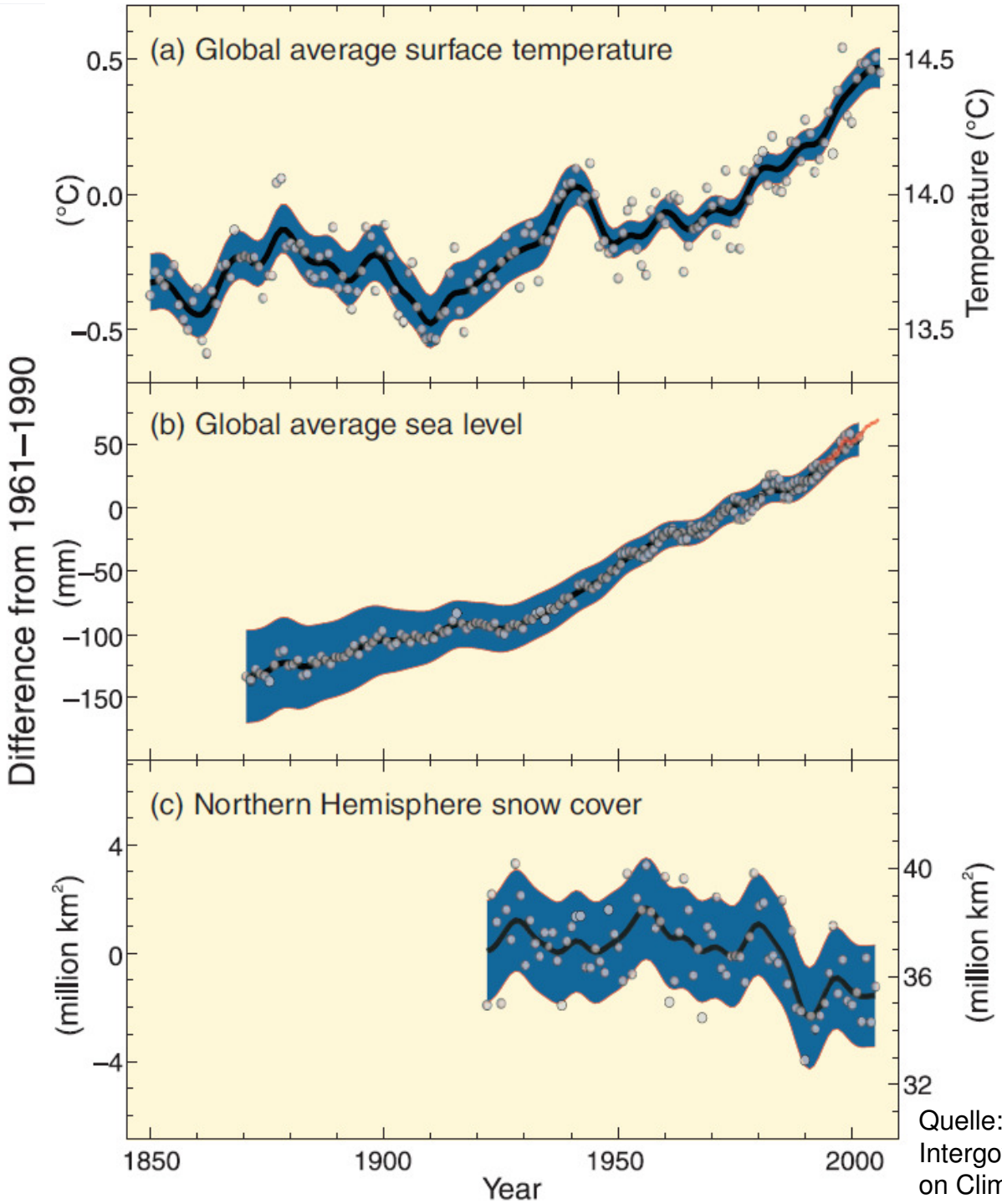
Solarenergie in der Wüste

Desertec - 400 Milliarden Investitionen deutscher Firmen

Prof. Dr. Eduard Heindl

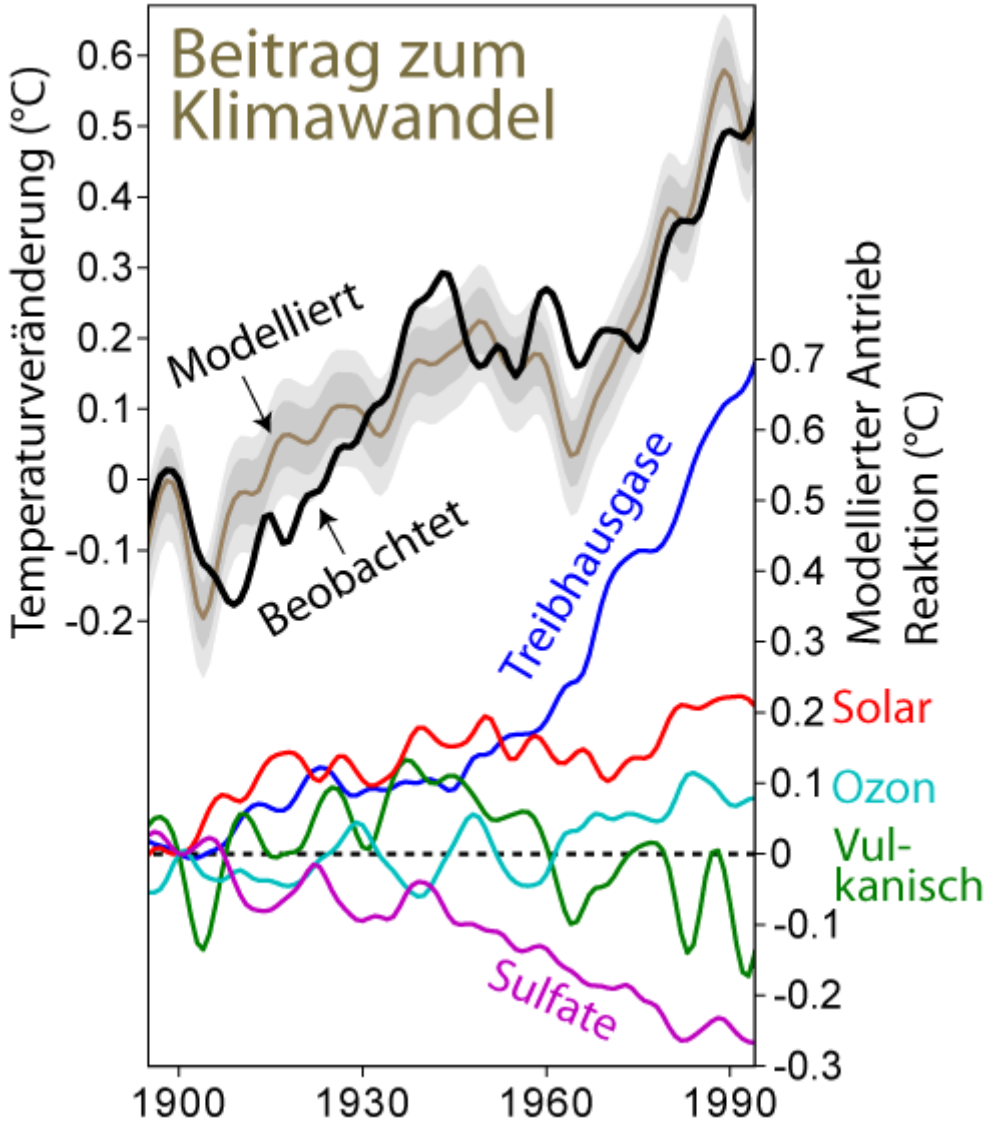
Inhalt

- Klimaproblem
- Energiequellen
- Wüsten und Solarenergie
- Technologien
- Projekt Desertec
- Risiken und Alternativen



Quelle:
Intergovernmental Panel
on Climate Change

Ursachen der Temperaturänderung

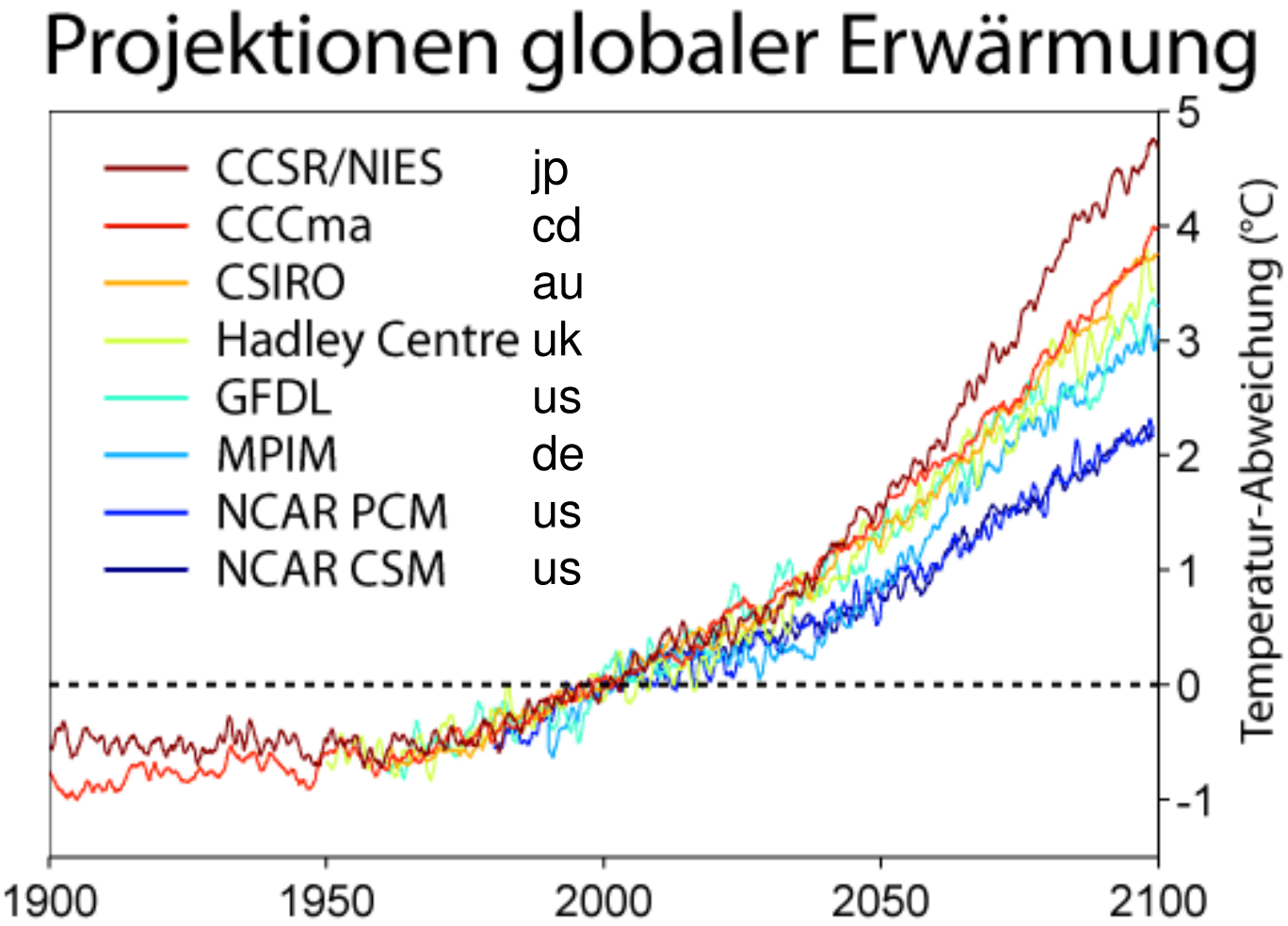


Hauptursache:

CO_2

Quelle:
Wikipedia

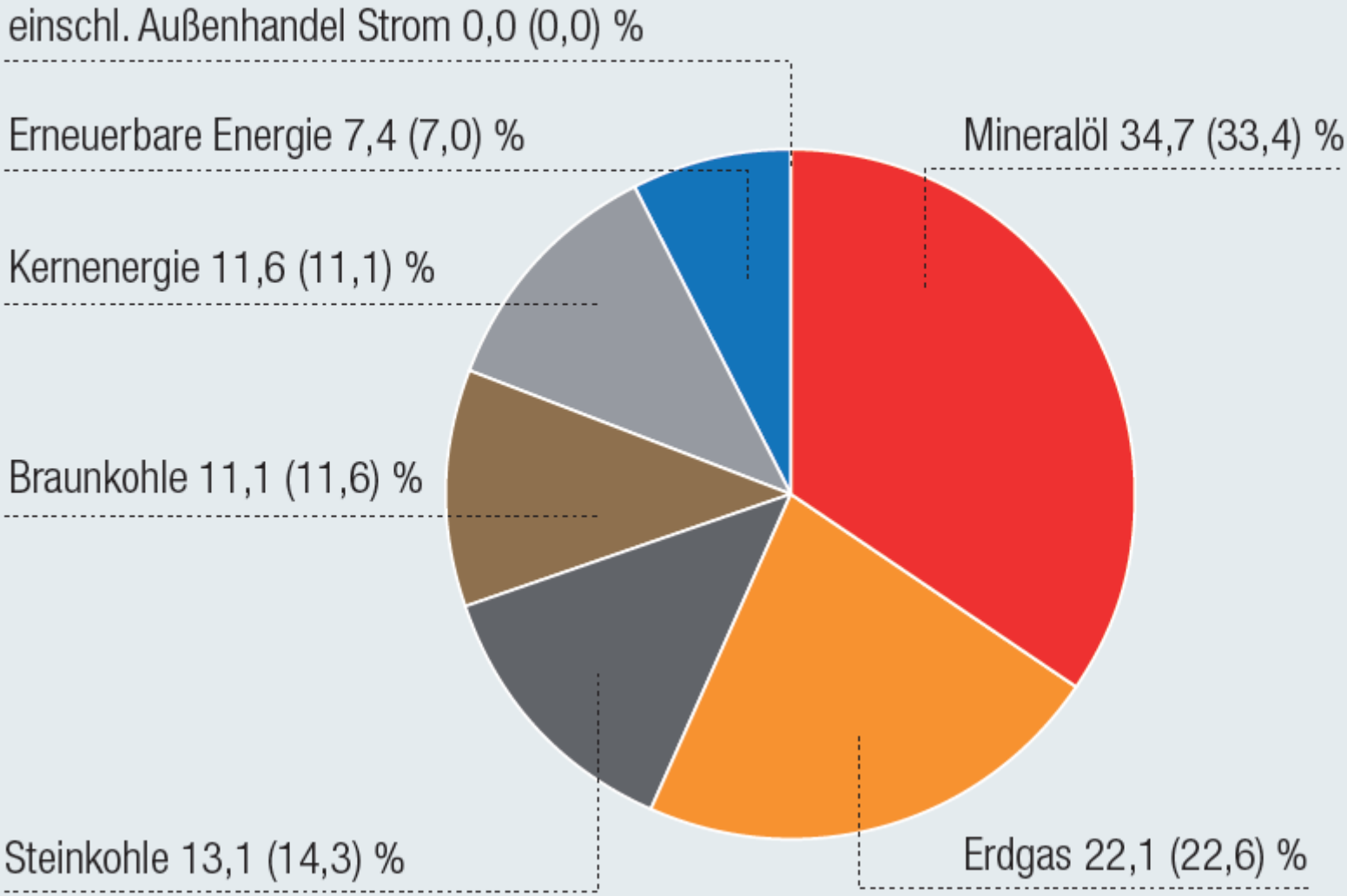
Vorhersage Erwärmung



Bildquelle:
Wikipedia

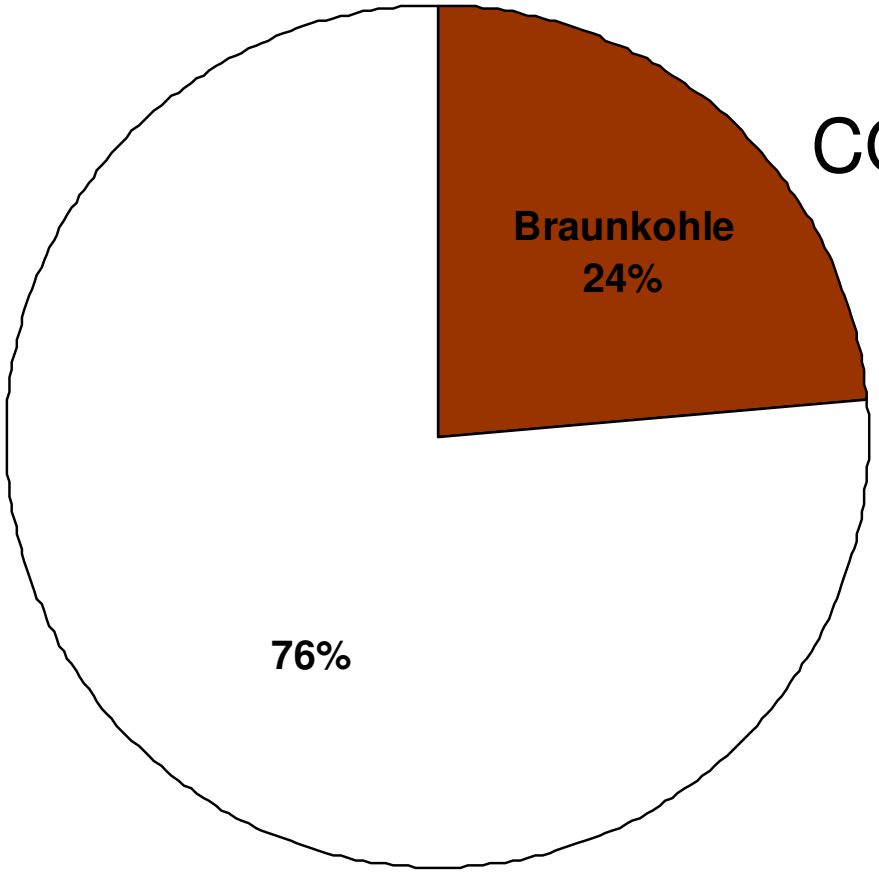
Energiequellen

AGEB
AG Energiebilanzen e.V.



Quelle: AGEB

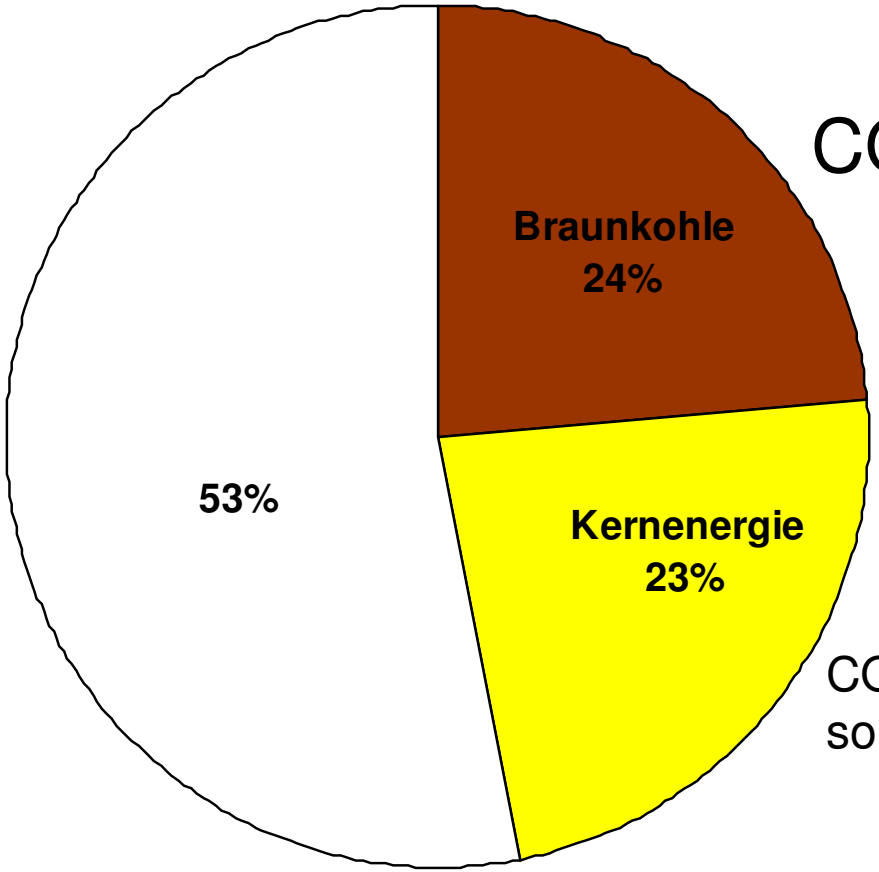
Stromquellen



CO_2 Desaster!

Datenquelle:
Arbeitsgemeinschaft
Energiebilanzen eV

Stromquellen



CO_2 Desaster!

CO_2 neutral,
soll abgeschaltet werden

Datenquelle:
Arbeitsgemeinschaft
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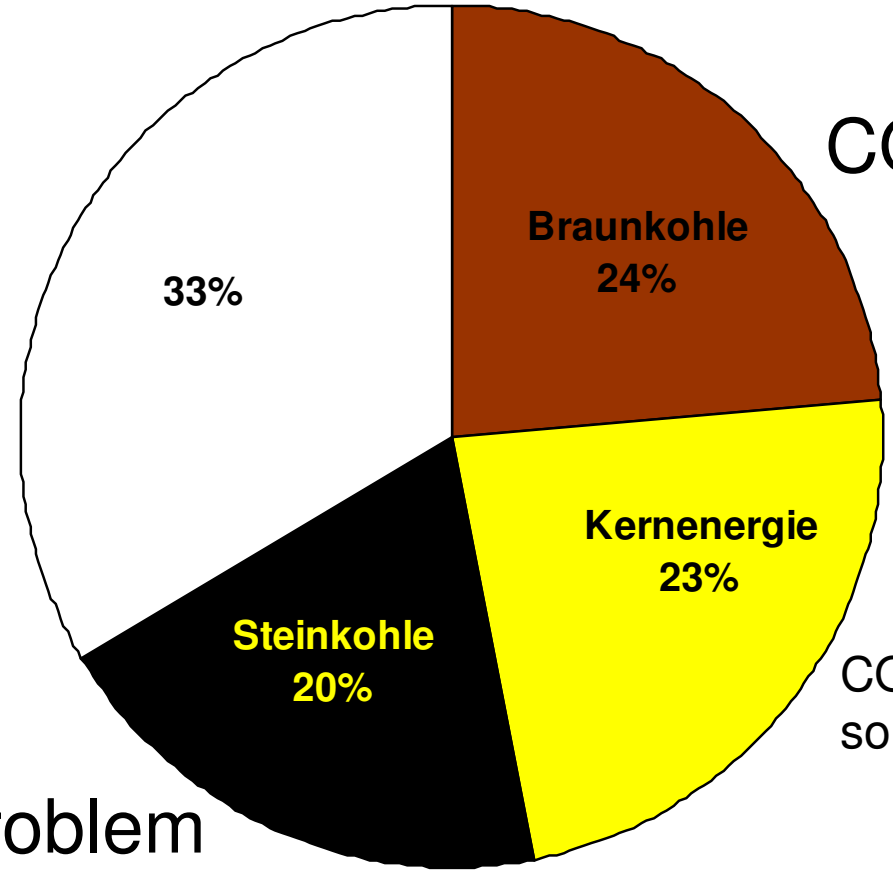
Stromquellen



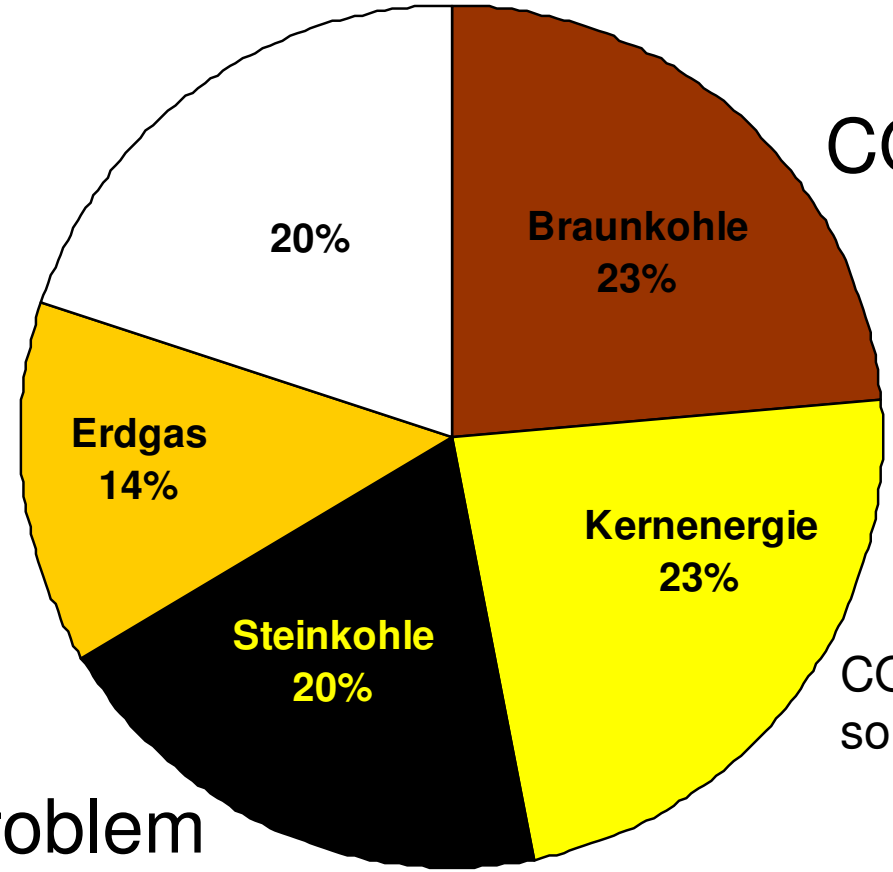
CO_2 Desaster!

CO_2 neutral,
soll abgeschaltet werden

CO_2 Problem

Datenquelle:
Arbeitsgemeinschaft
Energiebilanzen eV

Stromquellen



CO_2 Desaster!

