Battery Ageing • Battery Models • Battery Diagnostics • Battery Pack Design • Electromobility • Stationary Energy Storage • Energy System Analysis

# What is the Role of CSP in the Future South African Electricity System with $CO_2$ Emission Targets?

Workshop 2017, Pretoria

J. Badeda, P. Stöcker, D.U. Sauer
Advisory team: Mark Mehos, Oelof De Meyer, Prof. Pitz-Paal

**Chair for Electrochemical Energy Conversion and Storage Systems**

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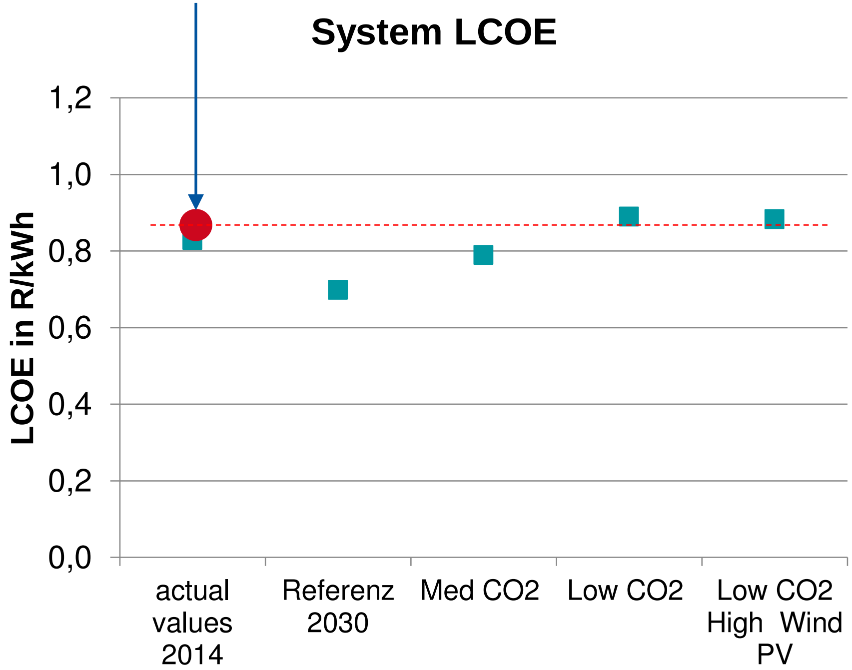
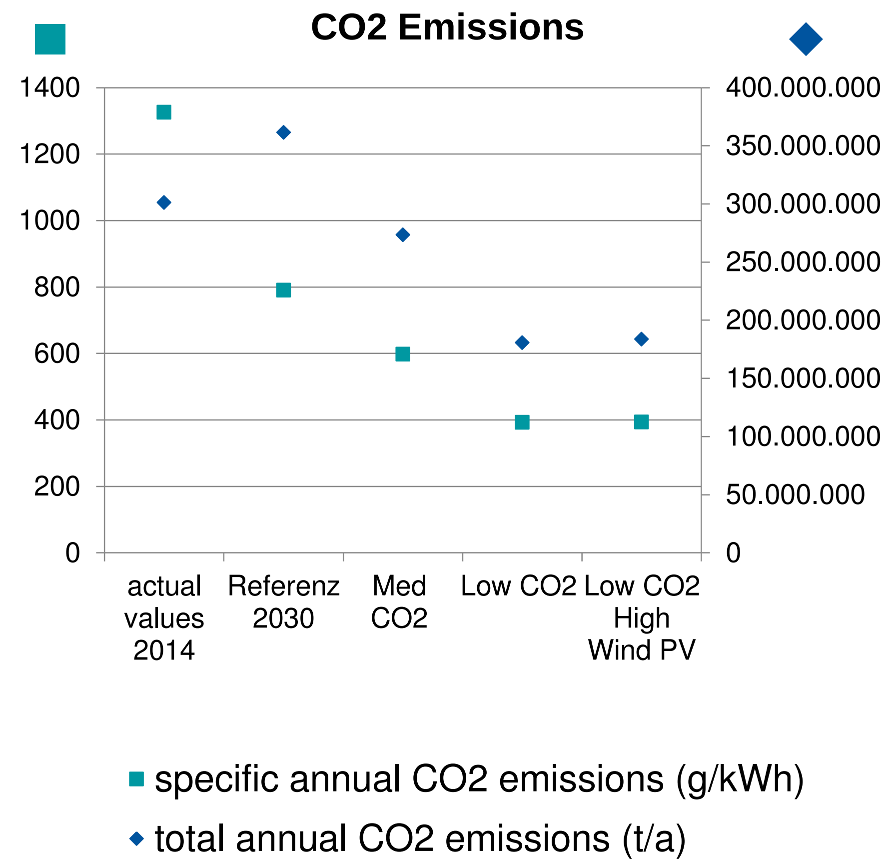
# Motivation
# Find the most cost-optimal system at specific CO2 target

