Optimized Integration of Renewable Energy Technologies into Jordan's Power Plant Portfolio

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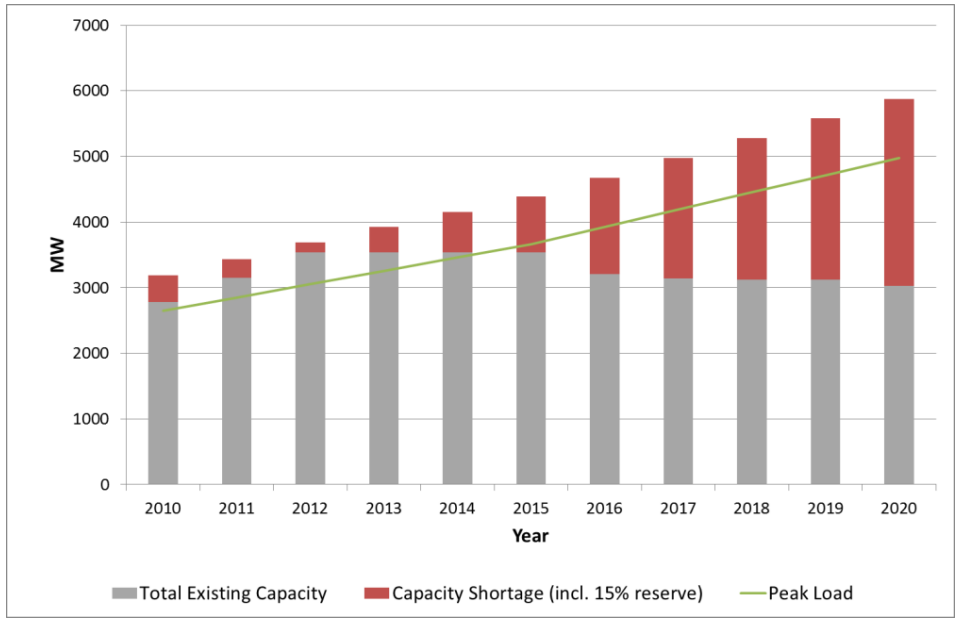
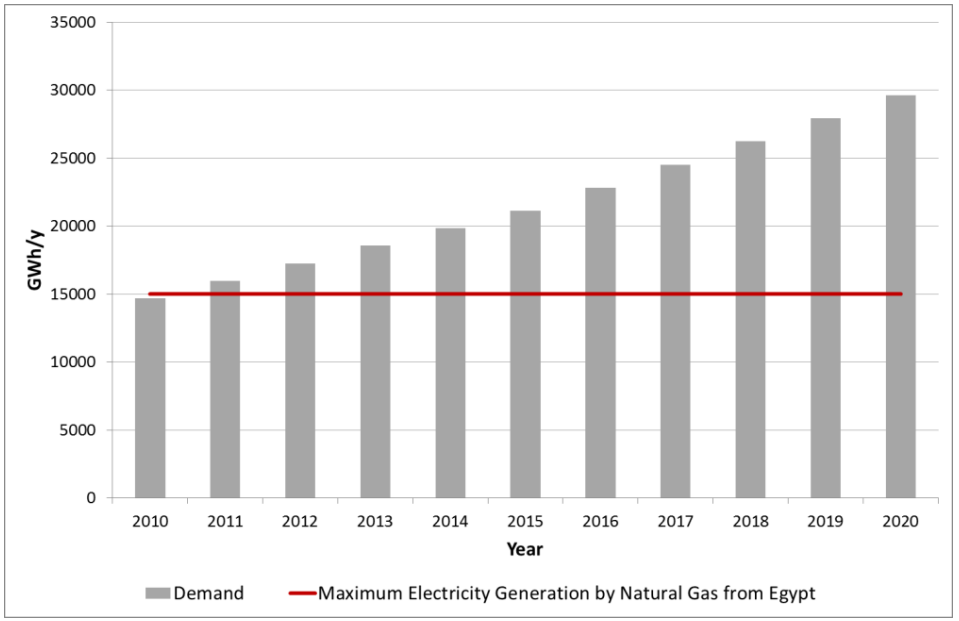
2. Most important RE technologies for Jordan
3. Methodology
4. Results of the Jordan case study
5. Conclusion

Jordan‘s situation

Strong increasing electricity demand

- Experienced growth rates of the past will continue (ca. 8% p.a.)
- High demand of additional firm power generation capacity
- Relatively cheap N.G. from Egypt by far not enough to meet future electricity demand



