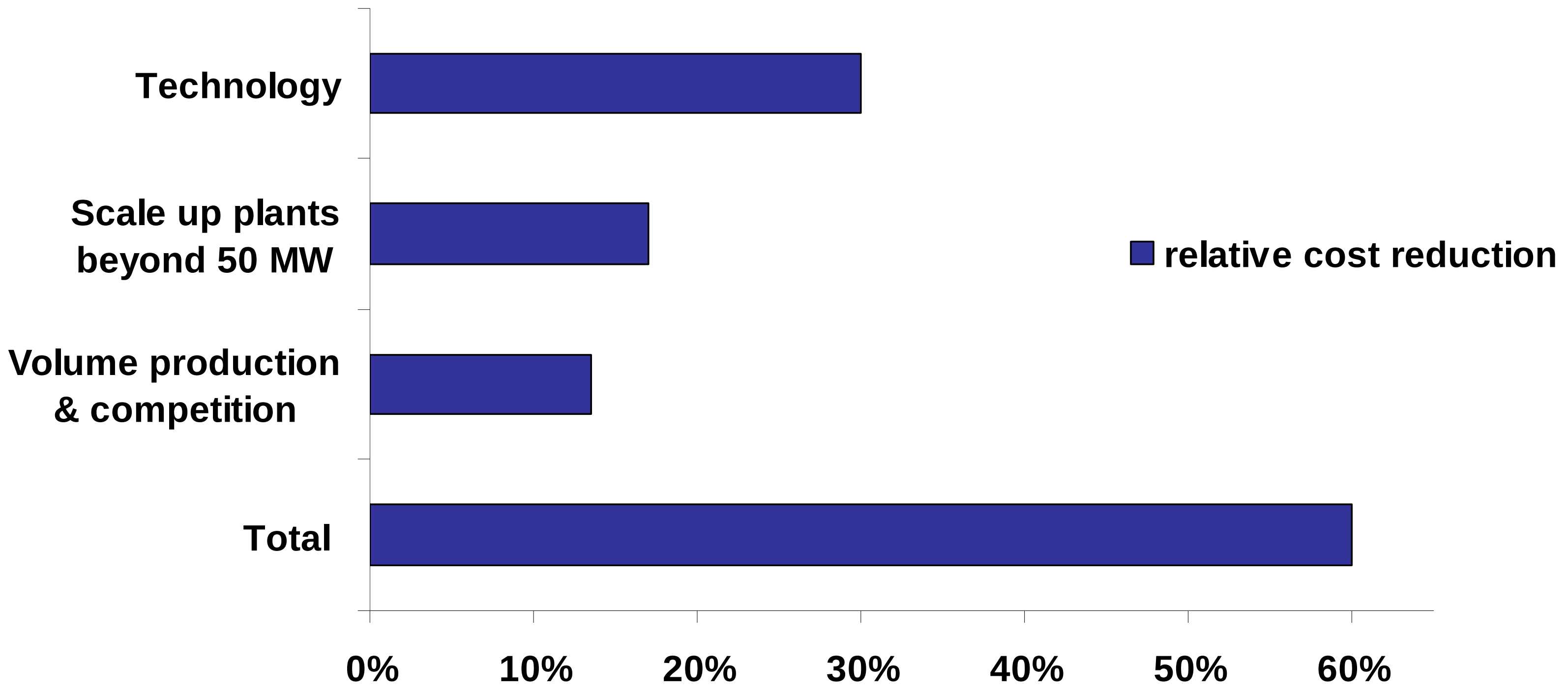


The cost figures in the left bar were initially based on real CSP plants without storage commissioned by 2009. To simulate the cost with storage, the power plant capacity was decreased so that the storage could be fuelled with the same area of mirrors. Specific investment costs are expected to decrease substantially in the future. Still, the range of possible cost reductions through local Chinese manufacturing is still pivotal.