Real cost ca. 0.83 R/kWh




**Even high CO2 reduction can be reached with minor impact on total system LCOE**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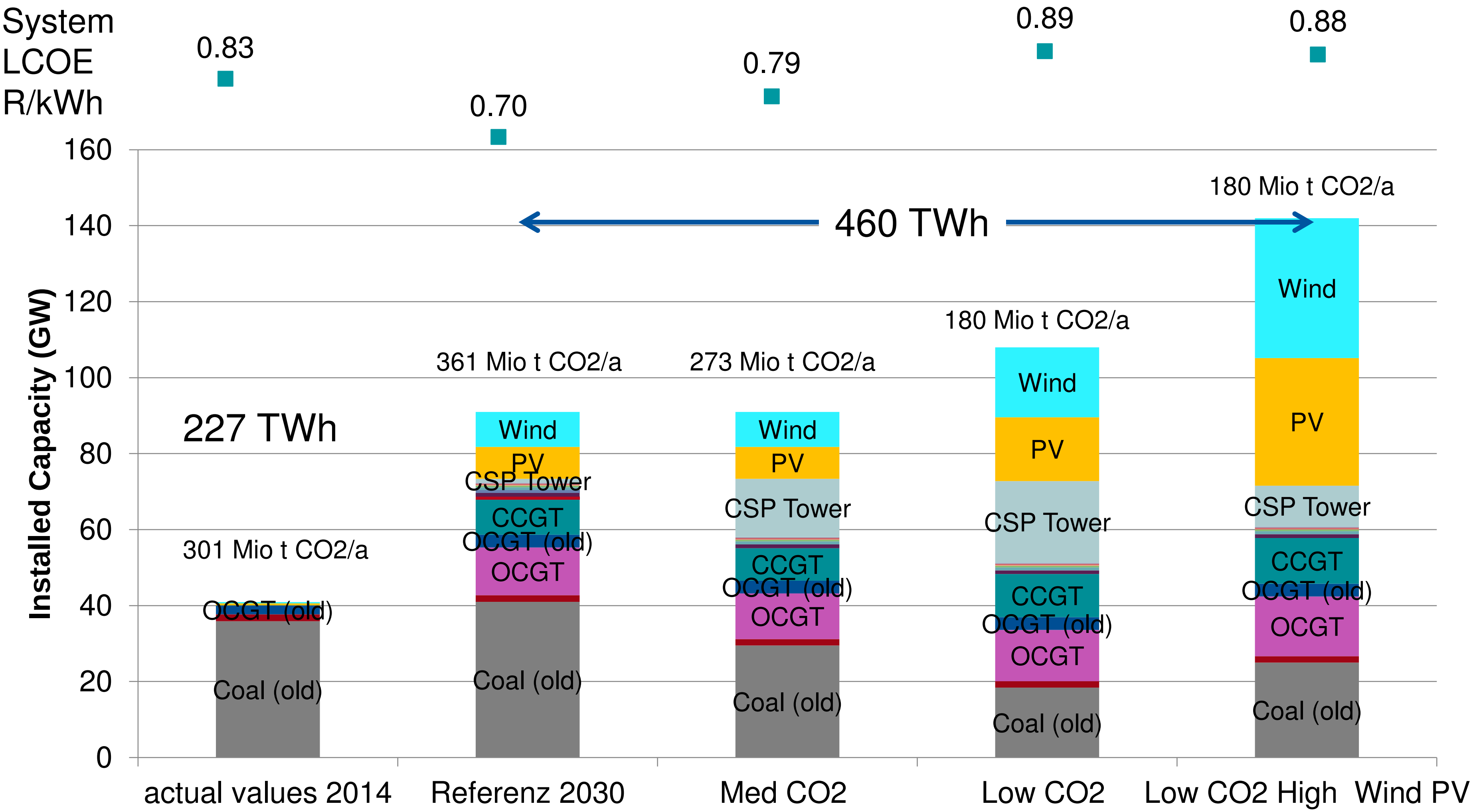
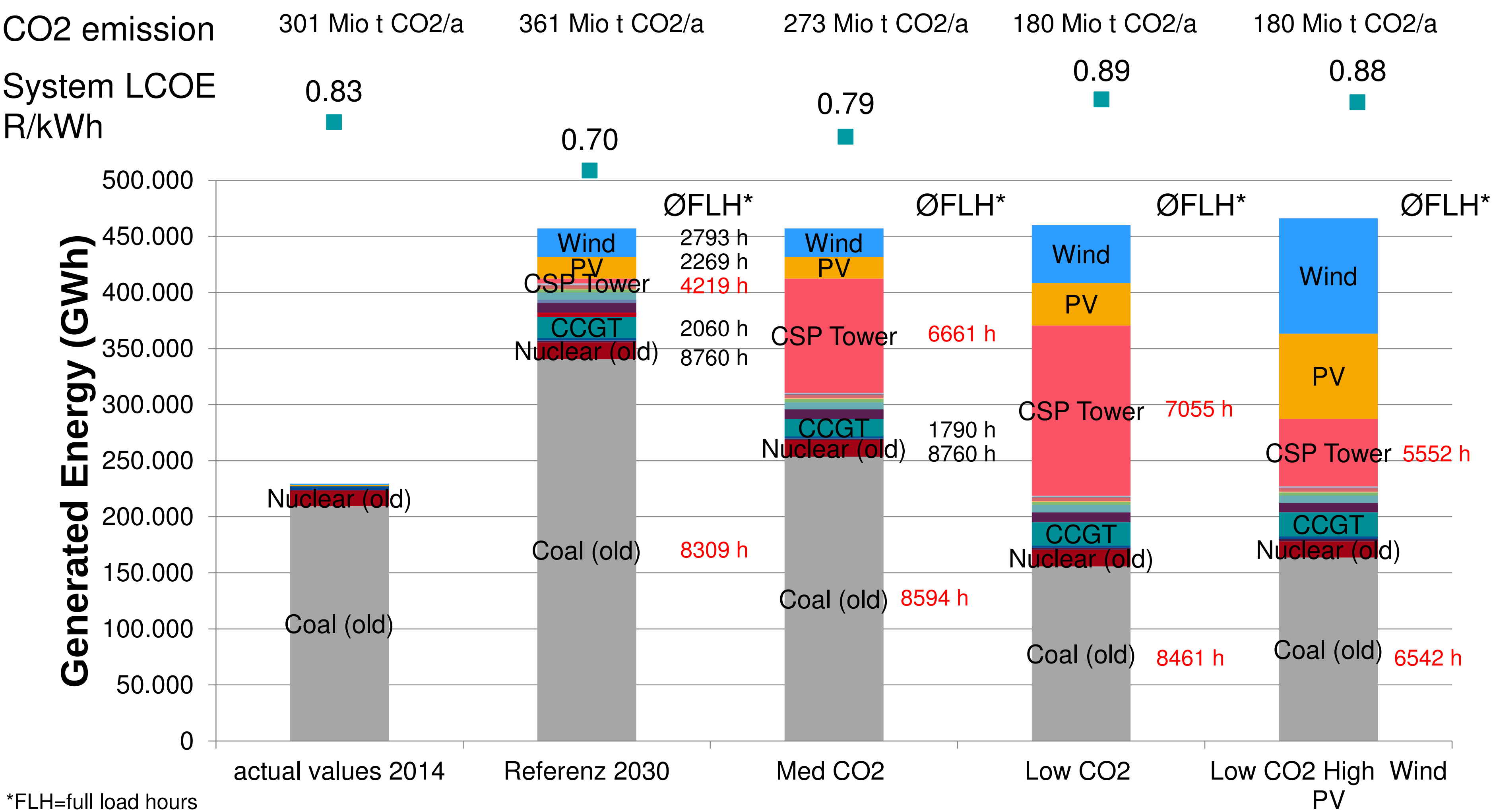
# Motivation
# Find the most cost-optimal system at specific CO2 target




**CSP is in the mix that reduces CO2 emission at system cost lower than today's values**

# Motivation
# Find the most cost-optimal system at specific CO2 target




*FLH=full load hours

**High Wind and PV penetration requires higher capacity of coal with fewer operation hours**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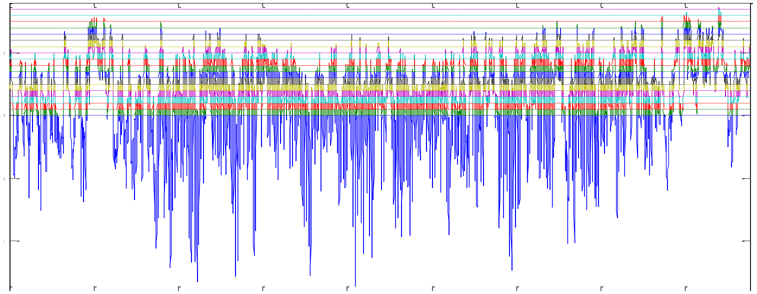
# Agenda

