Transmission of dispatchable solar energy from Morocco to Baden-Württemberg

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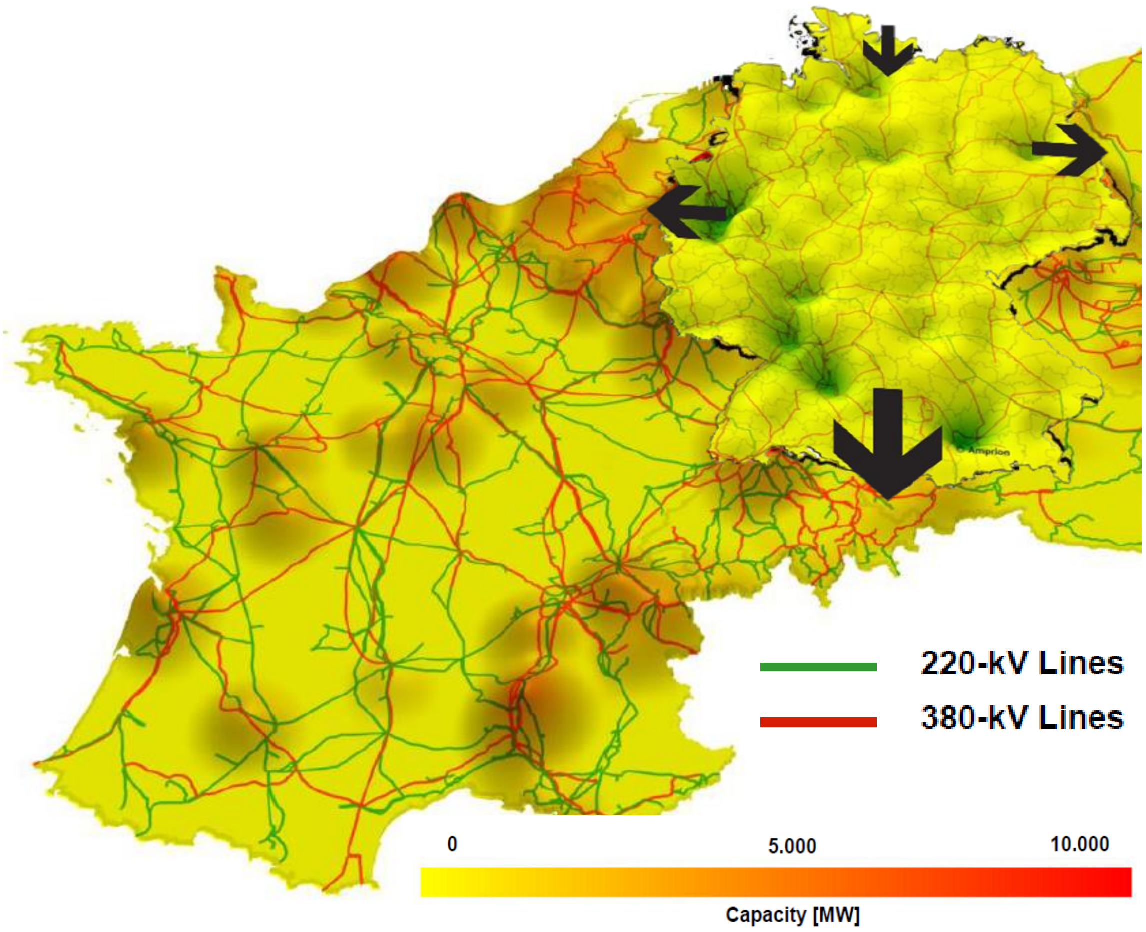
DLR

Overview

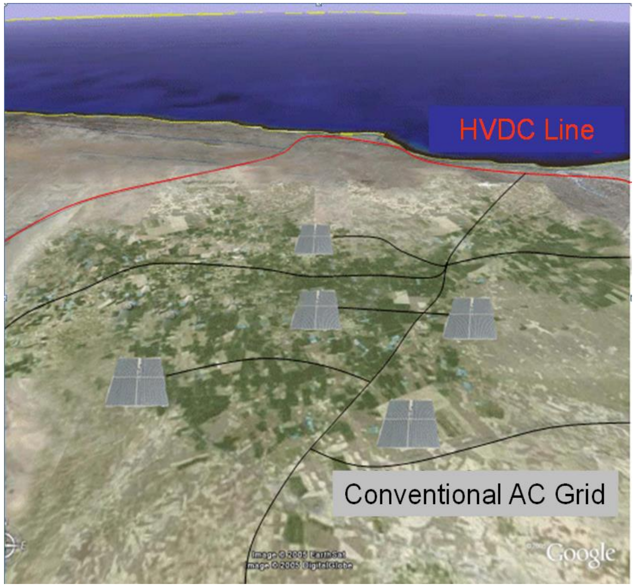
- Demand in Baden-Württemberg
- Potential in Morocco
- Transmission – technology and costs
- Decision levels, civil participation
- Financing

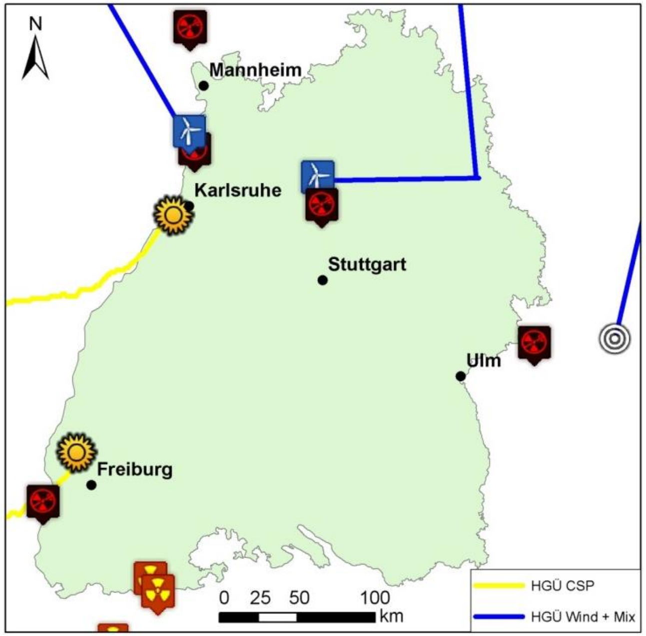
Electricity production sites and demand sites



Source: Ampiron and NEP 2012

Electricity imports from North Africa to Baden-Württemberg by High Voltage Direct Current (HVDC) transmission from 2022





- Nuclear power plants in operation
- Nuclear power plants out of operation
- Import of windenergy + Mix
- Import Mix
- Import CSP