Future cost reduction potential due to technology development

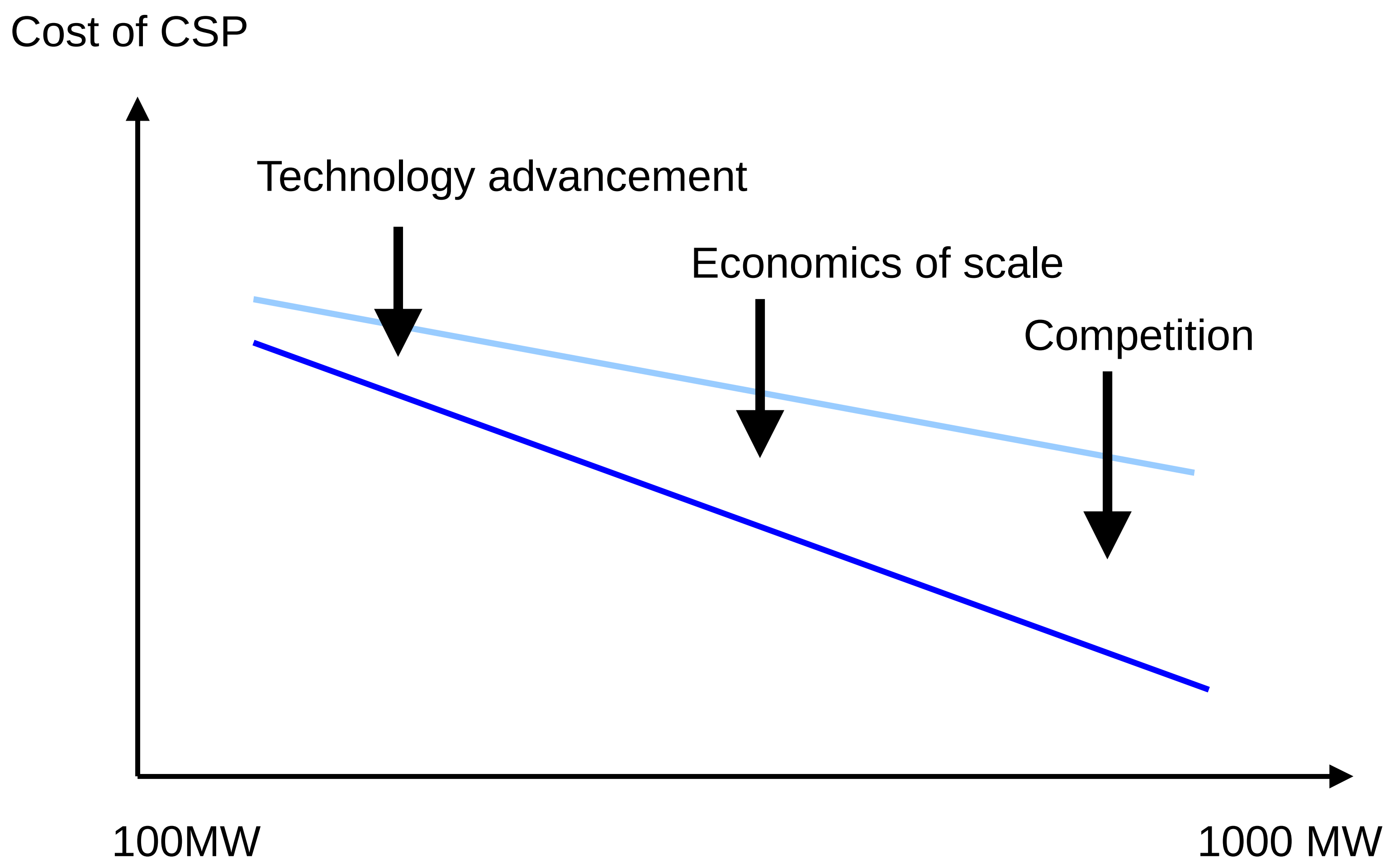
Several aspects may lead to a substantial cost reduction in CSP technology