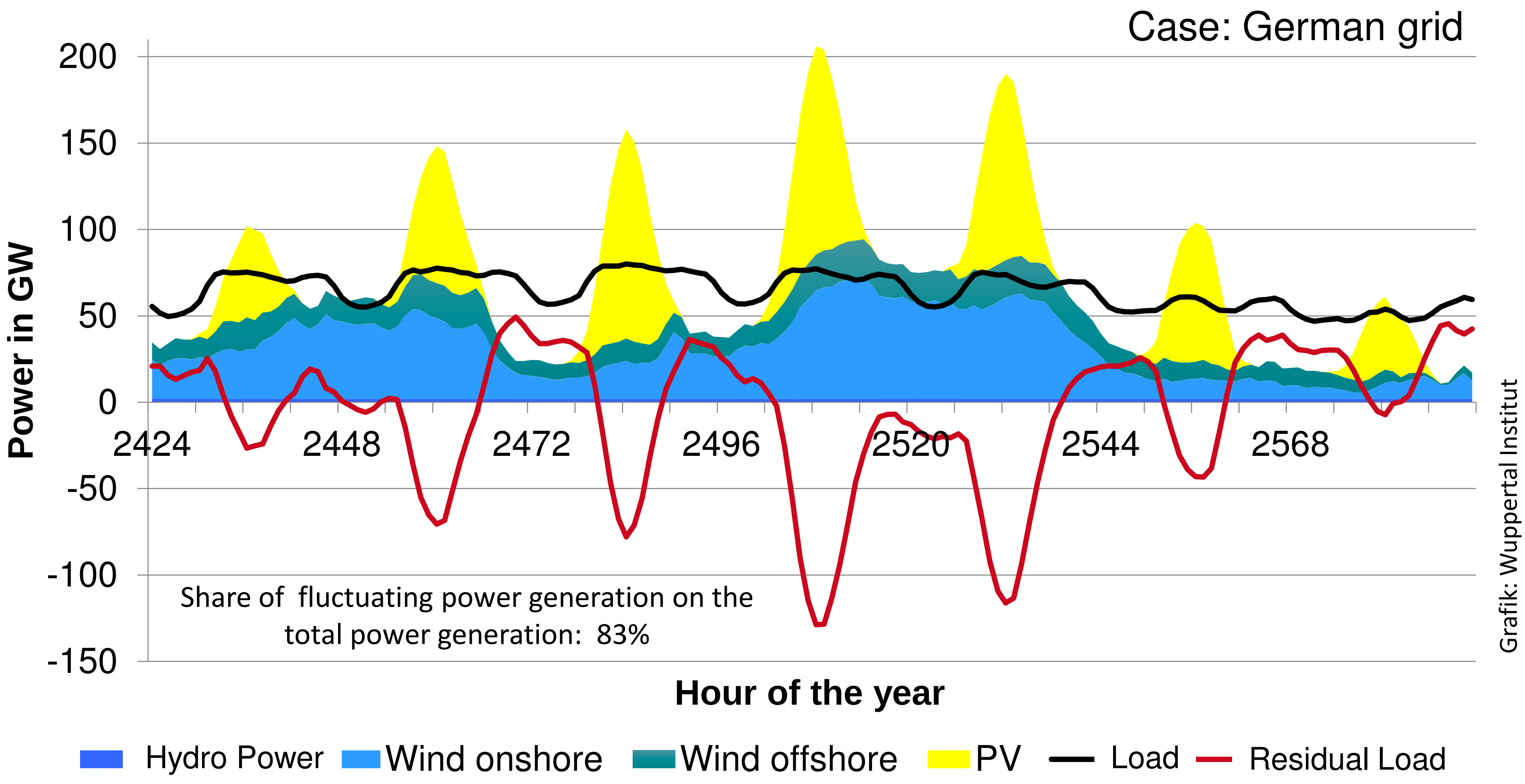

- Background
  - ESYS
  - Solar PACES Task1 request



- Method of Modeling
  - Structure
  - Concept

- Sensitivity analysis
  - Results for SA 2030 system

# Background
# Future Energy Systems - Development of residual load




PV: 151 GW, Wind onshore: 82 GW, Wind offshore: 20 GW, Electricity consumption: 602 TWh/year, FEE-share: 83 %

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# Background
# The „ESYS“ study

- ESYS = Energy Systems of the Future
- Financed by the German Ministery of Education and Research
- Three German Academies of Science

Leopoldina Nationale Akademie der Wissenschaften

acatech DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

UNION DER DEUTSCHEN AKADEMIEN DER WISSENSCHAFTEN

- Task force of hundreds of experts from technology, economics, material resources, social science and law


- Aim: Counseling of government and society
- Subproject: Flexibility technologies

→ Calculate cost optimum under given restrictions

# Background
# SolarPACES Task1 request

- Long-Term goal:
  - Working group to evaluate CSP for different electricity markets with favorable conditions for renewable generation

- First Phase:
  - Define scenarios and evaluate the role of CSP for two different countries
  - Spain & **South Africa**

- Partner:

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DLR

NREL NATIONAL RENEWABLE ENERGY LABORATORY

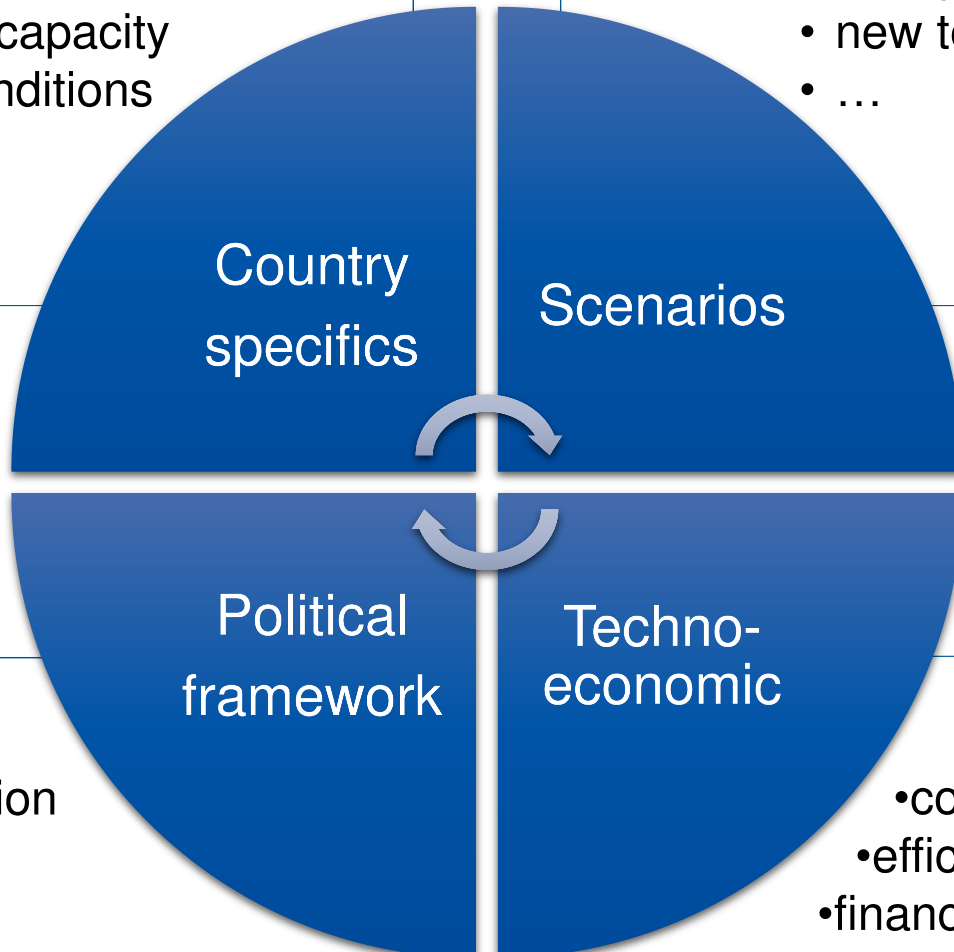
Eskom | Powering your world

# Method of Modeling
# Basic setup

- load profile
- generation capacity
- weather conditions

- load profile
- new technologies
- …

Concipated as green-field approach




Changed to brown-field for SolarPaces

- CO2-emission targets
- RE-share

- cost
- efficiencies
- finance
- CO2-values…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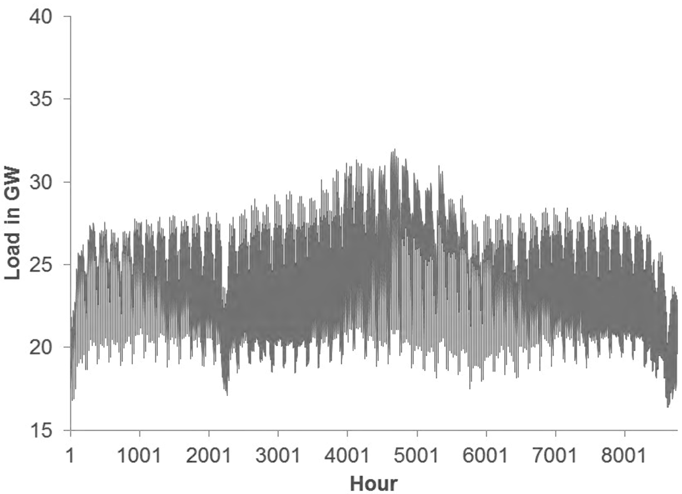
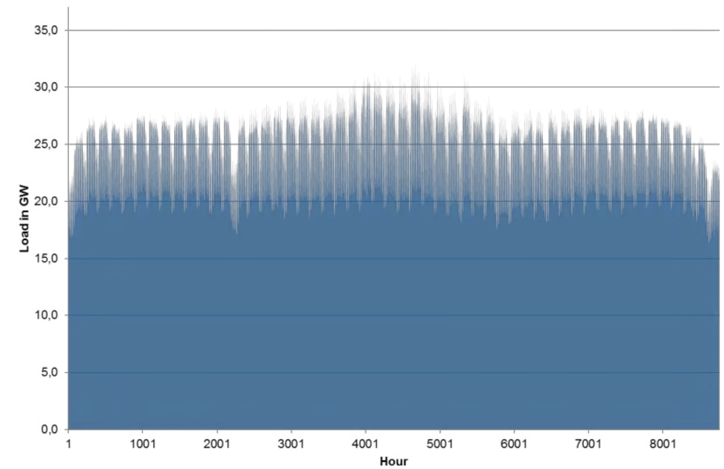
# Method of Modeling
# calculation of the residual load

Load




Residual Load (RL)




Power of existing generation

Production data

Weather data

Which technologies cover the residual load at minimal cost?



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# Method of Modeling
# Categorization of Technologies

- Five categories of technologies:

Cat. 1

Fluctuating Generation

Cat. 2

Constant Generation

Cat. 3

Fluctuating + Storage

Cat. 4

Storages

Cat. 5

Power-to-X

Residual Load

$$P_{res}(t) = P_{load}(t) - P_{\mathrm{cat.1}}(t)$$

Compensate residual load

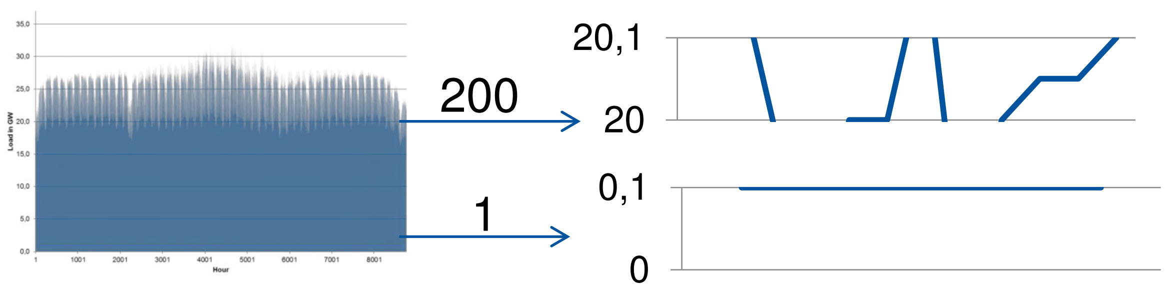
Take up surpluses

# Method of Modeling
# Divide the residual load into bands

**Compute residual load**
- Demand-FRE
- Hourly resolution over one year

**Divide RL into bands**
- 100MW bands were taken here
- Characteristic per band:
  - Full Load Hours
  - Starts & Stops
  - Individual Profile

**Find best technology**
- i.e. lowest LCOE
- For each band




Peak load (<1.000 h/a)

Baseload (>6.000 h/a)

- Key assumptions:
  - ‚Copper Plate‘
  - Only import, no export
  - Perfect competition

**The ESYS model is good for first estimation, bench mark of technologies for flexibility, getting decision maker engaged**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# Sensitivity analysis
# parameters to consider

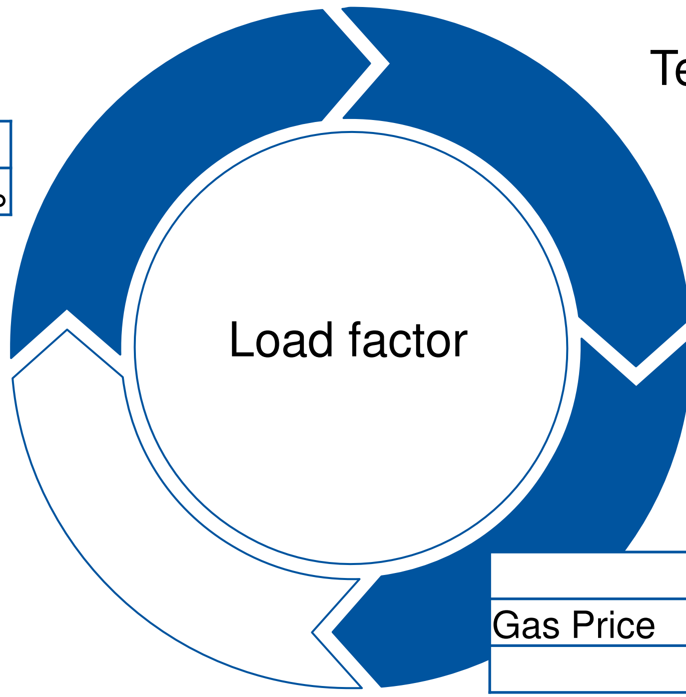
- Important: horizon here was set to be 2030!
- the reference values for the sensitivity are printed bold

