Transmission of dispatchable solar energy from Morocco to Baden-Württemberg

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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

Source: Trieb, F.; Hess, D.

Meeting with José Carlos Fernández REE in Madrid > Denis Hess > 2013-03-14
2025, 2030, 2050 BW without CSP -> surpluses, high installed capacity, expensive in 2050

% of RE:
- 2025: 55%
- 2030: 70%
- 2050: 95%

Inst. capacity:
- 2025: 36 GW
- 2030: 43 GW
- 2050: 55 GW

Source: F. Trieb, ELMOD-BW; J. Nitsch, Szen-BW 2012; Y. Scholz, ReMiX
2025, 2030, 2050 BW with CSP -> dispatchable energy, low inst. capacity, cheaper in 2050

% 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*
Exclusion Areas
Exclusion Areas

Source: Fichter, T.
Marrakesch

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

Source: SOLEMI (DLR)
Data for solar thermal power plants:

21 x 100 Mw\textsubscript{net} in parabolic trough design

\[ \rightarrow \] 147 km\textsuperscript{2} land requirements

Comparison:

Populated area:
Marrakesch ~ 145 km\textsuperscript{2}
Sid Zouine ~ 1 km\textsuperscript{2}

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

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

Source: SOLEMI (DLR)
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)
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.
<table>
<thead>
<tr>
<th>Morocco</th>
<th>Mediterranean</th>
<th>Spain</th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSP</td>
<td></td>
<td>bonding station</td>
<td></td>
<td></td>
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<tr>
<td>converter</td>
<td>submarine cable</td>
<td></td>
<td></td>
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<tr>
<td>overhead line</td>
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<tr>
<td>bonding station</td>
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<td>DC</td>
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<td>AC</td>
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<td>± 600kV submarine cable</td>
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<td></td>
<td>Is highest voltage limit for the system design</td>
<td>overhead line</td>
<td>submarine cable</td>
<td>overhead line</td>
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<td>Source: Hess, D.</td>
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</table>
underground cable

Tunnel in Madrid Brajas

Source: CESI Madrid, CIGRÉ
Decision level

- Project idea and political intention
- Information for citizens
- Political framework decision
- Participation of concerned citizens
- Formal procedures including implementation options
- Permit
- Project implementation

The traffic light model

- Media: Passive information
- Active information: Discourse and deliberation
- Evaluative information

Representative democracy
- Petitions, citizens' decision

Participatory democracy

Legal certainty

Implementation: yes or no?
Implementation: yes, but how?

Source: Hess, D., following Prof. J.-D. Wörner, Planung: U
Time schedule [y]

optimistic

1 1 4 1 4

realistic

1 2 6 1 4

time shift X

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

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

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?