Prospects for the short-term Integration of Renewable Energies into Jordan's Power Plant Fleet

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- Situation and Challenge of Jordan‘s Electricity Sector
- Renewable Energy Potential of Jordan
- Capacity Expansion Optimization Model REMix-CEM
- Jordan Case Study
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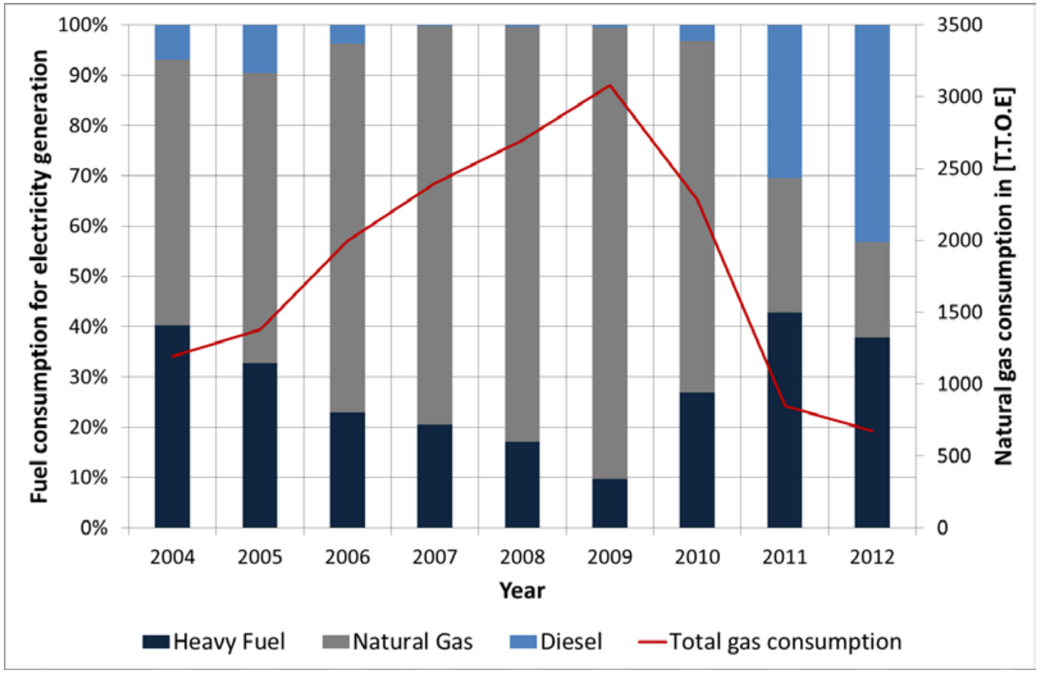
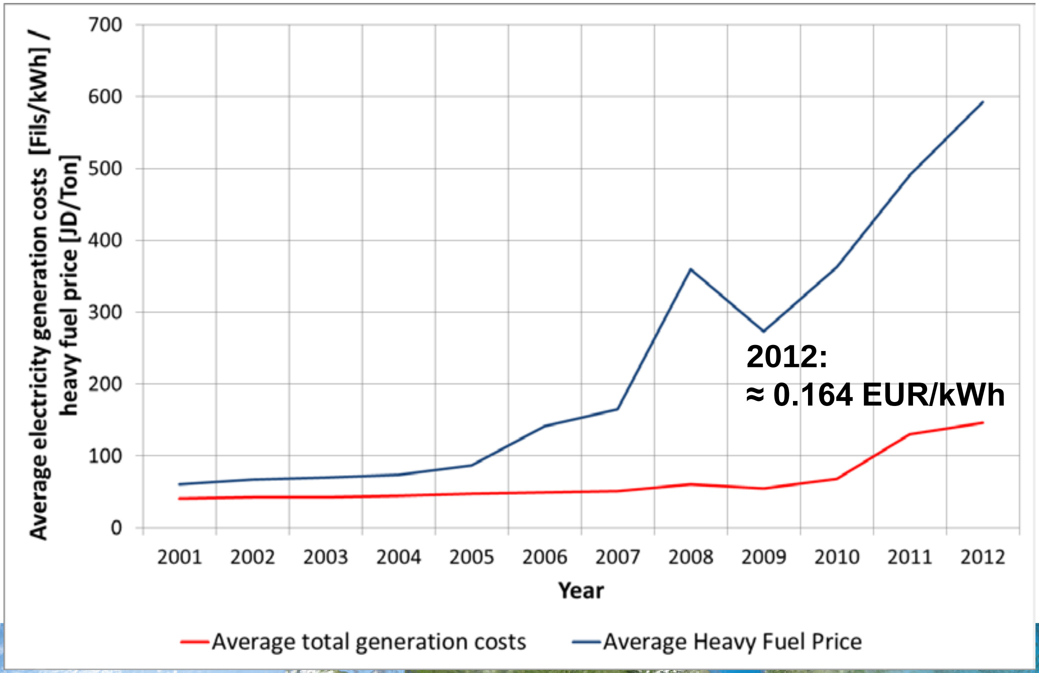
Jordan‘s Situation (1)

- Electricity sector highly depends on fossil fuel imports
- Until 2009, electricity generation mainly by Egyptian gas imported well below market prices
- Since 2010, unreliable supply and strong price increase of Egyptian gas
- As a consequence, electricity generation by expensive HFO and Diesel increased significantly