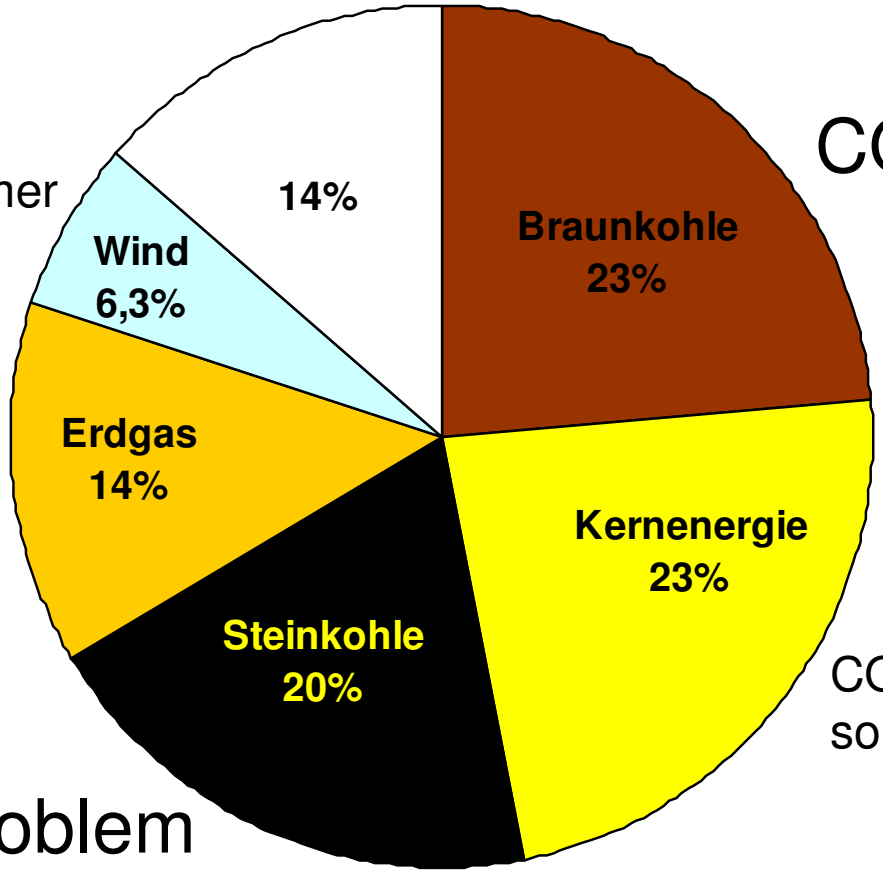
fast
100% Import

CO_2 neutral,
soll abgeschaltet werden

CO_2 Problem

Datenquelle:
Arbeitsgemeinschaft
Energiebilanzen eV

Stromquellen



weht nicht immer

fast
100% Import

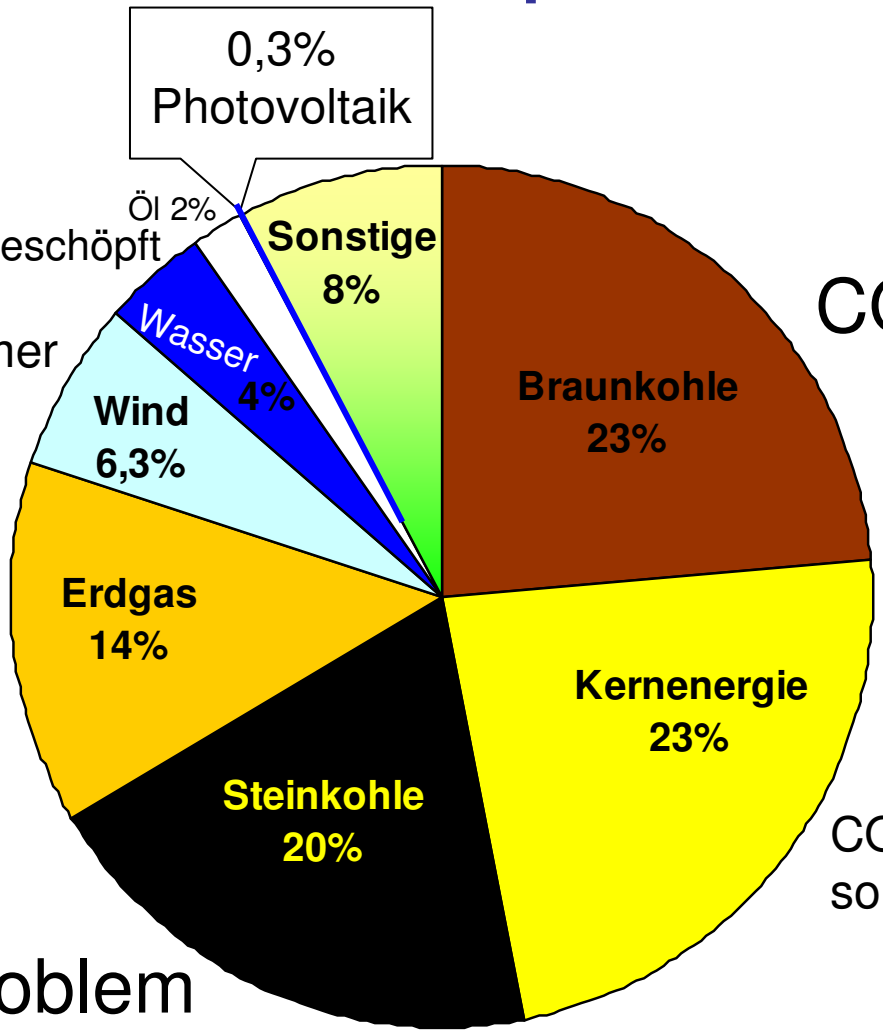
CO_2 Desaster!

CO_2 neutral,
soll abgeschaltet werden

CO_2 Problem

Datenquelle:
Arbeitsgemeinschaft
Energiebilanzen eV

Stromquellen



weht nicht immer

fast
100% Import

CO_2 Desaster!

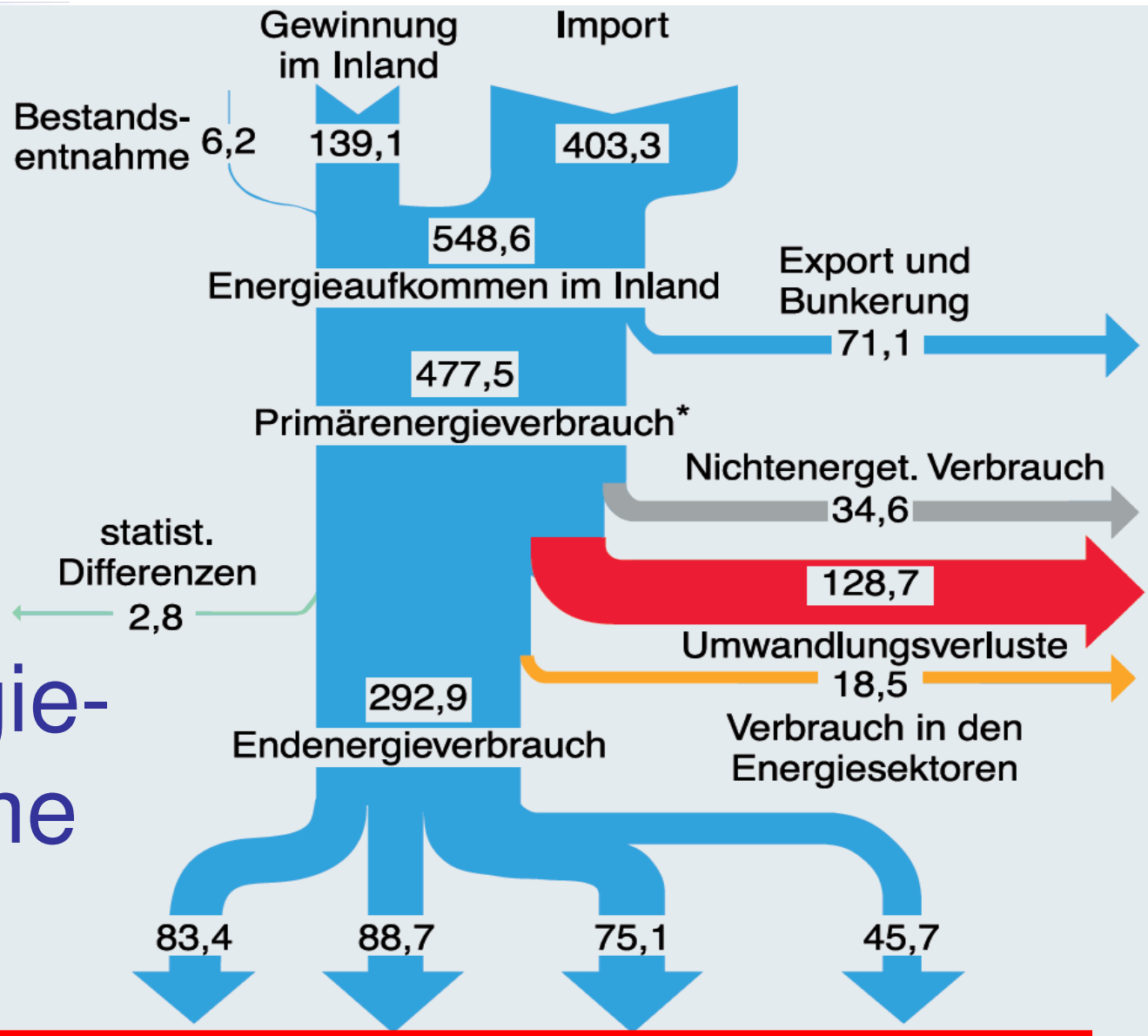
CO_2 neutral,
soll abgeschaltet werden

CO_2 Problem

Datenquelle:
Arbeitsgemeinschaft
Energiebilanzen eV

Energie-ströme

MtSKE



Jeder Deutsche verbraucht ständig **6 kW** Energie
24 Stunden, 365 Tage!

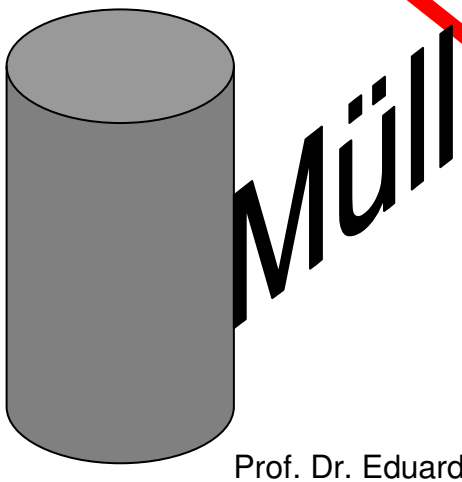
*Der

Alle Zahlen vorläufig/geschätzt.
Quelle: Arbeitsgemeinschaft Energiebilanzen 08/2008

