GCREEDER 2018
April 3-5, 2018 Amman, Jordan

HYMENSO

HYMENSO
Hybrid CSP – PV Plants for MENA Region

DLR (German Aerospace Center, Institute of Solar Research)

The University of Jordan (Jordan)

CDER (Renewable Energy Development Center, Algeria)

CRTEn (Research and Technology Centre of Energy, Tunisia)

University of Patras (Greece)

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Project Objectives

HYMENSO aims at increasing the **deployment of solar power plants in the MENA region**, considering the specific boundary conditions in Tunisia, Algeria and Jordan.

It may have an impact on the energetic and environmental sector and provide improvements to the social and labor situation in these countries.

Work Packages

- **WP1 Market Research**: meteorological conditions, electricity demand, water and fuel costs, energy policy, potential sites, etc. for Jordan, Tunisia and Algeria.
- **WP2 Technology Development**: select CSP-PV technologies, determine technical and economic parameters, calculate yearly energy yield and search optimal configurations.
- **WP3 Demonstration**: Identify infrastructure at the partner's facilities to be used for data collection, refurbish those systems, operate and gather measured data.
- **WP4 & WP5 Knowledge Transfer & Dissemination** of project results

Main Results: WP1 Market Research

Sites Selected for Simulation

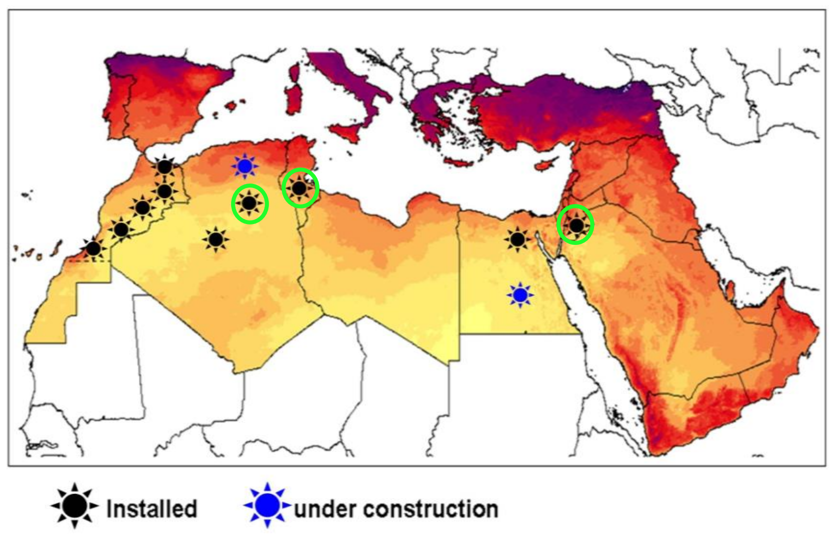
Ma’an, Jordan
Source: Google 2018

Ghardaia, Algeria
Source: Google 2018

Tataouine, Tunisia
Source: Google 2018

Main Results: WP1 Market Research

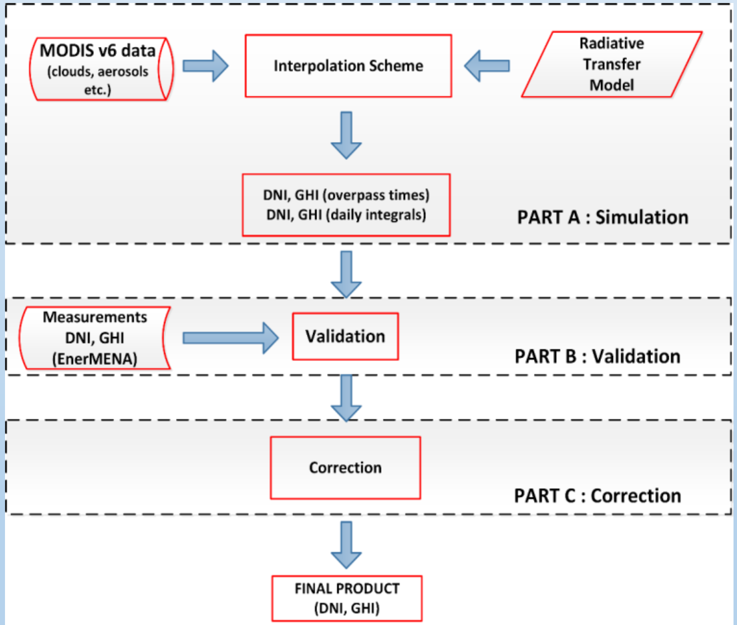
Location of enerMENA meteostations



Source: DLR

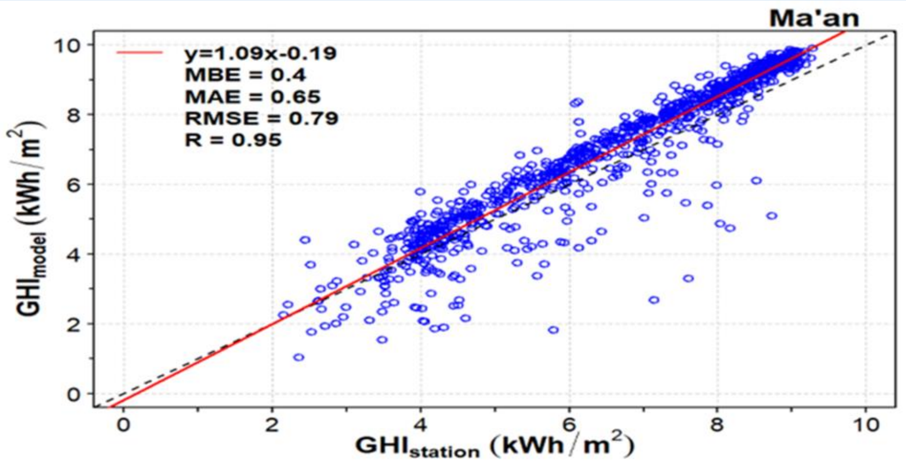
Solar irradiance model calculations and validation

Methodology:



Source: University of Patras

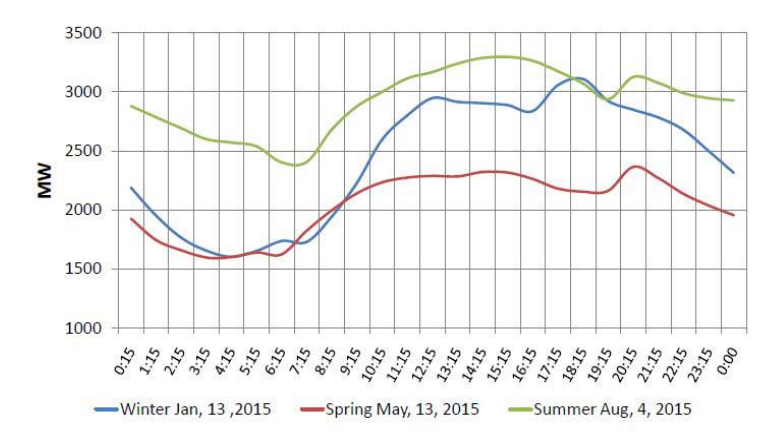
Sample Results:



