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# **PV energy – A key energy source for a power system with a high share of RES**

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# Content of the presentation

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## 1. What is the impact (and value) of PV energy on the power system?

- *Correlation of the PV Energy with the Load*
- *Seasonal Complementarity of Wind and Solar Energy*

## 2. Is a high penetration of RES in the power system possible?

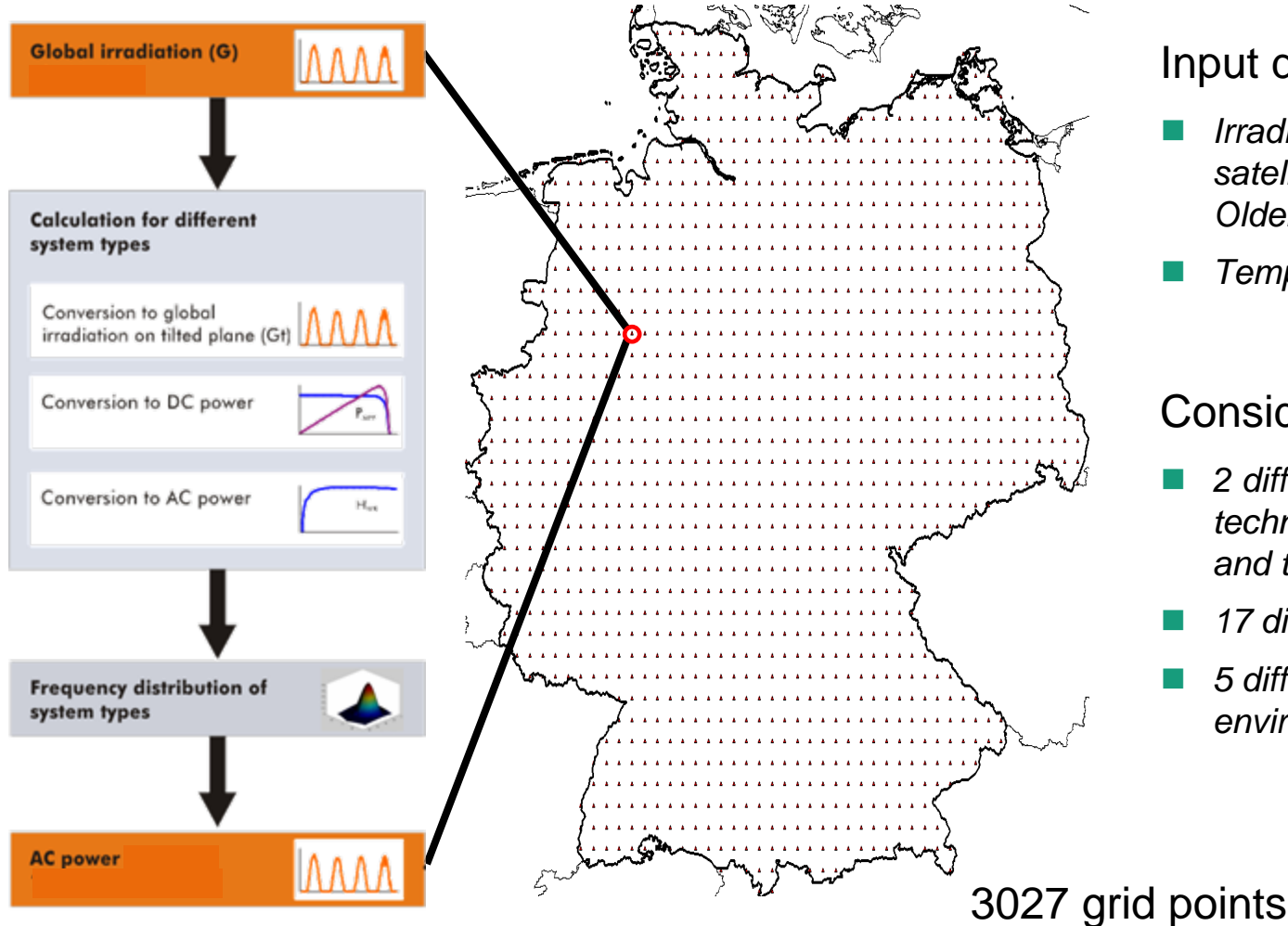
- *Demonstration of the feasibility of a 100% RES power system (the Kombikraftwerk project)*

## 3. The way to a power system with a high RES penetration

- *Dynamical simulation of RES generation based on the BEE Scenario for Germany (RES penetration of 47%)*
- *Assessment of the impact of RES generation on the power system*