→ Strong increase of electricity generation costs due to high dependency on fossil fuel imports



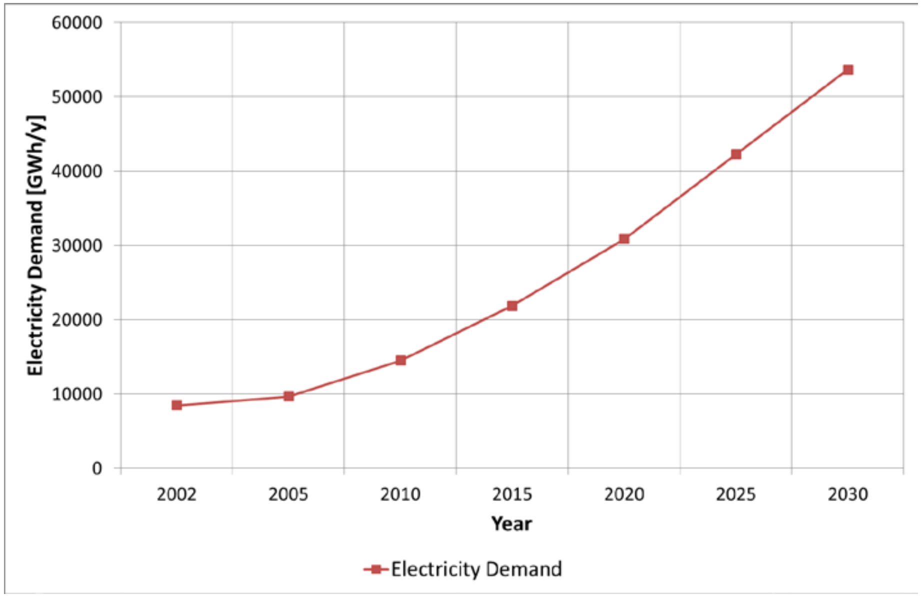


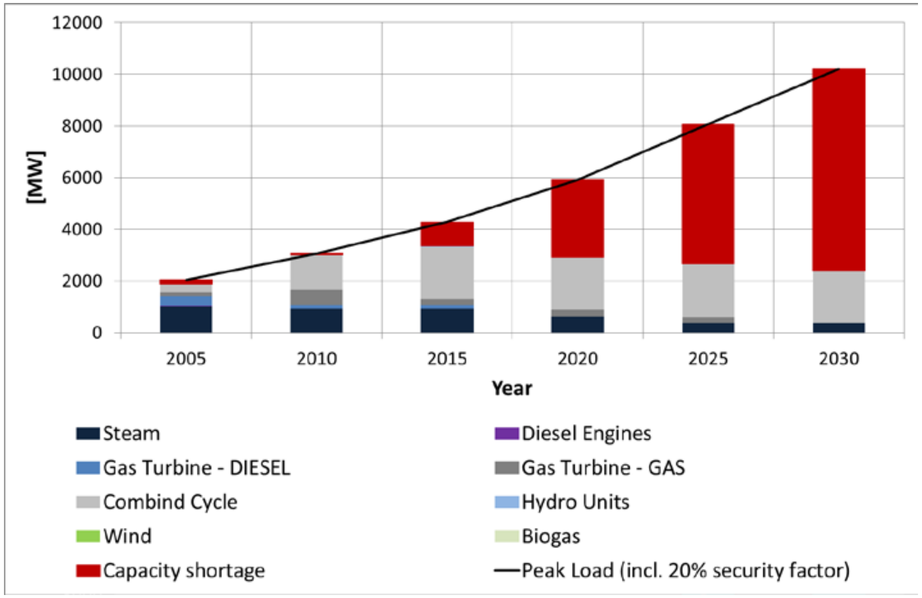
Data: NEPCO Annual Reports 2002 - 2012

Jordan's Situation (2)

- Strong increase of electricity demand and peak load will continue (5-8%/year)
- Until 2030, Jordan has to install about 7000 MW of new firm power generation capacity in order to ensure security of supply

→ 400 MW of firm capacity required each year!!!





Data: NEPCO Annual Reports 2002 - 2012

The challenge of Jordan‘s electricity sector

1. Become more independent from fossil fuel imports and the associated high risk of price escalation and unreliable supply.
2. Closing the capacity gap in order to meet strong increasing demand.

→ **Provide reliable electricity at reasonable and stable prices in the future.**

→ Questions when planning future electricity system:

- → How much capacity?
- → Which capacity?
- → Where to install capacity?
- → How can RE technologies be integrated in the short-term?