→ Projection for 2020



Source: Deutsche Bank Research

Cost reduction prospects



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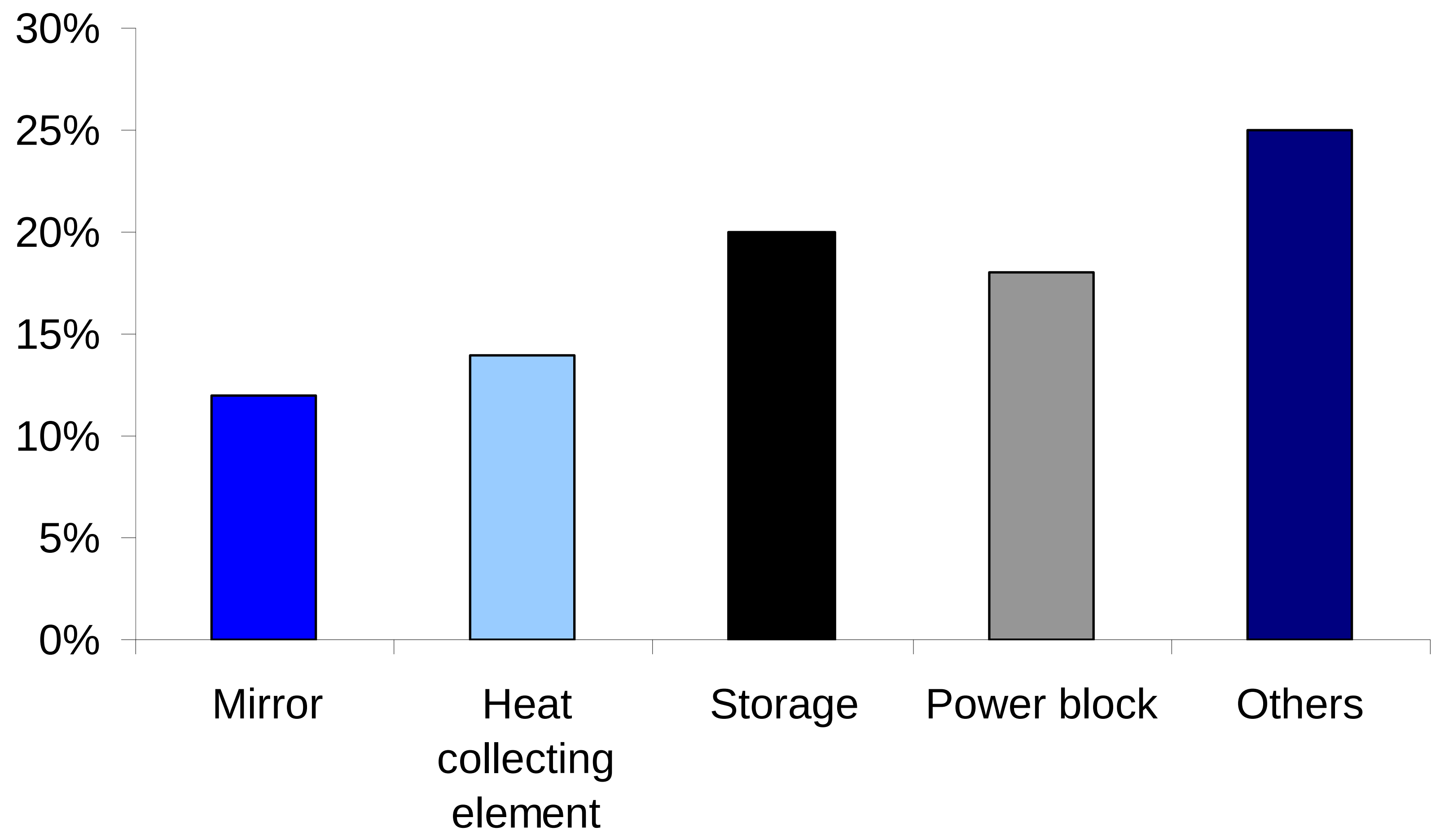
…split up into the plant's components (technology development)