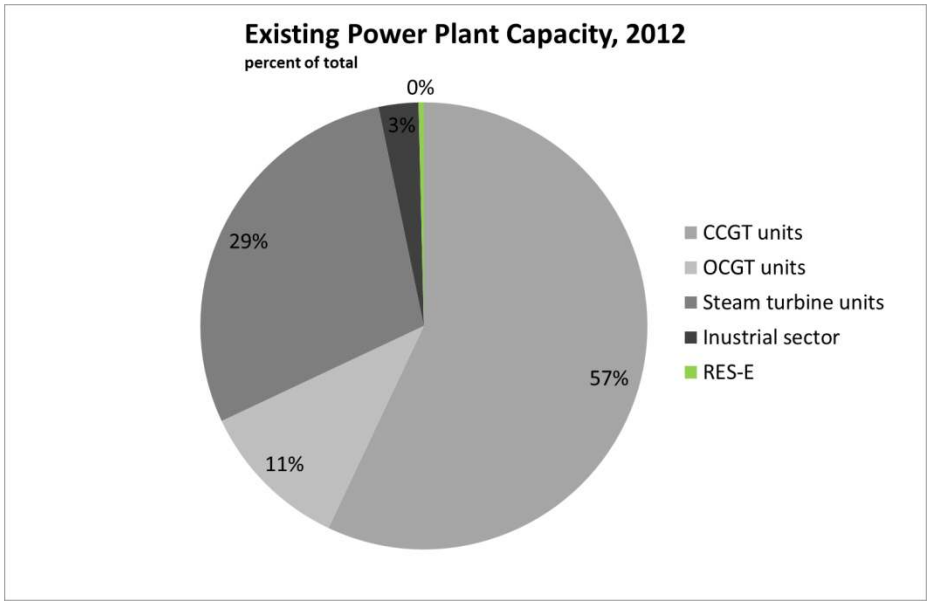


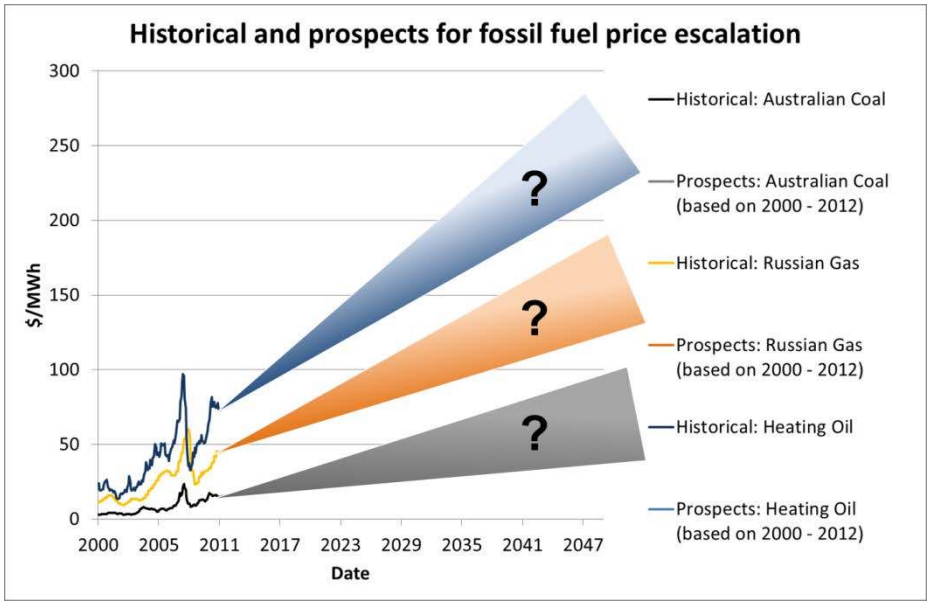
Jordan‘s situation

Fossil fuel import dependency

- Jordan depends highly on fossil fuel imports (ca. 96%)
- Strong historical and prospected future fossil fuel price escalation

→ Significant increase of power generation costs





Historical fuel prices: www.indexmundi.com

Jordan's situation
The challenge

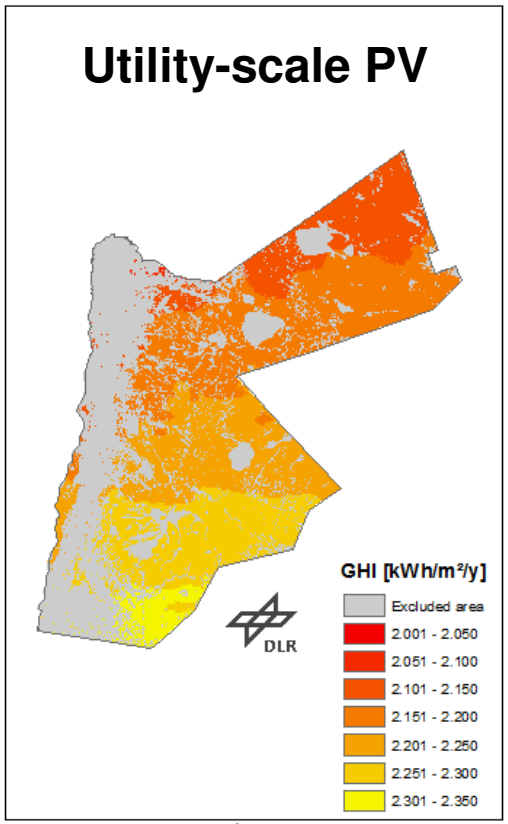
1. Keep up with increasing electricity demand
2. Increase independency from fossil fuel imports
3. Provide electricity at reasonable prices in the future