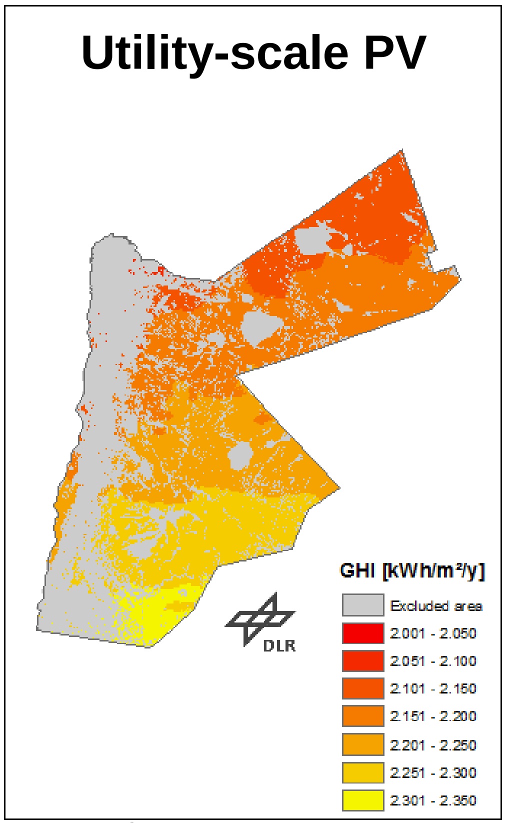
Aimed to be answered by REMix-CEM

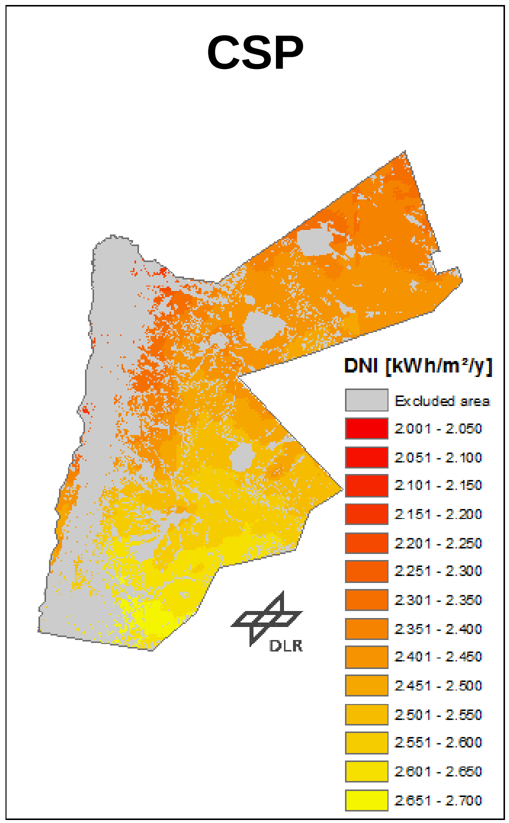
Renewable Energy Potentials

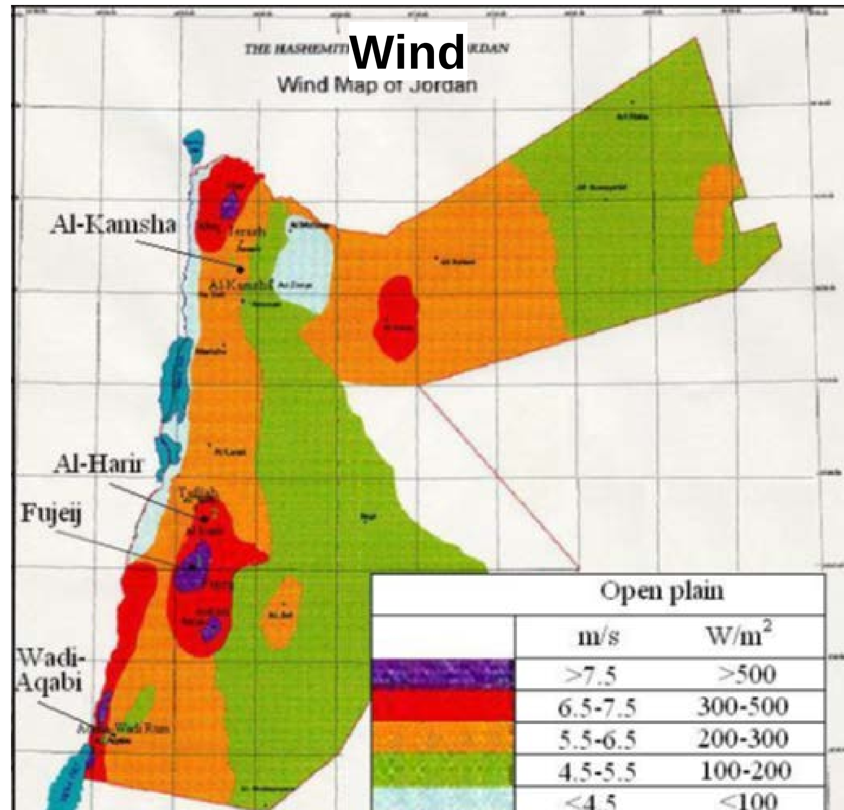
Outstanding solar and wind resources allowing RE power generation at very low costs!

Electricity demand 2050: ca. 53 TWh/y

Solar potential: ca. 6000 TWh/y







Sources: Solar Maps (DLR), Wind Map (MEMR)

Methodology for an Optimized Capacity Expansion and Integration of RE technologies into Existing Power Plant Fleets in the short-term

Step 1 — **Hot Spot Identification**
Site-Ranking Analysis (GIS)

↓

Step 2 — **REMix-CEM**
Step-wise **C**apacity **E**xpansion **M**odel & Unit Commitment Optimization Tool