Financing

| | | | |
|---|---|---|---|
| Options | 1 | **2** | 3 |
| IRR/WACC | 4% | **6%** | 12% |

Technology cost

| | | |
|---|---|---|
| | Sunshot | **Sunshot** |
| Options | 2025 | **2030** |



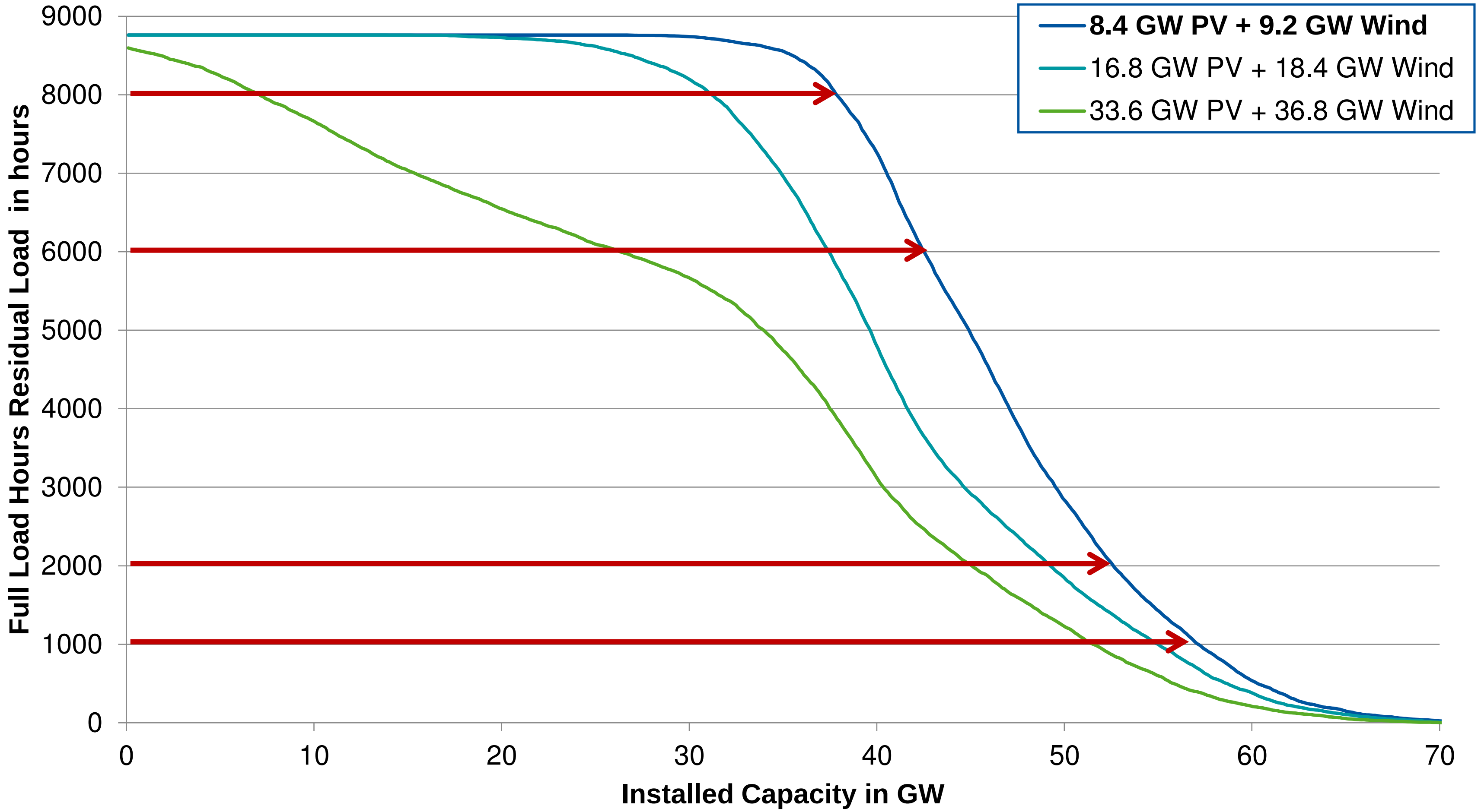

CO2-targets

Fuel prices

| | Low | **Med** | High | |
|---|---|---|---|---|
| Gas Price | 200.000 | 300.000 | 400.000 | $R/GWh_{th}$ |
| | 4 | **6** | 8 | US$/GJ |