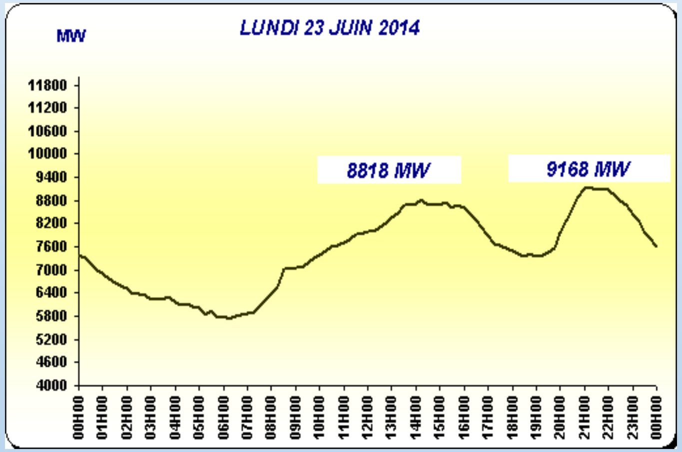
Source: University of Patras

Main Results: WP1 Market Research

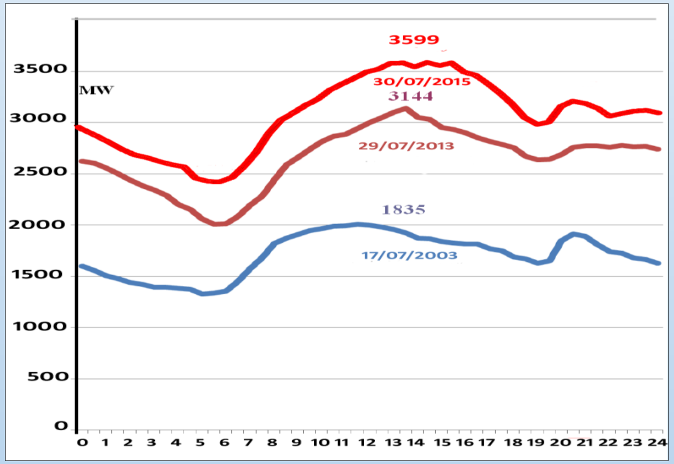
Load Curves



Jordan
Source: NEPCO



Algeria
Source: SONELGAZ



Tunisia
Source: STEG

Main Results: WP1 Market Research

Example of Local Boundary Conditions

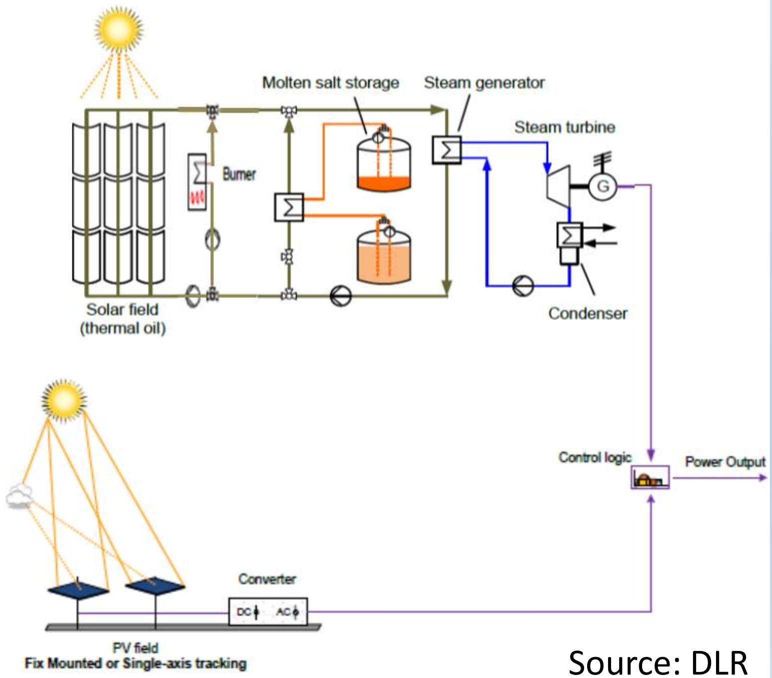
Country	Jordan	Algeria	Tunisia
Land Cost ($/m^2) or Rent cost ($/m^2/year)	**5.46 $/m²**	**0.01 $/m²/year**	Power plant **0$/m2** (source:STEG) Regular Land Cost 20 $/m^2
Water Cost ($/m^3)	Treated wastewater tariff is **0,07 $/m³** for industrial reuses including power generating and cooling	**0.05 $/m³**	**0.24 $/m³** Water pumped from well
Fuel Type & Cost	Natural Gas for industries: **34.3 $/MWh** (4/2017)	Natural Gas 1.48 to 2.86 $/MWh (average value **2.5 $/MWh**)	- Natural Gas for industry: **30,7 US$/MWh**

Country	Jordan	Algeria	Tunisia
Electrical Energy demand			
Total Installed Capacity in The Country	4282 MW, 18911 GWh (2015)	15385 MW	In 2016 the installed capacity reached 5400 MW
Max Demand in the Country	3485 MW (2016)	13000 MW	3599 MW (2015)
Expected Demand in the Following years	3678 MW (2017), 3884 MW (2018), 4106 MW(2019)	25415 MW by 2025	CDER projection: 7800 MW by 2030

Main Results: WP2 Technology Development

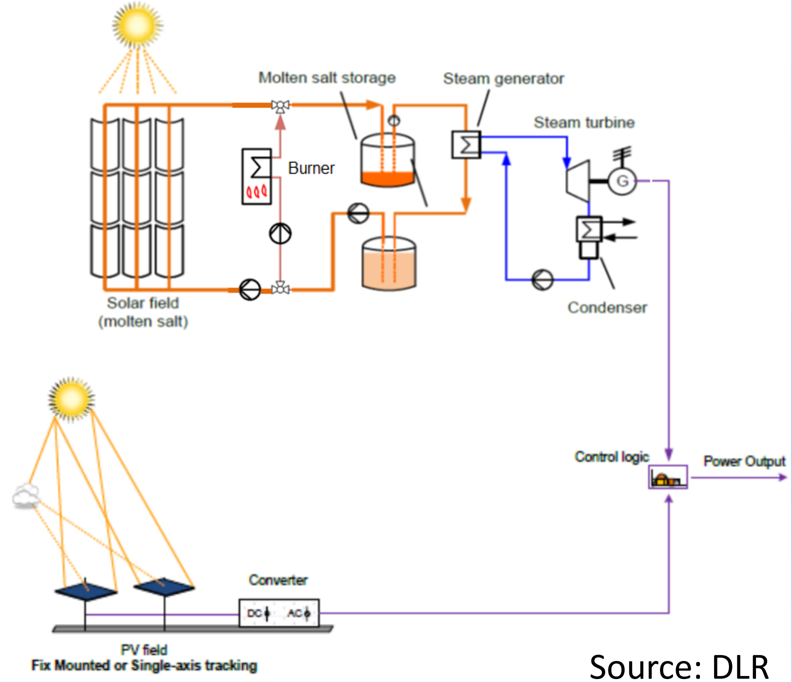
Selected Cases

Case CP1:
Parabolic Trough with **Thermal Oil** HTF and Thermal Energy Storage
+ **Natural Gas** Back-Up
+ **PV Polycrystalline** single axis tracked