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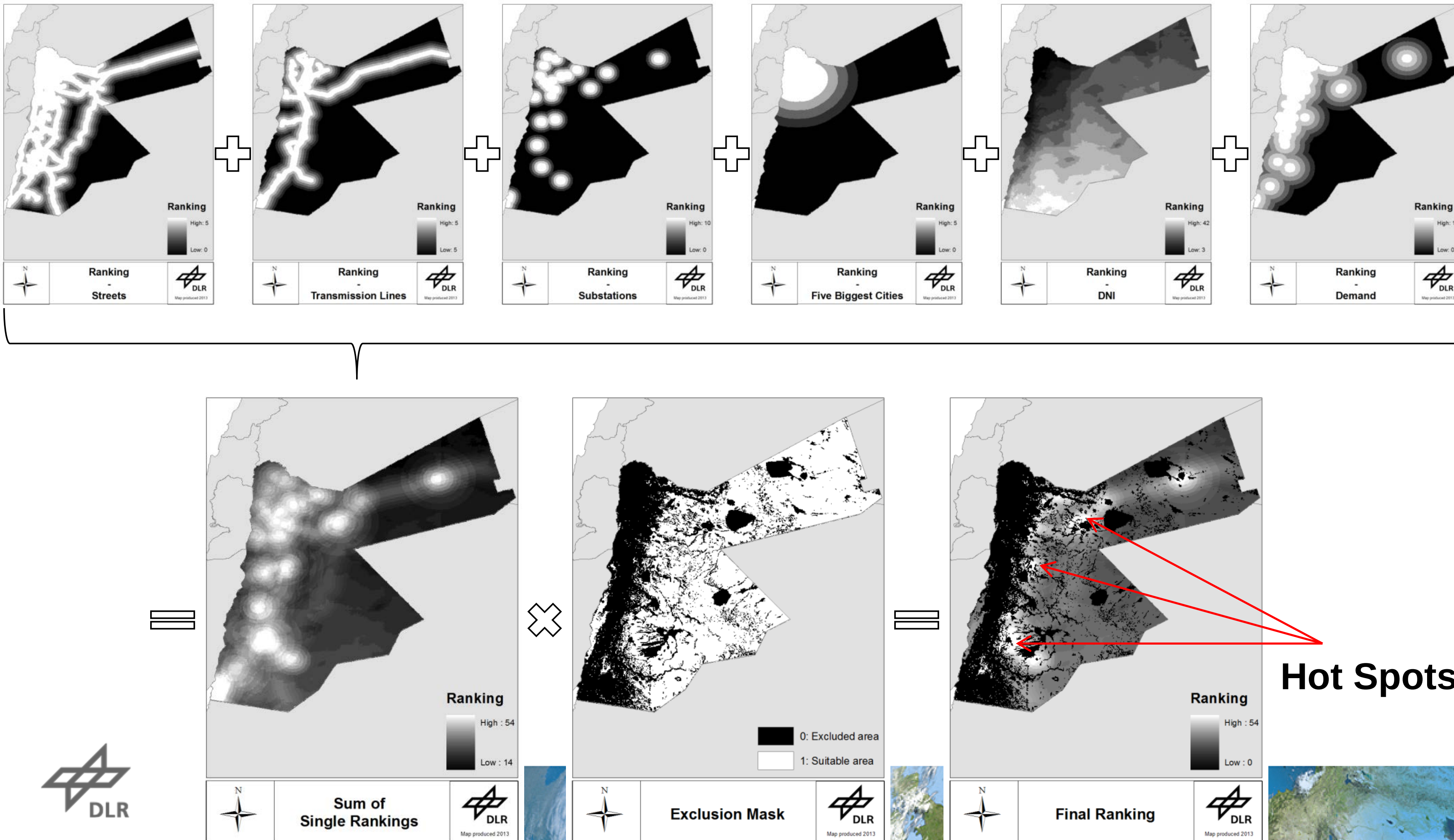
Step 3 — **Decision Support**
Required capacity · Siting of capacity · Technology specific tenders · Required PPA/FIT

Hot-Spot Identification

- Using spatial data within Geographic Information Systems (GIS)



REMix-CEM

Step-wise Capacity Expansion Model & Unit Commitment Optimization Tool

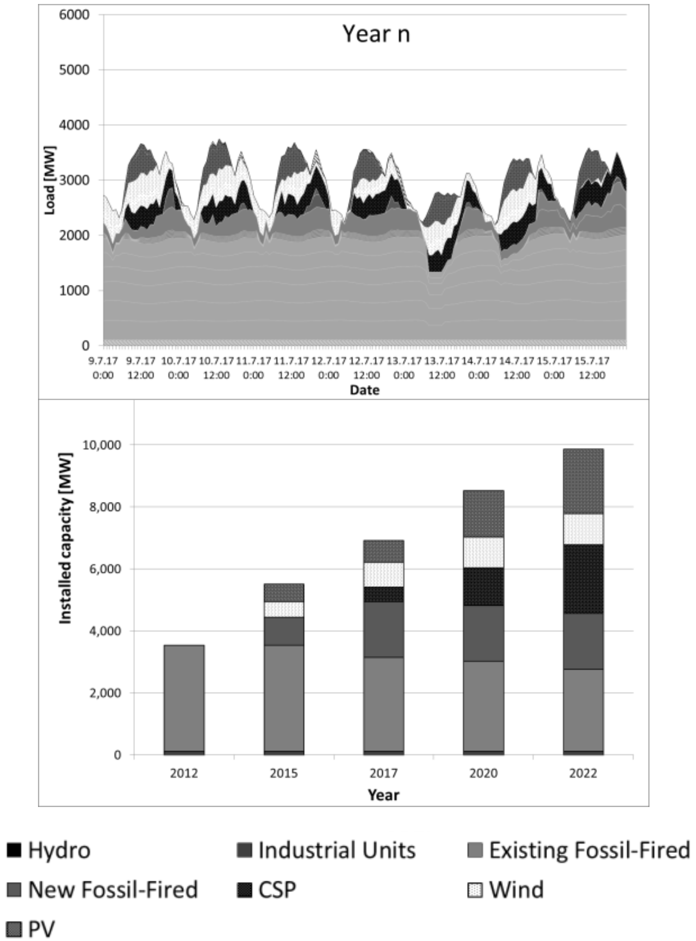
Database → *Optimization Tool*

Power System Data
- Electricity demand
- Hourly load profiles
- Fuel availability
- Fuel prices
- …