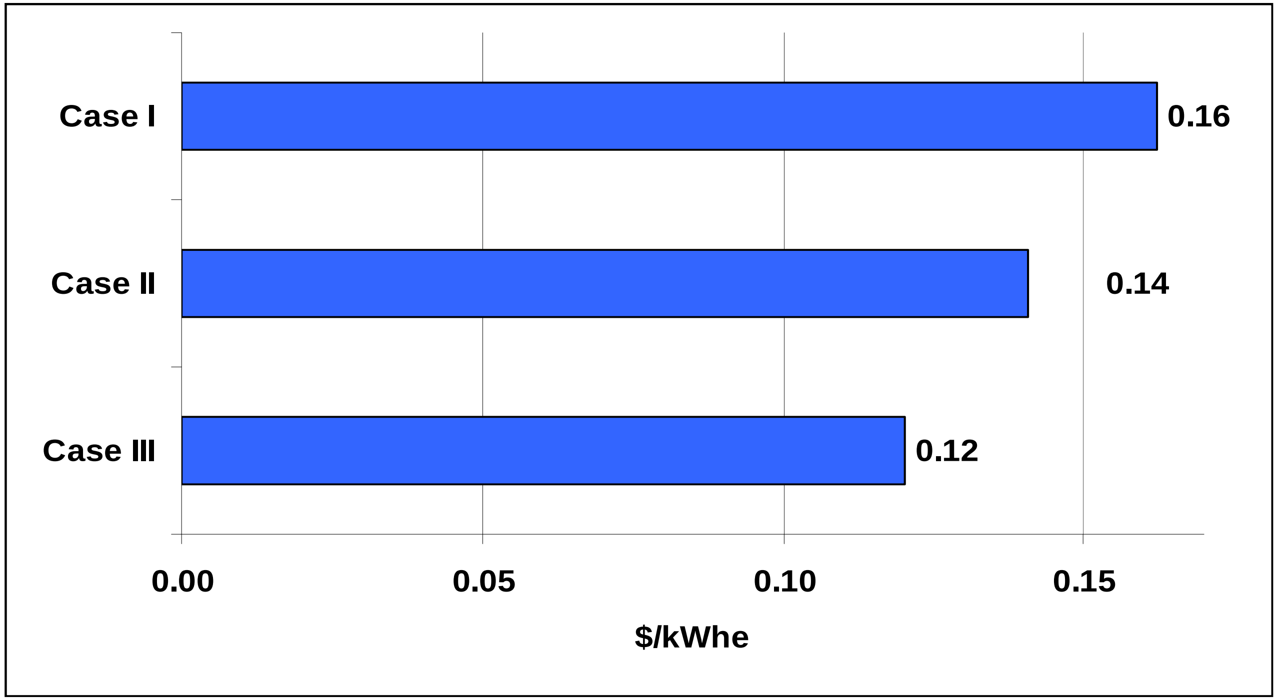
Source: Deutsche Bank Research

Case study China

- **Case I:** 100MW Solar trough, today, Chinese market benefits
- **Case II:** 1000MW Solar trough, today, Chinese market benefits, cost reduction by economics of scale
- **Case III:** 1000MW Solar trough, 2020, Chinese market benefits, cost reduction by economics of scale and learning factors

These case studies are based on expected costs of new CSP plants with economically viable sizes

Electricity costs at generation site:

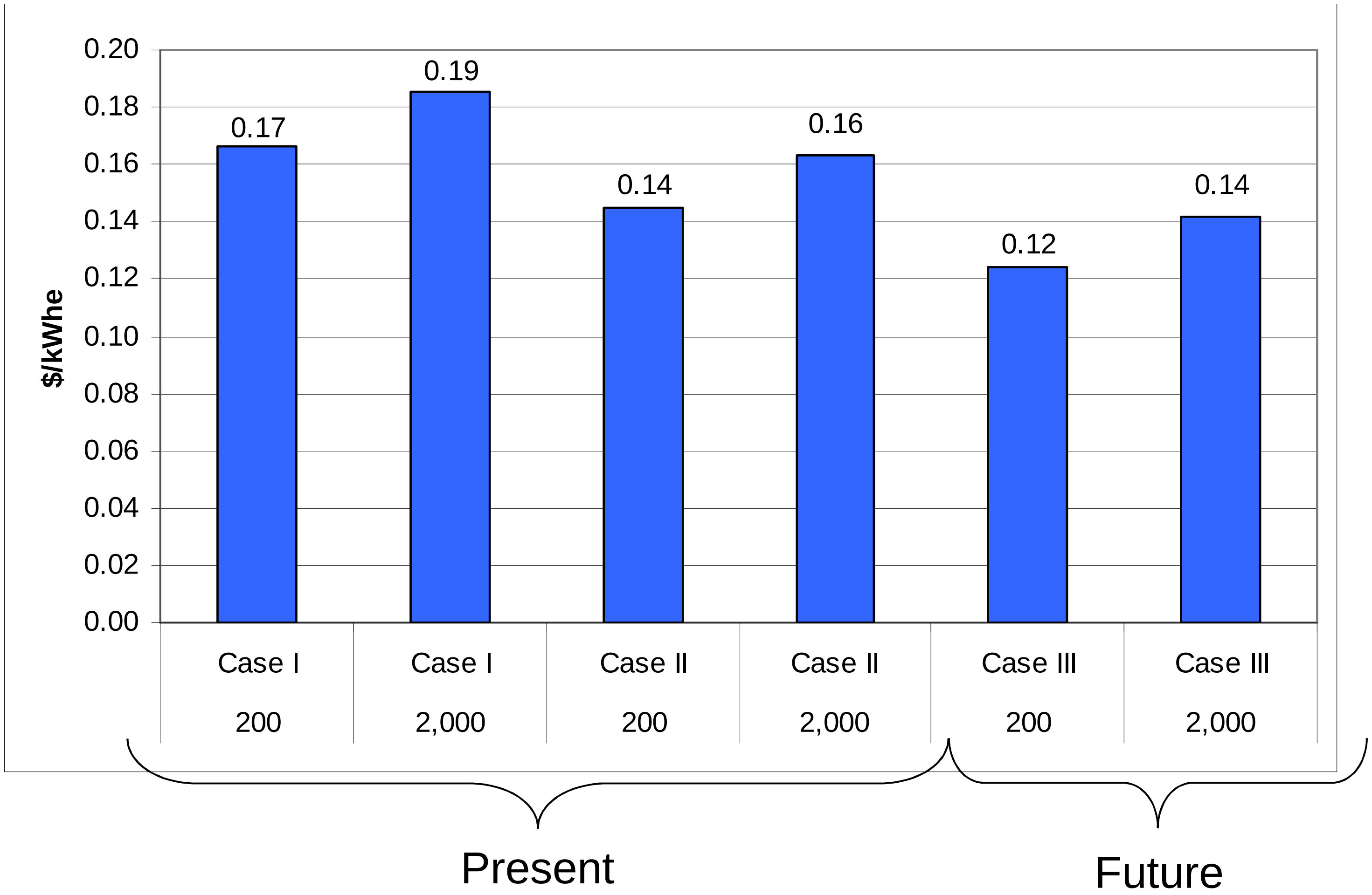


Source: Fichtner

Electricity costs at load centers

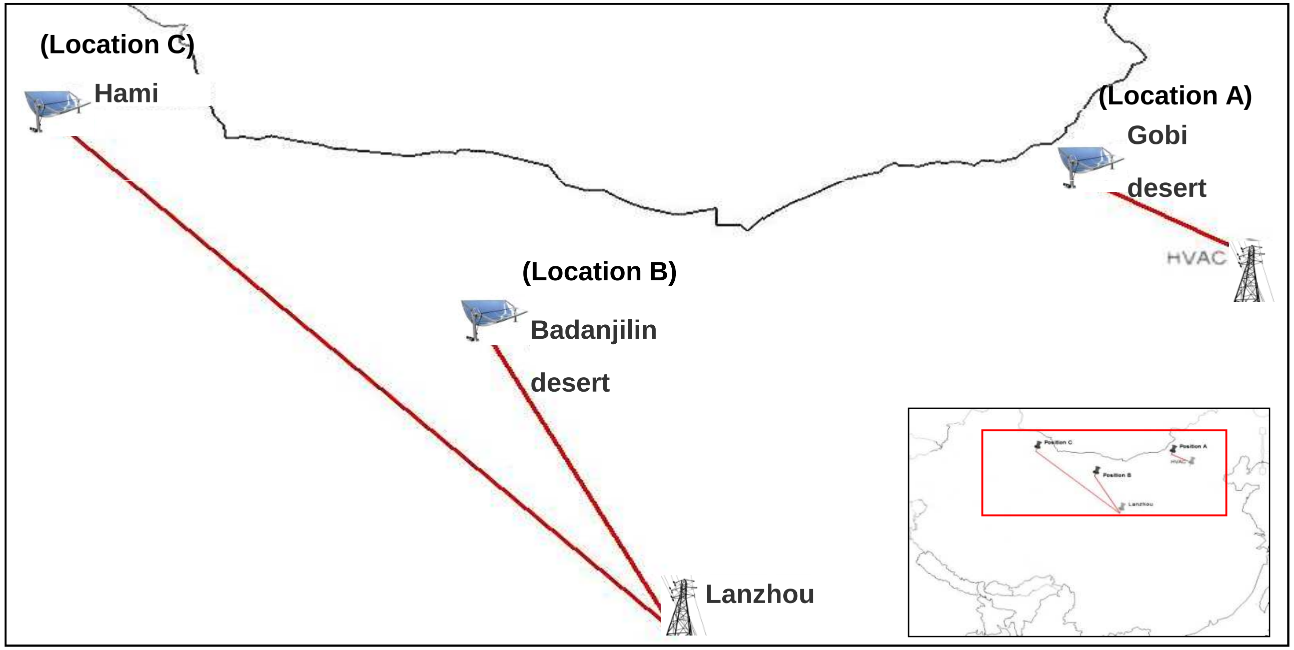
- New power lines have to be built (200-2000km)
- Electricity costs at power line outlet