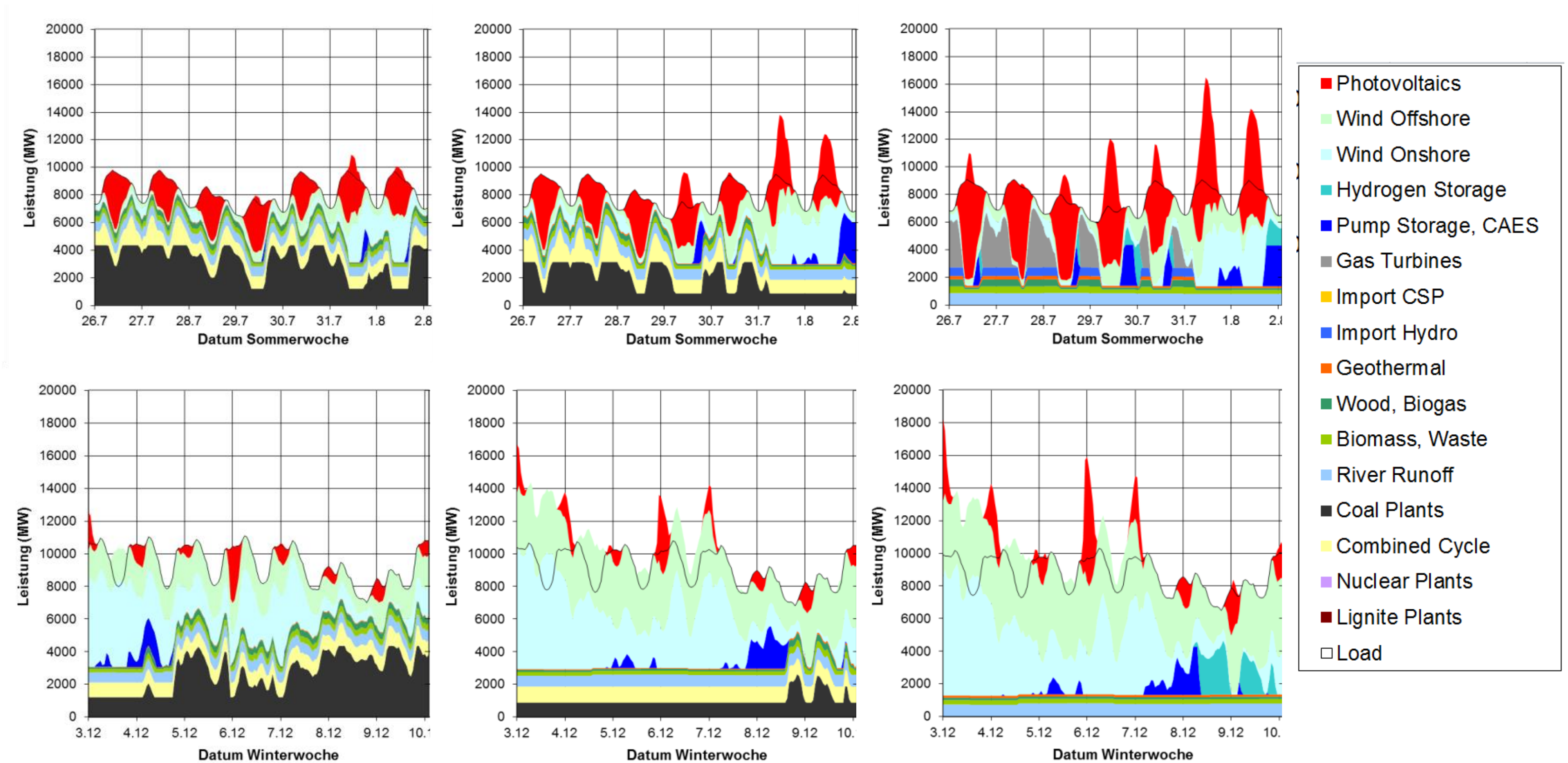
Source: Trieb, F.; Hess, D.

2025, 2030, 2050 BW without CSP -> surpluses, high installed capacity, expensive in 2050

2025 | 2030 | 2050

week in summer

week in winter



% of RE: 55% 70% 95%

inst. capacity: 36 GW 43 GW 55 GW

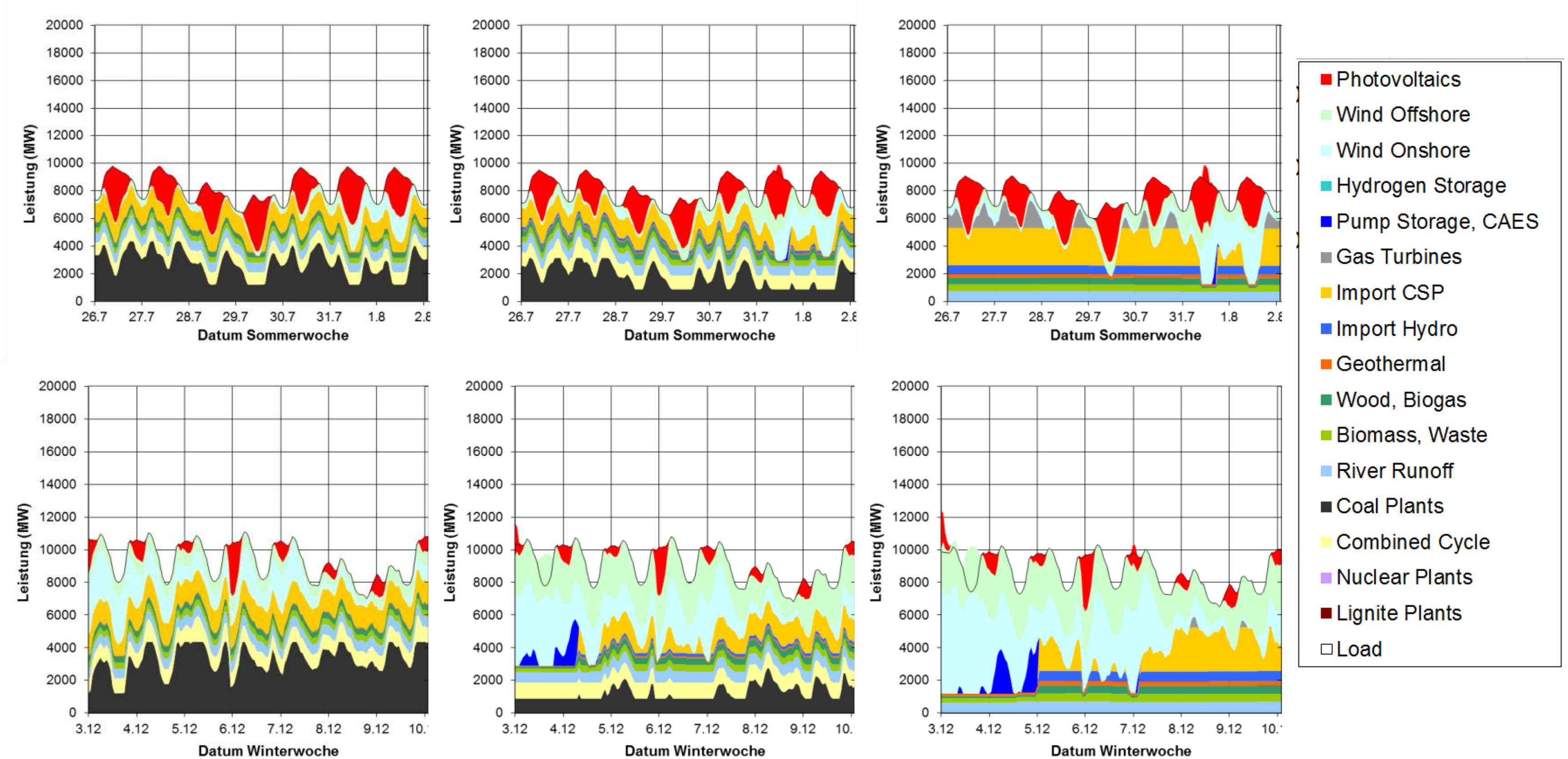
Source: F. Trieb, ELMOD-BW; J. Nitsch, Szen-BW 2012; Y. Scholz, ReMIX

2025, 2030, 2050 BW with CSP -> dispatchabel energy, low inst. capacity, cheaper in 2050

	2025	2030	2050

week in summer

week in winter



% of RE:	55%	70%	95%
inst. capacity:	30 GW	33 GW	35 GW

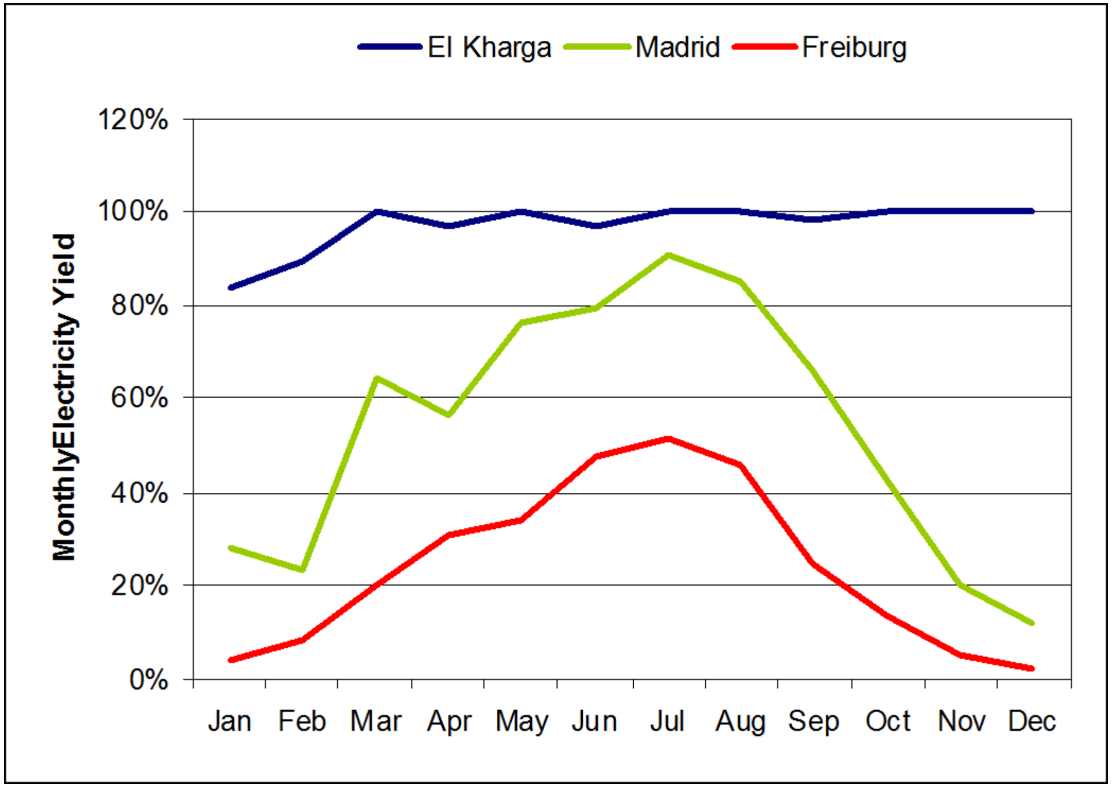
Source: F. Trieb, ELMOD-BW; J. Nitsch, Szen-BW 2012; Y. Scholz, ReMIX

Why concentrating solar power plants in North Africa?