Gespeicherte Energie

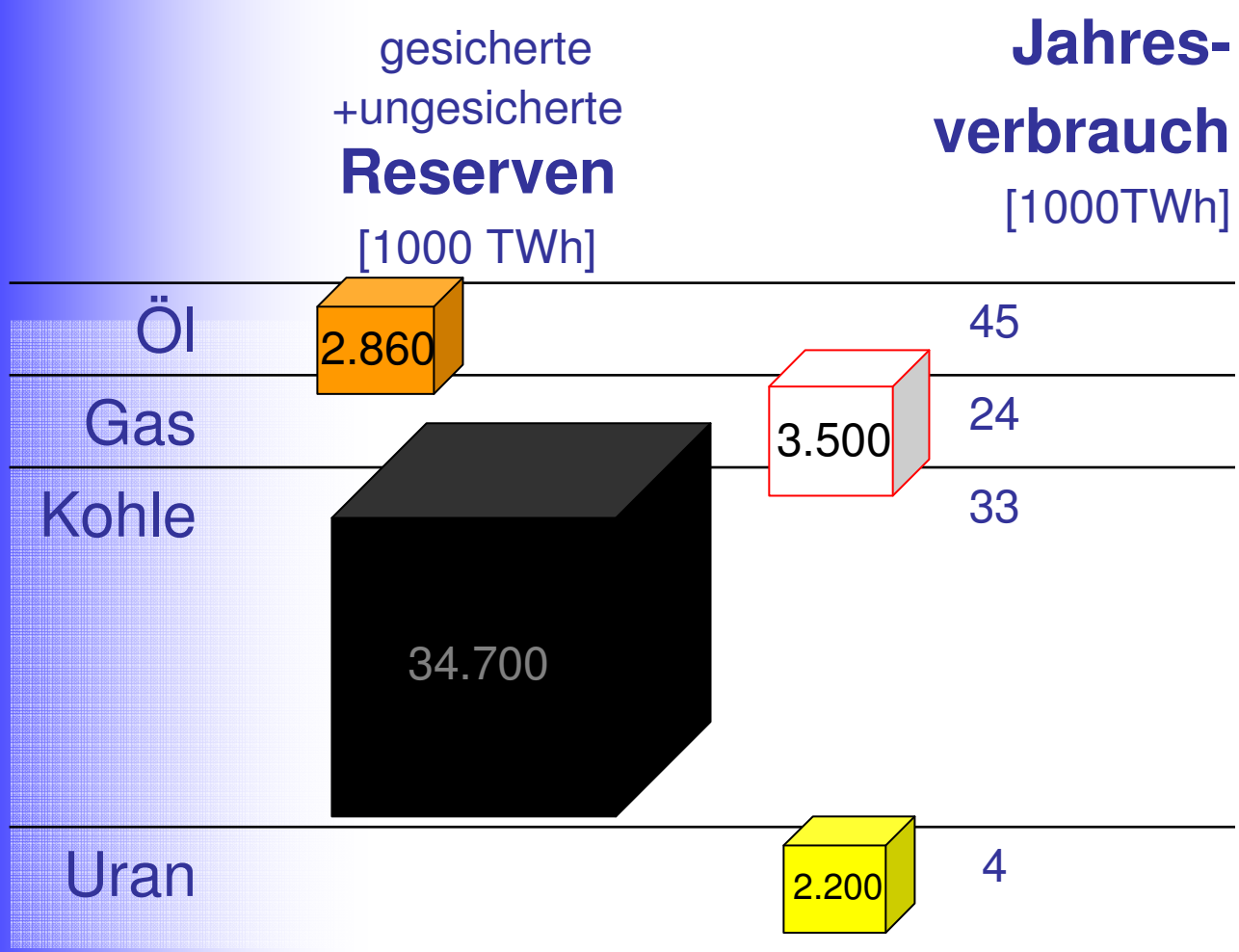
- Kohle
- Öl
- Gas
- Uran

endlich
und
ökologisch
bedenklich



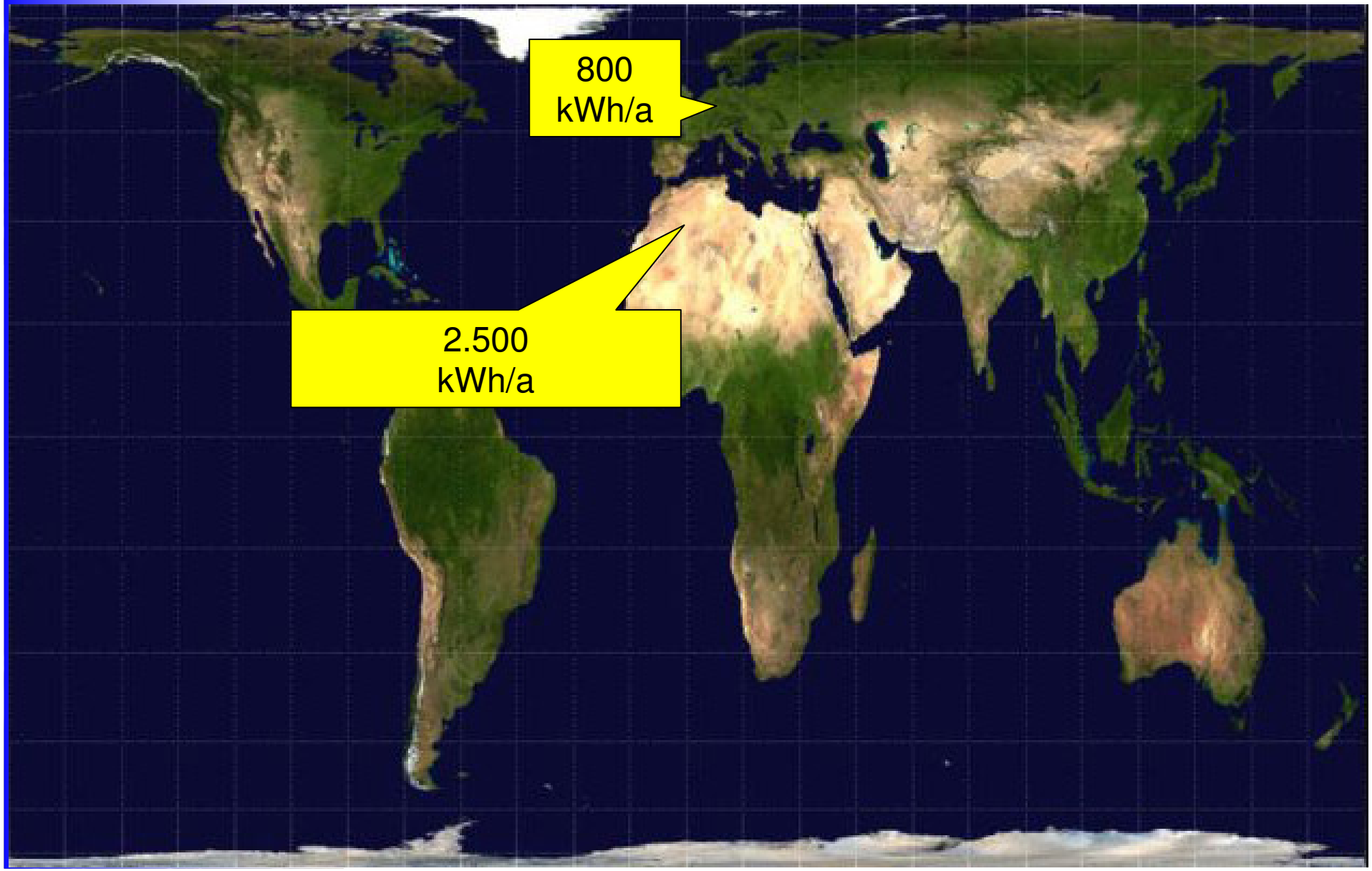
ENDE

Verbrauch und Reserven

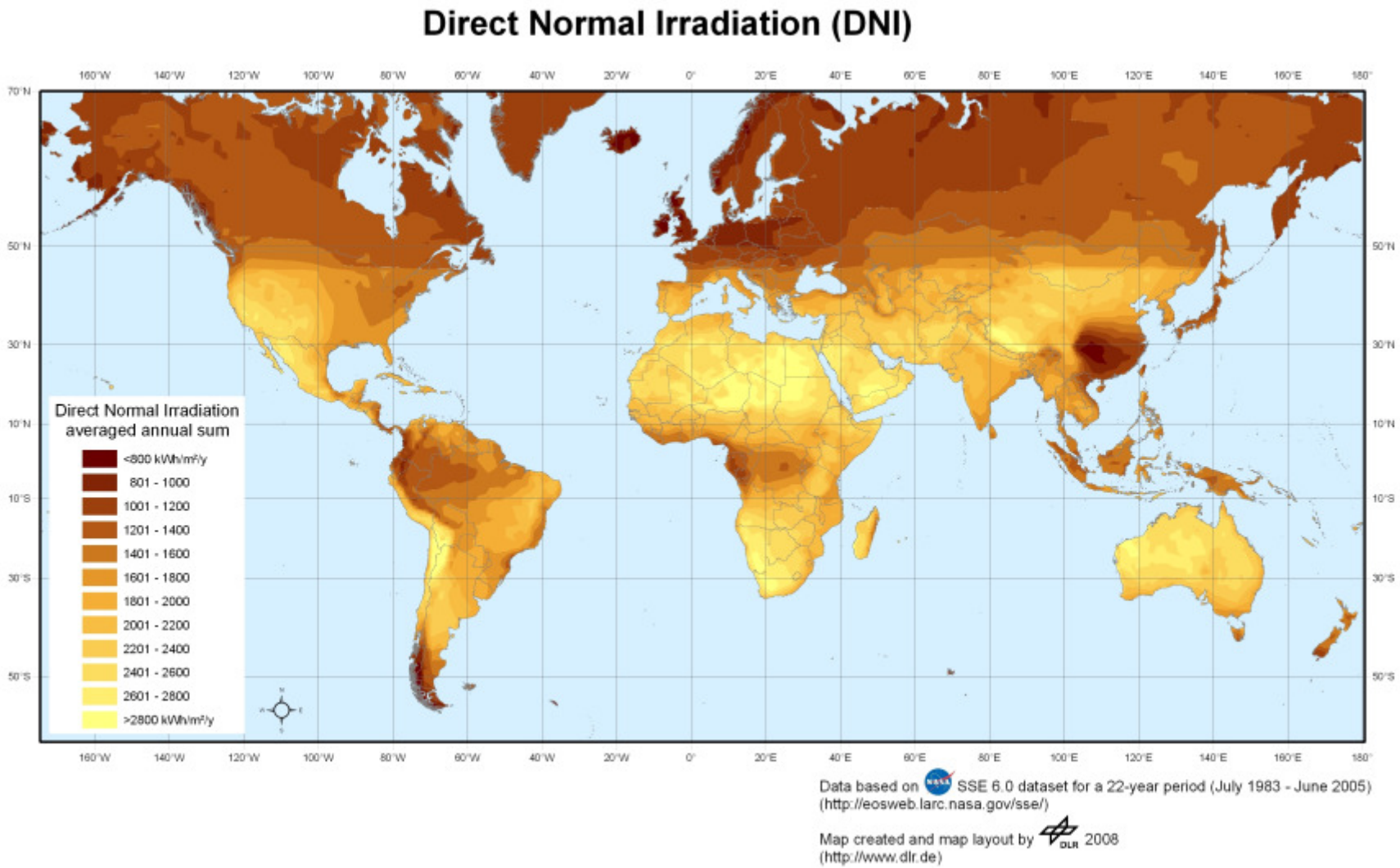


“Erneuerbare Energie” = Solar

Welt der Wüsten



Welt der Wüsten



Sonneneinstrahlung

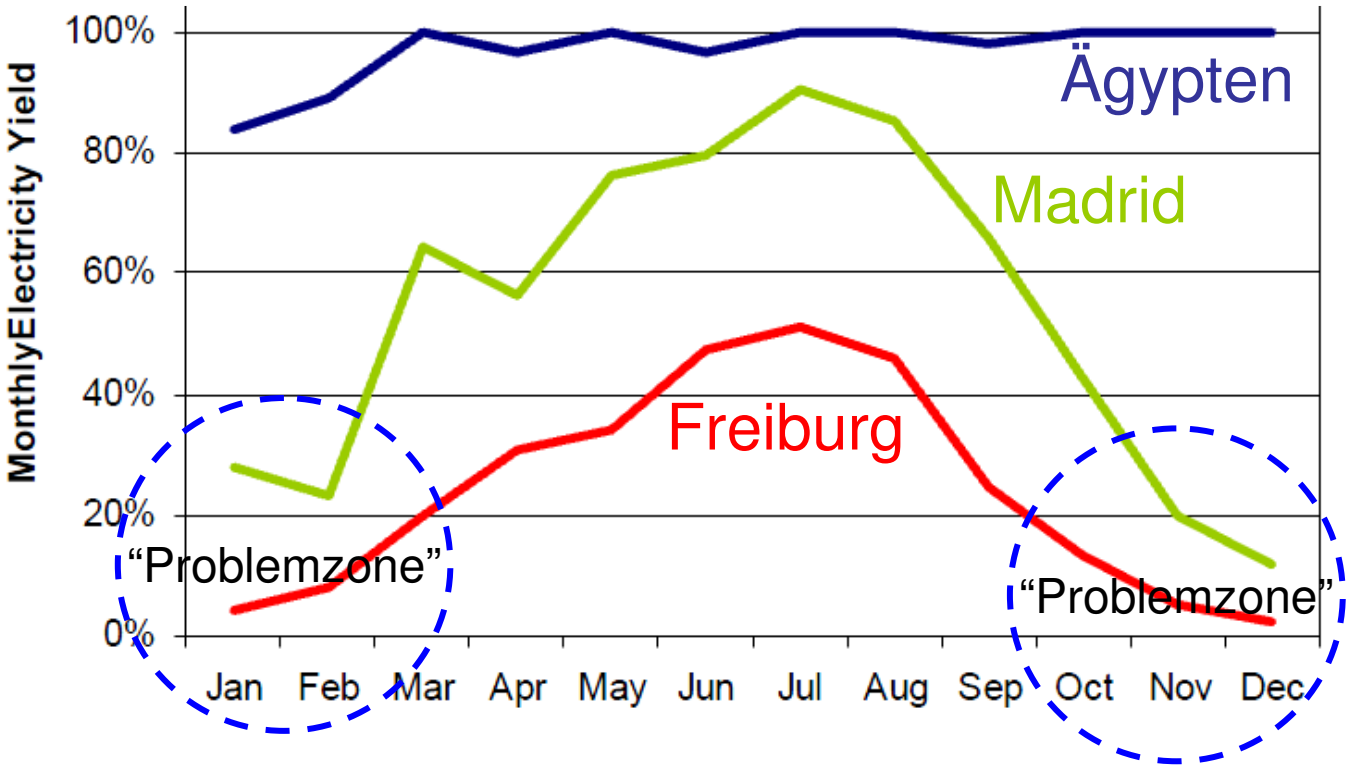
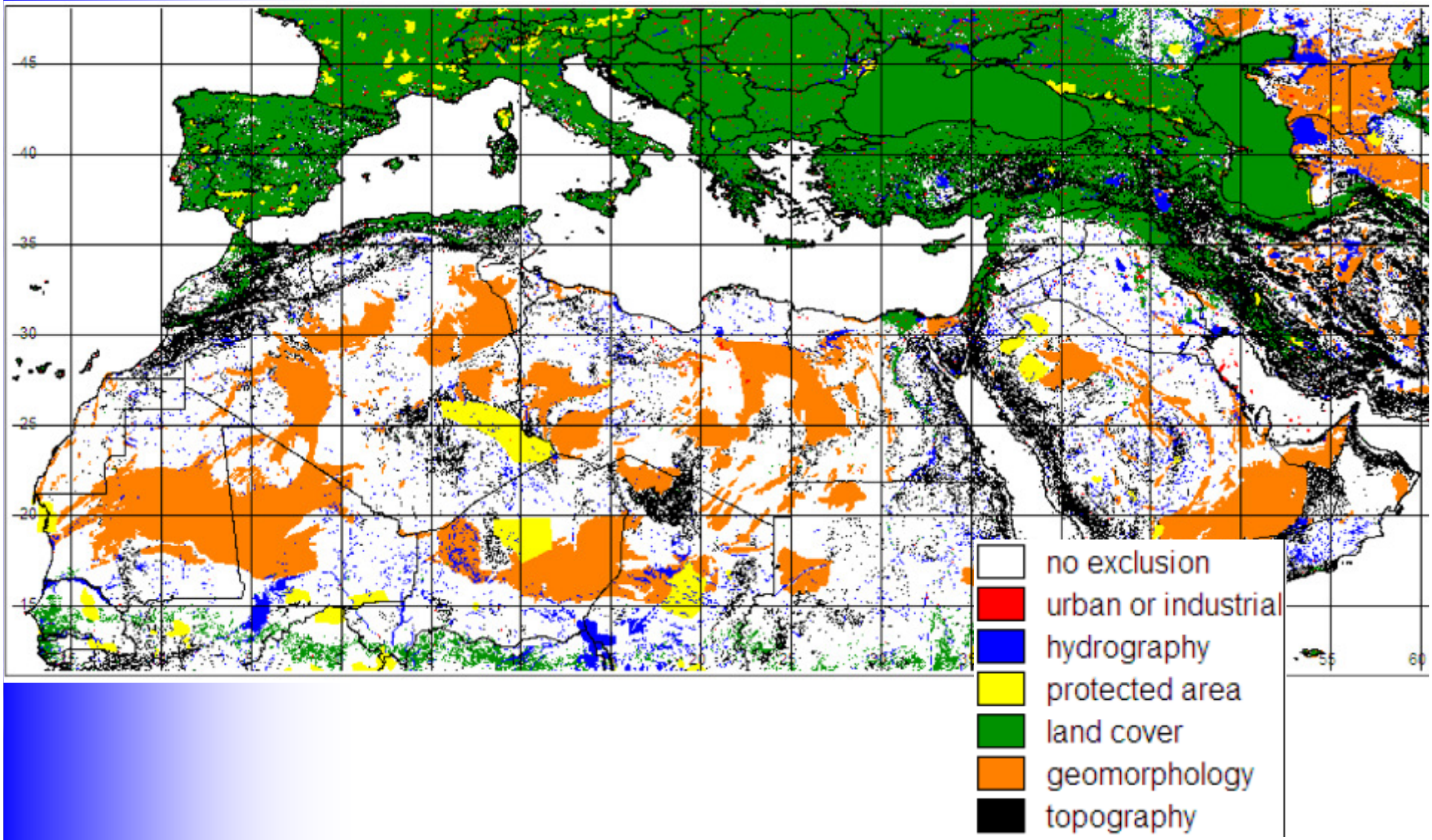


Figure 3-34: Simulation of the relative monthly electricity yield of a solar thermal power plant with 24 hour storage at sites with different annual solar irradiance and latitude assuming solar only operation without fuel input. Total equivalent annual full load hours achieved: Freiburg (Germany) 2260 h/y, Madrid (Spain) 5150 h/y, El Kharga (Egypt) 8500 h/y. Source: (May 2005).