# Impact of PV energy on the power system

## Modelling of the PV power for Germany:



### Input data:

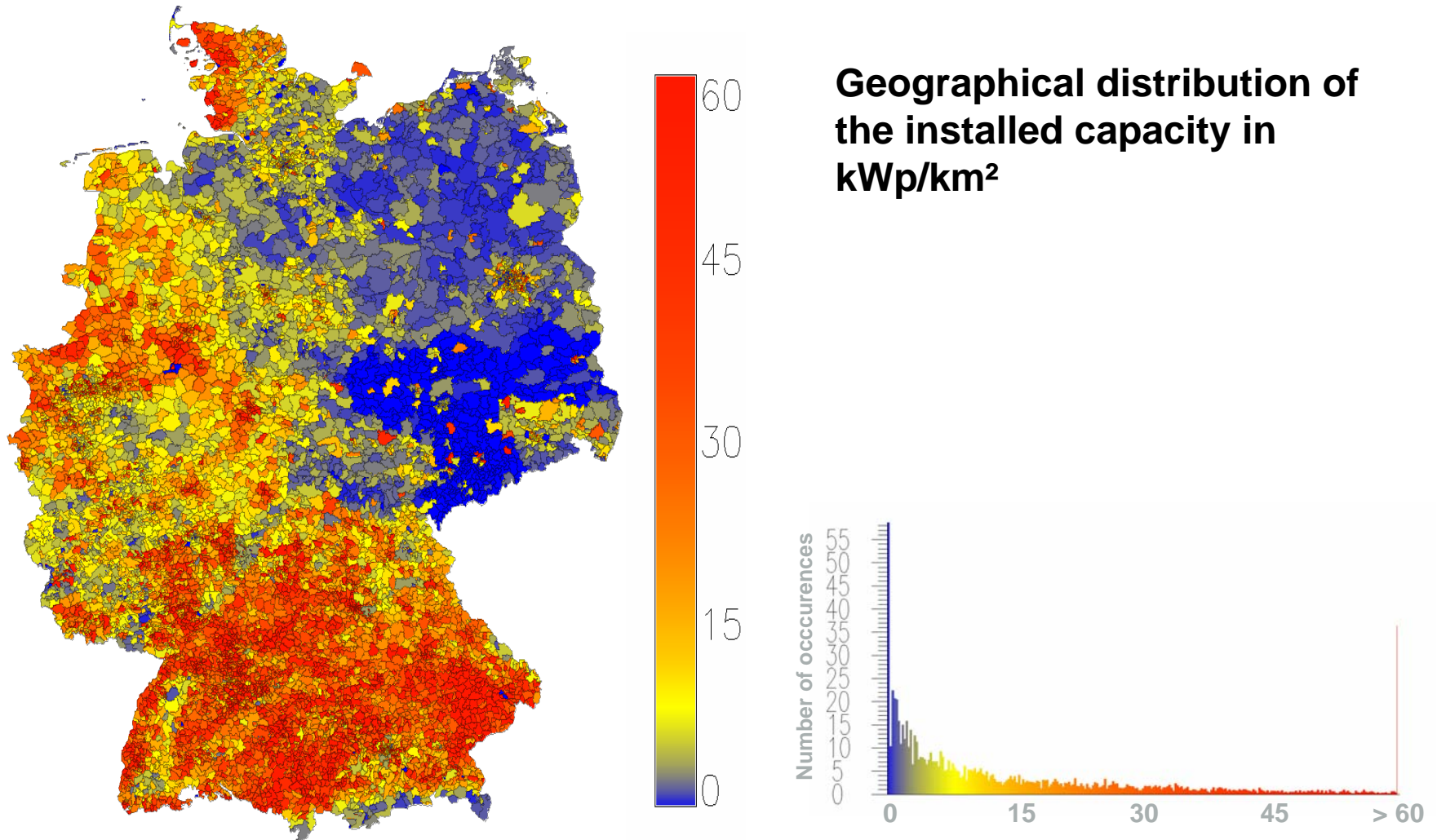
- Irradiation derived from satellite picture (SODA, Uni Oldenburg)
- Temperature from DWD

### Consideration of:

- 2 different module technologies (crystalline and thin-film)
- 17 different orientations
- 5 different installation environments

3027 grid points

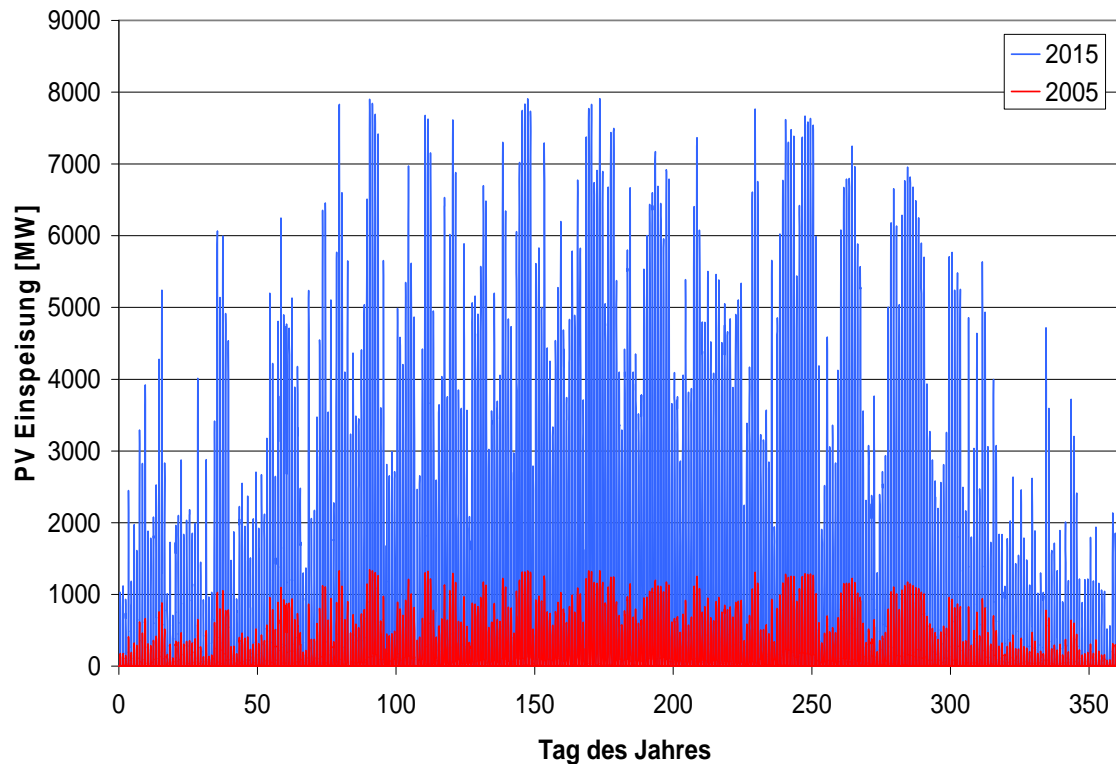
# Impact of PV energy on the power system