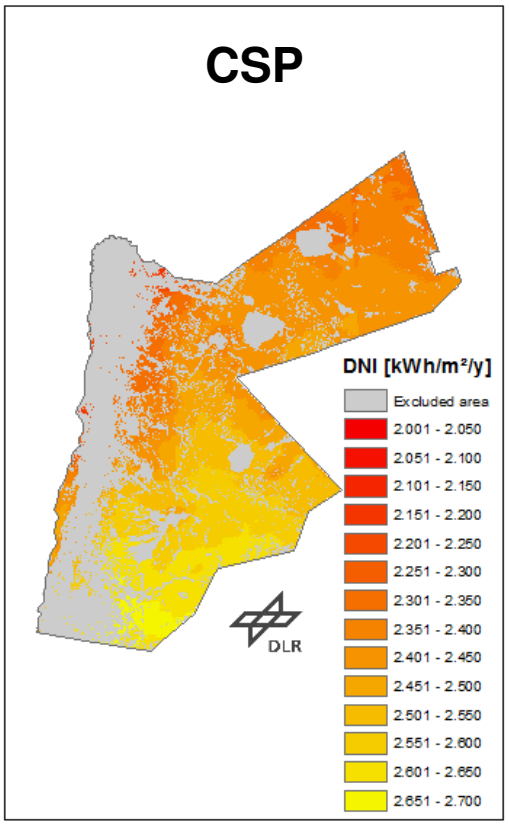
Jordan's situation

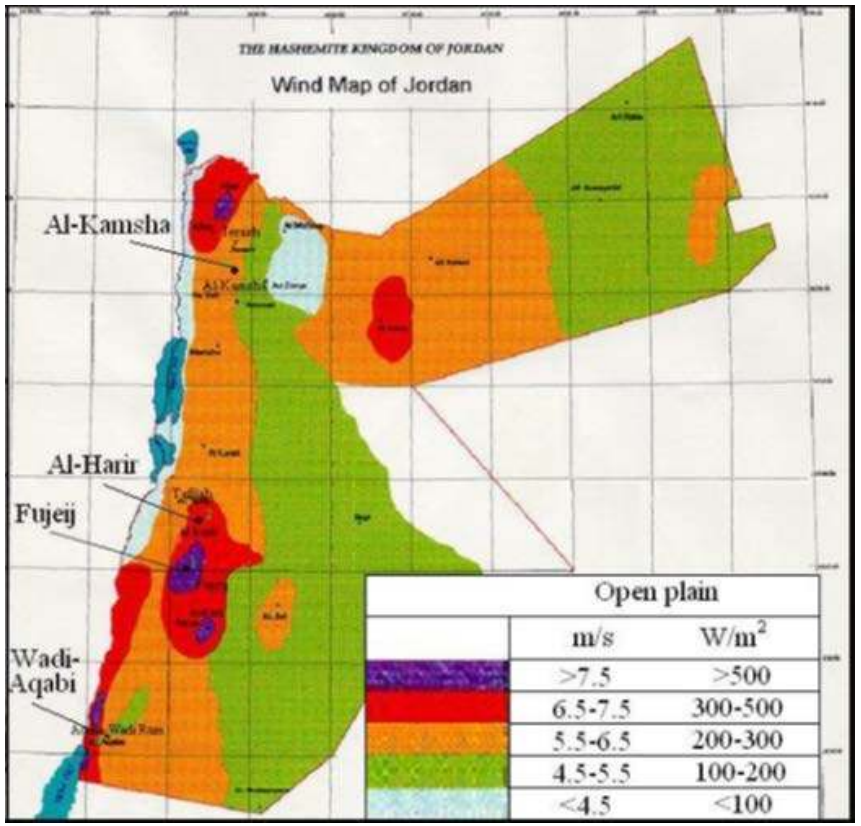
Outstanding RE potential

- Demand 2050: ca. 53 TWh/y
- Solar potential: ca. 6000 TWh/y

- Large number of sites with outstanding solar and wind resources allowing RE power generation at very low costs







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

Comparison of most import RE technologies for Jordan

		Utility-scale PV	Onshore wind	CSP
Global installed capacity	GW	70 GW	239 GW	2 GW
Specific investment costs	€/kW	1500 – 1700	1200 – 1600	2900 – 11000*
Typical plant size	MW	0.2 – 100	1.5 – 3.5	20 – 500
Typical electricity costs (MENA)	€/kWh	0.08 – 0.15	0.06 – 0.11	0.14 – 0.22
Quality of power generation		- Fluctuating - Non-dispatchable - No firm capacity		- Dispatchable - Firm & flexible - System services

* Depending on SM

⇨ We are not looking for the cheapest single technology but we are looking for the cheapest mix of conventional and RE technologies in order to meet the future electricity demand.

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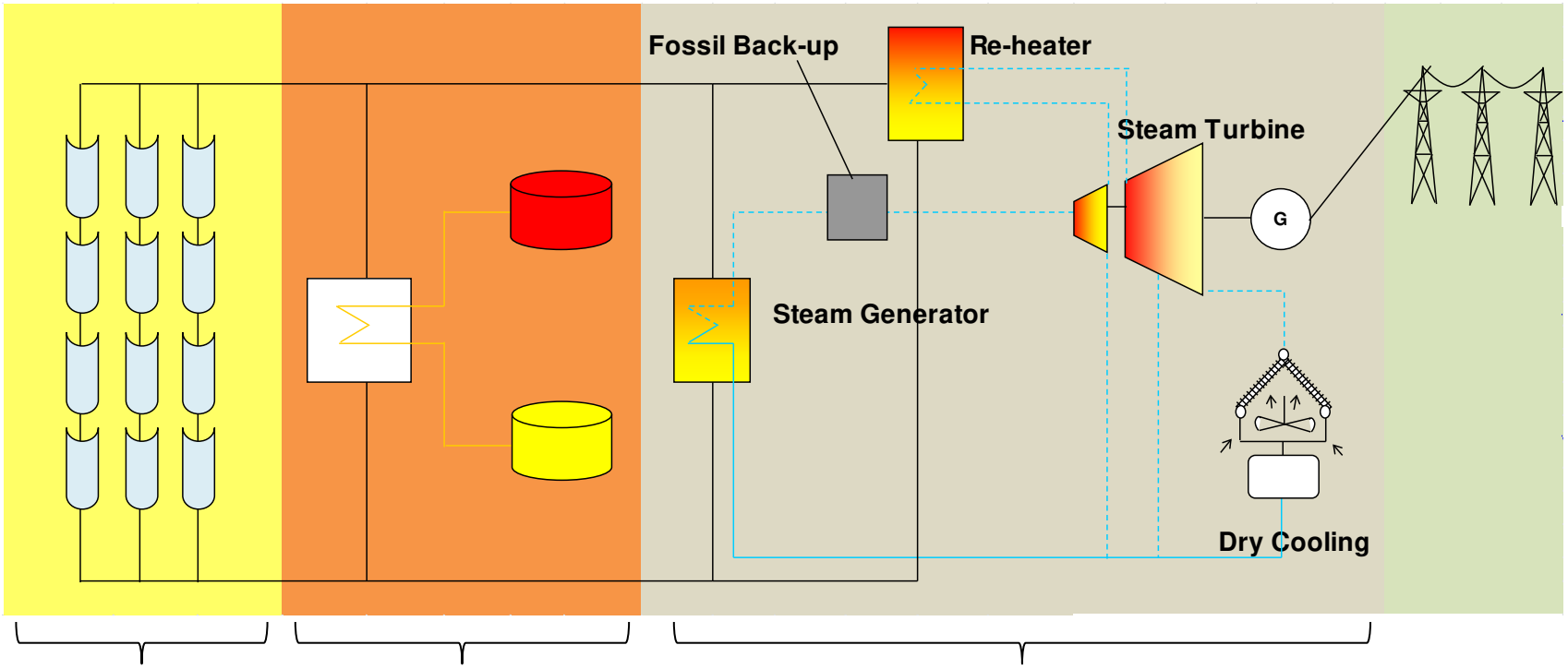
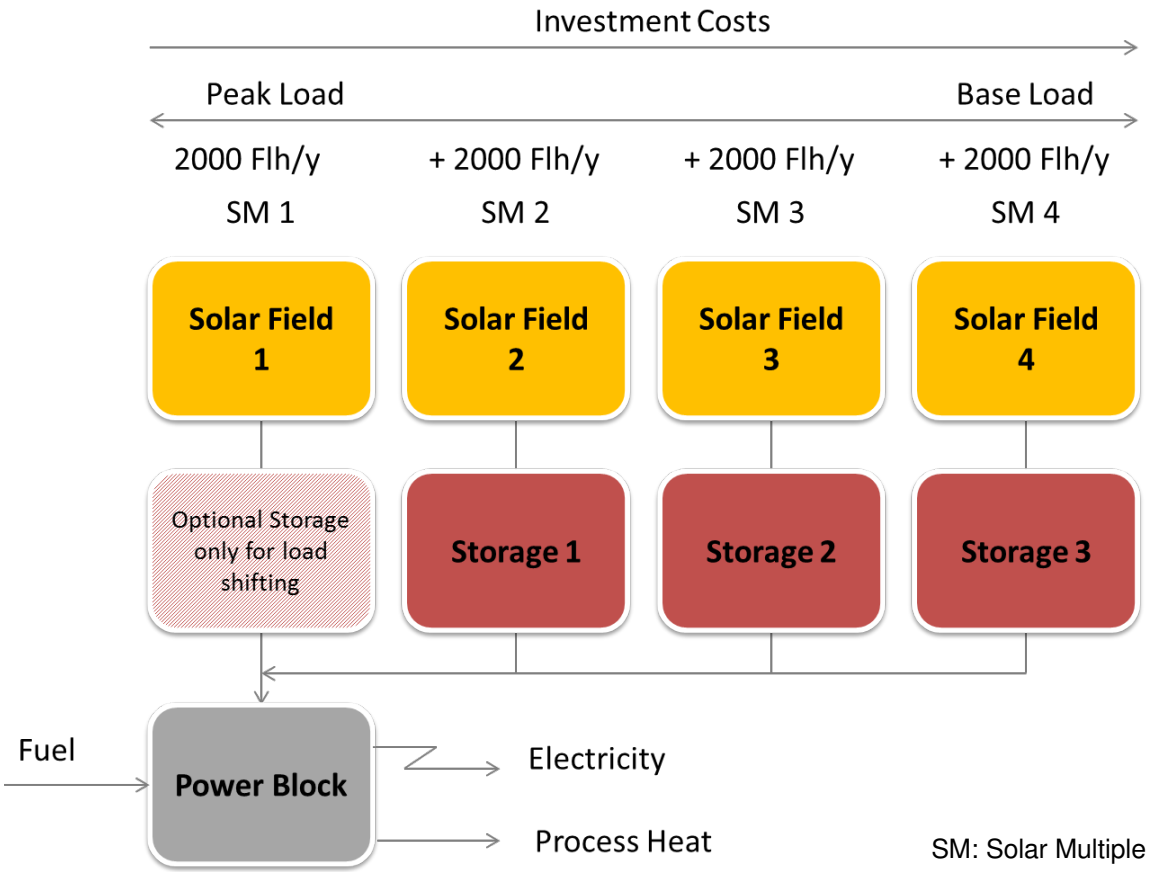
Concentrating Solar Power Plants