Look at influence of the different parameters on the LCOE of a technology

# Residual Load under different scenarios of PV/Wind implementation

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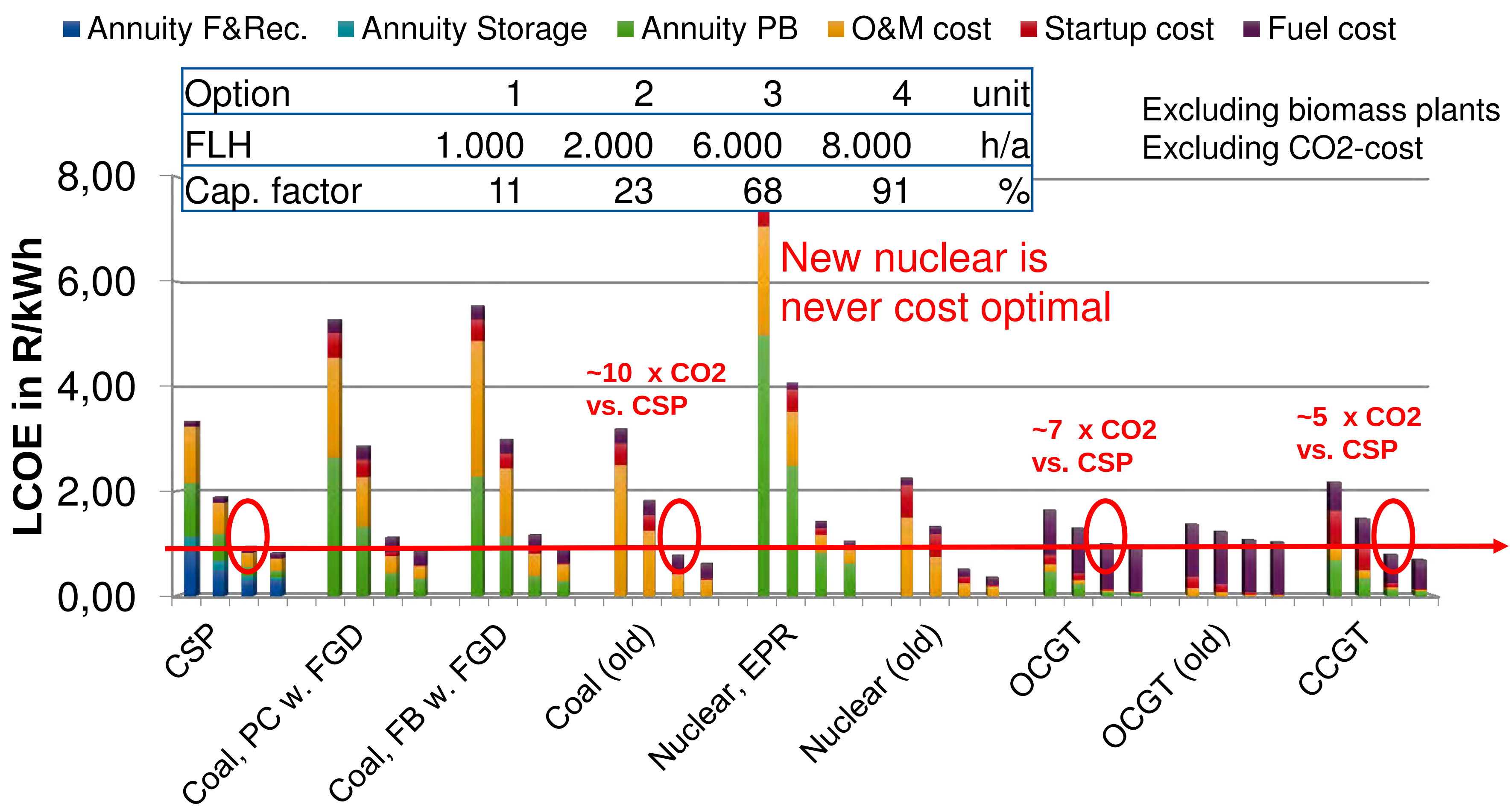
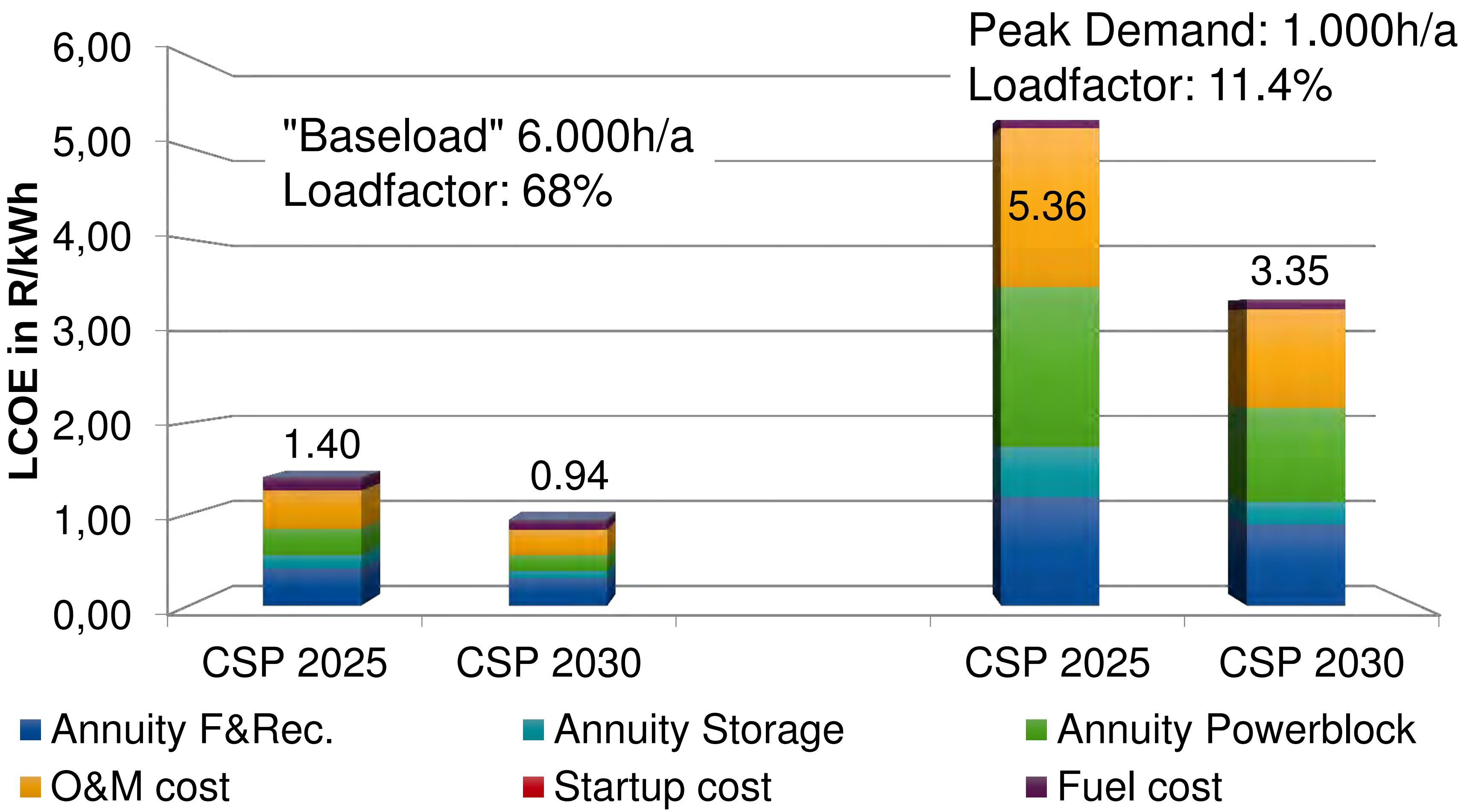
# Sensitivity analysis
# Cost development with load factor




| Option | 1 | 2 | 3 | 4 | unit |
|---|---|---|---|---|---|
| FLH | 1.000 | 2.000 | 6.000 | 8.000 | h/a |
| Cap. factor | 11 | 23 | 68 | 91 | % |

**Systems LCOE need to be compared at the same capacity factors**
**Some technologies are very close in LCOE but at very different levels of $CO_2$ Emissions**