(Source: EEG-Stammdaten, 30/07/2009)

# Impact of PV energy on the power system

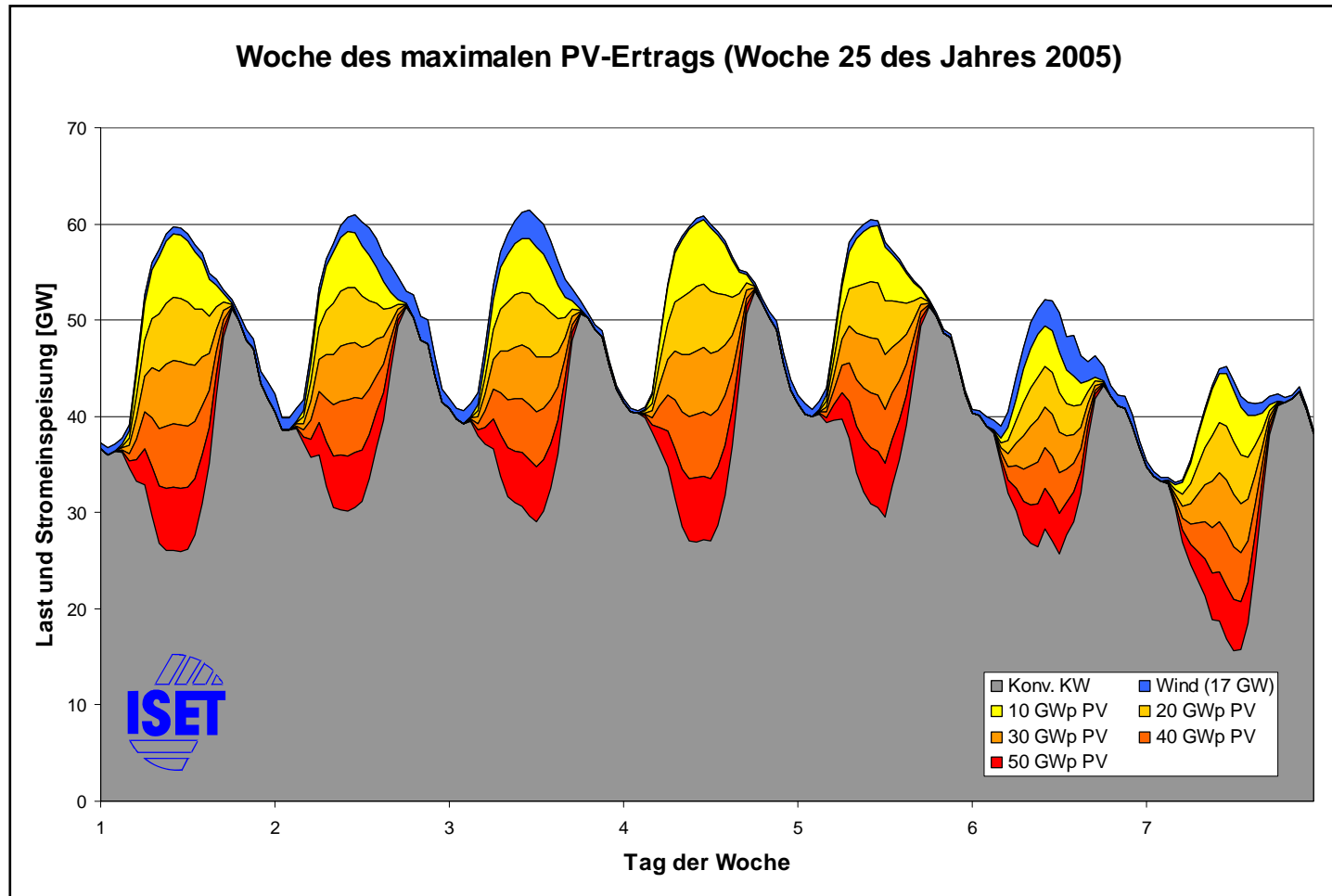
## Simulated PV Power time series for Germany (15 minute time resolution)



Cumulated PV power time series calculated for 2005 (2 GWp)  
and 2015 (12 GWp)

(Source: „Welche Wertigkeit hat PV Strom?“)