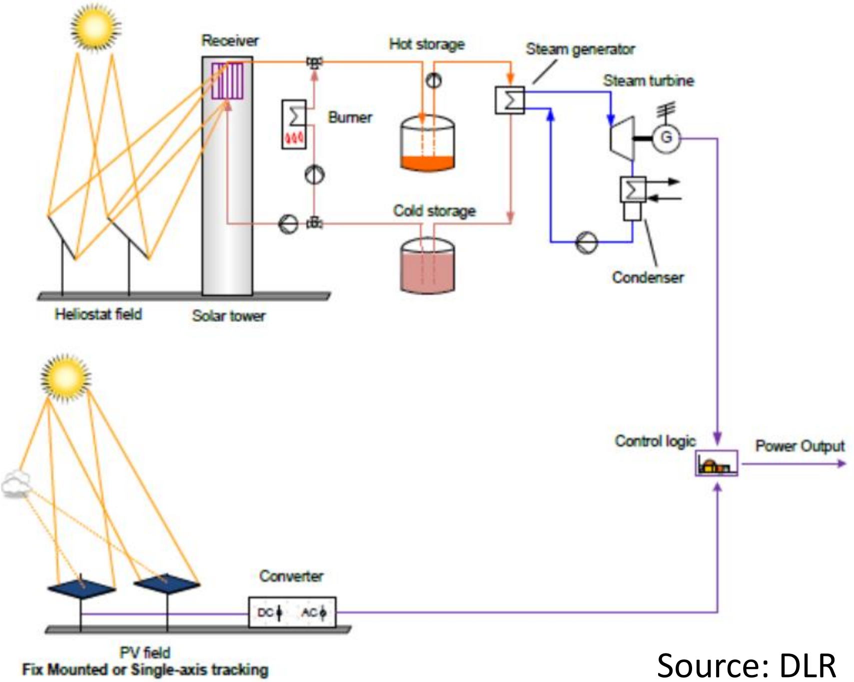
Source: DLR

Case CP2:
Parabolic Trough with **Molten Salt** HTF and Thermal Energy Storage
+ **Natural Gas** Back-Up
+ **PV Polycrystalline** single axis tracked



Source: DLR

Case CP3:
Solar Tower with **Molten Salt** HTF and Thermal Energy Storage
+ **Natural Gas** Back-Up
+ **PV Polycrystalline** single axis tracked



Source: DLR

Main Results: WP2 Technology Development

Methodology

Set-Ups Defined:

3 Sites:	Jordan, Algeria, Tunisia
3 Technology Cases:	CP1, CP2, CP3
2 Options:	with Natural Gas and Solar-Only

= 18 Set-Ups

Parametric variation ranges:

CSP Solar Multiple:	1.8 to 3.4 in 0.2 steps, plus 1.4 case
Thermal Energy Storage:	3 to 21 h capacity in steps of 3h
PV Capacity (DC output):	0 – 227 MWp (10 Steps, 28.4 MWp)

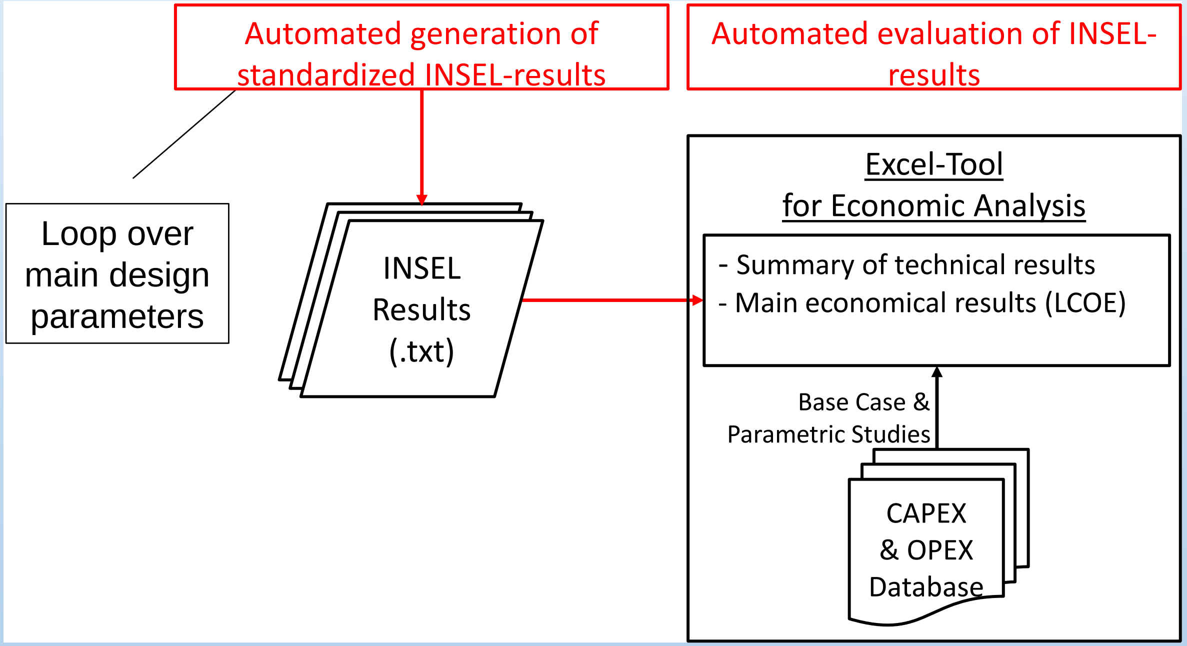
= 700 Configurations x 18 Set-Ups = **12.600 Configurations to Simulate**

Main Results: WP2 Technology Development

Methodology

1) Techno-Economic modelling
2) Parametric variation ranges
3) Automatic performance calculation with **INSEL software**
4) Economic evaluation