Effect of Site Conditions on the Availability of CSP

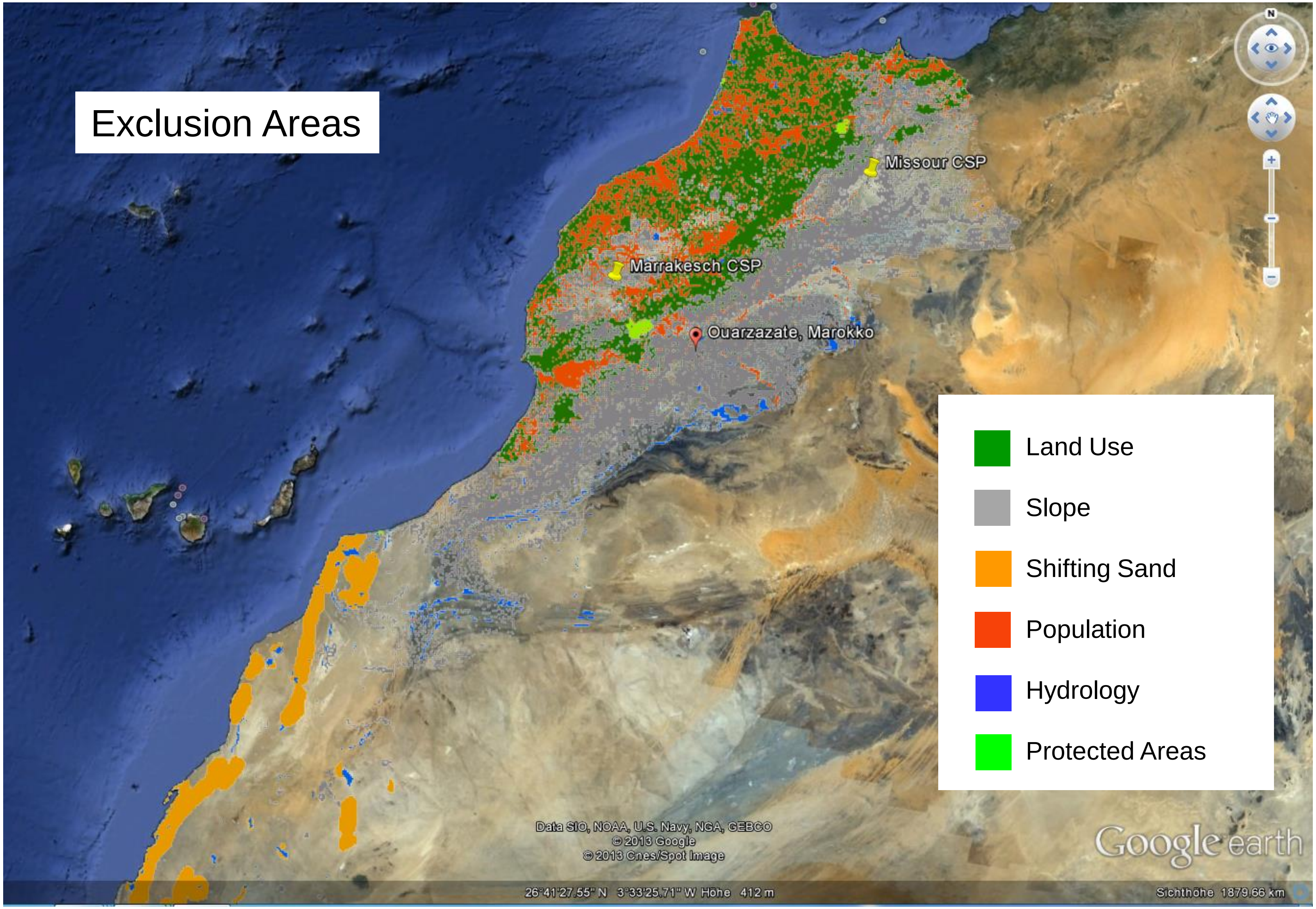
- more sunny days
- better incidence angle

➔ better availability of firm and flexible power

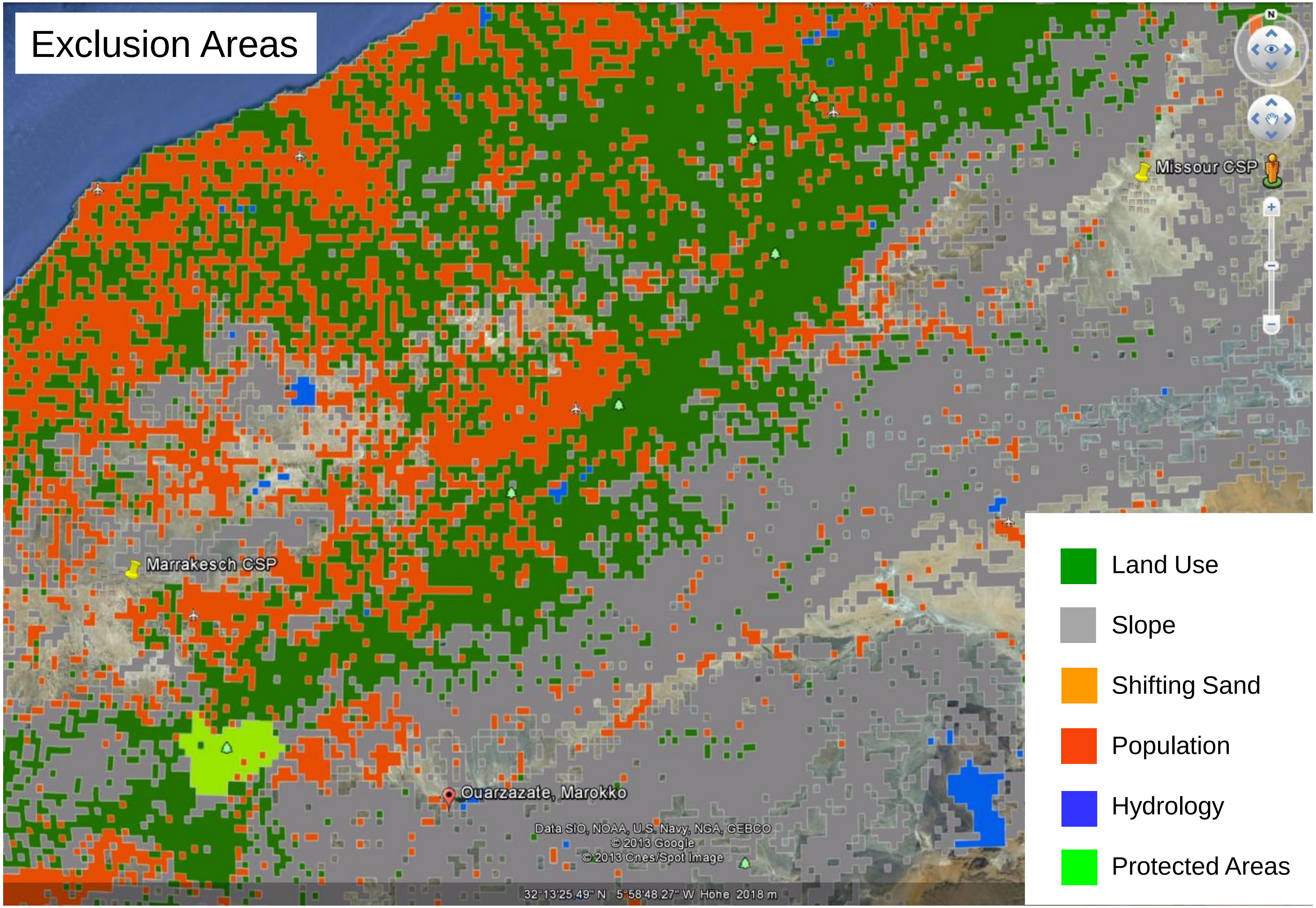


Relative monthly electricity yield of a CSP plant with large solar field and storage