# Impact of PV energy on the power system

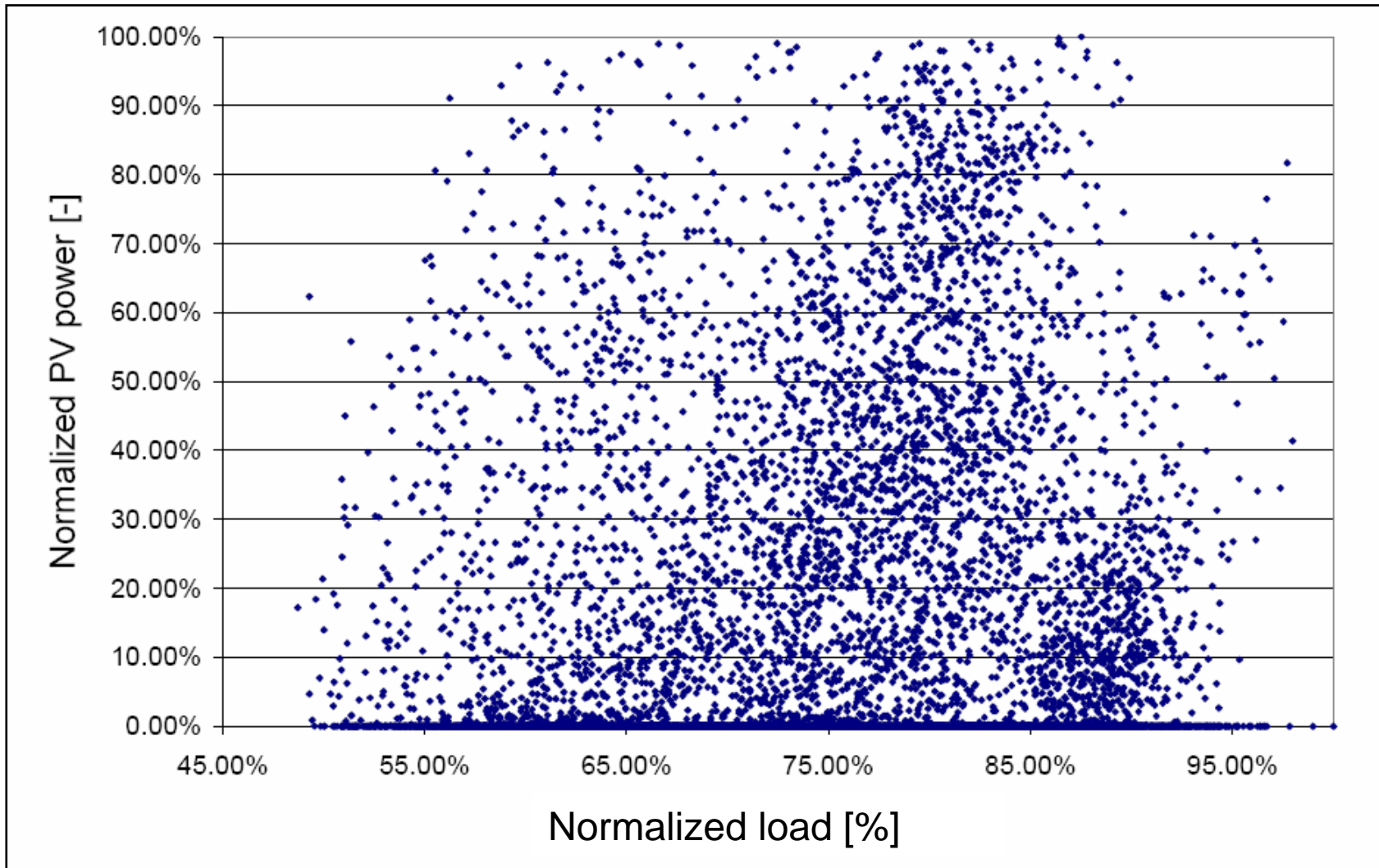


# Impact of PV energy on the power system

- A clear correlation between the load and the PV power can be observed during summer weeks
- A reduction of medium and peak load power occurs during these times

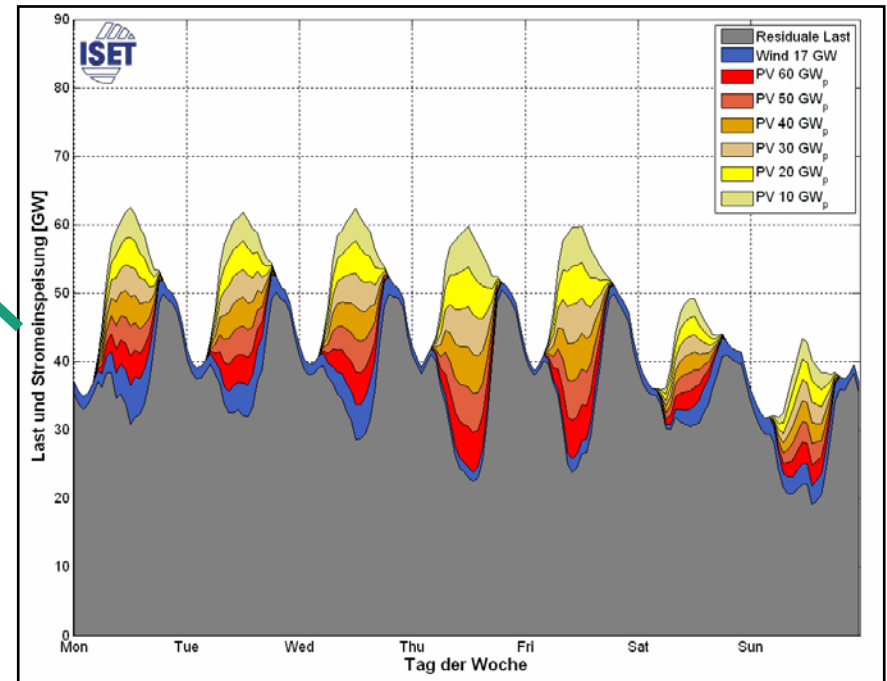
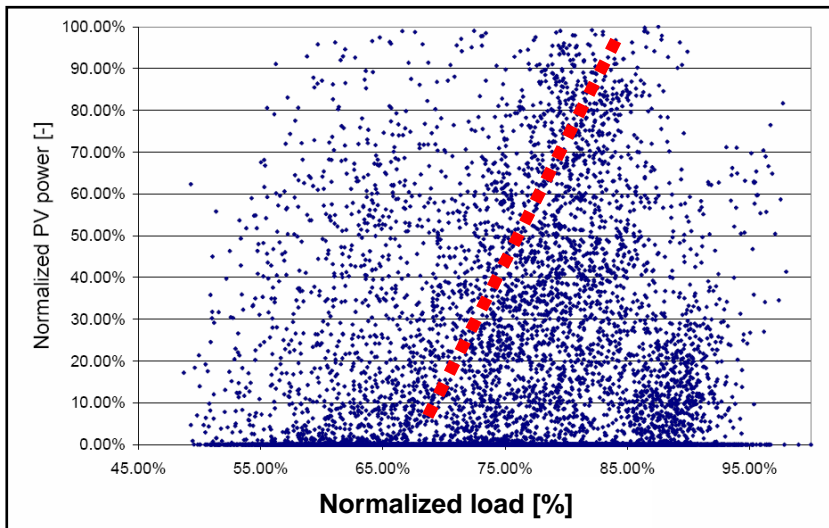
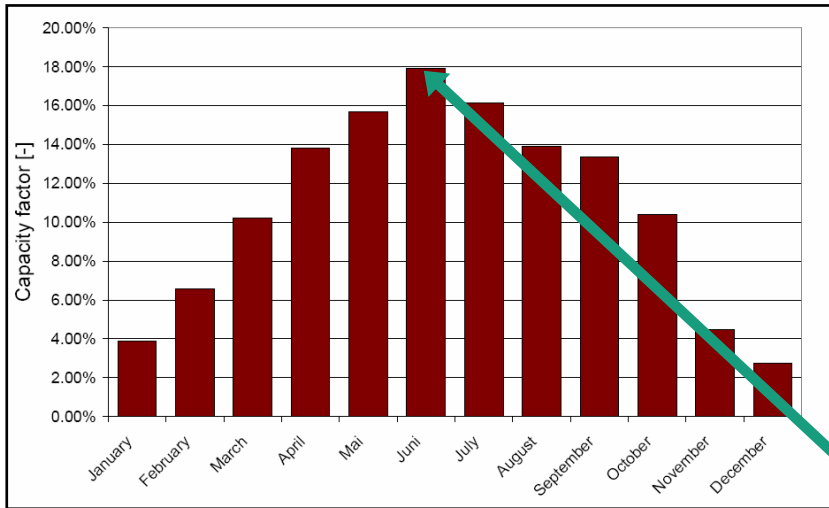
→ How does this correlation look like over the year?