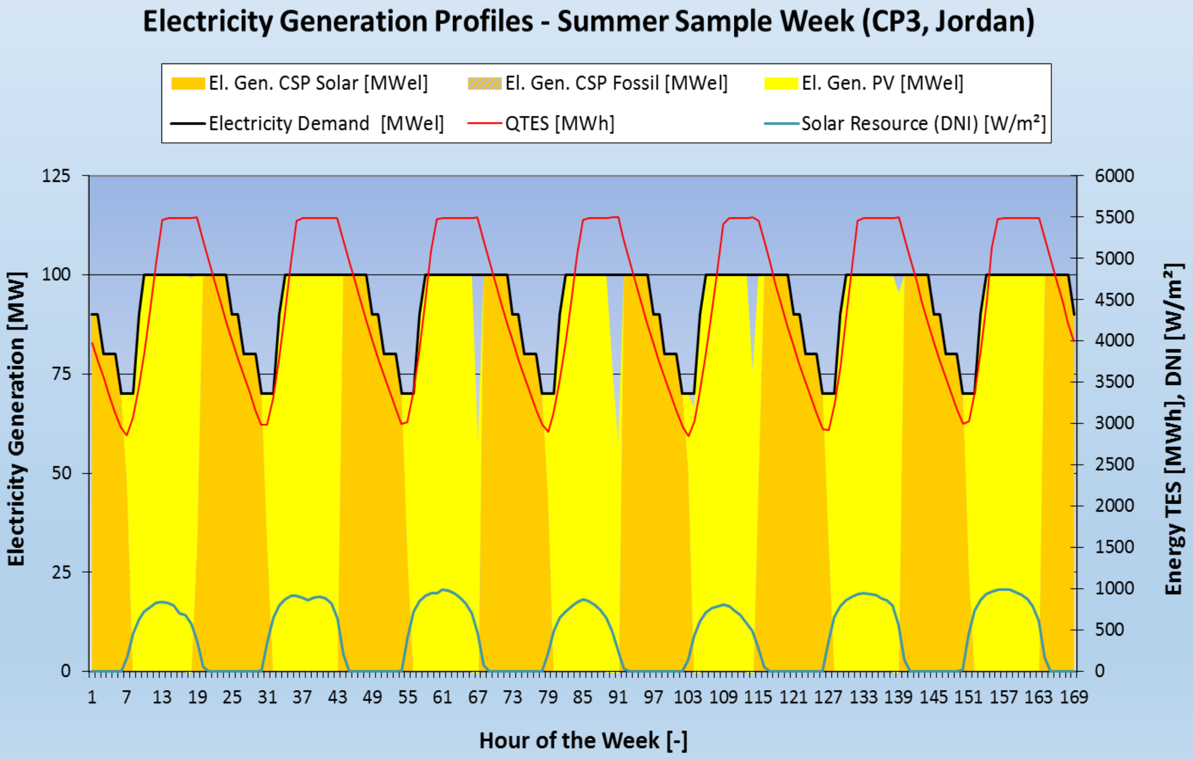
→ **Goal:** search for **LCOE minima** per CO_2 emission range or demand coverage