Source: F. Trieb

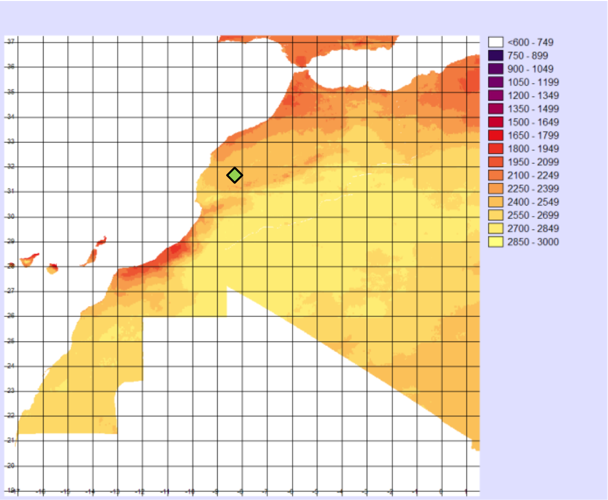


Source: Fichter, T.

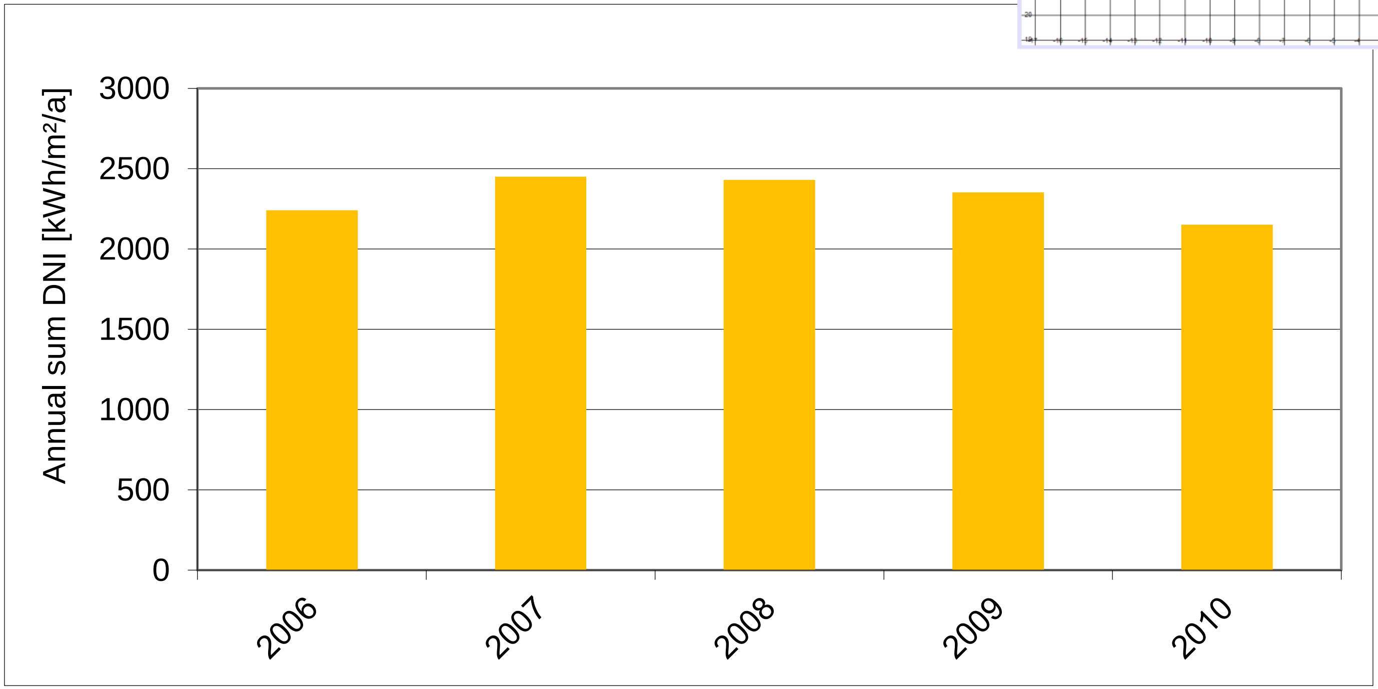


Source: Fichter, T.

Marrakesch



Average Annual Solar Radiation (DNI): 2325 kWh/m²/a



Source: SOLEMI (DLR)

Source: F. Trieb

DLR

Data for solar thermal power plants:

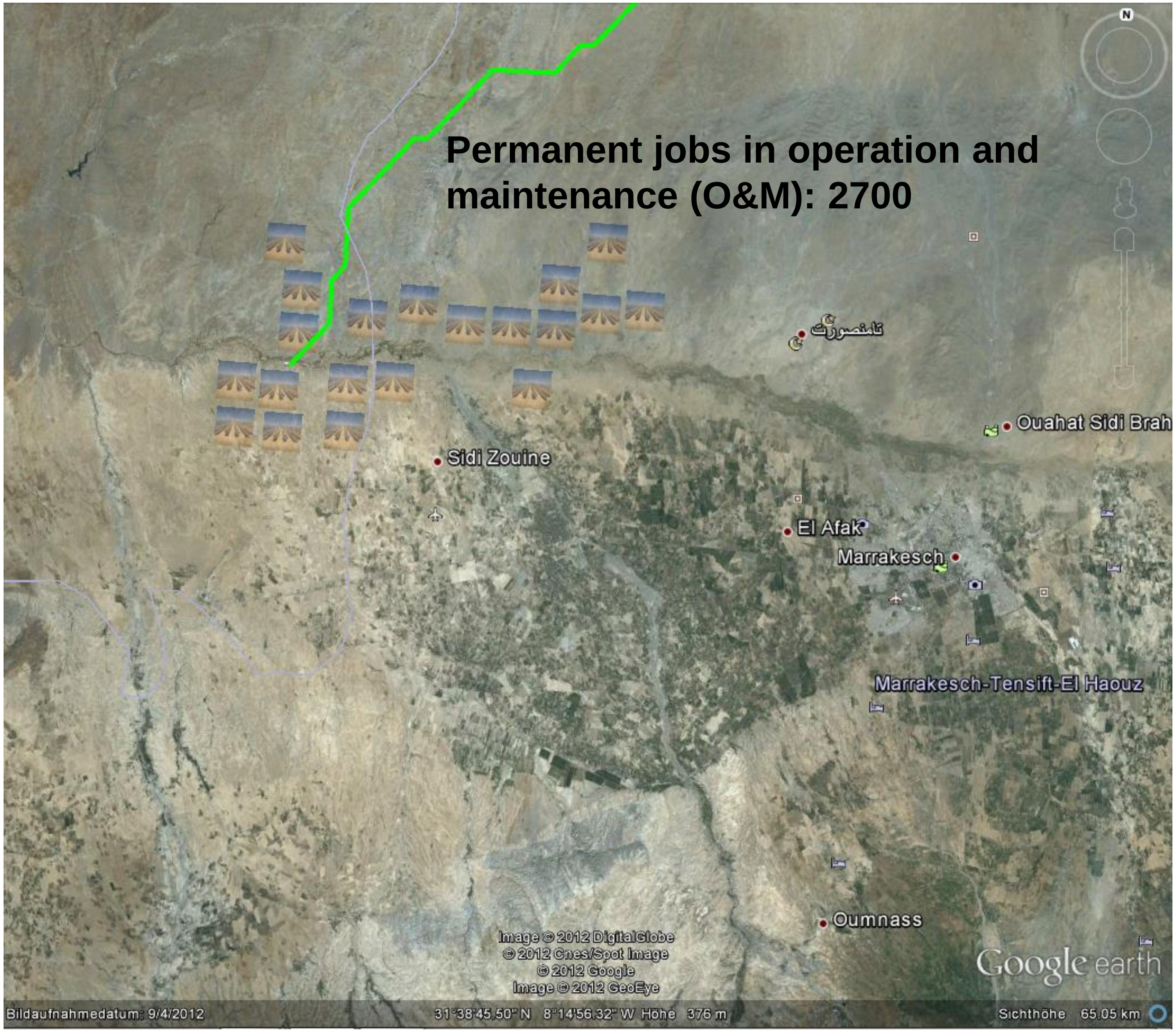
21 x 100 Mw_{net} in parabolic trough design