Source: Fichtner



Grid Inter-connection location

Distance between the plant and the grid between 200 km (Location A) and 2000 km (Location C); resources in Location C better than in the other locations; cost analysis shows that even with transmission expenditure, plants at location C can be economically competitive with plants at location A



Locations are geologically viable to install large CSP

Conclusion

- Bigger plants are more cost effective than small plants
- Better solar resources in remote areas may justify extra costs of transmission so that they are competitive with plants at locations less remote but with a poorer solar resource
- Large saving potential in Chinese manufacturing and service
- Good future prospects of CSP due to:
  - Sizeable resource potential in China
  - Technology advancement potential
  - Opportunities for low-cost technology and construction in China
  - Opportunities for integrated energy storage

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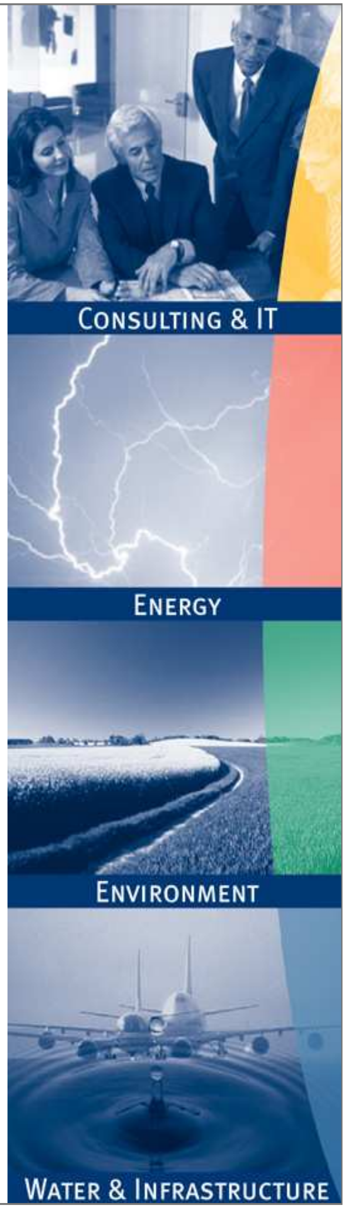
Annex: Detailed Cost Analysis of CSP



Parabolic Trough Investment cost

Broken down into 6 major cost components from 3 different data sources

Trough	Unit	Sargent & Lundy				Fichtner
		2003		2008		2008
Power Plant		SEGS VI	Trough 100	Trough 100	Trough 100	Trough 100
		Hybrid	Storage	No Storage	Storage	Hybrid
Support Structure	$/m²	67	67	171	172	160
Receivers	$/m²	43	43	53	53	60
Mirrors	$/m²	43	40	63	63	60
Solar BOP	$/m²	234	250	141	141	150
Power Block/BOP	$/kWe	527	306	1183	1183	2500
Thermal Storage	$/kWe	-	958	-	765	-
Total Investment cost	M$	92	254	447	671	559
	$/kWe	3052	5073	4471	6708	5594

Comparison of costs disclosed. Realised projects in the year 2008 have substantially higher costs than originally expected.

Operating & Maintenance Cost of Parabolic Trough

Trough	Unit	Sargent & Lundy				Fichtner
		2003		2008		2008
Power Plant		SEGS VI	Trough 50	Trough 100	Trough 100	Trough 100
		Hybrid	Storage	No Storage	Storage	Hybrid
Annual O&M	$/kWe	63	115	67	78	120