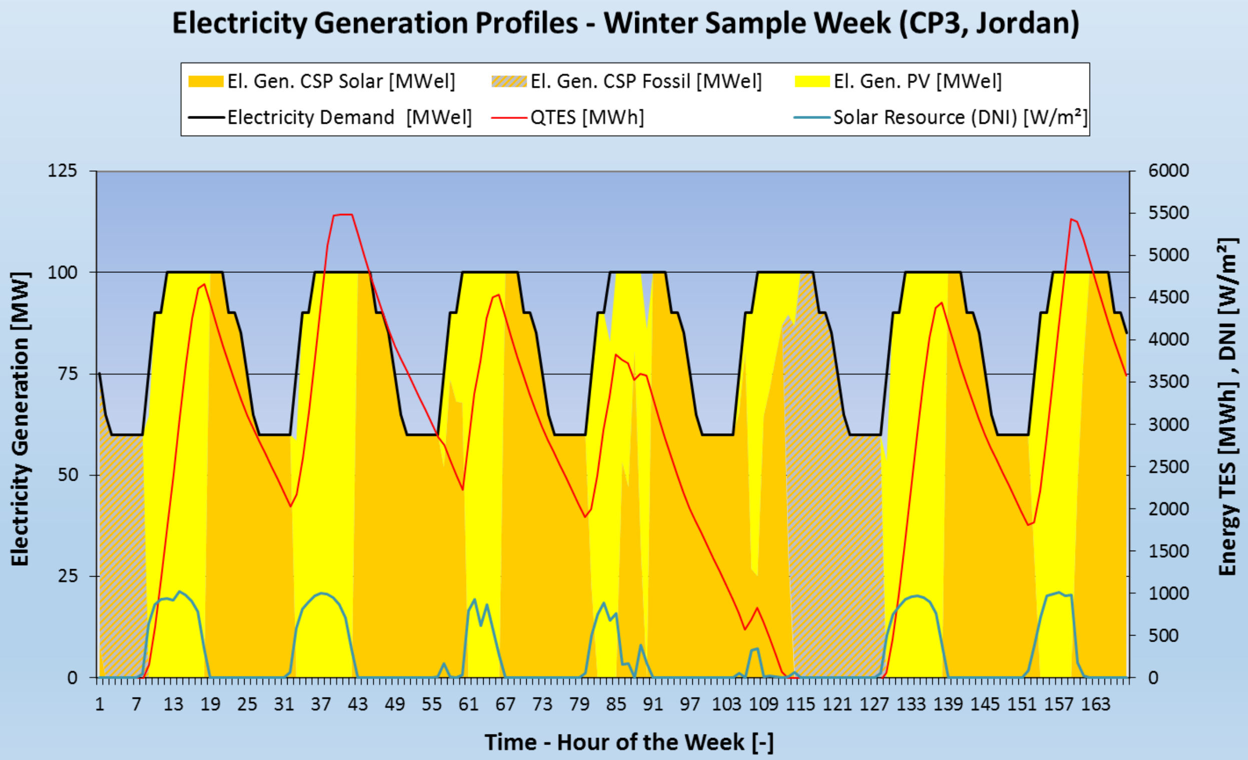


Main Results: WP2 Technology Development

Low Fuel Use example. 30 g CO2/kWhe, solar share 94%, LCOE 10.9 €cent/kWh

CSP solar multiple 2,4; TES capacity 21 h; PV cap. 170 MW





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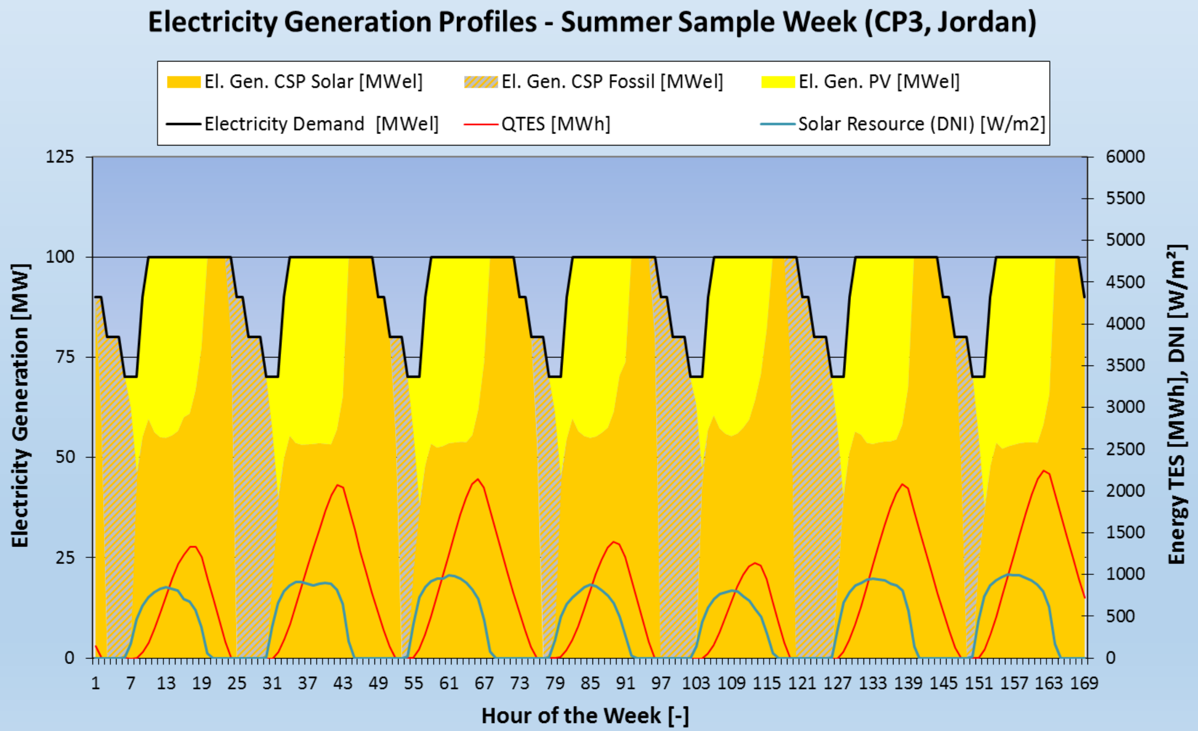
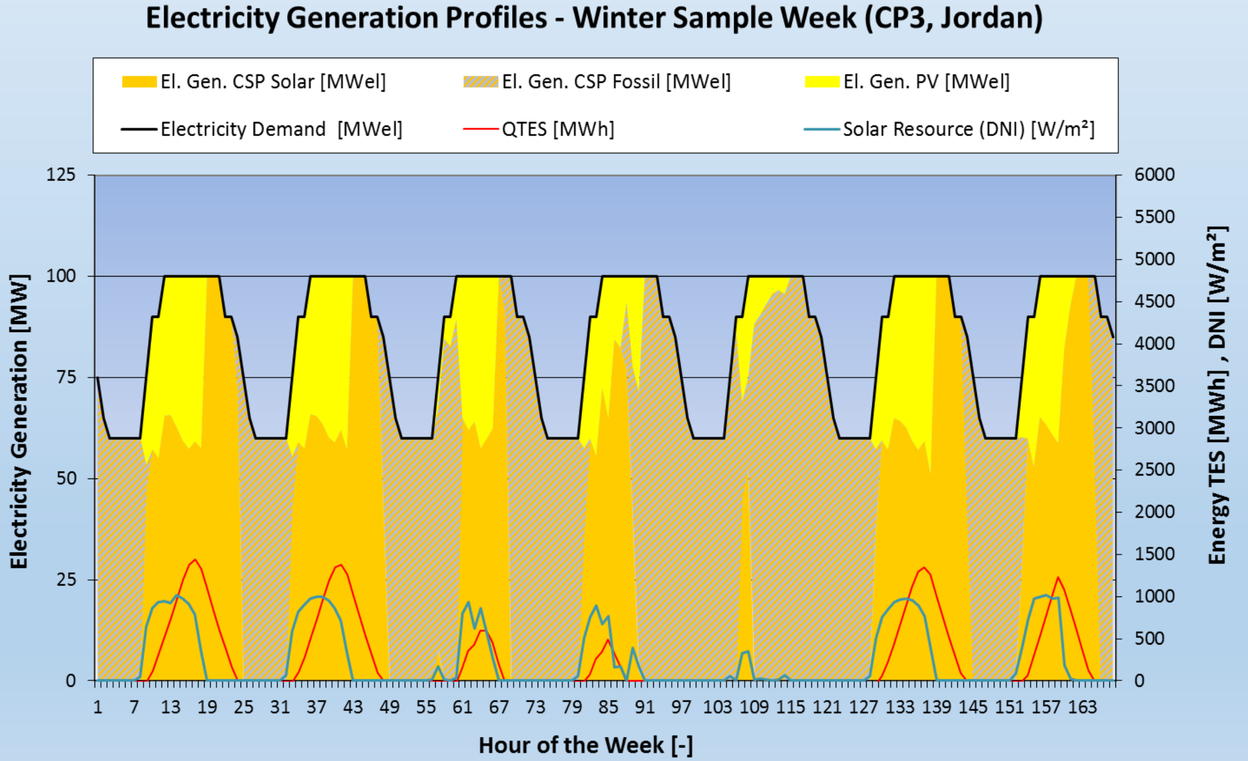
Main Results: WP2 Technology Development