-> 147 km² land requirements

comparison:

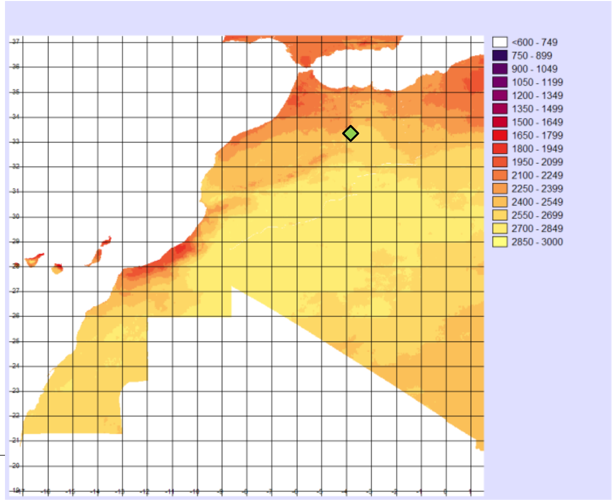
populated area:
Marrakesch ~ 145 km²
Sid Zouine ~ 1 km²

population:
Marrakesch ca. 910.000 (2010)
Sid Zouine ca. 11.000 (2004)

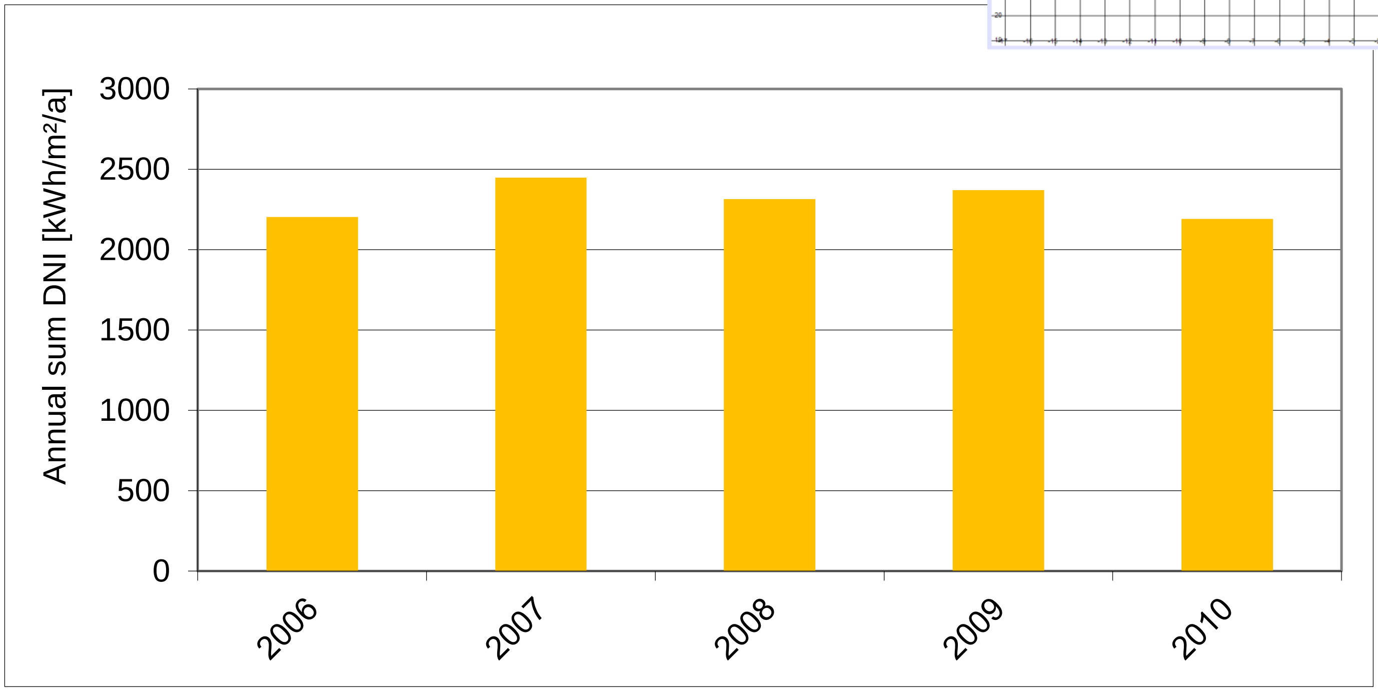


Source: Google Earth, Hess, D.

Missour



Average Annual Solar Radiation (DNI):
2300 kWh/m²/a



Source: SOLEMI (DLR)

DLR

Source: F. Trieb

Data for solar thermal power plants:

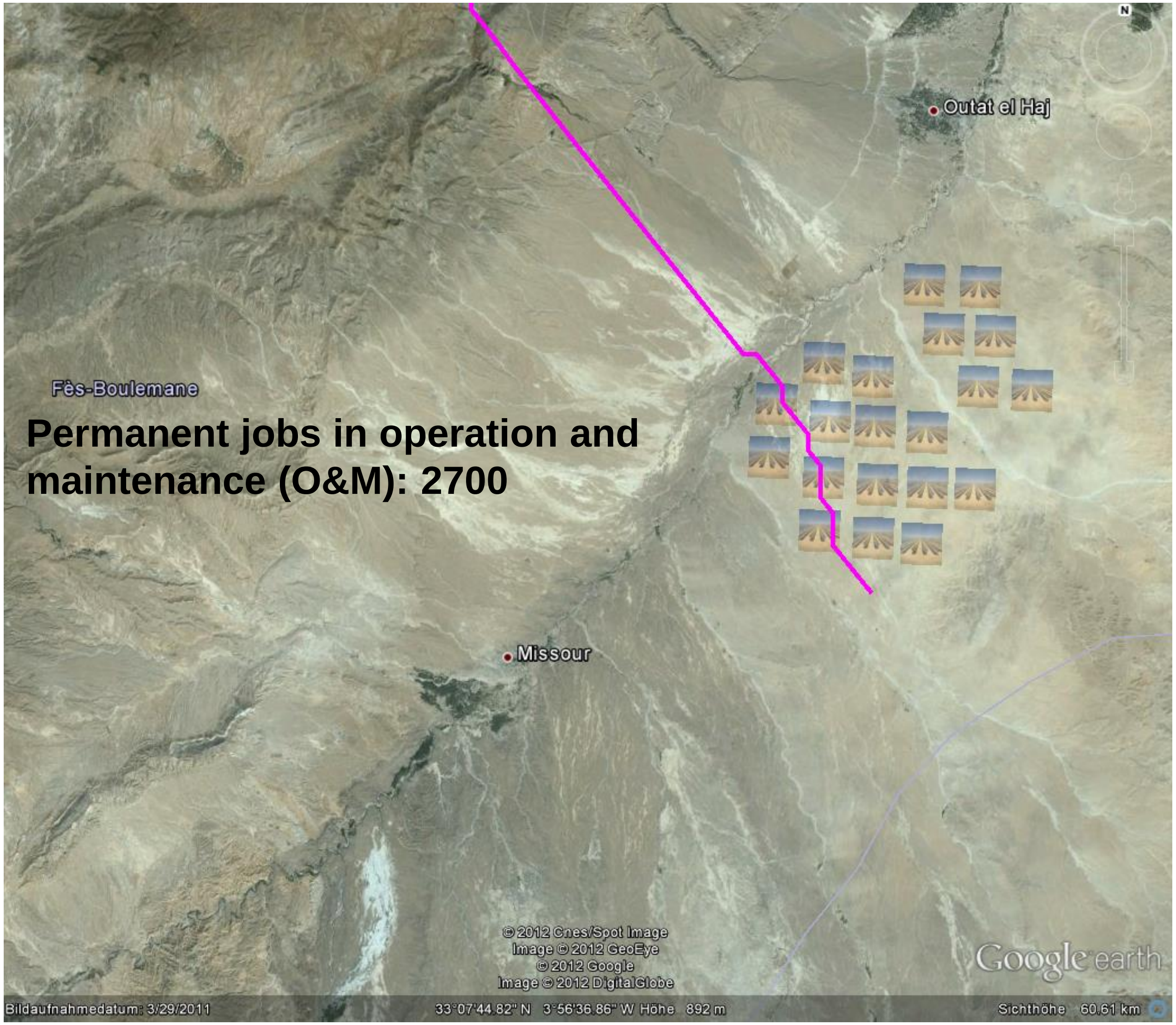
21 x 100 Mw_{net}
in parabolic trough design

-> 147 km²
land requirements

comparison:

populated area :
Missour ~ 2,3 km²
Outat el Haj ~ 2 km²

population:
Missour ca. 21.000 (2004)
Outat el Haj ca. 13.000 (2004)



Source: Google Earth, Hess, D.