Principle of a parabolic trough CSP plant



Concentrating Solar Power (CSP)
Characteristics

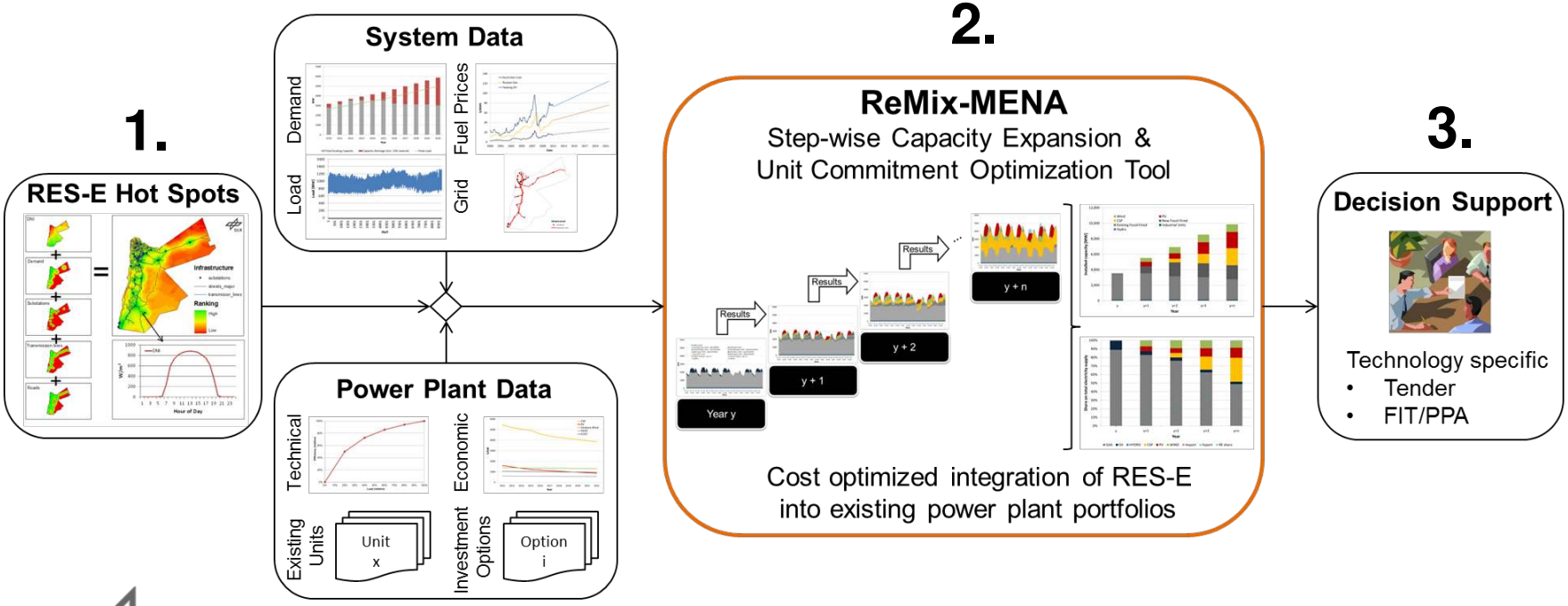


Qualities of CSP Plants:

- Operating as peak, medium or base load power plant
- Firm & flexible capacity due to storage system and back-up boiler
- Power generation on demand
- System services
- Combined generation of process heat for industry, cooling, desalination, etc.