Quelle: DLR 2009-07

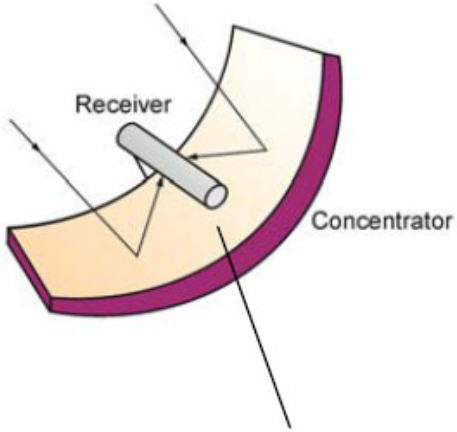
Mögliche Standorte



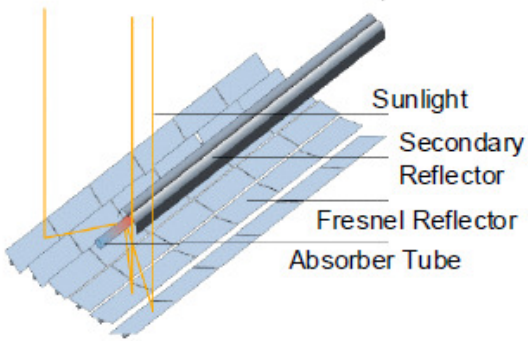
Quelle: DLR 2009-07

Mögliche Technologien

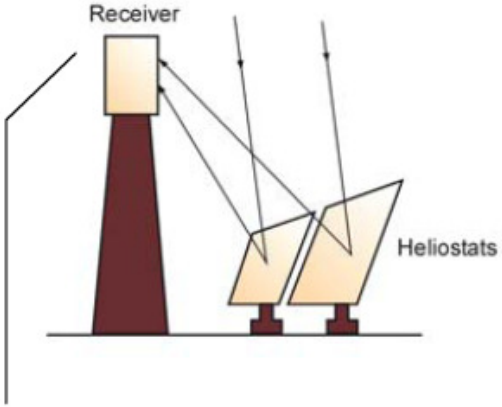
line concentrators



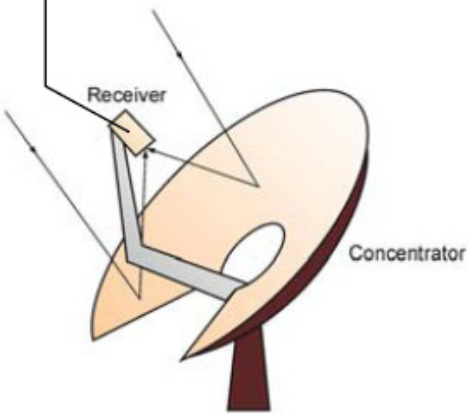
Steam at
350 - 550 °C
80 - 120 bar *



point concentrators



Molten Salt, Air or Helium at
600 - 1200 °C
1 - 20 bar *



Dish/Engine System

Quelle: DLR 2009-07

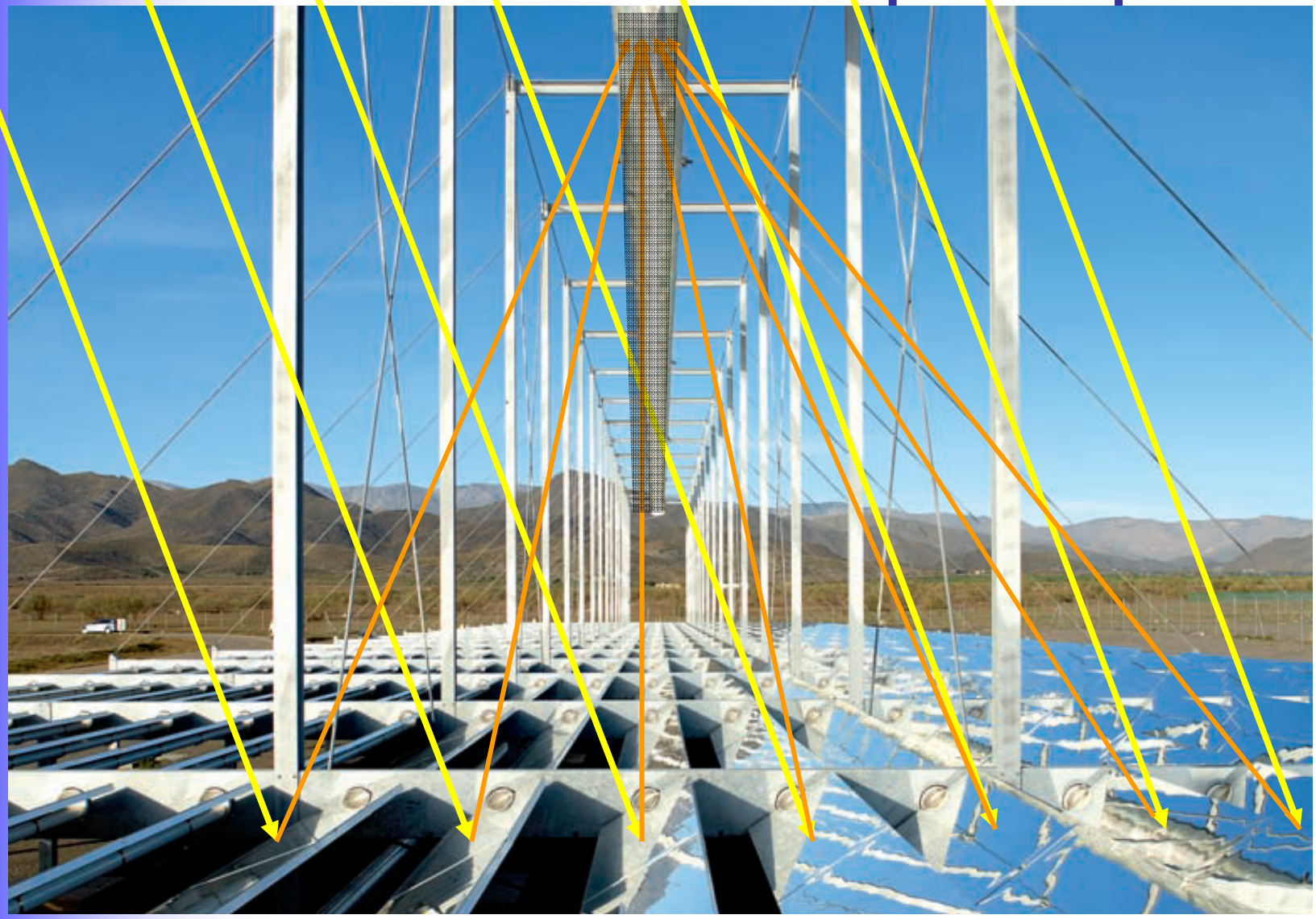
Concentrated Solar Power CSP

Quelle: www.volker-quaschning.de

Fresnel Demoanlage

Quelle: Energy 2.0

Fresnel Arbeitsprinzip



Quelle: Energy 2.0

Turm

Figure 3-43: PS 10 central receiver solar tower facility near Sevilla, Spain (Abengoa Solar)

Quelle: DLR 2009-07

Dish-Stirling-Anlage

Quelle: www.volker-quaschning.de

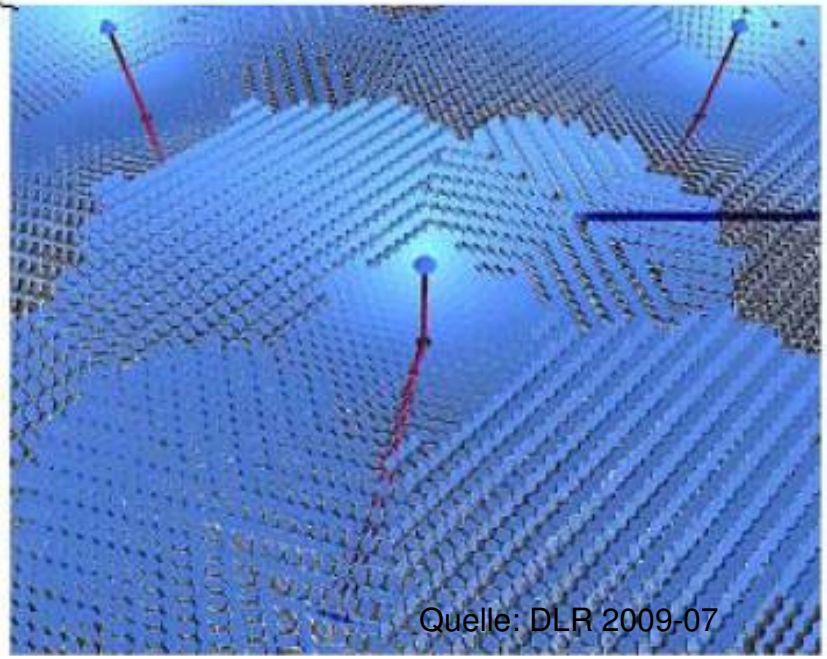
Flächenbedarf

Linear Fresnel

Central Receiver

Trough

MTSA



Quelle: DLR 2009-07

Anlagenkonzept

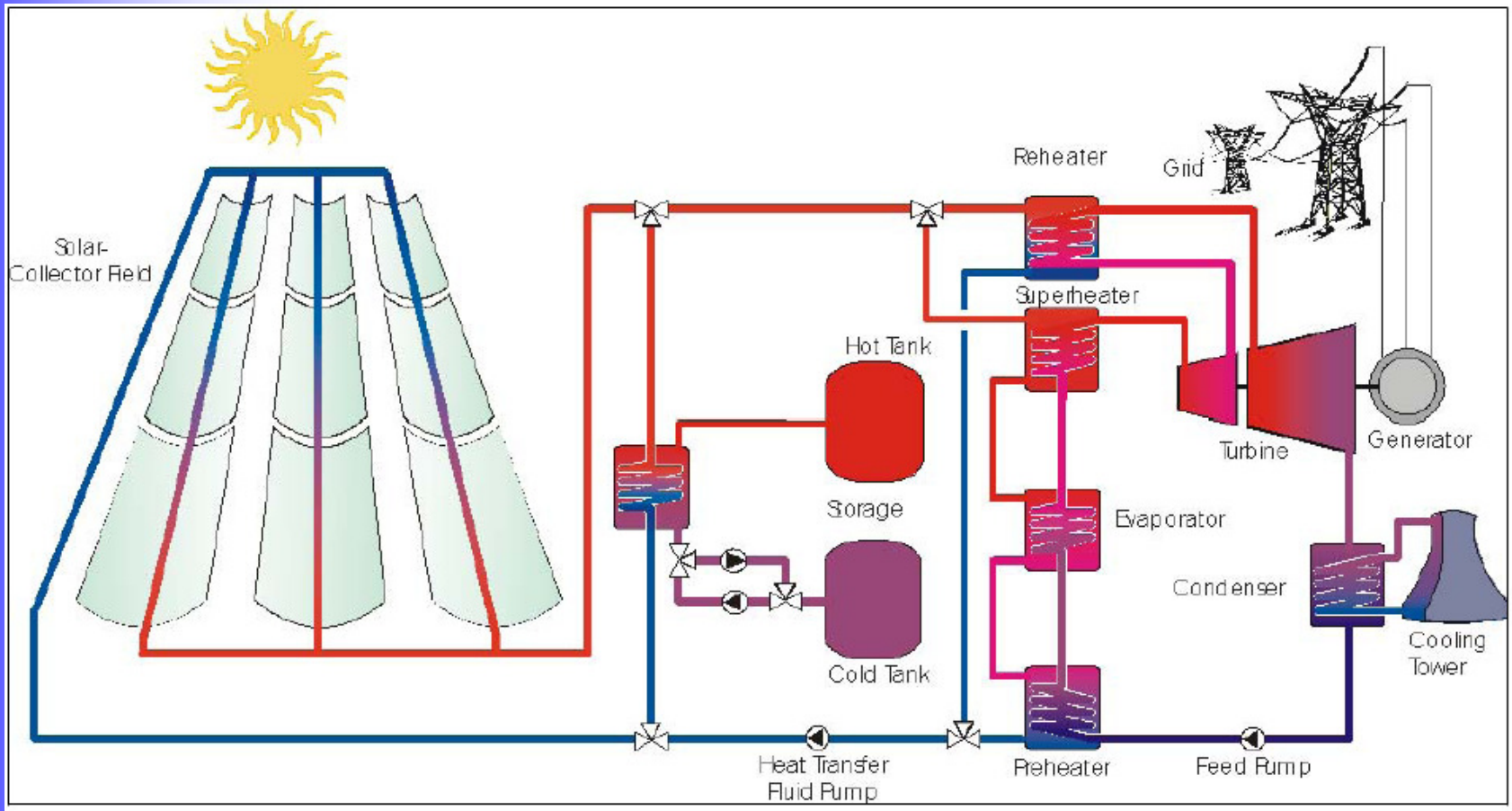


Figure 3-37: Oil-cooled parabolic trough collector coupled to a steam cycle power station.