First Draft of Transmission, Costs and land requirements

MOR-E-F-D

HVDC 2600 km
1.7 GW / 1.5 GW_{net}
1.3 Mrd.€
150 km²

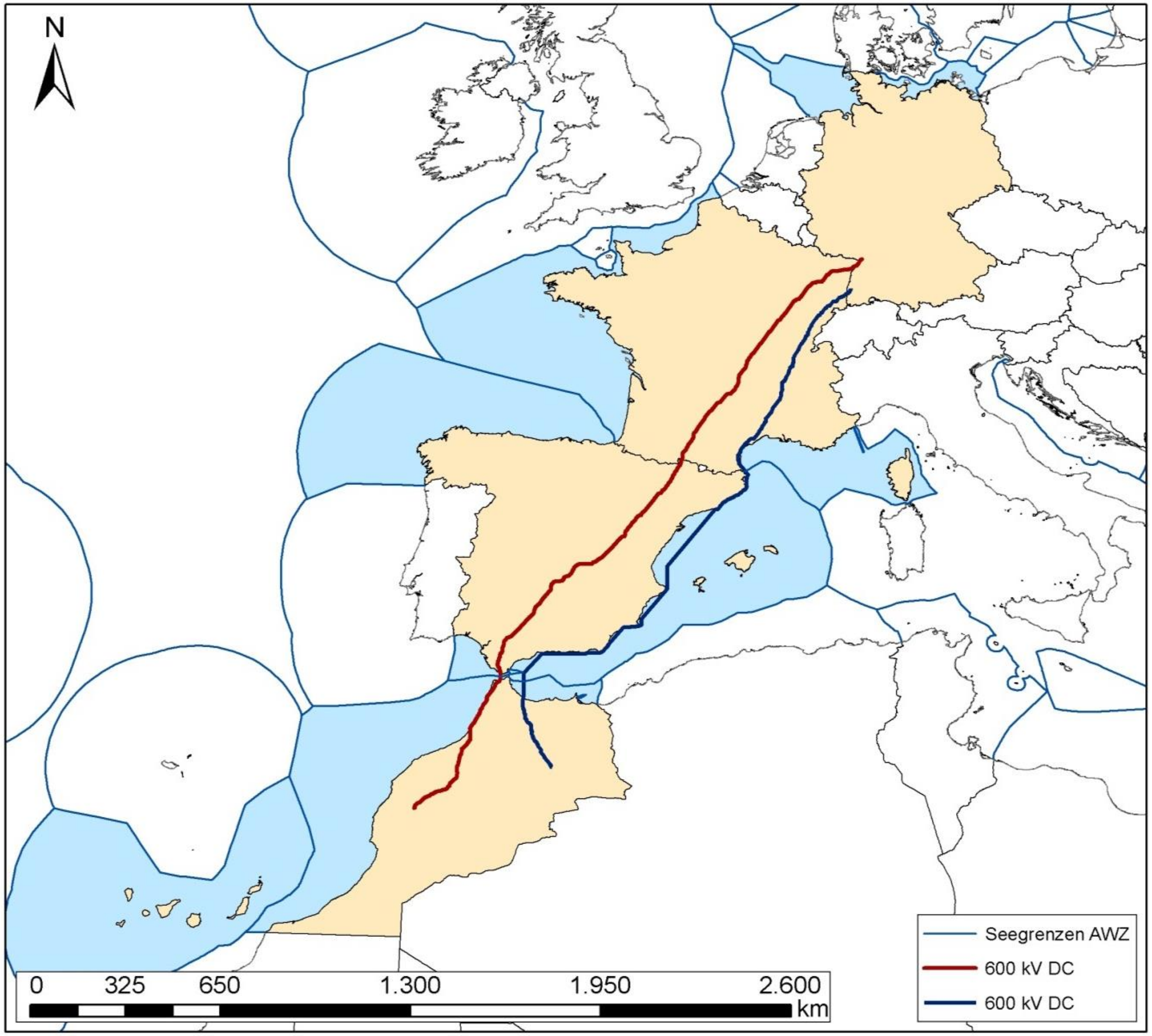
CSP 2.1 GW
CSP 12.0 Mrd.€
150 km²

MOR-E-F-D

HVDC 2300 km
1.7 GW / 1.5 GW_{net}
3.5 Mrd.€
75km²

CSP 2.1 GW
CSP 12.0 Mrd.€
150 km²

-> 15 Mrd.€ (real 2010)
feasible 2024



Source: Hess, D.

Morocco

CSP

converter

overhead line

bonding station

DC

AC

Mediterranean

submarine cable

±600kV submarine cable

Is highest voltage limit for the system design

Spain

bonding station

overhead line

France

overhead line

Germany

DC

AC

consumers in Germany

overhead line

converter

transmission grid

Source: Hess, D.

DLR

London
Jersey
Lissabon
Portugal
Amsterdam
Stadt Brüssel
Niederlande
Paris
Belgien
Luxemburg
Spanien
Madrid
Frankreich
Deutschlan
2679 m
1567 km
7.8%
Marrakesch
Rabat
Gibraltar
Daxlanden
Andorra
Marokko
Bern
Schweiz
Liechtenstein
Eivissa (Ibiza)
Mallorca
Monaco
Österreich
Pressburg
Laibach
Slowenien
Zagreb
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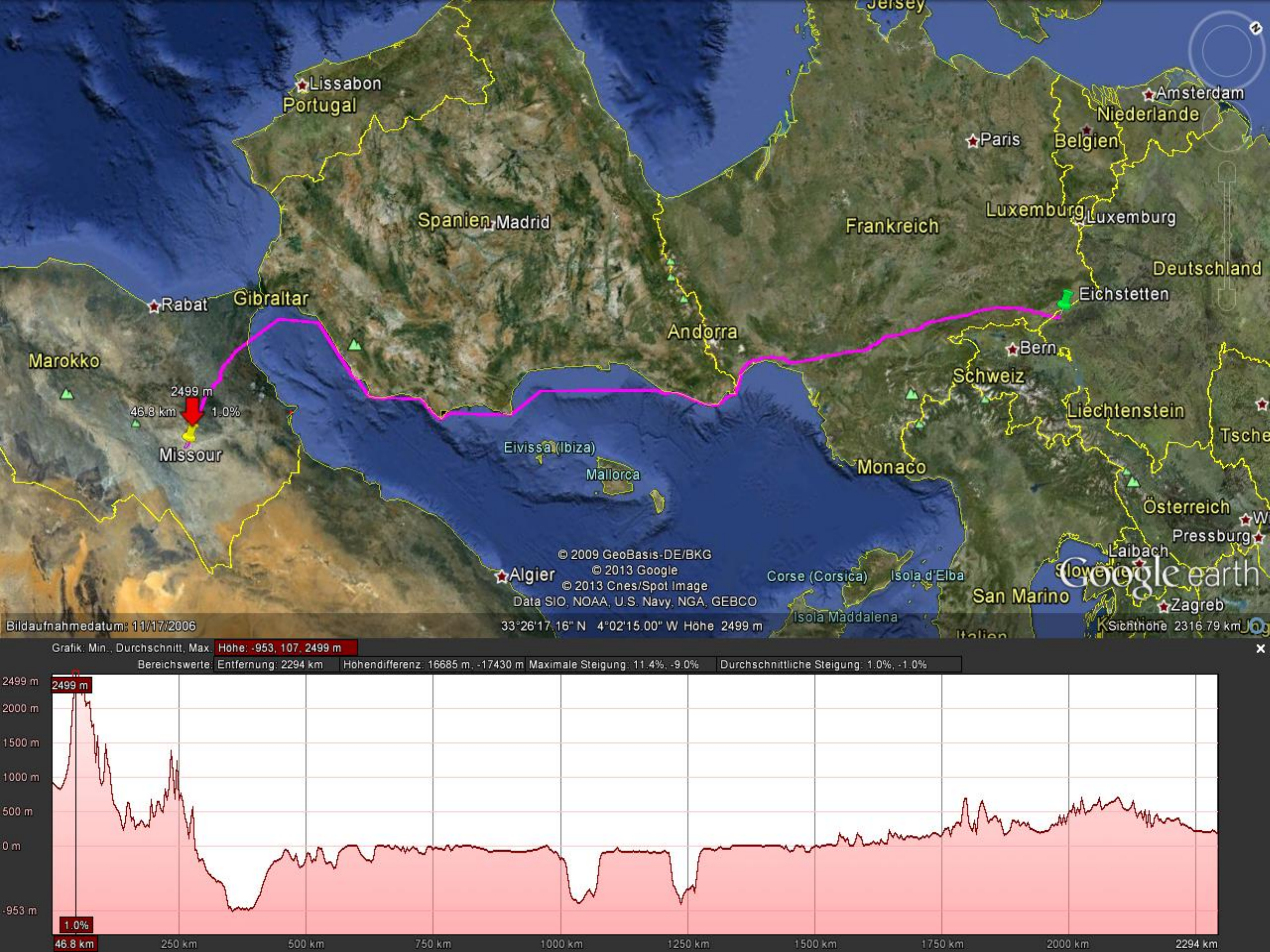
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 GeoBasis-DE/BKG
Algier
Corse (Corsica)
Isola d'Elba
San Marino
Isola Maddalena
Google earth
42°34'51.31" N 0°39'51.05" O Höhe 2679 m
Sichthöhe 2410.74 km
Grafik: Min., Durchschnitt, Max. Höhe: -545, 477, 2679 m
Bereichswerte: Entfernung: 2560 km
Höhendifferenz: 18708 m, -18879 m
Maximale Steigung: 8.1%, -11.7%
Durchschnittliche Steigung: 0.9%, -0.9%
2679 m
2000 m
1500 m
1000 m
500 m
0 m
-545 m
250 km
500 km
750 km
1000 km
1250 km
1567 km
1750 km
2000 km
2250 km
2560 km