Methodology for an optimized integration of RE technologies into existing power plant portfolios

- Emphasis on cost optimized short-term integration of RE technologies and maintenance of security of electricity supply
- Results for decision support for electricity authorities and utilities in MENA



Hot spots for utility-scale PV and CSP plants in Jordan

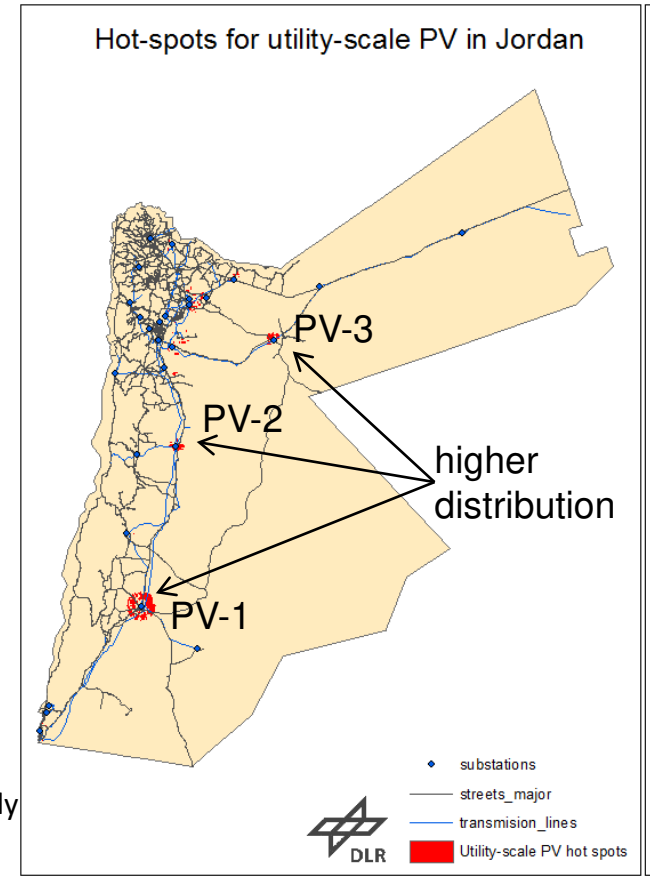
General methodology & results

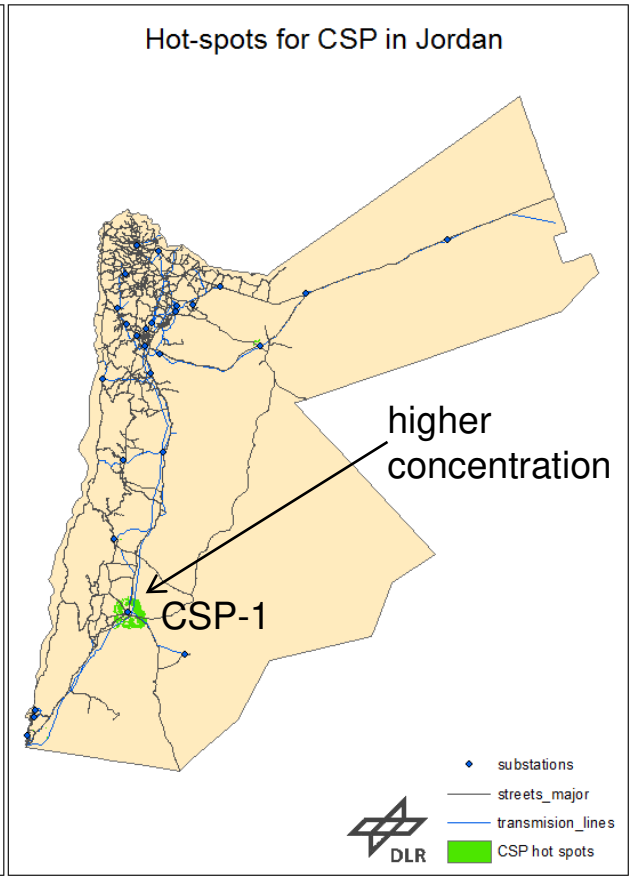
Solar resource assessment
- DNI
- GHI
- Wind speed

Land resource assessment
- GIS data
- Technology specific land exclusion

Site ranking
- Distance to infrastructure
- Resource availability
- …

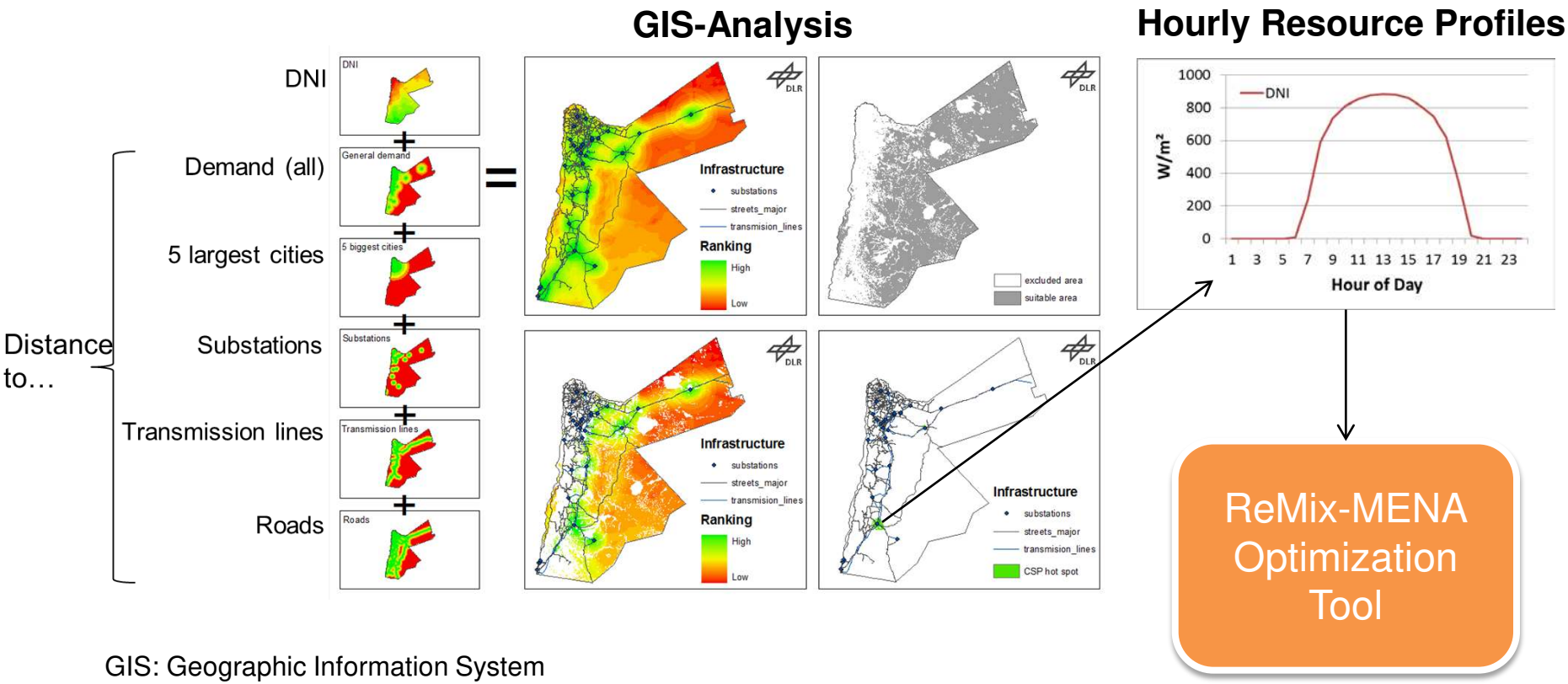
Hot spots
- Available area
- Max. installable capacity
- Representative hourly resource profiles