Levelized Energy Cost of Parabolic Trough

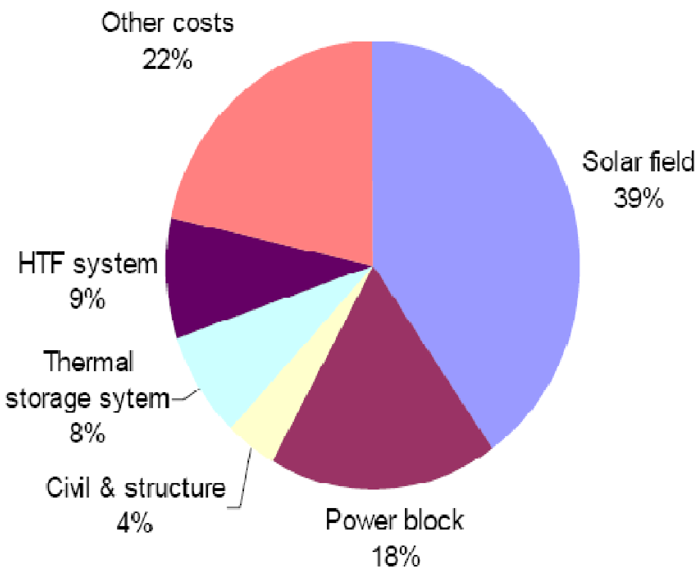
Trough	Unit	Sargent & Lundy				Fichtner
		2003		2008		2008
Power Plant		SEGS VI	Trough 50	Trough 100	Trough 100	Trough 100
		Hybrid	Storage	No Storage	Storage	Hybrid
Annual net electricity output	GWh	58	206	290	451	223
LEC	$/kWhe	0.181	0.143	0.168	0.157	0.293

crf : 9.37%

Internal Rate of Return: 8%

LEC for project Andasol 1

An example of the first commercial CSP project in Europe

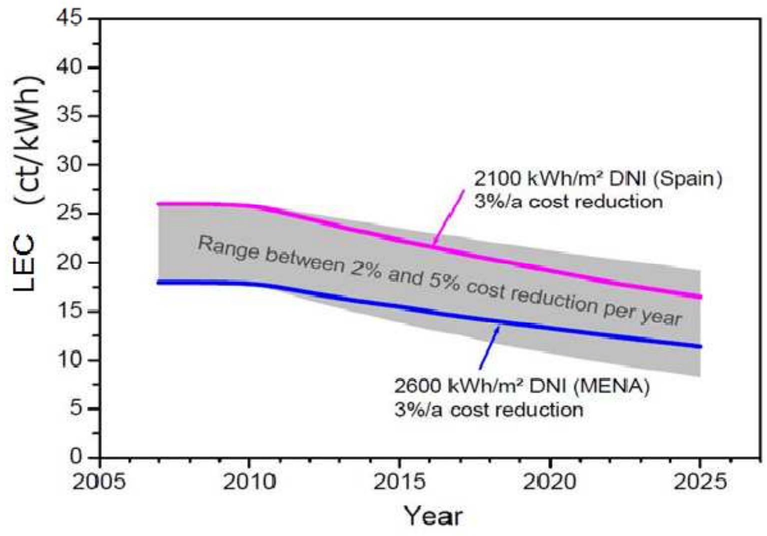


Name	Location	Capacity
Technical Data		
Reflector Area	km²	0.51
Storage	h	9
Electricity Capacity	MWe	50
Annual Electricity Generation, net	GWh	179
Investment costs		
Solar field	M $	172
Power block	M $	76
Civil and structure	M $	18
Thermal storage system	M $	33
HTF system incl. solar heat exchanger	M $	37
Other costs	M $	92
Total	**M $**	428
Specific	**$/kWe**	8551
O&M Cost		
Total	**M $**	12.8
Specific	**$/kWe**	0.072
Electricity Generation Cost		
LEC	**$/kWh**	0.296
		crf : 9.37%

Cost Reduction Prospects for Parabolic Trough

Technological Advancements

- Improve the efficiency of the solar field, the reflectivity of mirror and the absorber
- Advanced structural design with lower weight and costs
- Application of advanced heat transfer fluid
- Adapt turbine design for the CSP power-plant to night-time operation



Source ESTELA report

Solar Power Tower Investment Cost

Broken down in 7 major cost components

Tower	Unit	Sargent & Lundy		Fichtner
		2003	2008	2008
Powe Plant		Solar Tres 13.65 MW	Solar Tres 13.65 MW	Tower 47.25
		Storage	Storage	Solar-Only
Site development / Infrastructure	$/m²	11.6	-	25.3
Heliostat field	$/m²	160	230.6	191.2
Receiver		280m²	280m²	155MWth
		57,143$/m²	12,1680$/m²	151.5$/kWth
Tower & Piping	$/m²	11.6	21.99	18.9
Power Bolck & Balance of Plant	$/kWe	1,397.7	4,719.6	1,556.6
Thermal storage	$/kWt	49	24.9	-
Total investment cost	M$	119	219	214
	$/kWe	8,753	16,905	4,534