Jersey
Lissabon
Portugal
Paris
Amsterdam
Niederlande
Belgien
Spanien
Madrid
Frankreich
Luxemburg
Luxemburg
Deutschland
Eichstetten
Rabat
Gibraltar
Andorra
Bern
Marokko
Schweiz
2499 m
46.8 km
1.0%
Liechtenstein
Tsche
Missour
Eivissa (Ibiza)
Mallorca
Monaco
Österreich
Pressburg
Laibach
© 2009 GeoBasis-DE/BKG
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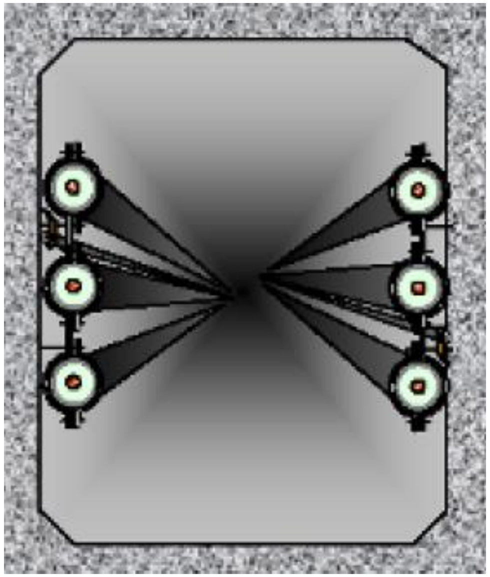
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Algier
Corse (Corsica)
Isola d'Elba
San Marino
Zagreb
Isola Maddalena
Google earth
Bildaufnahmedatum: 11/17/2006
33°26'17.16" N 4°02'15.00" W Höhe 2499 m
Sichthöhe 2316.79 km
Grafik: Min., Durchschnitt, Max. Höhe: -953, 107, 2499 m
Bereichswerte: Entfernung: 2294 km
Höhendifferenz: 16685 m, -17430 m
Maximale Steigung: 11.4%, -9.0%
Durchschnittliche Steigung: 1.0%, -1.0%
2499 m
2000 m
1500 m
1000 m
500 m
0 m
-953 m
2499 m
1.0%
46.8 km
250 km
500 km
750 km
1000 km
1250 km
1500 km
1750 km
2000 km
2294 km