Methodology for hot spot identification (site ranking)

Example CSP



GIS: Geographic Information System

ReMix-MENA:

Optimization tool for cost efficient integration of RE technologies in MENA countries

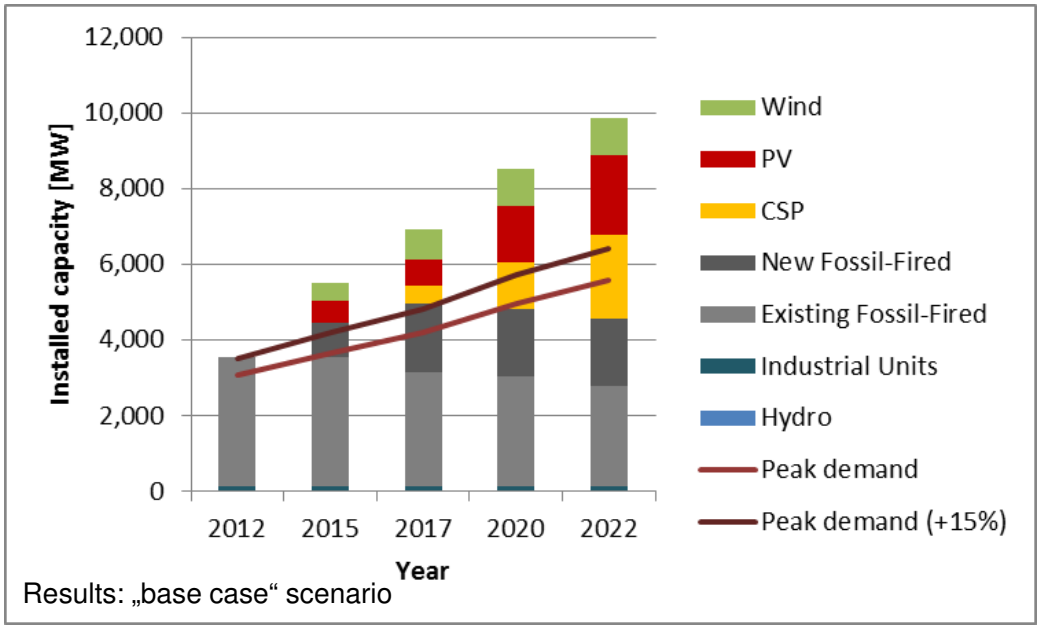
- Model for step-wise capacity expansion, replacement and unit commitment optimization (minimization of total system costs)
- Algorithm ensures that RE technologies are only integrated when their utilization contributes to lower total power generation costs
- Starting from present power plant portfolio of the investigated country
- Detailed hourly modeling of technical and economical restrictions and dynamics of each single conventional and RE power generation unit
- Optimization of CSP configuration (solar field and storage size)
- Taking into account all necessary system restrictions (firm capacity requirements, spinning reserve, tertiary reserve, etc.)

Jordan case study
Main assumptions

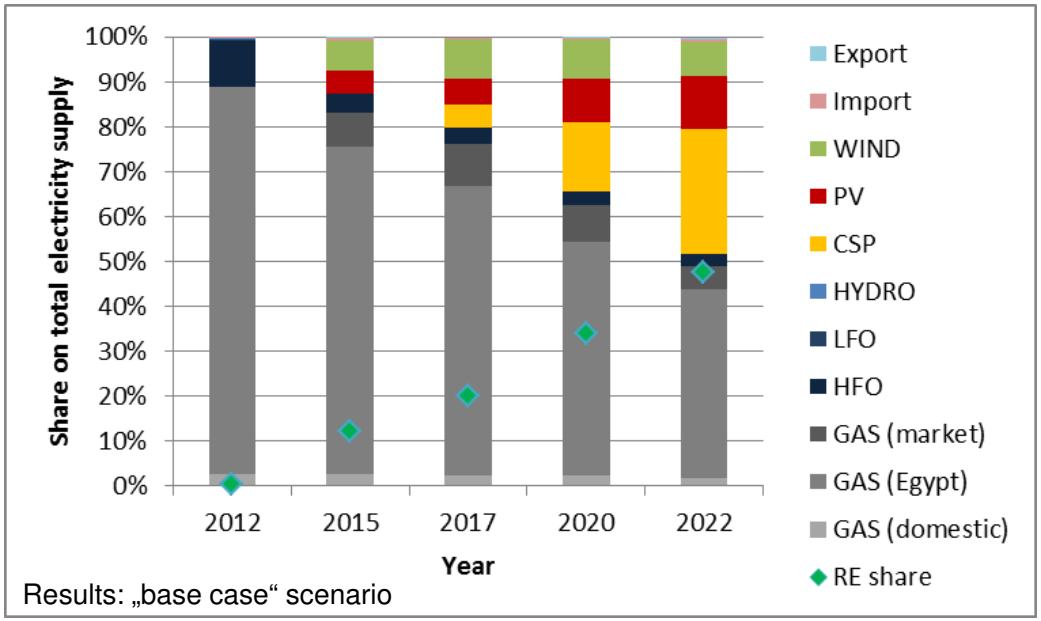
- Time-frame 2012 – 2022,
  optimization time-steps: 2012, 2015, 2017, 2020, 2022
- Starting from Jordan‘s existing power plant portfolio in 2012
- Future availability of N.G. from Egypt is restricted to the amount of today
- Additional fossil fuels have to be bought at market prices
- Fossil fuel price escalation of 5% p.a.
- Investment options: CCGT, OCGT, PV, onshore wind power and CSP units
- Investments in oil shale and nuclear power plants are excluded due to water constraints, security, economic and environmental reasons as well as very long construction times