Power Plant Data
- Existing units
- Investment options
- Technical data
- Economic data
- …

Hot Spot Data
- Location
- Normalized profiles
- Meteorological data
- Maximum capacity
- …

Year y → y+1 → y+2 → y+n



- Optimization of capacity expansion and siting from a stat-owned utility perspective (e.g. NEPCO)

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Characteristics of REMix-CEM

- Step-wise capacity expansion optimization from a state-owned utility perspective
- Multi-node model
- Taking into account existing power plant fleet
- Algorithm ensures that RE technologies are only integrated if their utilization contributes to lower generation costs of the entire power plant fleet
- Detailed hourly modeling of each existing and potentially new conventional and RE power generation unit
- Optimization of CSP configuration in relation to the entire fleet (solar field, storage and back-up system size)
- Taking into account all necessary reserve requirements on system level (peak capacity requirements, spinning reserve, tertiary reserve, etc.)

Case Study Jordan – Assumptions

- Optimization steps 2013, 2016 and 2020
- 5 node system, 3 SOLAR and 4 WIND Hot Spots
- Available natural gas restricted to 1300 t.t.o.e. in 2016
- Coal available in 2020 at Node 5 (Aqaba)
- Net transfer capacity of transmission grid 500 MW
- Low fuel price escalation (1.5% p.a.)
- 300 MW DE-HFO and 300 MW DE-LFO to be built in 2016 (already decided)
- Available investment options:
  CSP (dry cooled), utility-scale PV, Wind Power, ST-Coal (wet cooled), CCGT-Gas/LFO (dry and wet cooled), OCGT-Gas/LFO, DE-HFO/Gas, DE-LFO
- Maximum RE capacity installation per optimization-step:
  CSP: 1000 MW, WIND: 1000 MW, PV: 3000 MW

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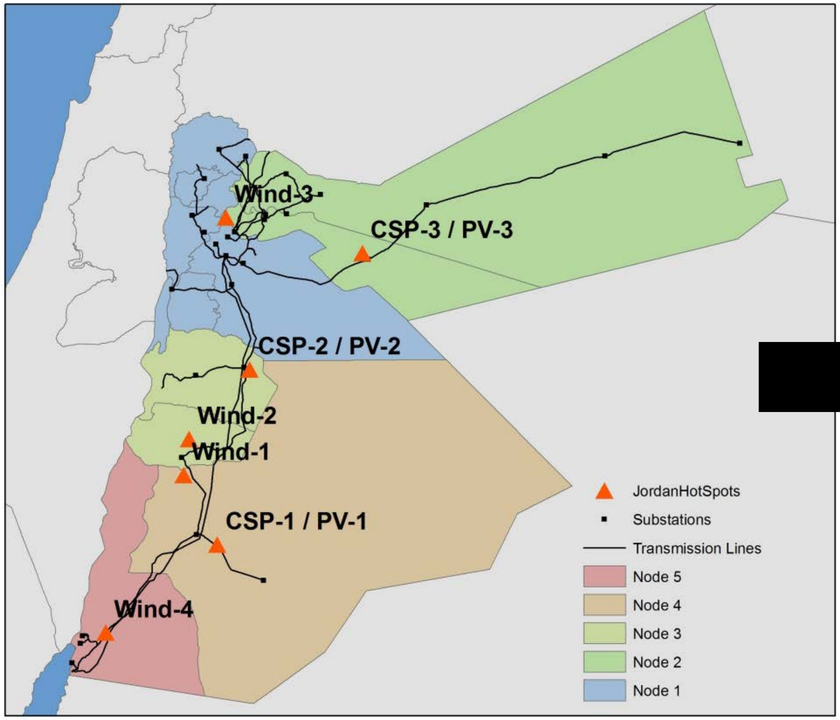
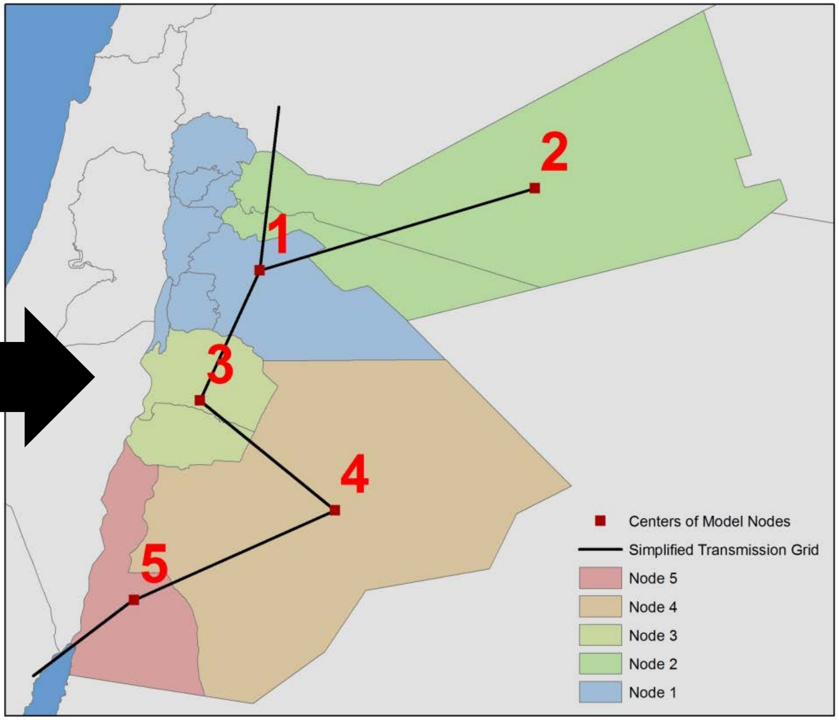
Simplified Power Transmission Model