Levelized Energy Cost of Solar Power Tower

Tower	Unit	Sargent & Lundy		Fichtner
		2003	2008	2008
Power Plant		Solar Tres 13.65 MW	Solar Tres 13.65 MW	Tower 47.25 MW
		Storage	Storage	Solar-only
Annual net electricity output	GWh	93	93	116
LEC	$/kWhe	0.15	0.22	0.22

crf : 9.37%

Internal Rate of Return: 8%

LEC for Project PS 10

An example of the first commercial solar power tower project in Europe

Name	Location	Capacity
Technical Data		
Reflector Area	km^2	0.075
Electricity Capacity	MWe	11
Annual Electricity Generation, net	GWh	24
Investment costs		
Total	M $	47
Specific	$/kWe	4273
O&M Cost		
Total	M $	1.175
Specific	$/kWe	0.05
Electricity Generation Cost		
LEC	$/kWh	0.23

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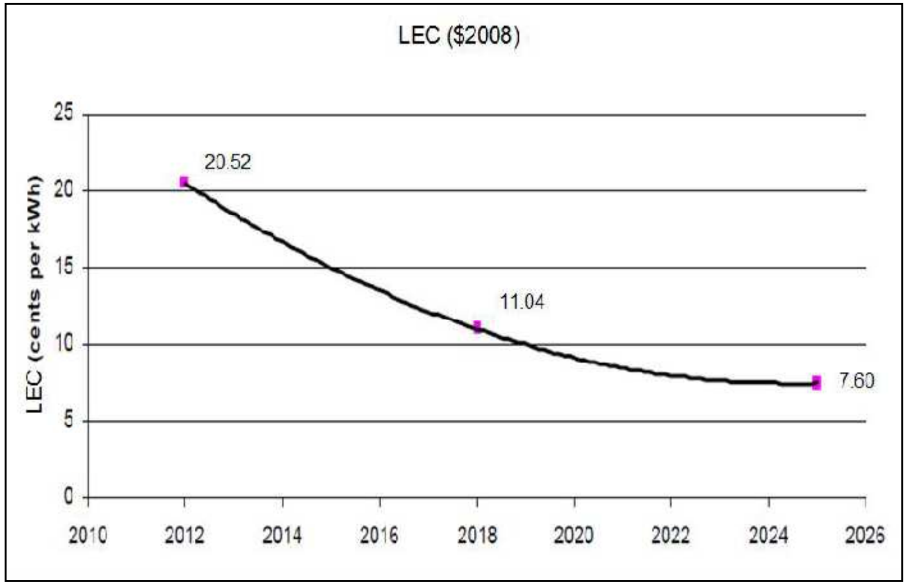
Cost Reduction Prospect of Solar Power Tower



- The parabolic trough plant with storage is about 28.6% lower than solar tower plant with storage
- It is expected that the costs of solar power tower will decrease more than for the parabolic trough technology.

Site Selection

Requirements

Solar Resource

CSP Power plant is only economical for locations >1,800 kWh/ ($m^2 \cdot a$)

Land Requirement

20,000 – 40,000m^2 per megawatt of electricity generation

Infrastructure

Proximity to transmission – line corridor, natural gas pipeline and rail transportation

Water Availability

Adequate supply, otherwise dry cooling

Location

System Design

A 41 MW Project

Location: Badanjilin Inner Mongolia

- Solar resource of 5 to 5.5 kWh/(m²·day)
- Satisfied distance to local centre
- Low Wind speed
- High Temperature in Summer

Technical data	
Electrical capacity	41 MW
Collector area	580,000 m²
Total power plant area	ca. 2 km²
Thermal storage	6 hours
Annual operating hours	ca. 4000 hours
Forecast electricity generation	about 165 GW per year

Cost Status of CSP Project in China

- Investment Cost

Specific investment cost ($/kWe) in China is 6,810 $/kWe (two thirds of the price in Europe)

- O & M Cost

1.25% of the total investment cost per year in China (2%/yr in Europe)

- Levelized Energy Cost

The electricity cost of a 41 MW parabolic trough power plant in China is 44% lower than that in Europe