# Impact of PV energy on the power system



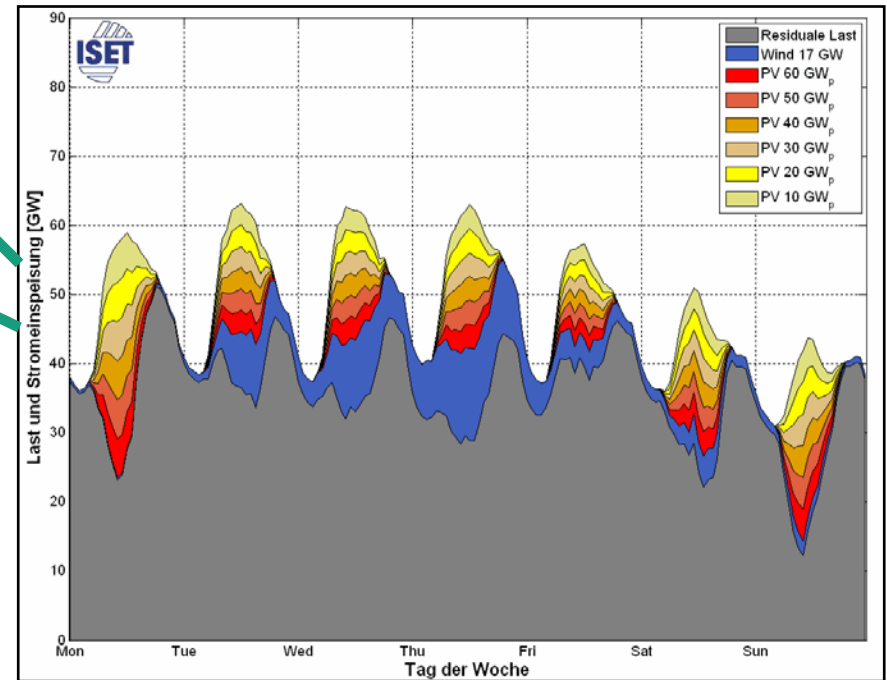
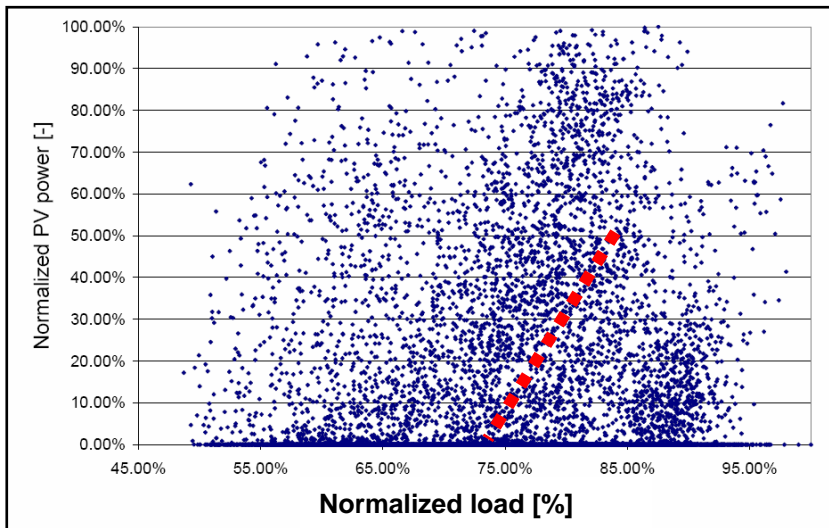
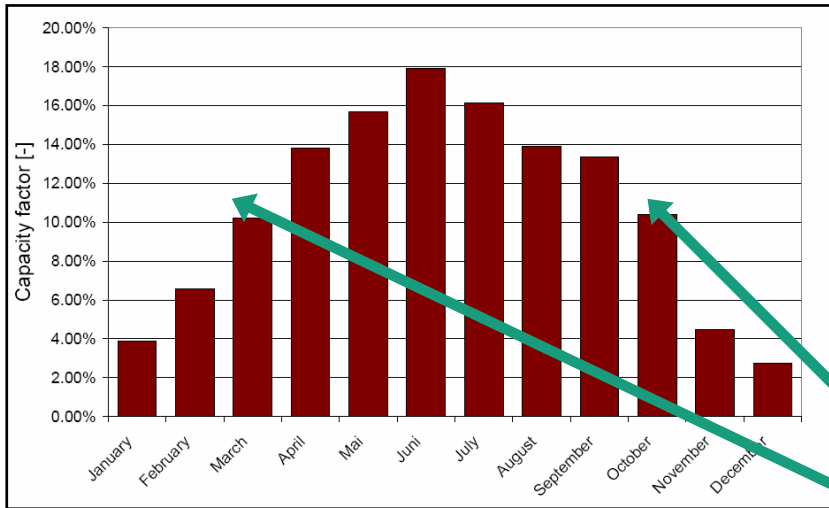