- Existing Transmission Grid and RE Hot-Spots derived from GIS analysis



- Simplified Transmission Grid
- NTC 500 MW

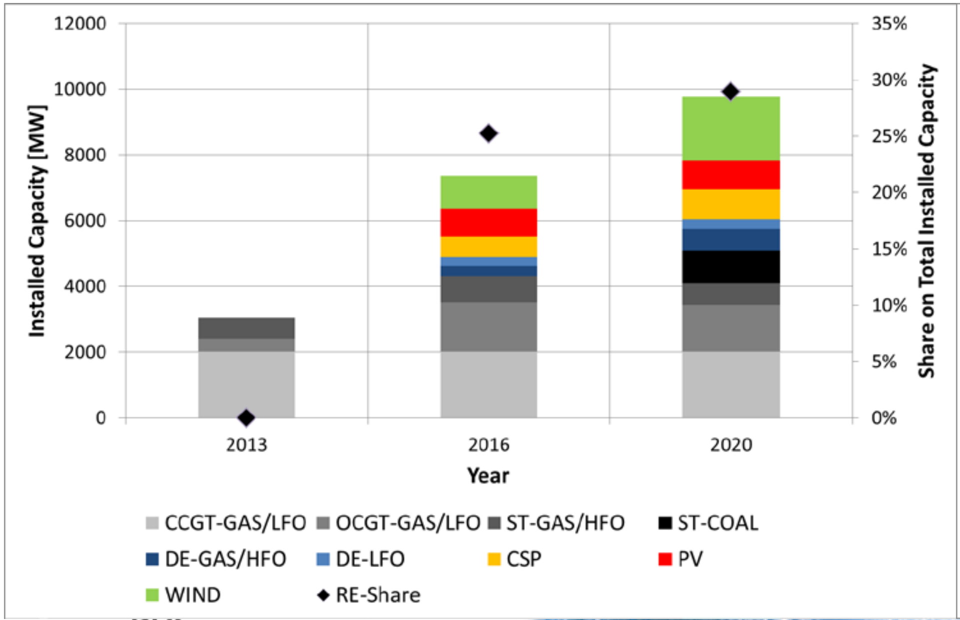


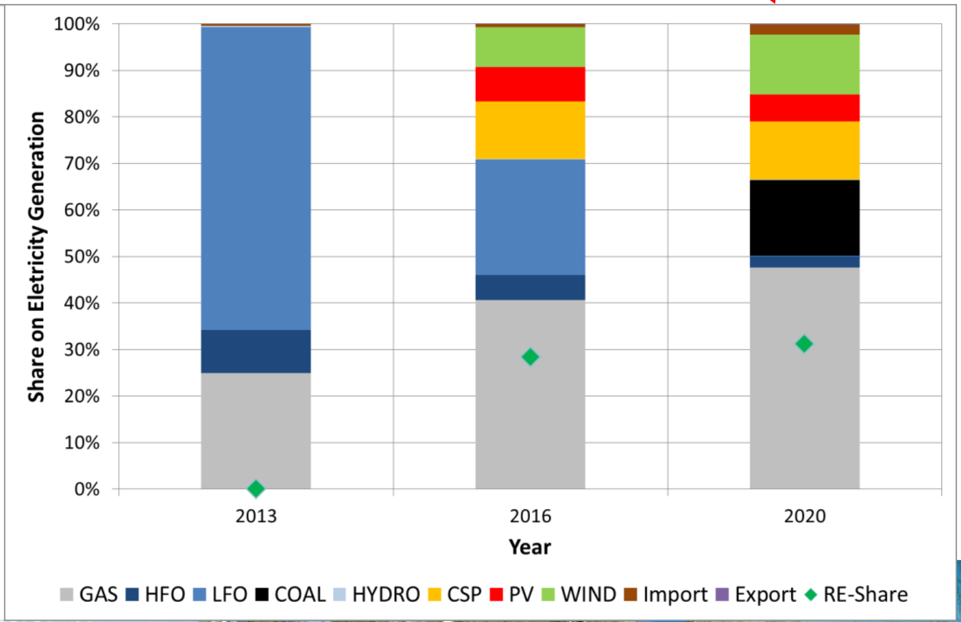
Case Study Jordan – Results (1)
Capacity Expansion & Electricity Generation