Quelle: DLR 2009-07

Andasol-1

Figure 3-38: Andasol-1 parabolic trough solar field, storage tanks and power station during construction in December 2007 (Source: ACS Cobra S.A., Spain).

High-Tech

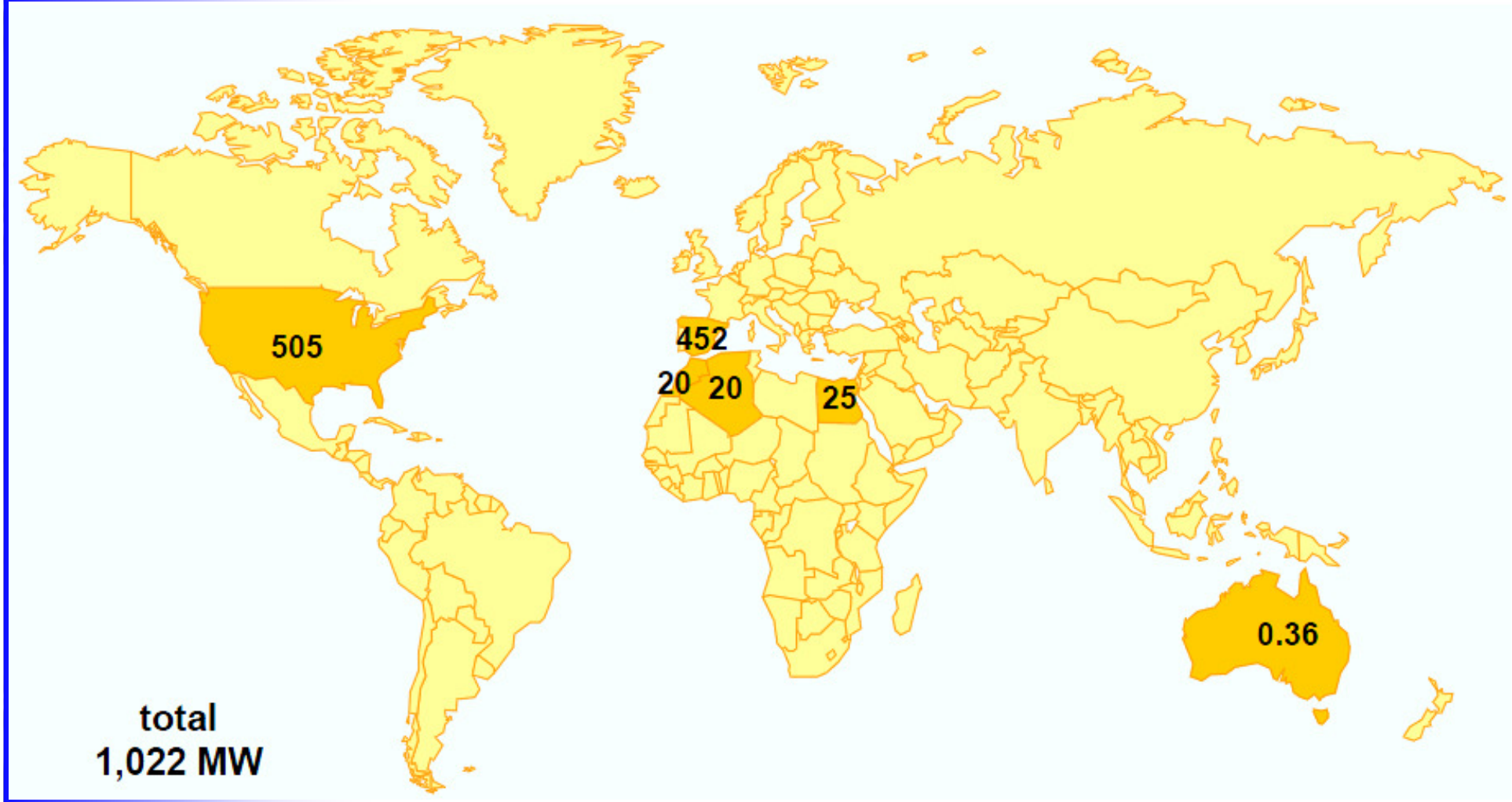
Figure 3-36: Absorber tube with selective coating and evacuated glass envelope by Schott Solar AG, Germany (left) and parabolic trough collector assembly at the Plataforma Solar de Almeria, Spain (right).

Quelle: DLR 2009-07

Materialaufwand

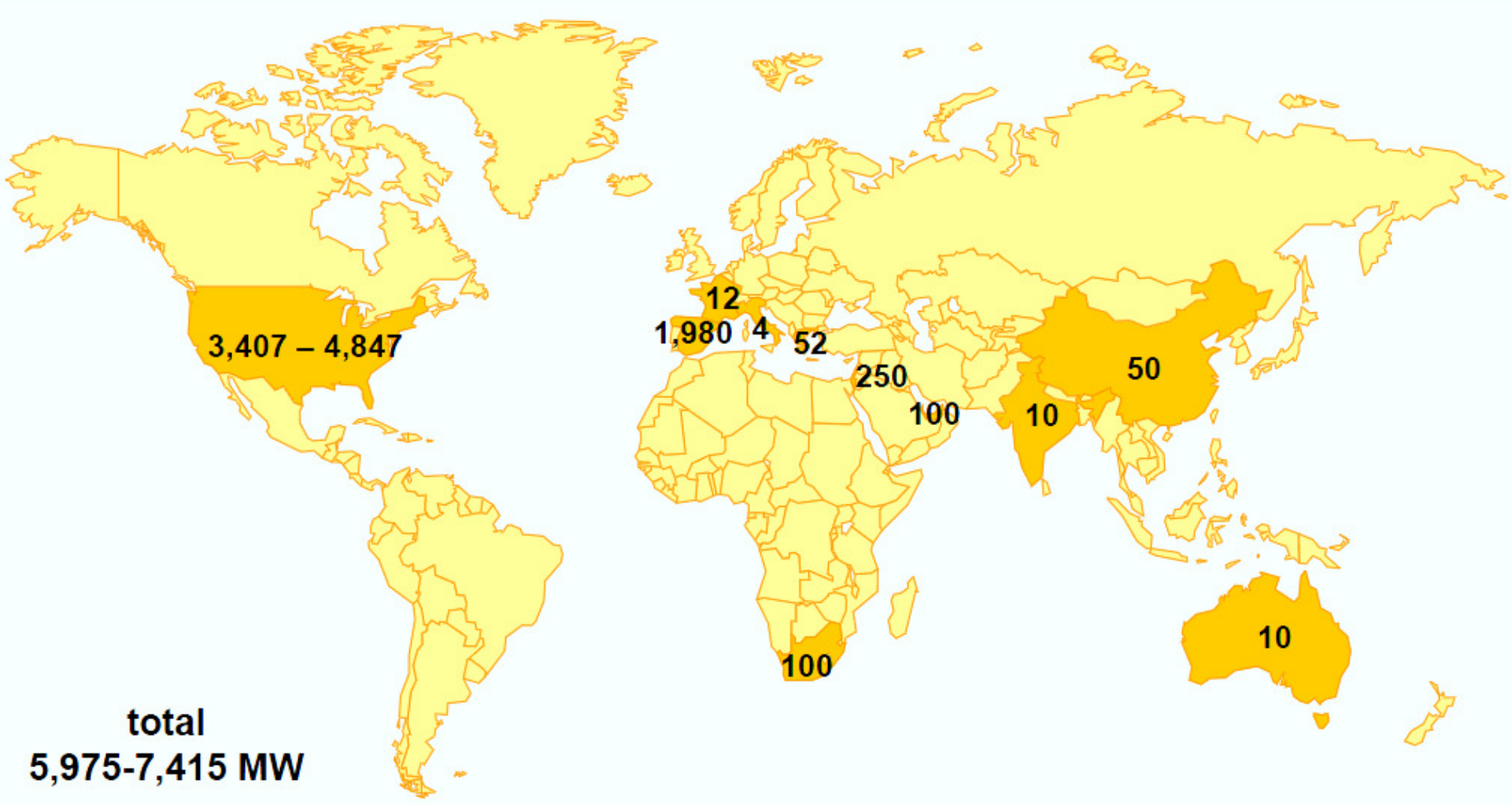
- Rinnenkollektor
  - Material
    - 18kg Stahl/m²
    - 11kg Glas/m²
  - Anlagenkosten
    - 200€/m²
    - 0,10-0,15€/kWh
- Preisgrenze
  - 20€/m²
- Produktionsgrenze
  - 50.000km²/a (Stahl)
  - 125.000.TWh/a
  - 107.000 TWh/a Weltenergiebedarf (primär)
- Stahlproduktion
  - 1000.000.000t/a
  - Preis 1000€/t
- Stahlkosten
  - 18€/m²
- Flachglasproduktion
  - 40.000.000t/a
  - Preis 2€/m² (China)
- Glaskosten
  - 2€/m²