underground cable

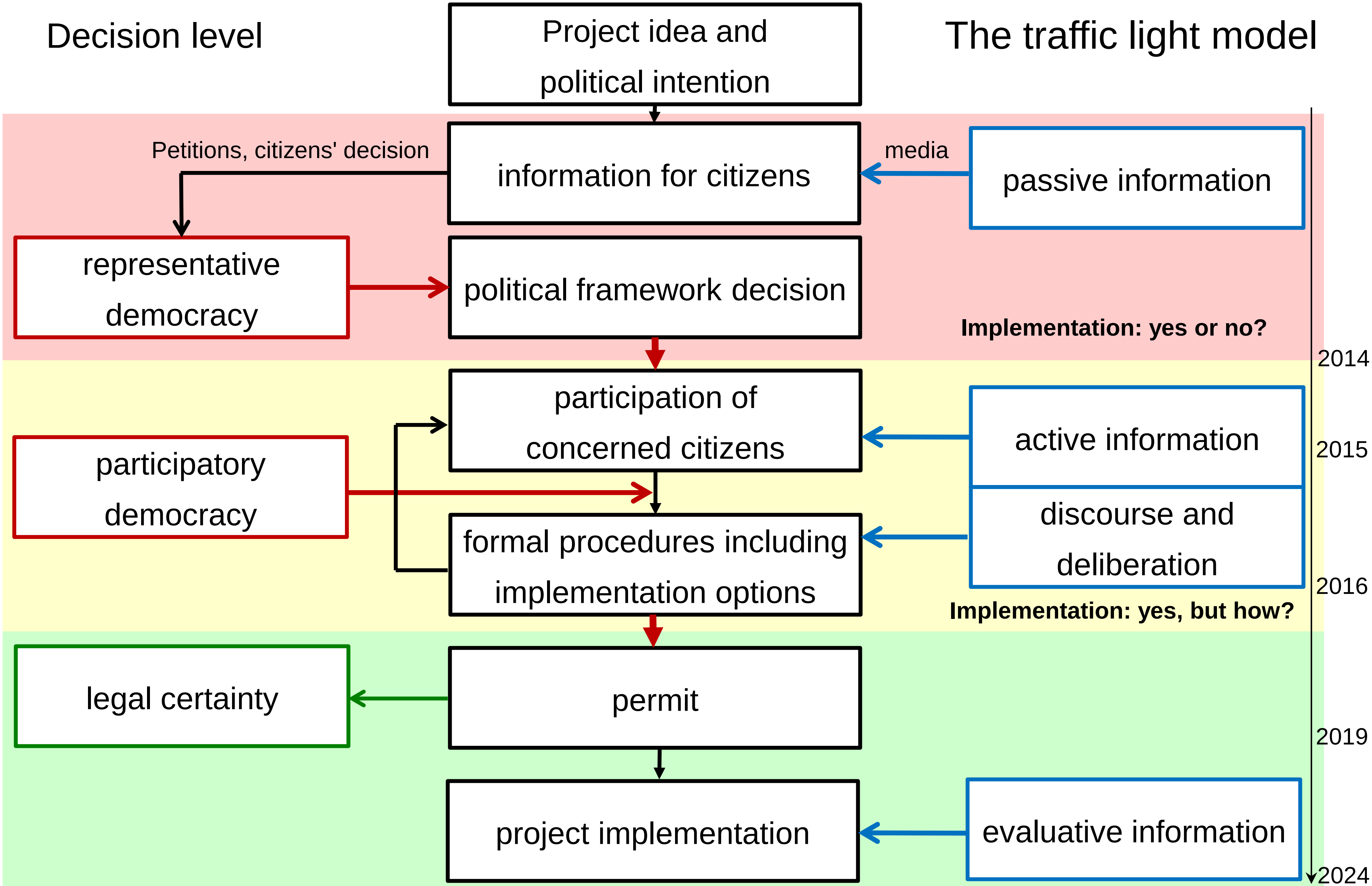



Tunnel in Madrid Brajas



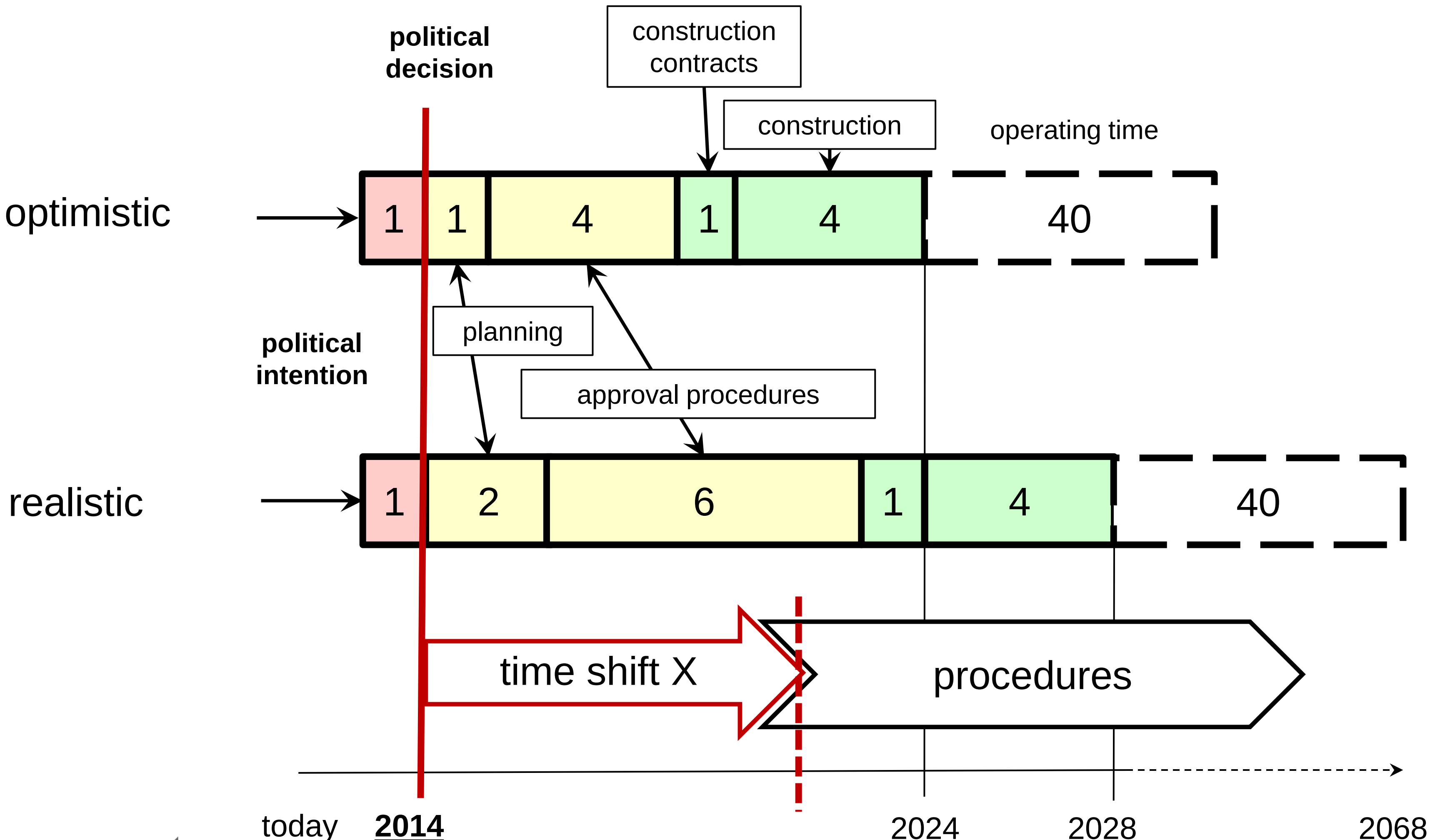

Source: CESI Madrid, CIGRÉ

The traffic light model



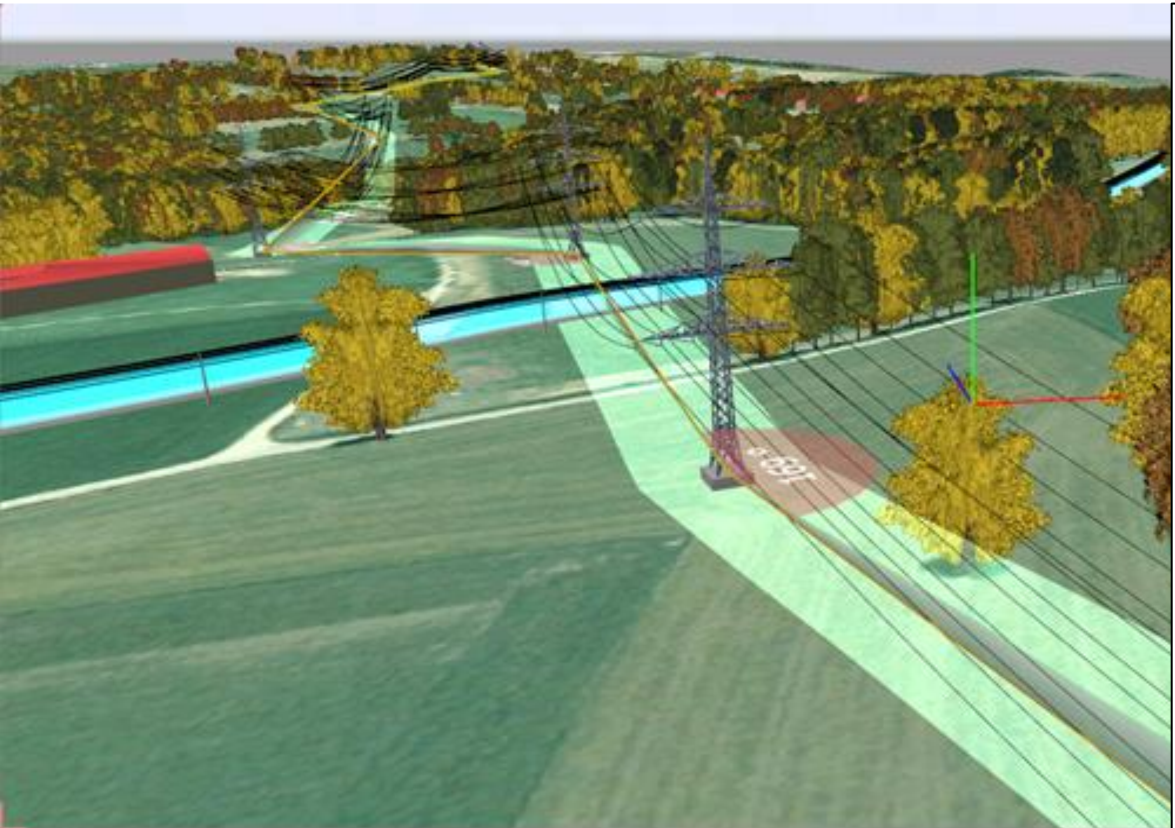
Source: Hess, D., following Prof. J.-D. Wörner, Pfenning, U.

Time schedule [y]



Source :Drees&Sommer Dr. Uwe Knauer, Leipzig 14.01.2013

Optimization of planning for and with persons concerned



Optimization criteria

- visual aspects
  - Sag calculation: Automatic control of critical distances for overhead lines (houses, vegetation, infrastructure, etc.)
  - Considering the lateral deflections (land use)
  - Fitting into the landscape and environment-related areas (environmental boundaries, etc.)
  - Effect on residents
- Minimization of construction costs
  - Find and optimize the pylon locations while complying all design specifications

Source: A+S Consult

Balance for Spain

Costs	Benefit
environment (area (70 km²), landscape)	contribution to climate protection (Saving 8 Mt CO2 / a)
	capital gains through compensation measures (€ 40 mio./a)
	partnerships, municipalities + cities
	evtl. pylon tourism

Source: own chart

Thank you for your attention!

„Wege entstehen dadurch, dass man sie geht."
Ways are made by walking

– Franz Kafka (1883 - 1924)

Source: http://www.ribapylondesign.com/

Questions

- How is the ownership situation of the land in Spain divided (% public/ % private)?

- What is the current legislative framework by new construction of power lines? What laws are responsible for that?

- Is there a standard, which is used for the design for construction of the pylons for wind and ice load?

- Are there citizens' initiatives to ban the construction of power lines or large infrastructures in Spain? Which? How is the communication process?

- What are the compensation measures for owners of the surface by expropriation for the construction of new power lines?