High Fuel Use example: 188 g CO2/kWhe, solar share 66%, LCOE 8,6 €cent/kWh

CSP solar multiple 1,4; TES capacity 9 h; PV cap. 57 MW





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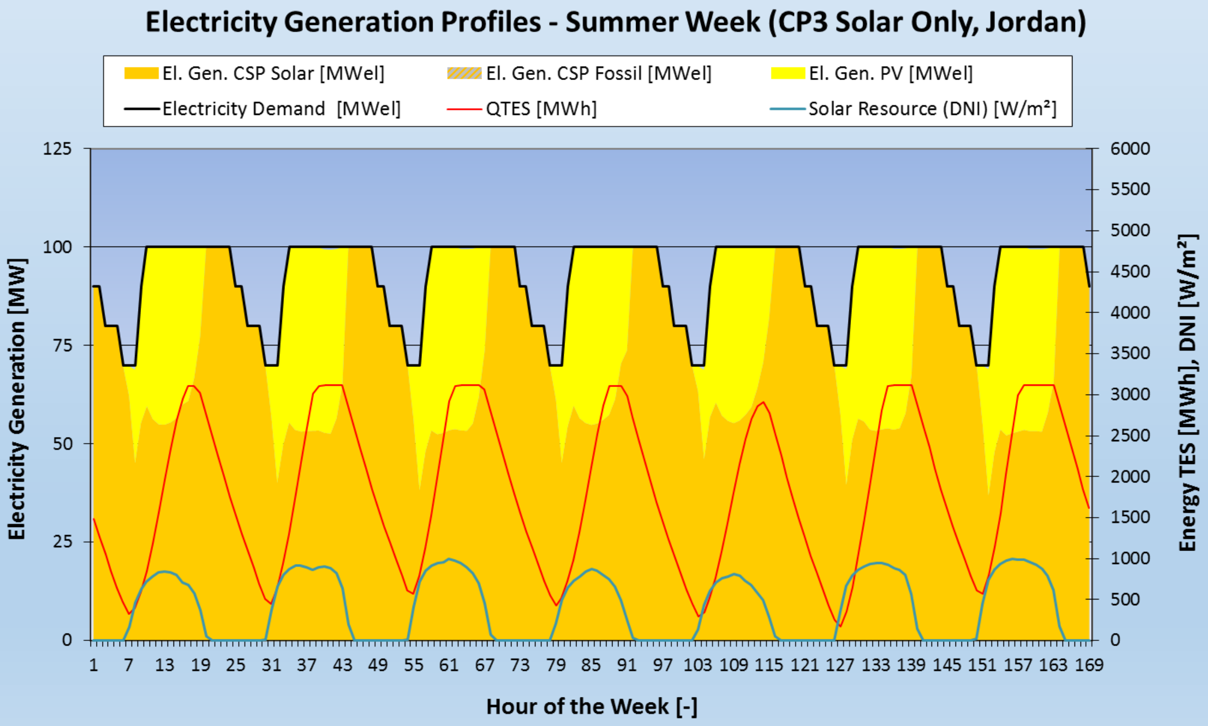
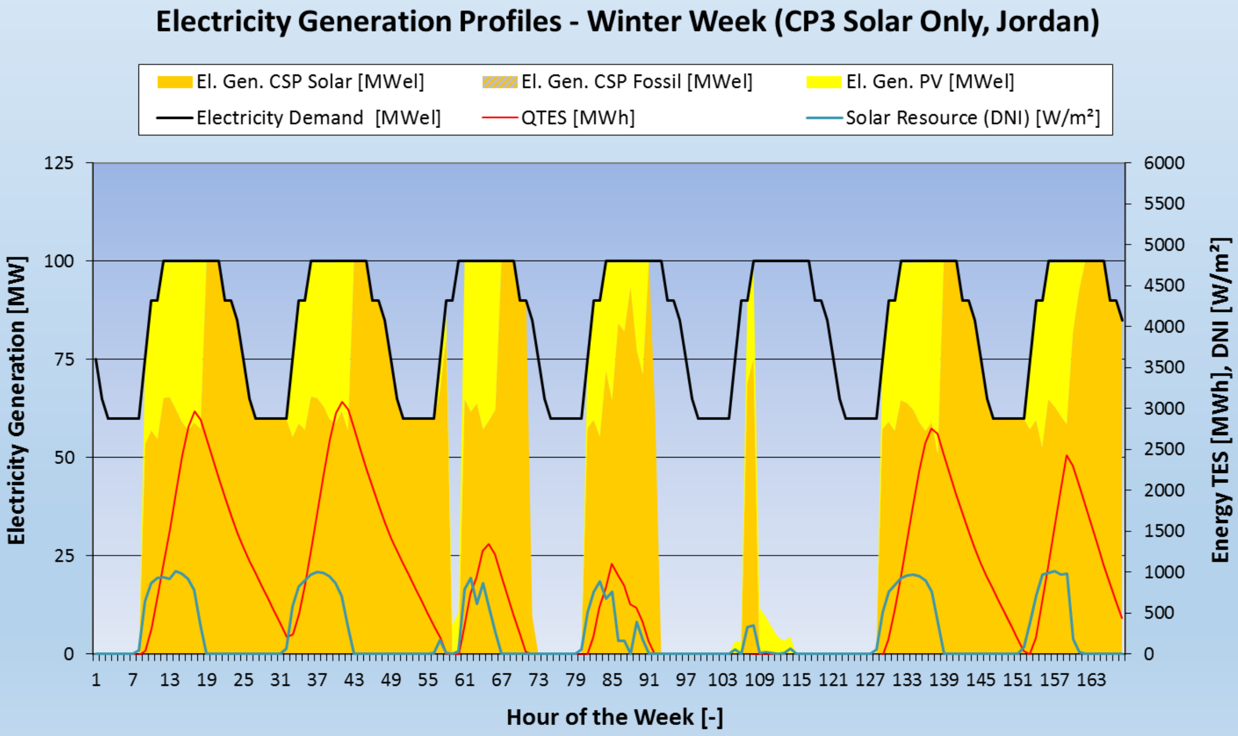
Main Results: WP2 Technology Development

Solar-Only example: 0 g CO2/kWhe, Demand covered 80%, LCOE 9,1 €cent/kWh

CSP solar multiple 2,2; TES capacity 12 h; PV cap. 57 MW





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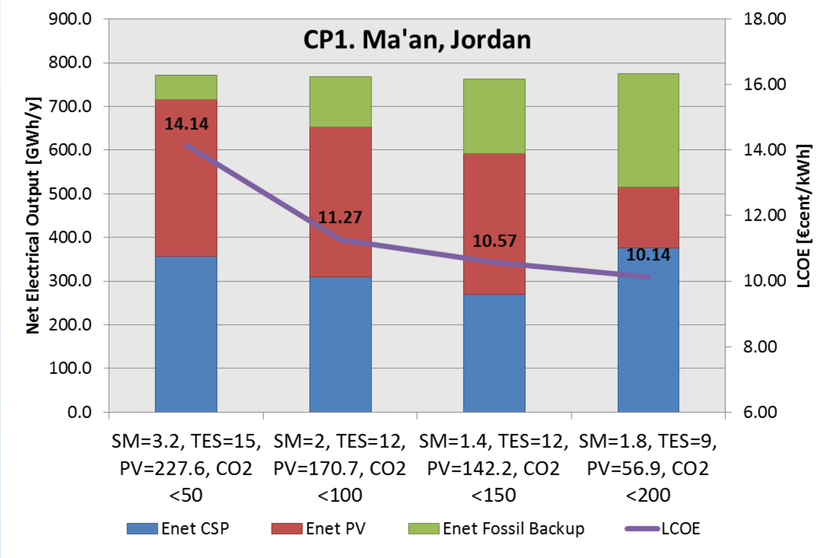
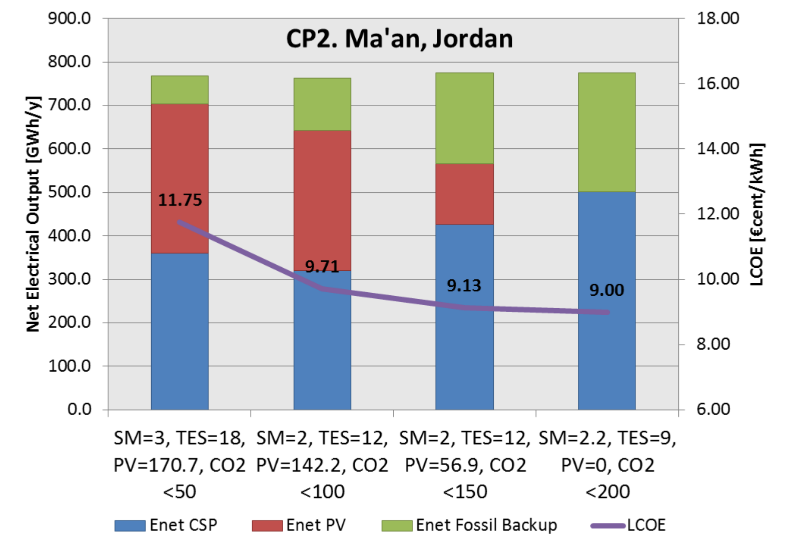
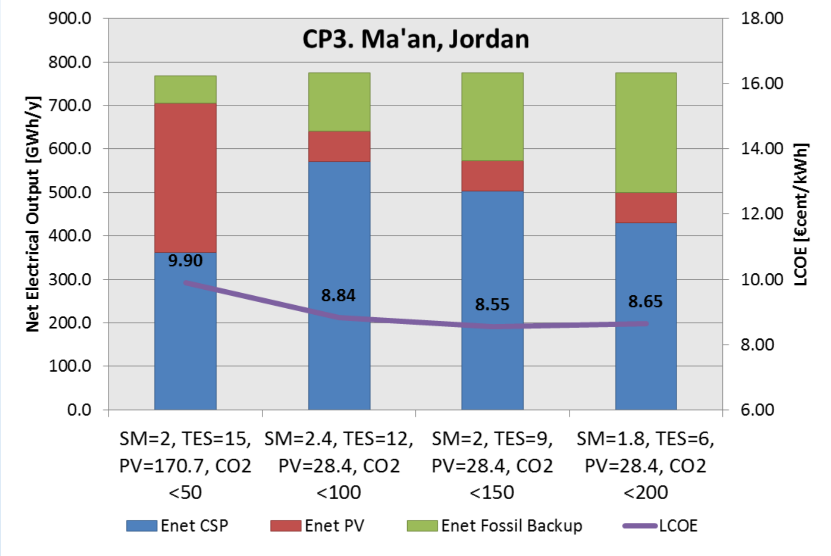
Main Results: WP2 Technology Development