Fertige Anlagen



Quelle: DLR 2009-07

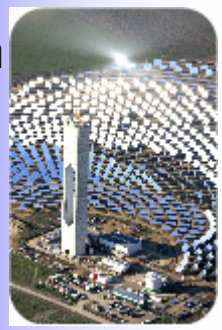
Geplante Anlagen



Quelle: DLR 2009-07

Baustellen

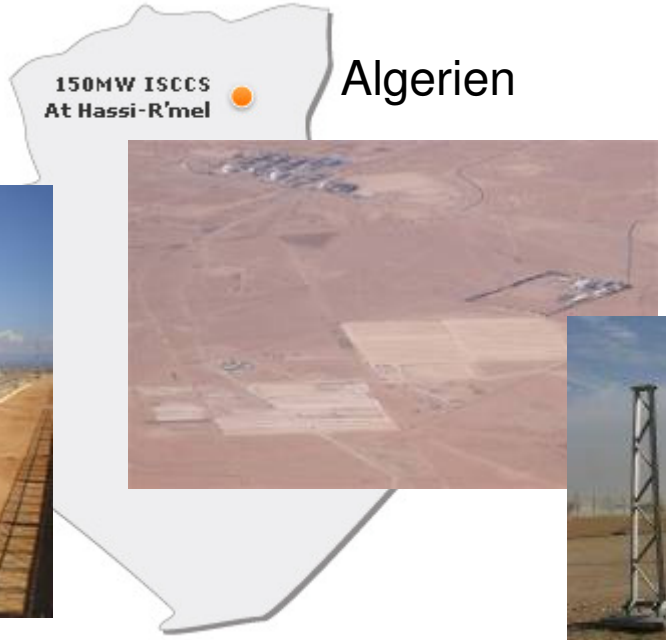
Spanien



Jordanien

Marokko

Algerien



Ägypten

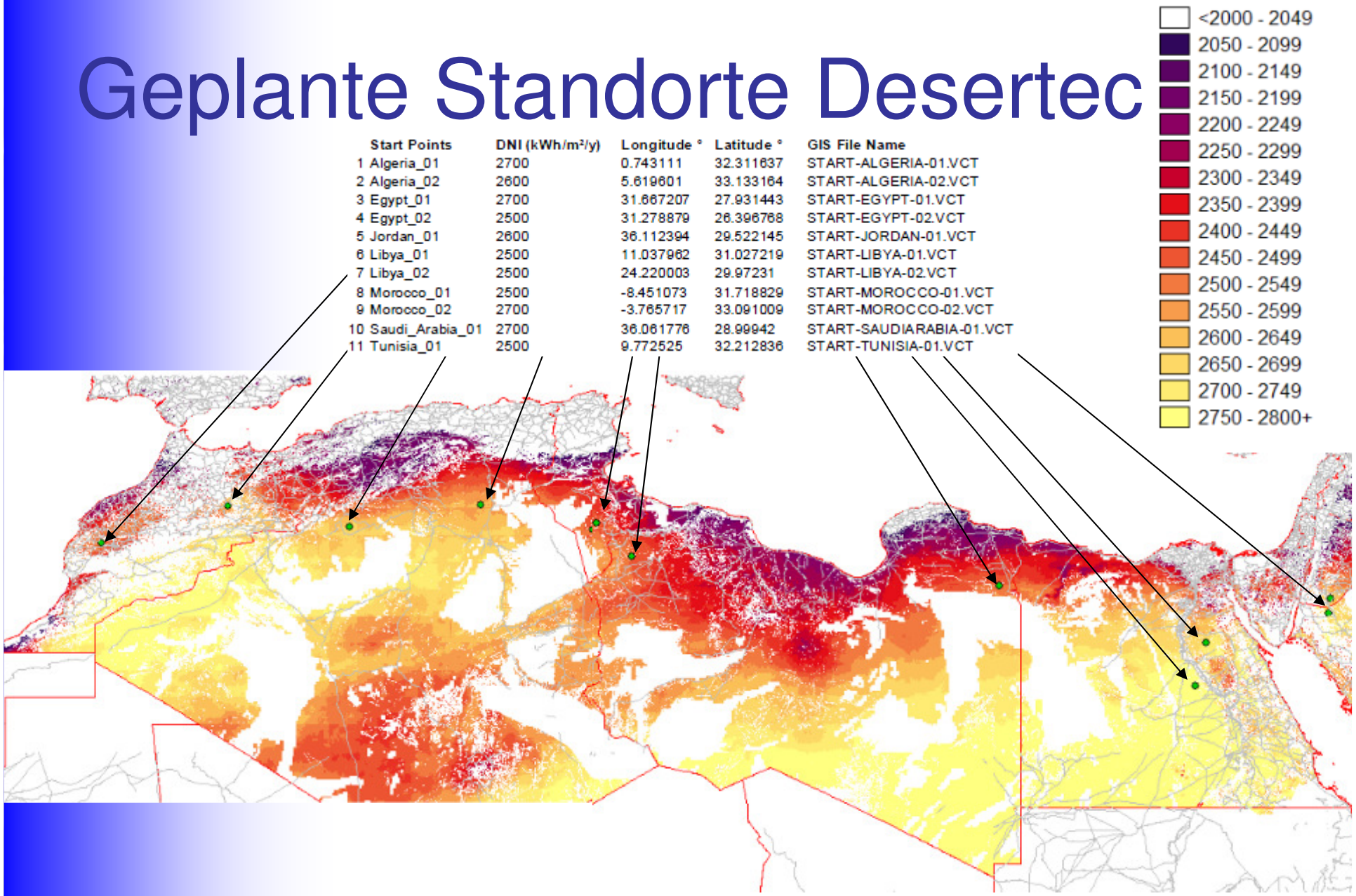
Das Consortium

- ABB
- ABENGOA Solar (US)
- Cevital (Algerien)
- Deutsche Bank
- E.ON
- HSH Nordbank
- MAN Solar Millennium
- Münchener Rück
- M+W Zander
- RWE
- SCHOTT Solar
- SIEMENS

Quelle: DLR 2009-07

Geplante Standorte Desertec

	Start Points	DNI (kWh/m²/y)	Longitude °	Latitude °	GIS File Name
1	Algeria_01	2700	0.743111	32.311637	START-ALGERIA-01.VCT
2	Algeria_02	2600	5.619601	33.133164	START-ALGERIA-02.VCT
3	Egypt_01	2700	31.667207	27.931443	START-EGYPT-01.VCT
4	Egypt_02	2500	31.278879	26.396768	START-EGYPT-02.VCT
5	Jordan_01	2600	36.112394	29.522145	START-JORDAN-01.VCT
6	Libya_01	2500	11.037962	31.027219	START-LIBYA-01.VCT
7	Libya_02	2500	24.220003	29.97231	START-LIBYA-02.VCT
8	Morocco_01	2500	-8.451073	31.718829	START-MOROCCO-01.VCT
9	Morocco_02	2700	-3.765717	33.091009	START-MOROCCO-02.VCT
10	Saudi_Arabia_01	2700	36.061776	28.99942	START-SAUDIARABIA-01.VCT
11	Tunisia_01	2500	9.772525	32.212836	START-TUNISIA-01.VCT



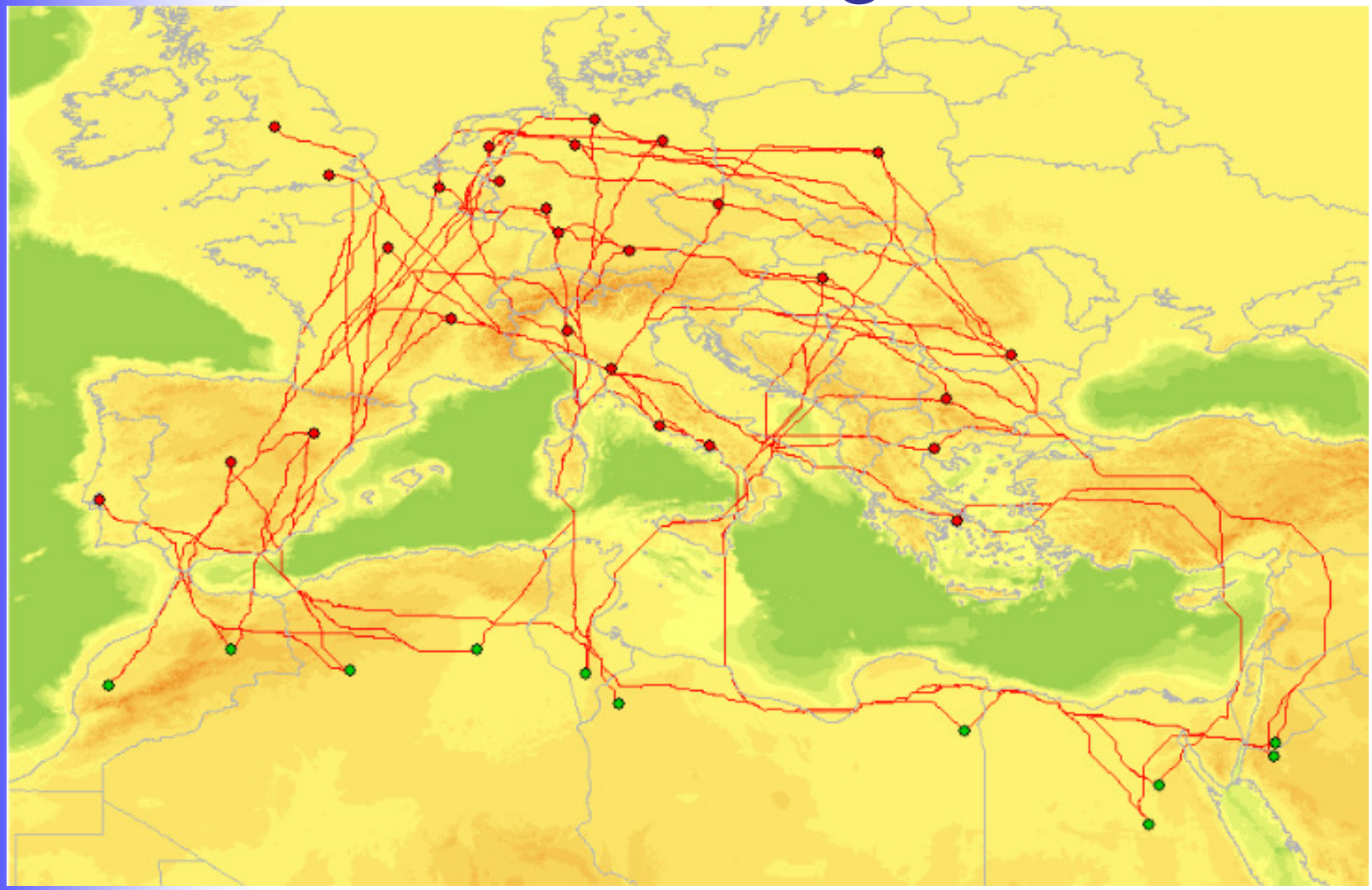
Quelle: DLR 2009-07

HGÜ Stromtransport

- Hochspannungs Gleichstrom Übertragung
- keine Abstrahlungsverluste
- Ohmscher Verlust: 3% pro 1.000km
- Beispiele*:
  - Itaipú (Brasilien) ±600 kV, 6296 MW, 800km
  - Yunnan – Shanghai (China), ± 800 kV, 6400 MW, 2071 km

*IEEE Transmission and Distribution Committee

Das Leitungsnetz



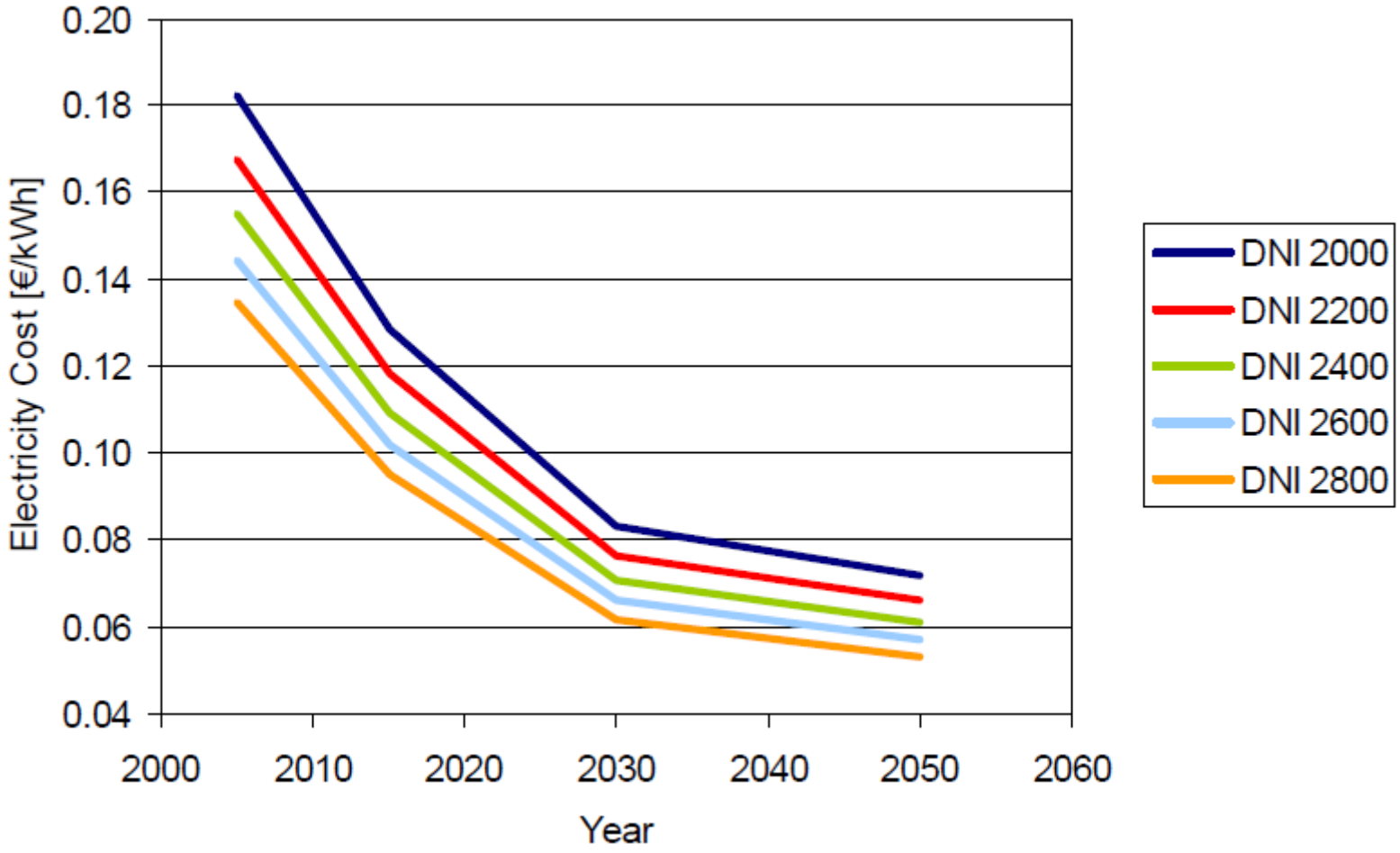
Quelle: DLR 2009-07

Kostenstruktur

Year	2005	2015	2030	2050	Unit
World CSP Capacity	354	5000	150000	500000	MW
Solar Field Cost	360	241	144	120	€/m²
Power Block Cost	1200	1111	1006	971	€/kW
Solar Field Size (SM1)	6	6	6	6	m²/kW
Total Solar Field Size	24	24	24	24	m²/kW
Storage Cost	60	44	29	25	€/kWh
Storage Capacity	18.0	18.0	18.0	18.0	kWh/kW
Storage Cost	1080	785	522	451	€/kW
Solar Field Cost	8640	5792	3454	2876	€/kW
Discount Rate	6.0%	6.0%	6.0%	6.0%	%/y
Plant Lifetime	30	30	30	30	y
Solar Multiple	4	4	4	4	
Direct Normal Irradiance	2700	2700	2700	2700	kWh/m²/y
Specific Investment	**10920**	**7688**	**4982**	**4299**	**€/kW**
Full Load Hours per Year	**7641**	**7641**	**7641**	**7641**	**kWh/kW/y**
Fixed Charge Rate	7.3%	7.3%	7.3%	7.3%	%/y
O&M Cost	2.0%	2.0%	2.0%	2.0%	%Inv./y
Insurance Cost	0.5%	0.5%	0.5%	0.5%	%Inv./y
Annual Capital Cost	793.3	558.5	361.9	312.3	€/kW/y
Annual O&M Cost	218.4	153.8	99.6	86.0	€/kW/y
Annual Insurance Cost	54.6	38.4	24.9	21.5	€/kW/y
Total Annual Cost	**1066.3**	**750.7**	**486.4**	**419.8**	**€/kW/y**
Levelised Electricity Cost	**0.140**	**0.098**	**0.064**	**0.055**	**€/kWh**