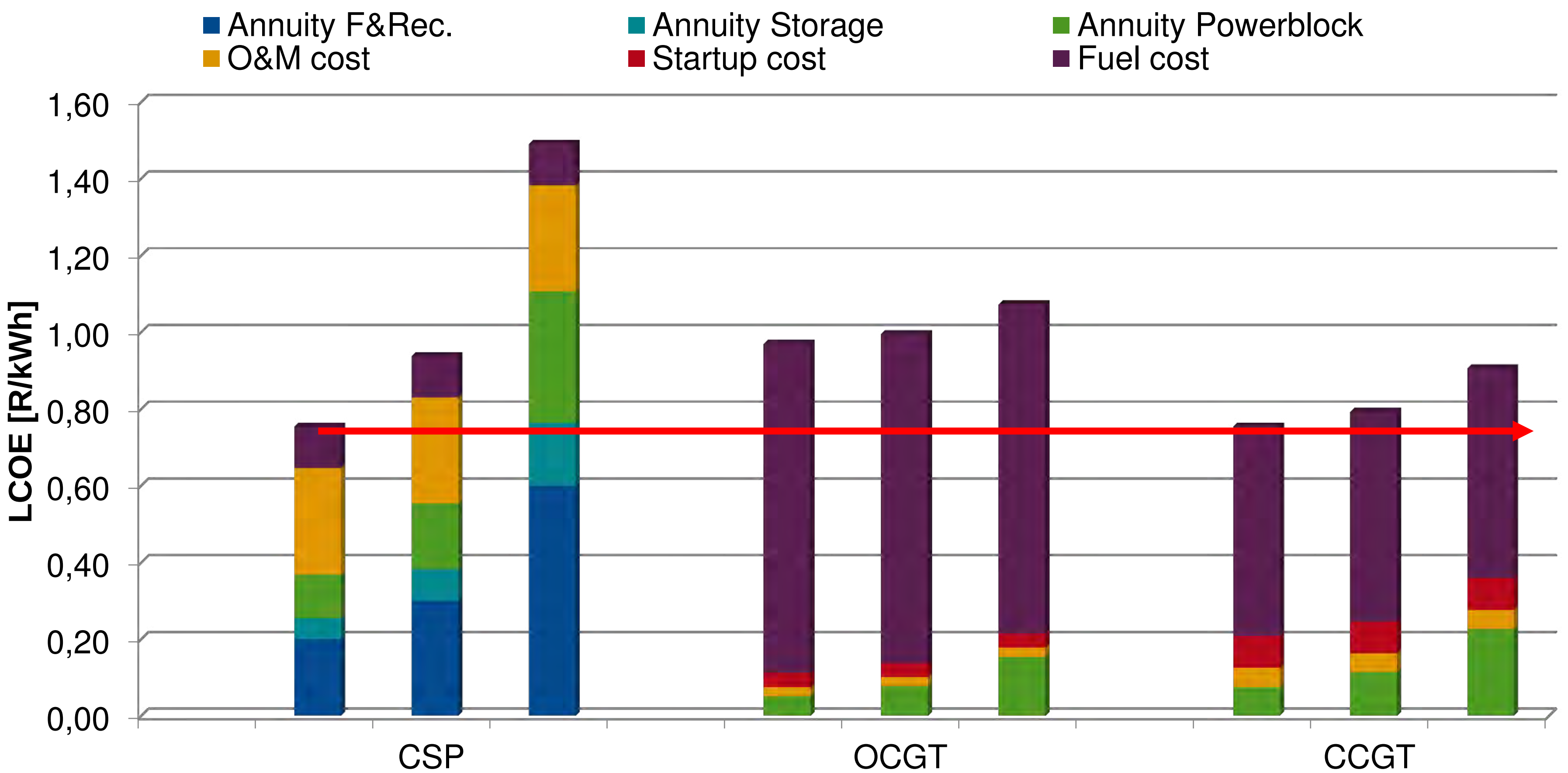
# Sensitivity analysis
# Costs for CSP with sunshot targets for 2025 and 2030




**CSP cost reduction is critical**
**CSP is competing at mid-load of 6000 FLH and not for peak load!**

# Sensitivity analysis
# Financing for newly installed capacity

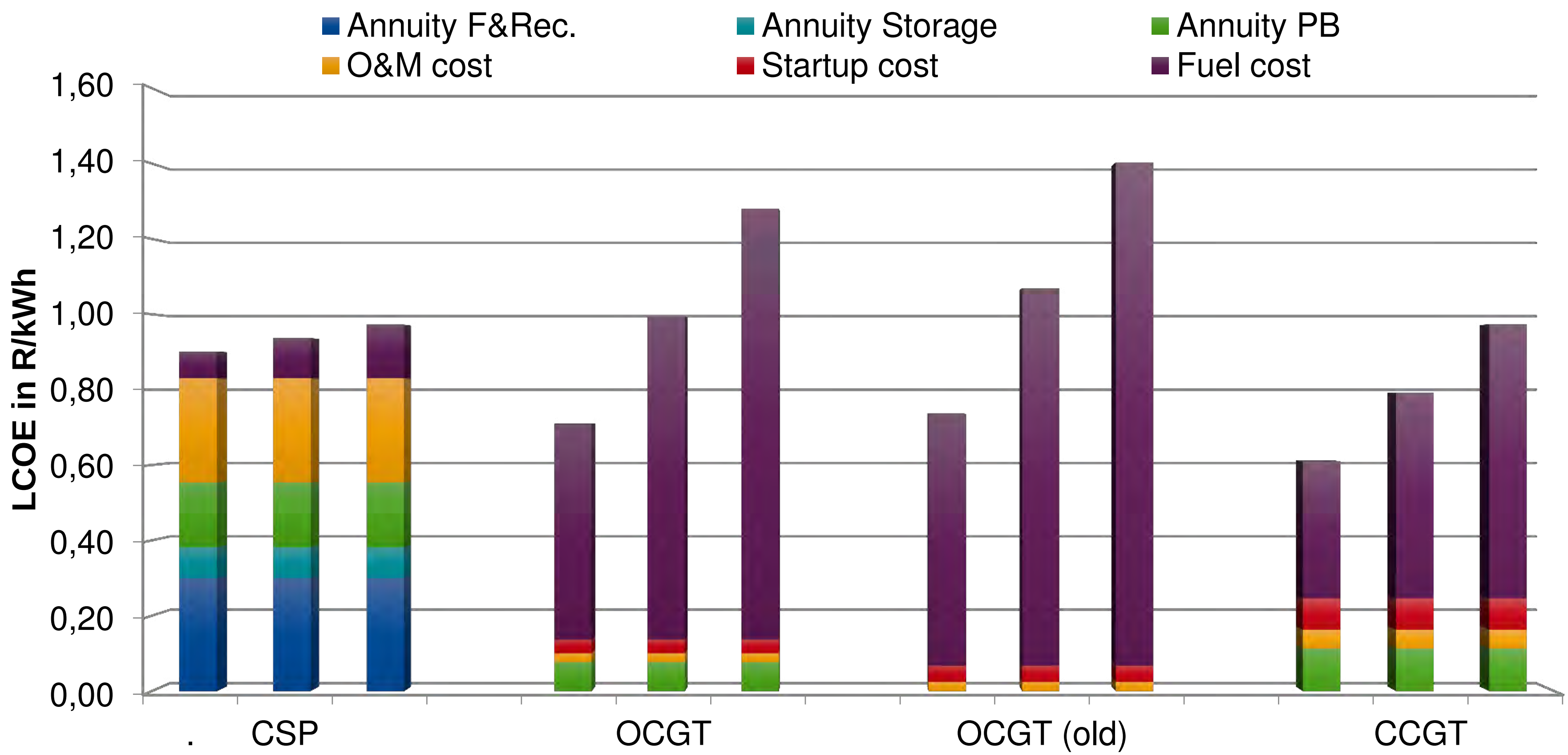
| Options | 1 | 2 | 3 |
|---|---|---|---|
| IRR/WACC | 4% | 6% | 12% |