Jordan case study
Results I

- PV, onshore wind power and CSP are already today competitive in certain load segments
- Until 2017, PV and onshore wind replacing expensive fossil fuels (LFO/Diesel)
- CSP latest from 2017 on main choice for highly required firm and flexible power capacity



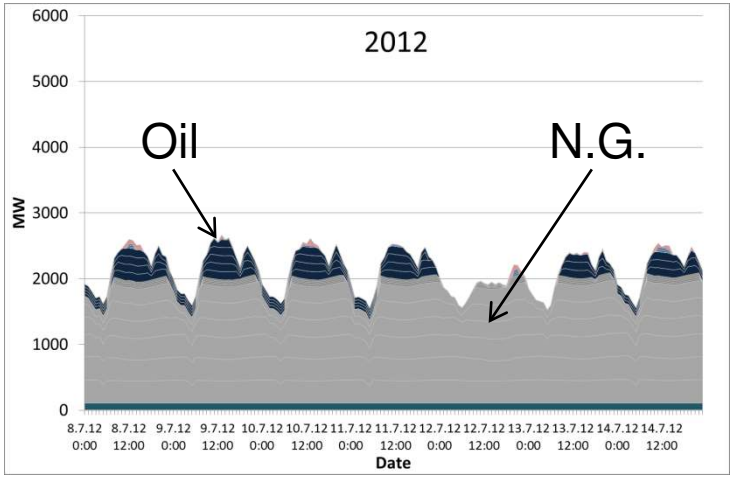
Results: „base case“ scenario

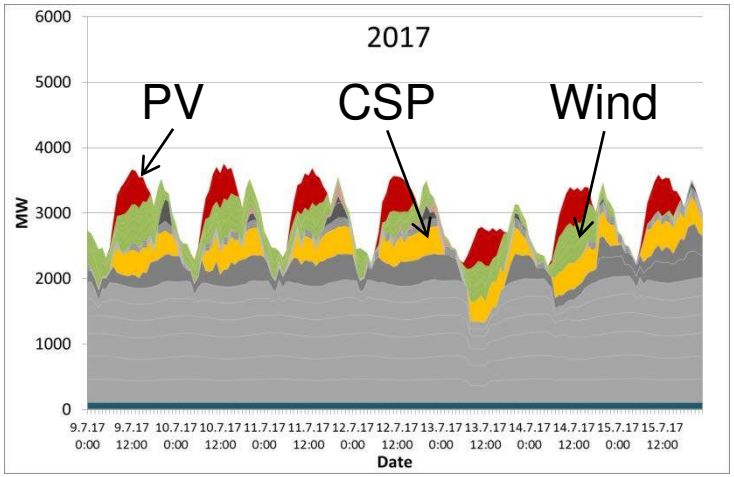


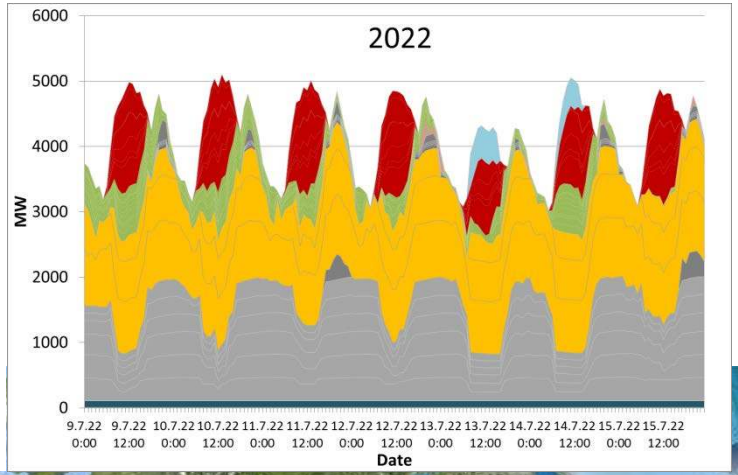
Results: „base case“ scenario

Jordan case study
Results II

- PV and wind power as cheap “fossil fuel saver”
- CSP competitive in the peak and upper-mid merit sector in the short-term
- CSP providing strongly required firm and flexible generation capacity
- First CSP plants with rather small solar field and storage (SM 1.4, Storage: 5 Flh)
- In the medium-term CSP competitive with mid-merit and base load sector. SM and storage capacity is increased (up to SM 2.3, Storage 12 Flh)
- CSP in long-term as back-bone of electricity supply



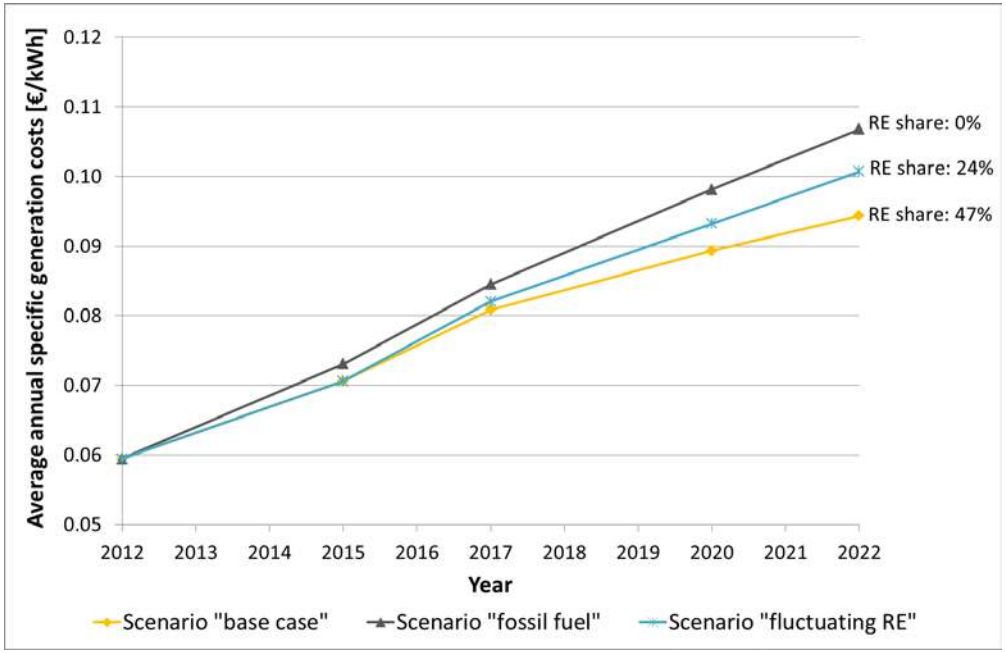




Export
Utility-scale PV - HS 1-3
CSP units - HS 1
New CCGT units - GAS (market)
Existing OCGT Units - LFO (market)
Existing CCGT Units - GAS (Egypt)
Hydro Units
Import
Onshore Wind - HS 1-4
New OCGT units - GAS (market)
Existing ST units - HFO (market)
Existing OCGT units - GAS (domestic)
Industrial Units