- RE already competitive in the short-term
- Replacing in a first step expensive OIL

- **Higher diversification!**
- **RE-Share: 31%**

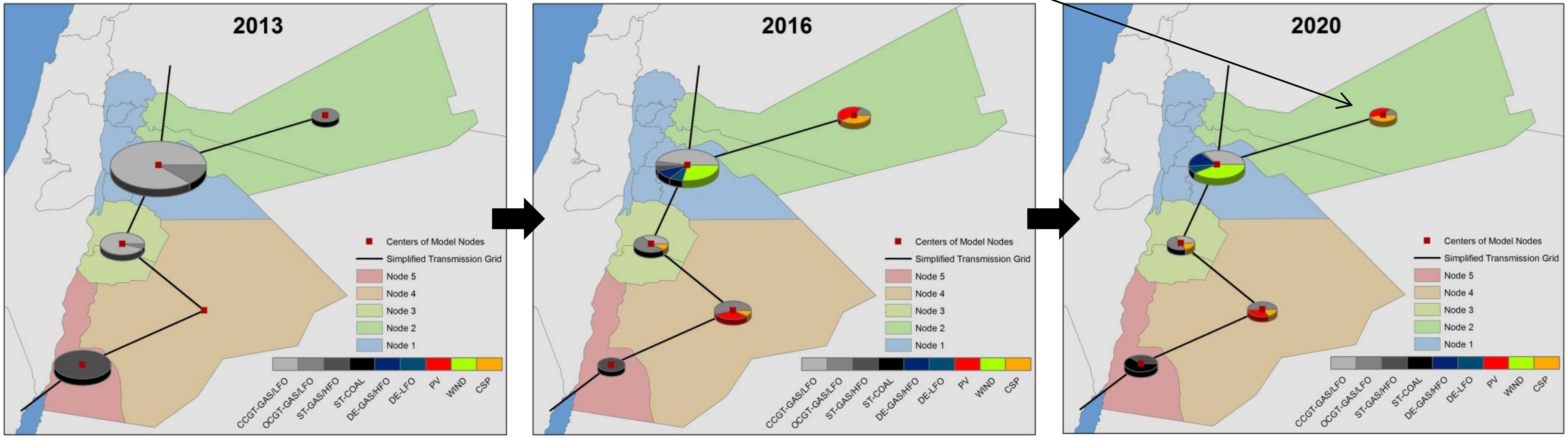
- RE until 2020:
  - CSP: 900 MW
  - PV: 880 MW
  - WIND: 1945 MW
- FOSSIL until 2020:
  - ST-COAL: 1000 MW
  - OCGT: 1210 MW
  - DE: 950 MW





Case Study Jordan – Results (2)
Capacity Distribution

- Capacity more distributed over time due to large-scale introduction of RE technologies.
- Most CSP Capacity (500 MW) at Node 2 even it is not the best site in terms of resource availability (DNI)