**Competitiveness of CSP strongly dependent on capital cost**

# Sensitivity analysis
# Dependence on gas price development

| | Low | Med | High | |
|---|---|---|---|---|
| Gas Price | 200.000 | 300.000 | 400.000 | R/$GWh_{th}$ |
| | 4 | 6 | 8 | US$/GJ |




**CSP can hedge against gas price and infrastructure uncertainties**

# Conclusions


- Even high CO2 reduction can be reached with minor impact on total system LCOE in South Africa
- Given future cost reduction, CSP is part of the mix that reduces CO2 emission at system cost lower than today's values

- CSP is best suited to provide mid-load power with around 6.000 FLH replacing old coal power plants
- High Wind and PV penetration is not reducing system cost as it results in higher necessary capacity of coal power plants with fewer operation hours
- CSP can compete with old coal power plants and new combined cycle gas power plants if expected further cost reductions are achieved

- Low financing cost and gas prices (even at values of 400kR/GWh) provide favorable economics for CSP
- CSP can hedge against uncertainties in gas price and infrastructure cost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# Thank you
# for your attention

## Contact

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## We thank

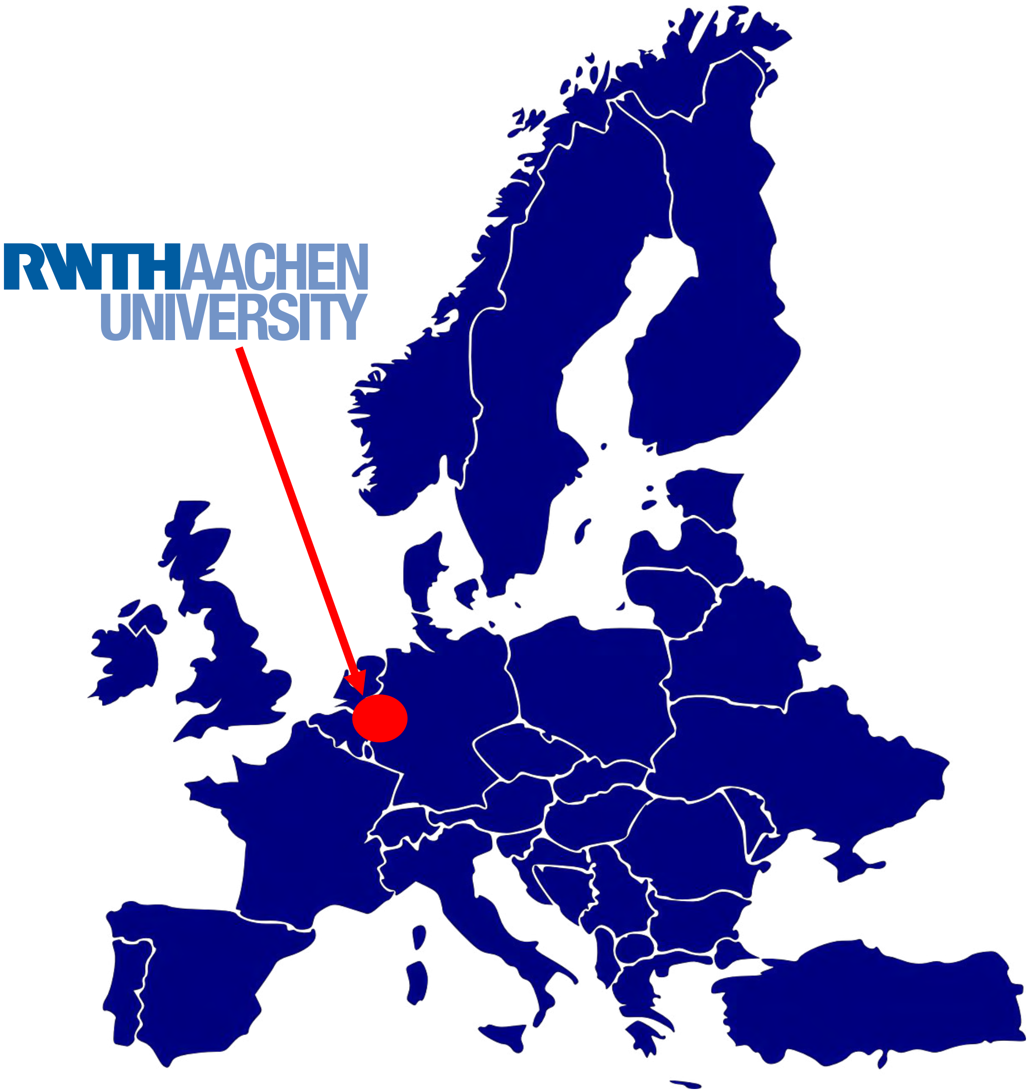
### Eskom for

Demand curve of the country for the year 2010
Demand curve of the country for the year 2014 & 2015
Aggregated Wind & PV contribution for year 2014 & 2015
TMY data for Upington site (for CSP performance)
Costing structure for 100 MW CSP plant

### For scientific advice and research

Oelof de Meyer
Mark Mehos
Prof. Dr. Pitz-Paal

# RWTH Aachen University in the center of Europe




~ 40,500 Students

> 4,500 Academics (without professors)

# Institute for Power Electronics and Electrical Drives (ISEA)


Prof. Sauer
ESS

Prof. De Doncker

Energy

Mobility



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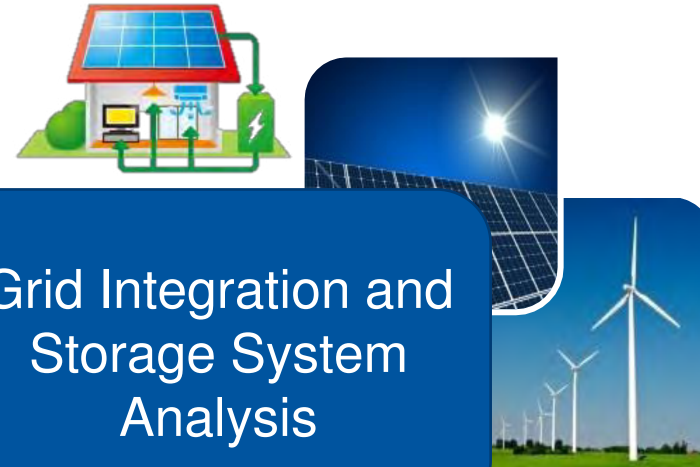
# ISEA
# ESS – Departments‘ research

Storage System Technology and Vehicle Integration



Grid Integration and Storage System Analysis

Modelling, Analytics and Lifetime Prediction