# Impact of PV energy on the power system



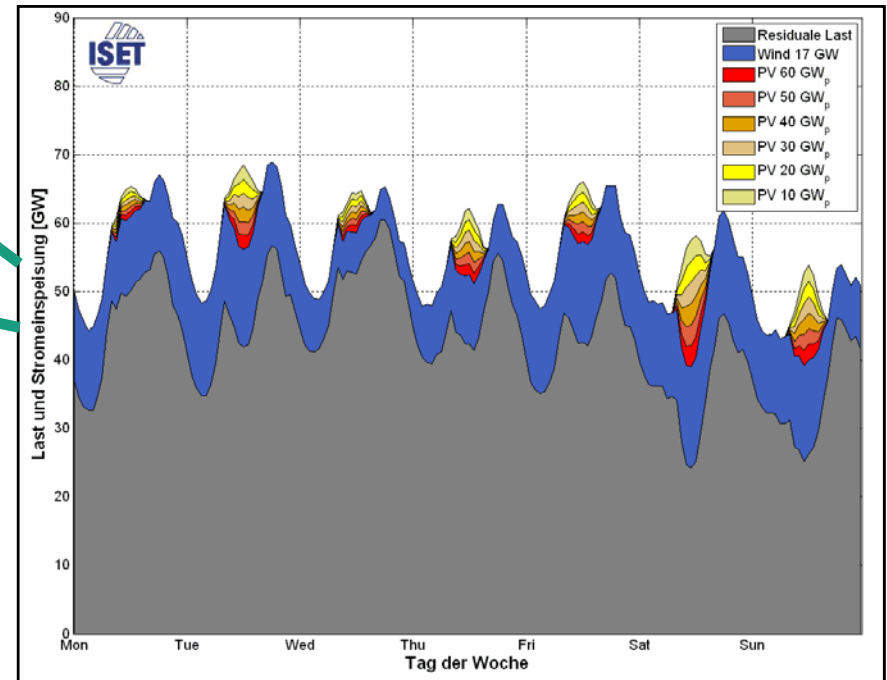
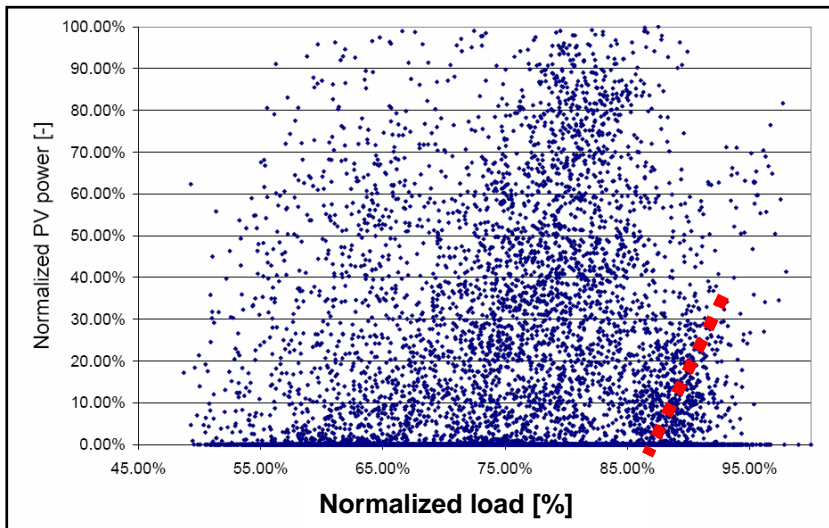
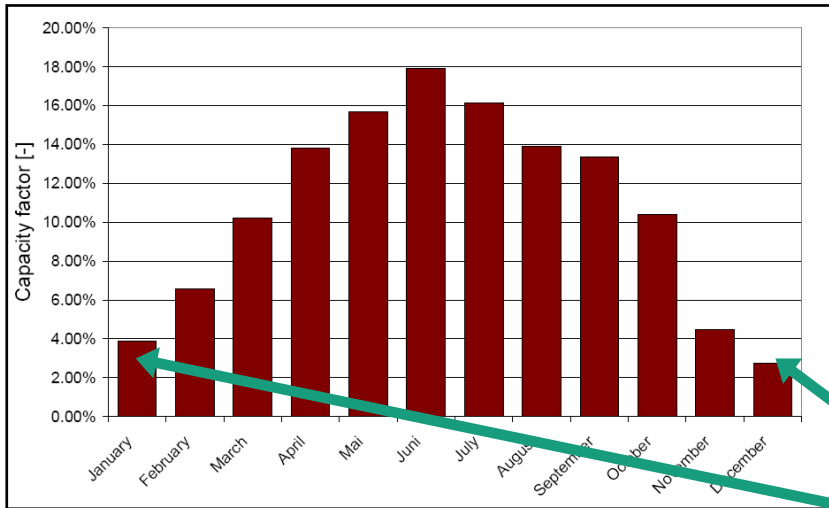
*Exemplary week*