Jordan case study
Results III

- Different scenarios have been investigated in addition to the “base case”
- Capacity mix of the “base case” scenario is the least cost option for Jordan to meet future electricity demand
- Large-scale integration of RE technologies will absorb significantly future electricity generation costs



Large-scale introduction of RE technologies in Jordan:

- Least cost option!
- Higher independency!
- Job creation!

Conclusions I
Jordan' situation

- Strong increasing electricity sector
- High need for additional firm and flexible power capacity
- High dependency on fossil fuel imports
- High potential of solar and wind resources allowing low cost generation
- Very limited pump-storage potential and limited biomass potential
- CSP only large-scale alternative for firm and flexible power in Jordan except of fossil-fired power plants

Conclusions II
Results from ReMix-MENA

- Today, PV, onshore wind and CSP are competitive in certain niche markets
- The large-scale integration of RE technologies and a well balanced mix of RE and conventional technologies is the least cost option for Jordan to keep up with the increasing electricity demand
- PV and wind power units can be used as low cost “fossil fuel saver”
- CSP most competitive technology for strongly required firm and flexible power in MENA
- CSP as backbone of electricity supply in the long-term allowing high shares of power generation by RE technologies
- The large-scale integration of RE technologies has significant economic advantages
- However, an appropriate market-framework has to be implemented

Setting an appropriate market framework
Suggestions

- recognize the need for large RE investment
  (RE investment replaces fuel consumption for decades!)
- Implement technology specific tenders in order to get the most suitable mix of conventional and RE power generation technologies
- reduce capital cost and thereby generation costs of RE technologies by increasing project ratings towards AAA
  (re-insured PPA, e.g. “World Bank Guarantee Program”)
- provide transparent, long-term stable regulatory and policy framework to trigger real RE markets
- start immediately in order to save money!

Thank you for your attention!

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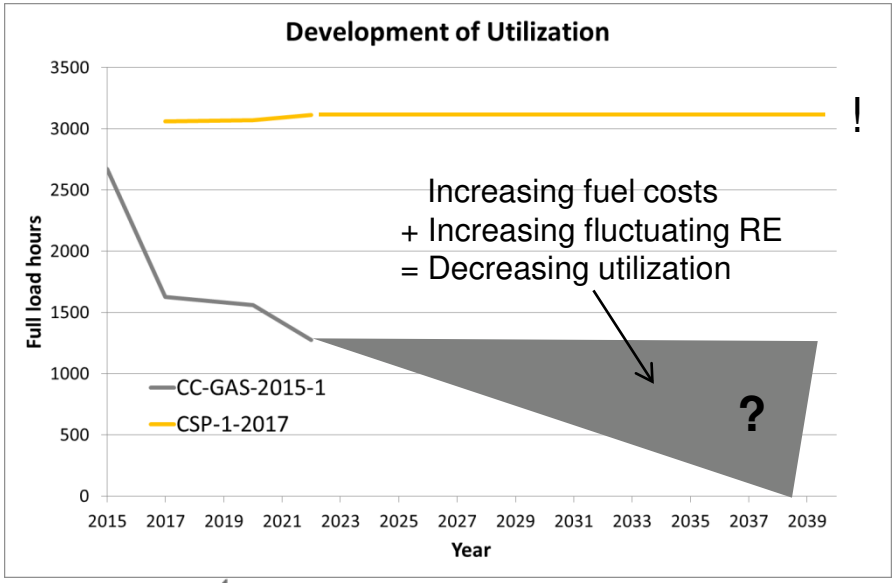
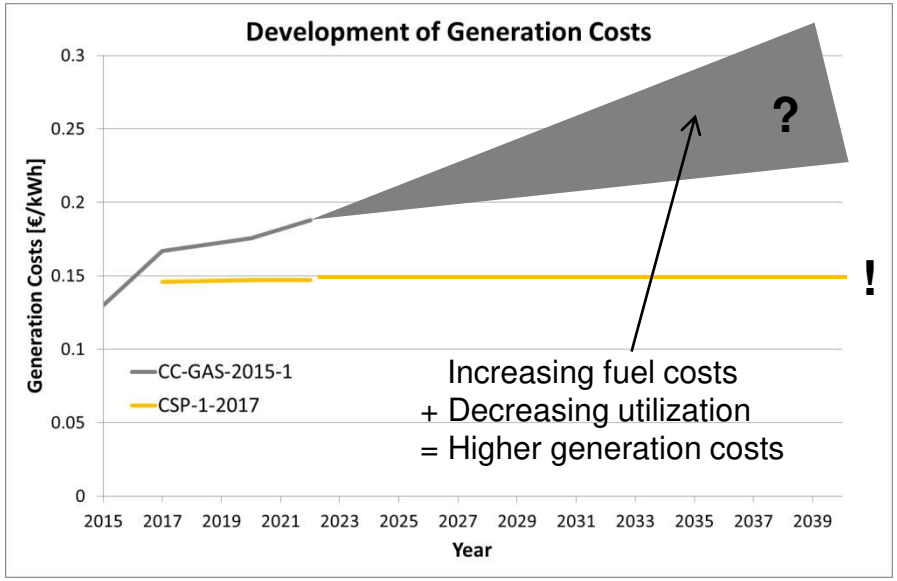
Back-Up Slides

Investments in new power generation capacity

Exemplary example

- CSP plants representing firm and flexible power generation capacity with fixed generation costs
- Conventional power plants representing firm and flexible generation capacity without fixed generation costs
- CSP competitive today when performance over entire lifetime is taken into account





Figures: Results for 2015-2022 from ReMix-MENA ("base case" scenario), 2023 – 2040 qualitative illustration