Configuration Selection, with Natural Gas







CO2 emissions (g/kWhe)

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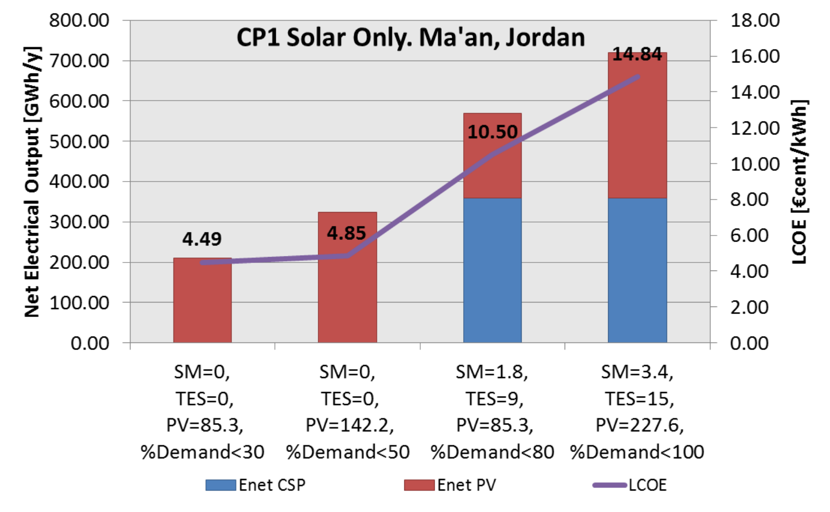
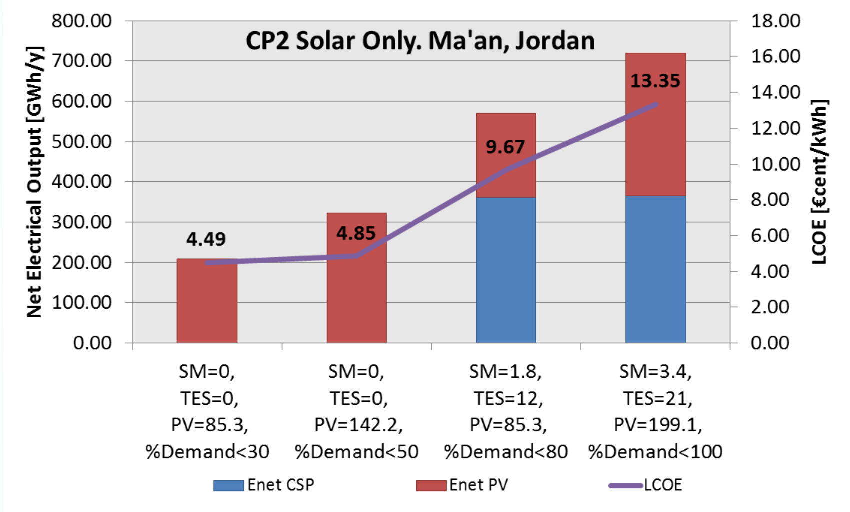
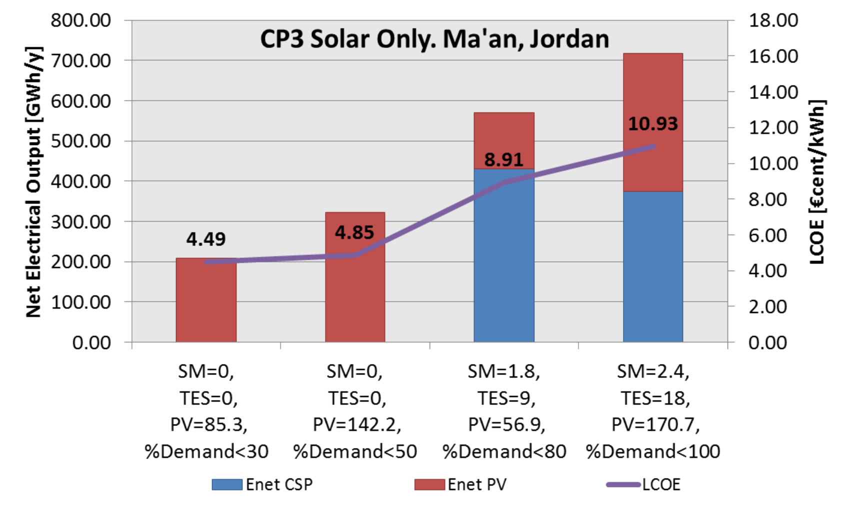
Configuration Selection, Solar-Only







→ % of demand covered

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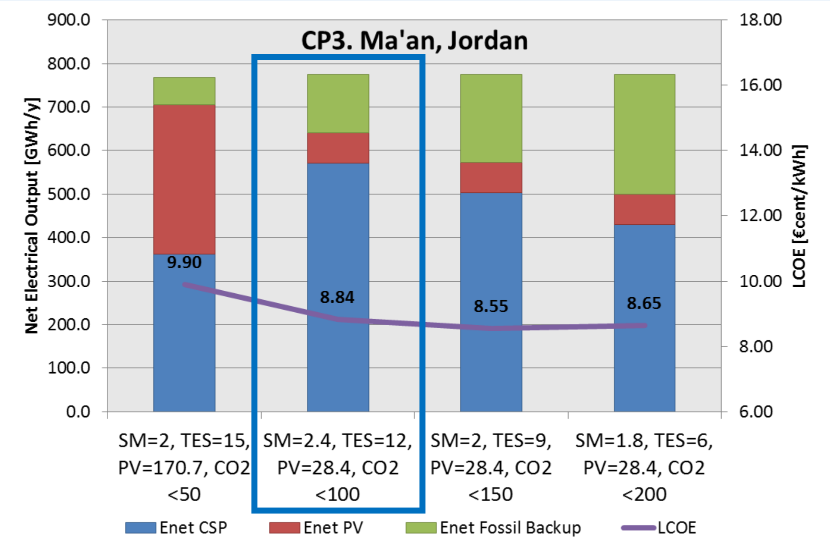
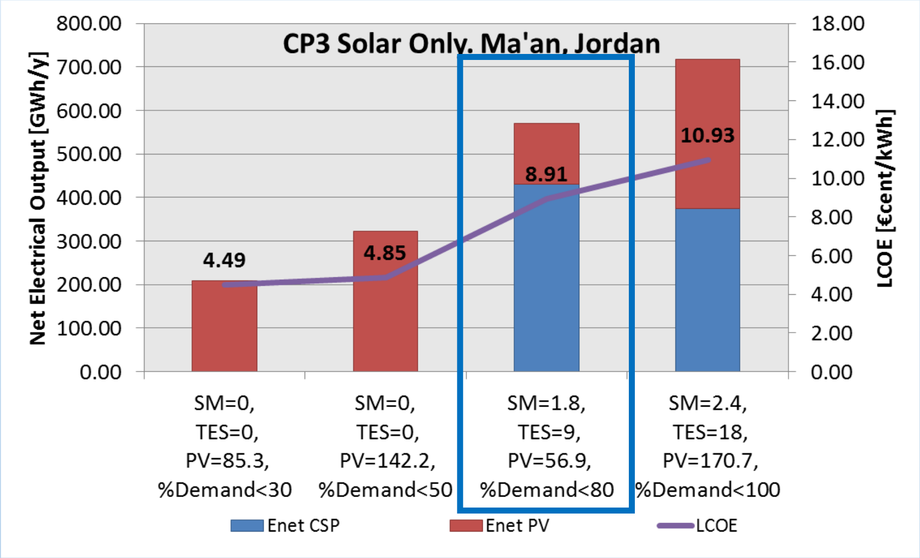
Main Results: WP2 Technology Development