# Impact of PV energy on the power system



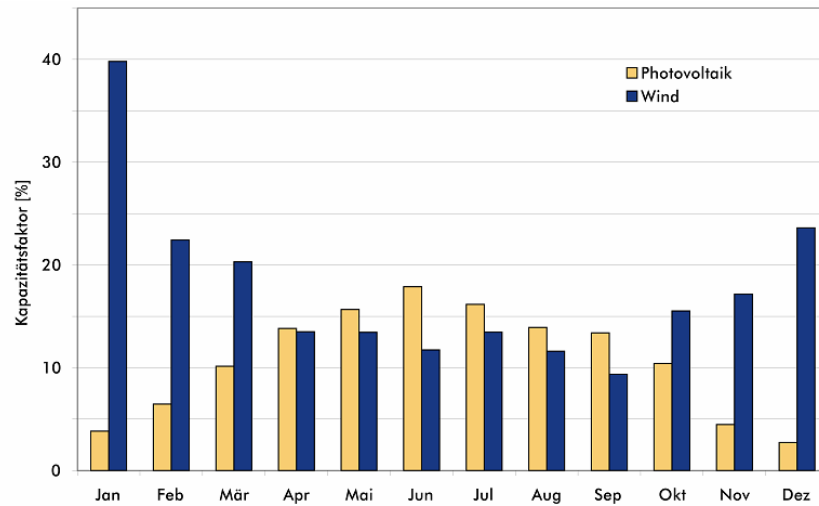
*Exemplary week*

# Impact of PV energy on the power system

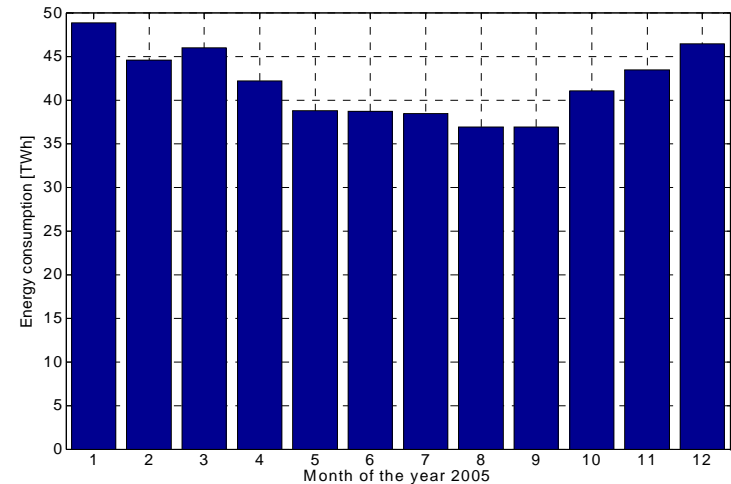


*Exemplary week*

# Impact of PV energy on the power system



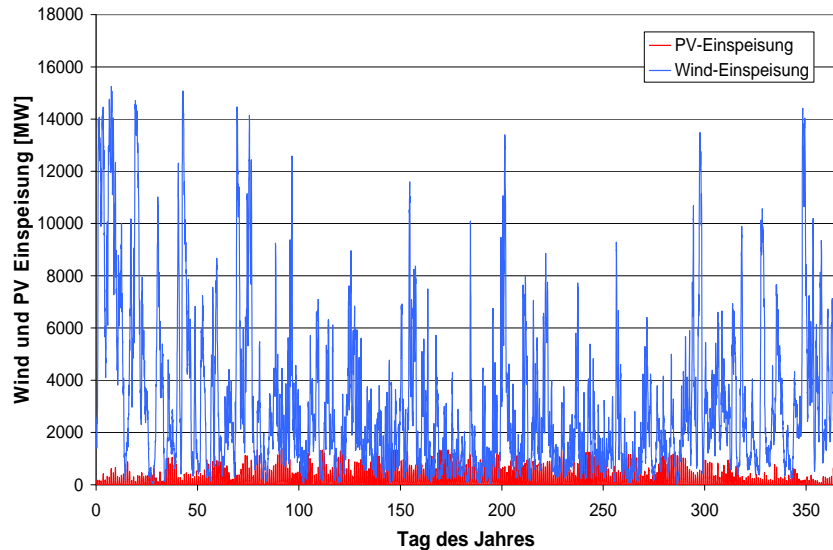
*Monthly capacity factor for wind and PV in 2005*



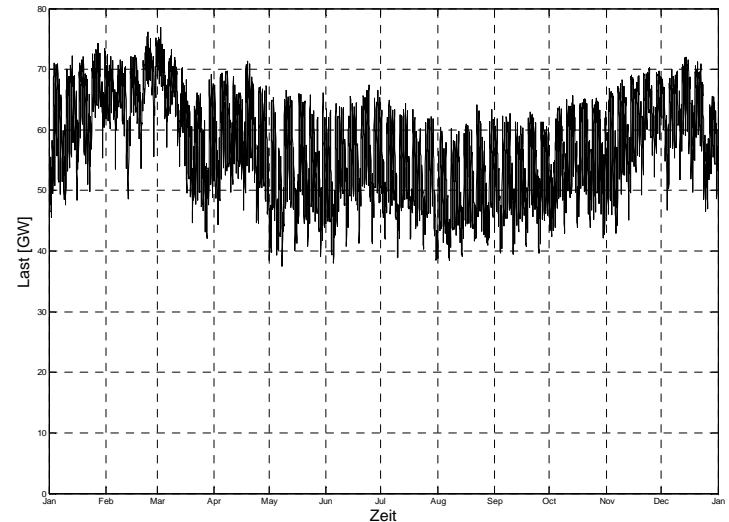
*Monthly energy consumption in 2005*

→ On a monthly basis, the combination of wind and PV power offers a source of renewable energy available all over the year.