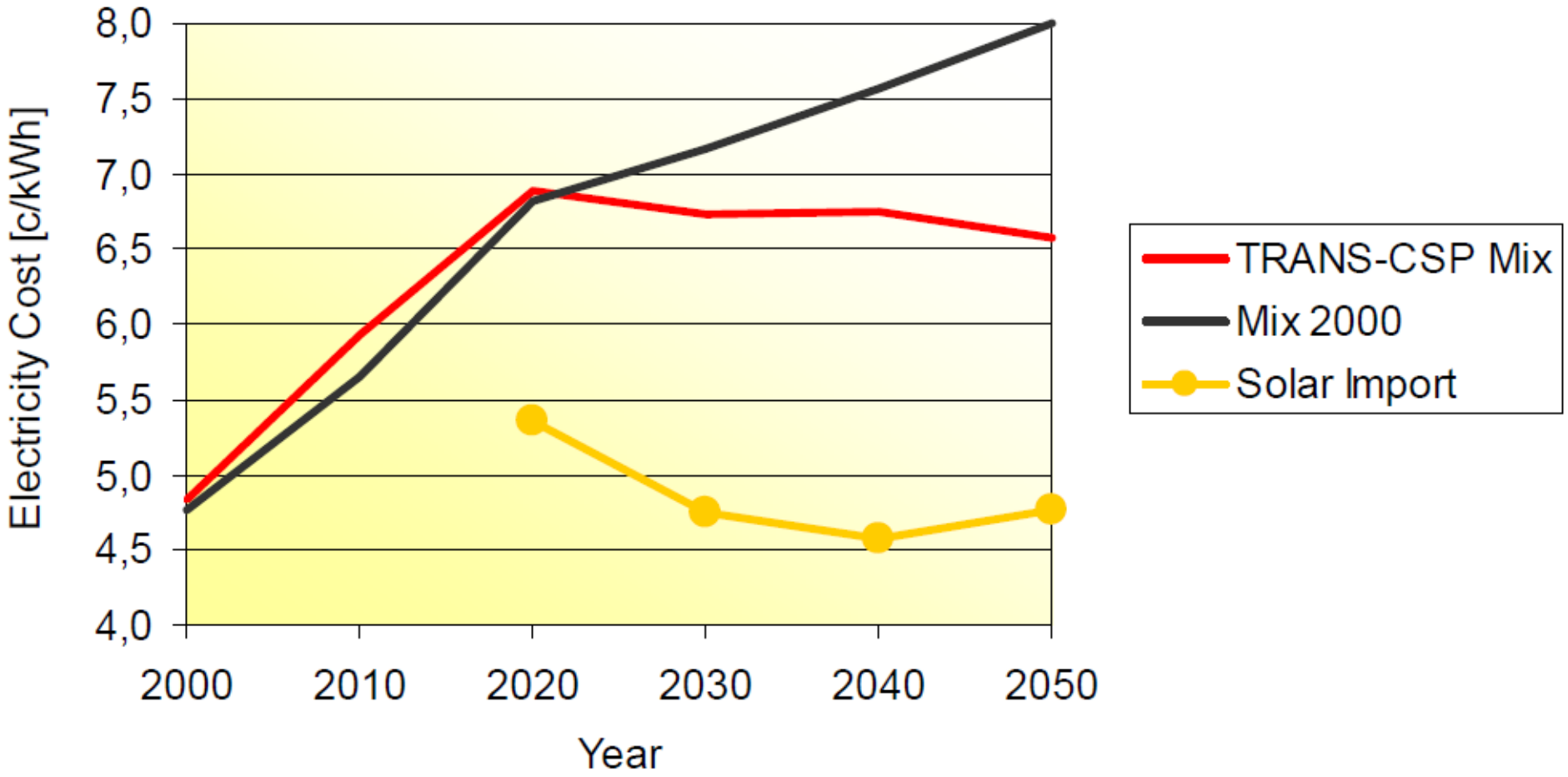
Quelle: DLR 2009-07

Strompreisentwicklung



Quelle: DLR 2009-07

Strompreis



Quelle: DLR 2009-07

Desertec: Business-Plan

Year		2020	2030	2040	2050
Transfer Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Electricity Transfer TWh/y		60	230	470	700
Capacity Factor		0.60	0.67	0.75	0.80
Turnover Billion €/y		3.8	12.5	24	35
Land Area	CSP	15 x 15	30 x 30	40 x 40	50 x 50
km x km	HVDC	3100 x 0.1	3600 x 0.4	3600 x 0.7	3600 x 1.0
Investment	CSP	42	143	245	350
Billion €	HVDC	5	20	31	45
Elec. Cost	CSP	0.050	0.045	0.040	0.040
€/kWh	HVDC	0.014	0.010	0.010	0.010

Quelle: DLR 2009-07

Importabhängigkeit

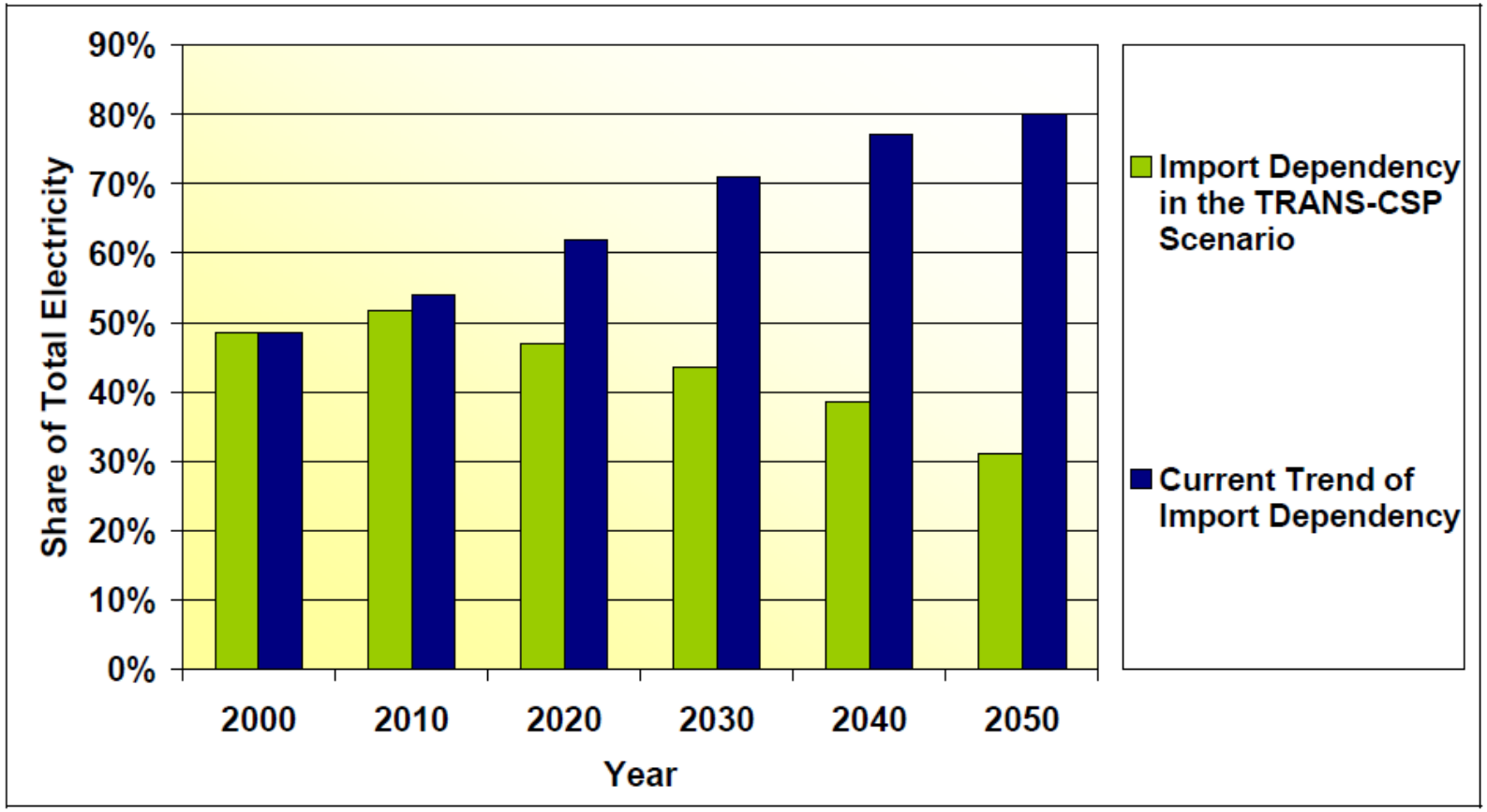


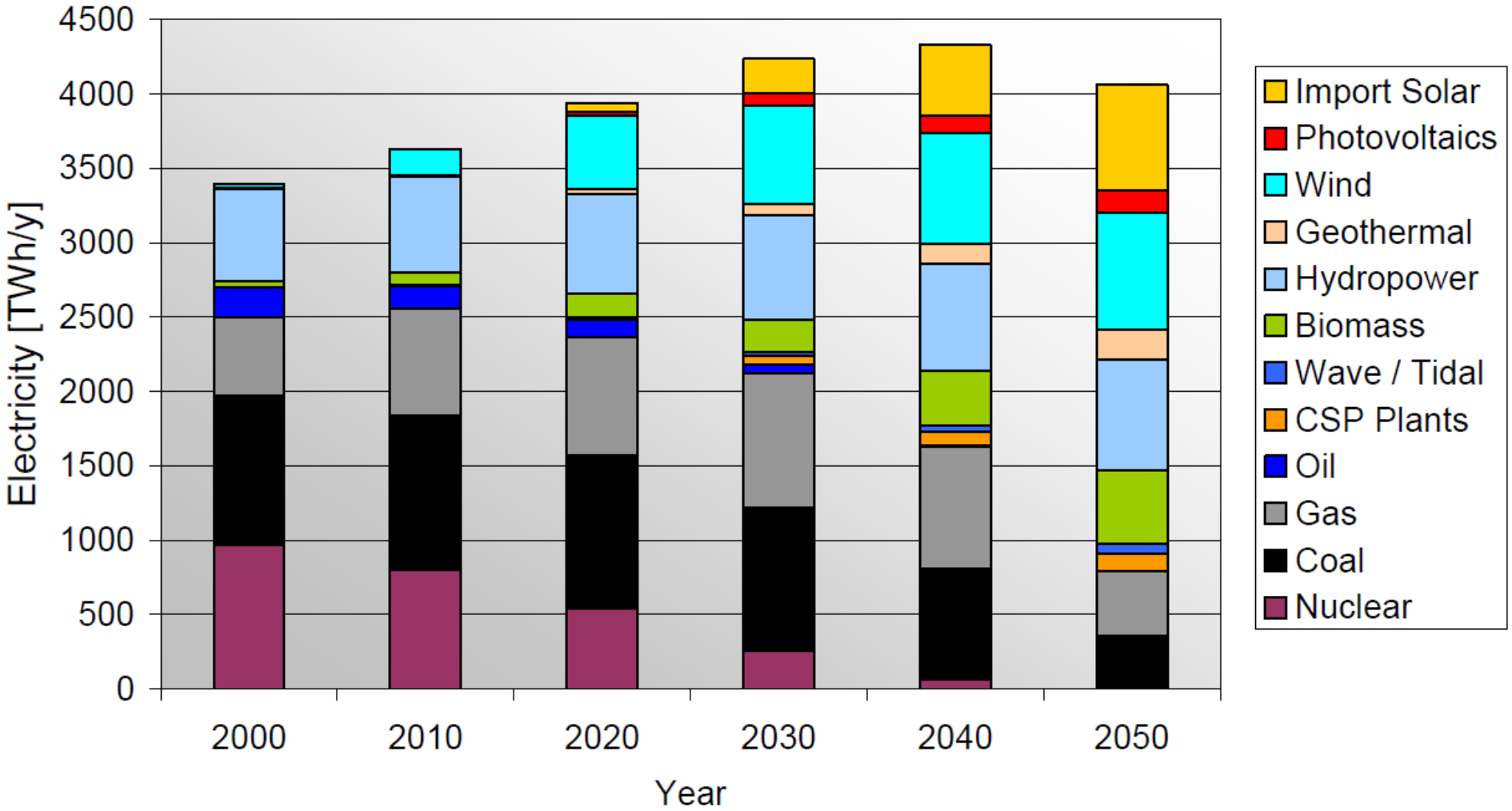
Figure 2-5: Import dependency inclusive CSP import in the TRANS-CSP scenario compared to the current trend of import dependency in the EU.

Quelle: DLR 2009-07

Politische Risiken

- Anschlagsrisiko
  - Bisher kaum aufgetreten (Ausnahmen: Südafrika, Atomkraft-Gegner)
  - Relativ unabhängig vom Erzeugerland!
- Erpressung
  - Steuung über mehrere Staaten
  - Strom, der nicht geliefert wird, verfällt, im Gegensatz zu Öl!

EU Energiemix 2050



Quelle: DLR 2009-07

Photovoltaik

- 1kW Installation in D kostet 3.000€
- 1kW Anlage liefert pro Jahr 1.000kWh
- Energiebedarf in D: 4.000TWh
- Kosten: 11.870.000.000.000,00 €
- das sind 11.870 Mrd. Euro (Ohne Batterien)
  pro Person ca. 150.000€
- Mit Desertec kostet das ca. 790 Mrd. Euro
  pro Person ca. 10.000€

Alternativen

Technik	GWh/km²/a	Lage
Biomassekraftwerk	1-2	(Mitteleuropa)

Zusammenfassung

- Solarenergie aus der Wüste
  - ist konkurenzfähig im Preis
  - kann über Nacht gespeichert werden
  - ist CO_2 neutral, umweltfreundlich
  - ist praktisch unbegrenzt vorhanden
  - kann mit heutiger Technologie gewonnen werden
  - politische Risiken sind überschaubar
  - wird in 30 Jahren die Hauptquelle für Strom

Quellen

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Vielen Dank für die Aufmerksamkeit!

Fragen?