Back-Up Fuel vs. Solar Only





Similar LCOE for configuration with **100 gCO2/kWhe** (84% Solar Share) and **100% demand covered as** solar-only (100% solar share) and **80% demand covered**

Main Results: WP3 Demonstration

57.6 KW (AC) Roof-mounted grid-connected PV system used for refrigeration rooms.
Suntech 320 W, (STP320-24-Vd polycrystalline)
Central Market for Vegetables and Fruits Zarqa city, Jordan

9.54 KW (DC) Grid – Connected Photovoltaic system at CDER, Algeria.
The PV system consists of 90 IsofotonI106 monocrystalline PV modules.

16 KWth Parabolic trough used to power an absorption chiller for air conditioning.
Borj Cedria Tunisia
CRTEn

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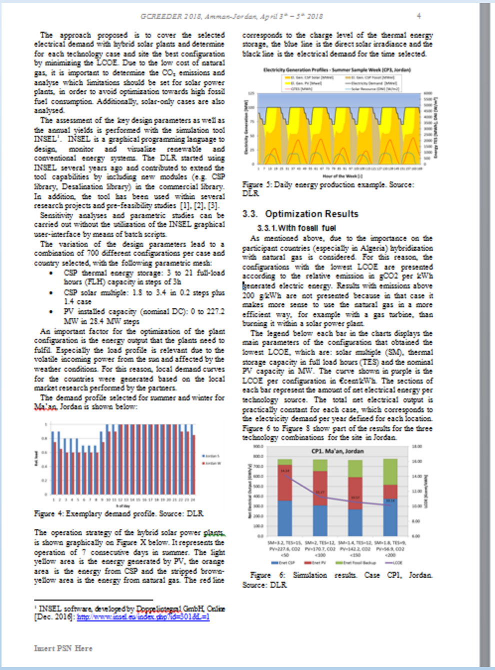
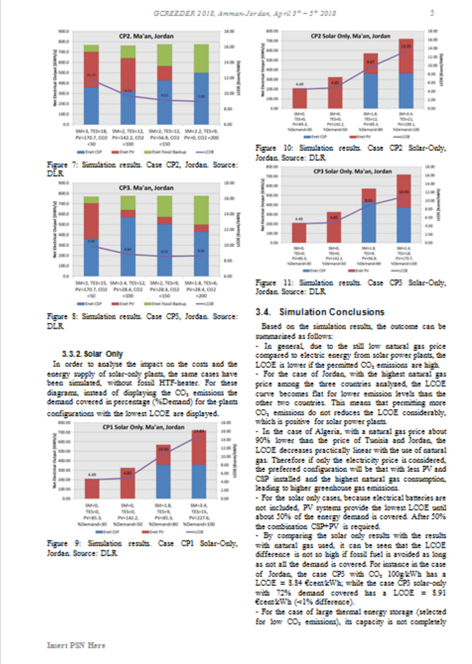
Main Results: WP4 & WP5 Knowledge Transfer & Dissemination





HYMENSO
MENA Hybrid Solar System

HYMENSO aims to support the implementation of solar energy systems in the MENA region by following a holistic approach covering aspects of cost, reliability and dispatchability.

HYMENSO aims to serve as a reference to guide local researchers and industry about the optimization of the power plants configurations to cover their necessities.

HYMENSO partners

ERANETMED is funded by the European Commission's 7th Framework Programme

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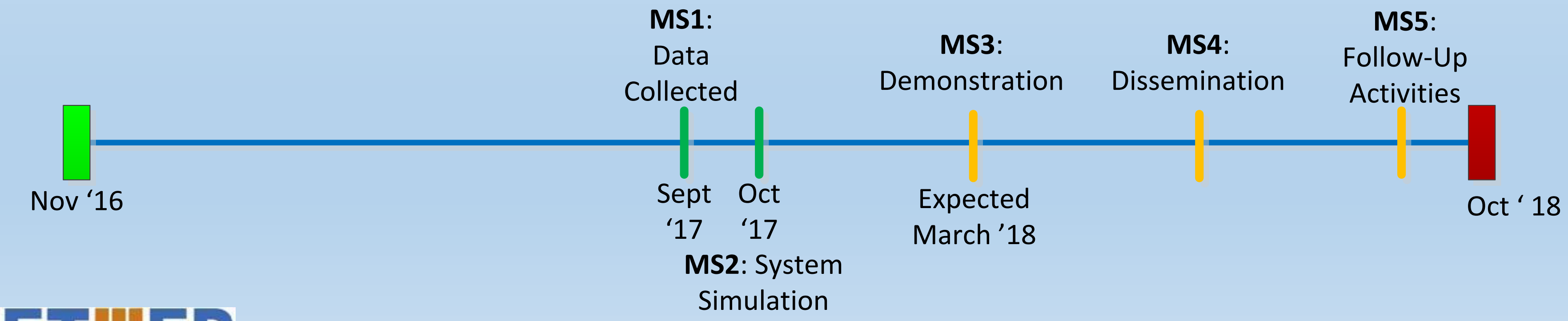
Conclusions and Next Steps

It has been confirmed, that the conditions in the analyzed MENA countries are excellent for the deployment of hybrid CSP-PV plants.

The load curves can be satisfied to a large extension with solar-only plants or to its totality if fossil back-up is allowed.

The combination of CSP + PV leads to electricity costs higher than PV but lower than CSP alone by increasing the capacity factor and the grid stability.

A complete system demonstration was not possible in HYMENSO due to lack of funding



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THANK YOU

for your attention!

THANKS to my colleagues

for their work and input

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