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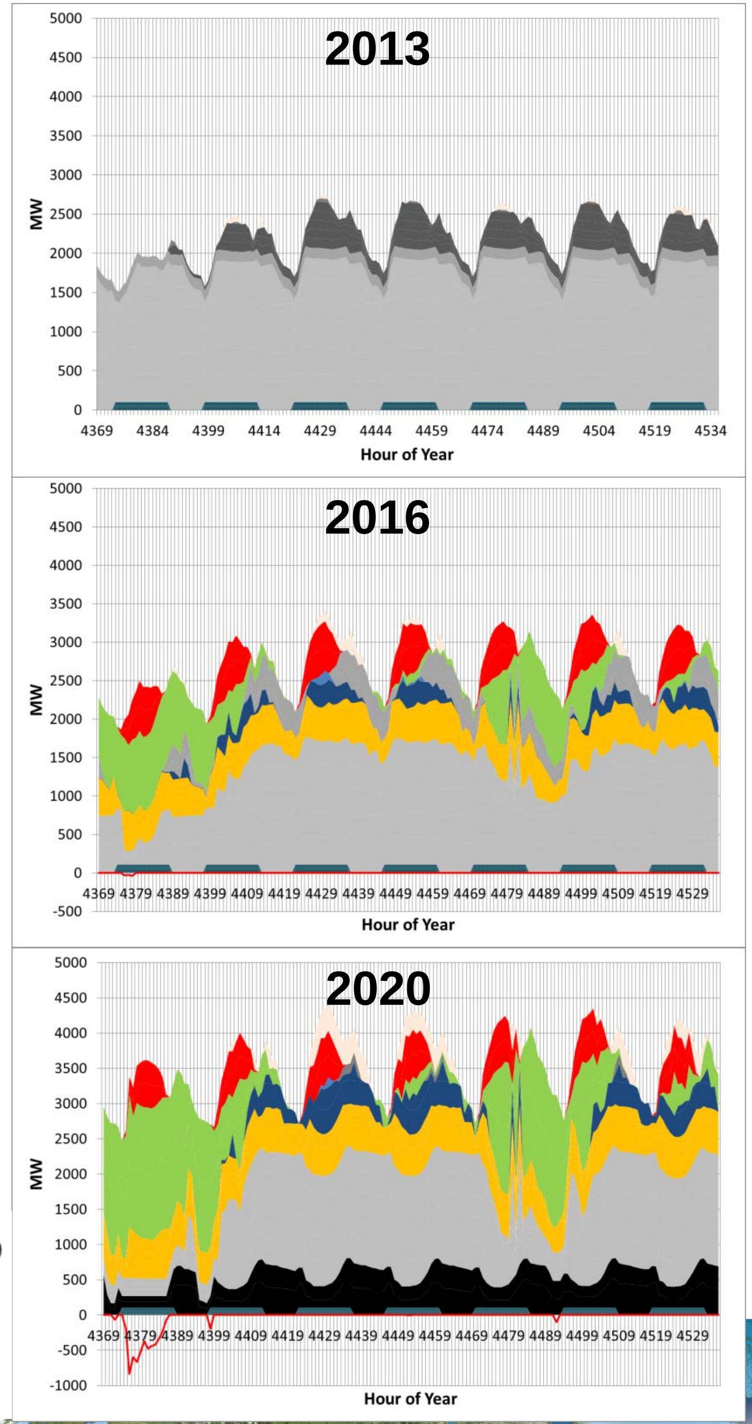
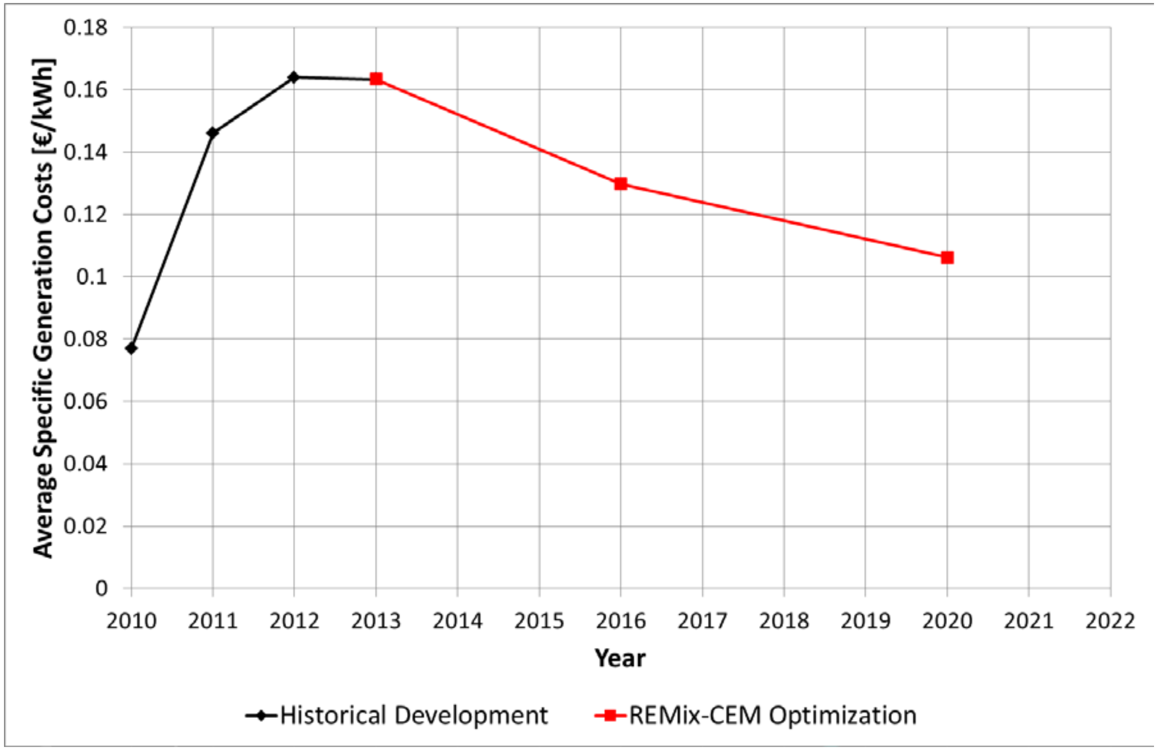
Case Study Jordan – Results (3)
Example Hourly Dispatch

- PV and wind power as cheap “fossil fuel saver”
- CSP providing strongly required firm and flexible generation capacity
- CSP units installed as both, peak load (SM: 1, TES: 3.5h) and mid load power plants (SM: 2.1, TES: 11.5h)
- Additional conventional units mainly used as peak load units (except of coal plants (ca. 5000 Flh)
- In the medium to long-term CSP as back-bone of electricity system due to technical characteristics



Case Study Jordan – Results (4)
Development of Electricity Generation Costs

- Specific Average Electricity Generation Costs of Power Plant Fleet



Large-scale introduction of RE technologies in Jordan:

- Least cost option!
- Reduced average generation costs of the entire system!
- Ensures security of supply!
- Higher independency!
- Job creation!

Conclusion

- Wind Power, PV and CSP are already competitive in the short-term in Jordan

- Each RE technology has its role in the future electricity system.
  - Fluctuating PV and Wind Power as cheap “fossil fuel saver“
  - CSP as strongly required dispatchable and firm RE power generation capacity

- Large-scale integration of RE will lead to a reduction of future electricity generation costs of the entire system

- Large-scale integration of RE will increase diversification of power plant fleet and will reduce dependency of fossil fuel imports with its associated high risk of price escalation and unreliable supply

- A well balanced mix of fluctuating RE and dispatchable conventional and RE technologies will ensure a reliable and least cost electricity supply in the future

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Thank you very much !!!!

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