# Impact of PV energy on the power system



*Hourly wind and PV power time series in 2005*



*Hourly energy consumption in 2005*

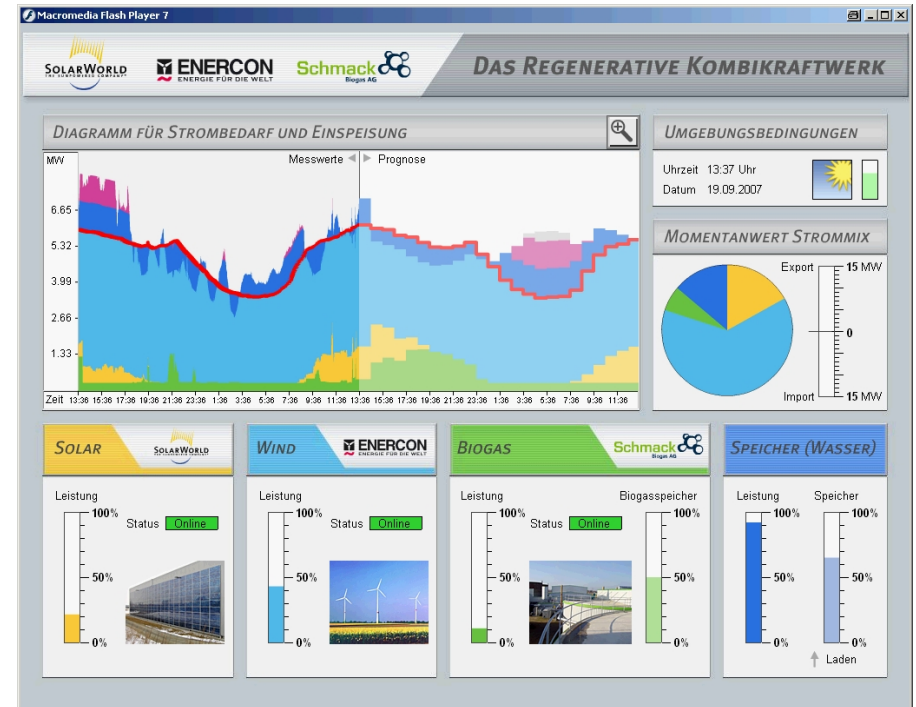
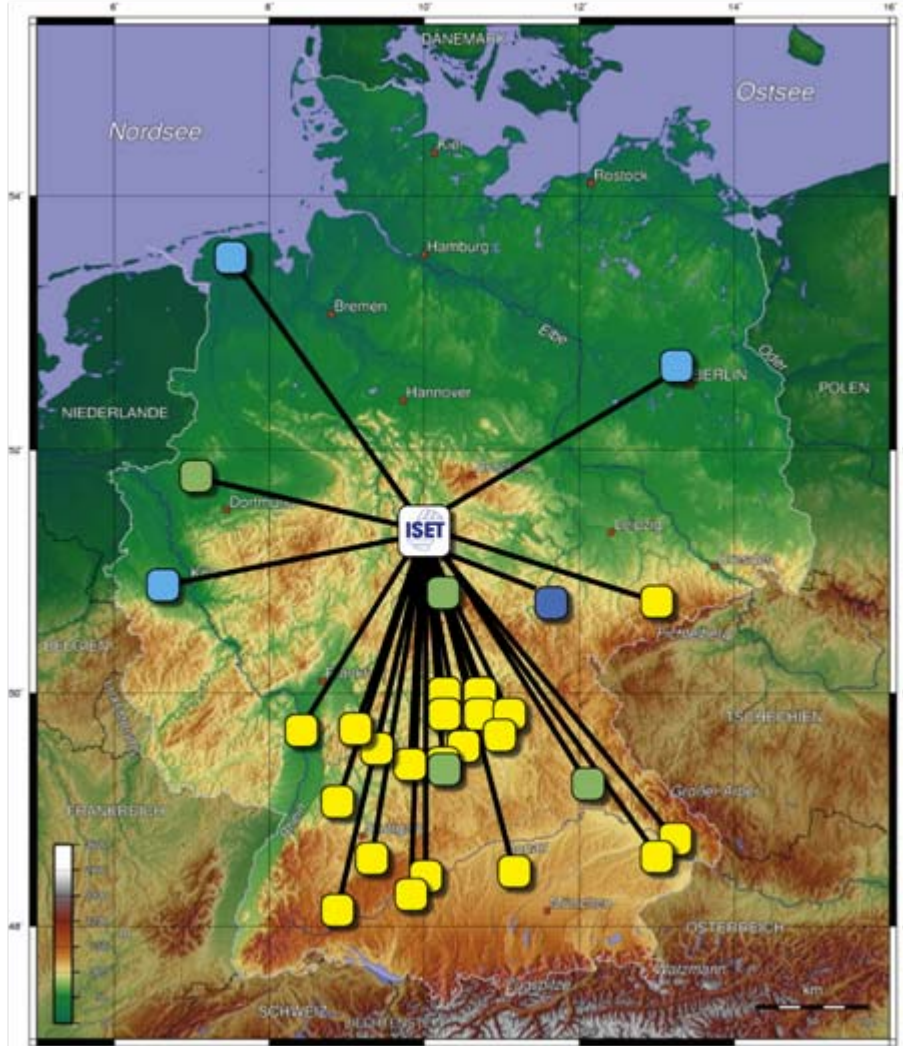
→ On a smaller time scale, the use of storage systems and flexible units is necessary to match the RES energy supply with the demand (e.g. PSW, flexible biogas plant)

**Is a 100% RES energy supply technically possible?**



# Is a high Penetration of RES in the power system possible?

## Das Regenerative Kombikraftwerk



- German load curve scaled down by 1:10000
- full supply by wind, PV, biogas and pump storage

# Is a a high Penetration of RES in the power system possible?

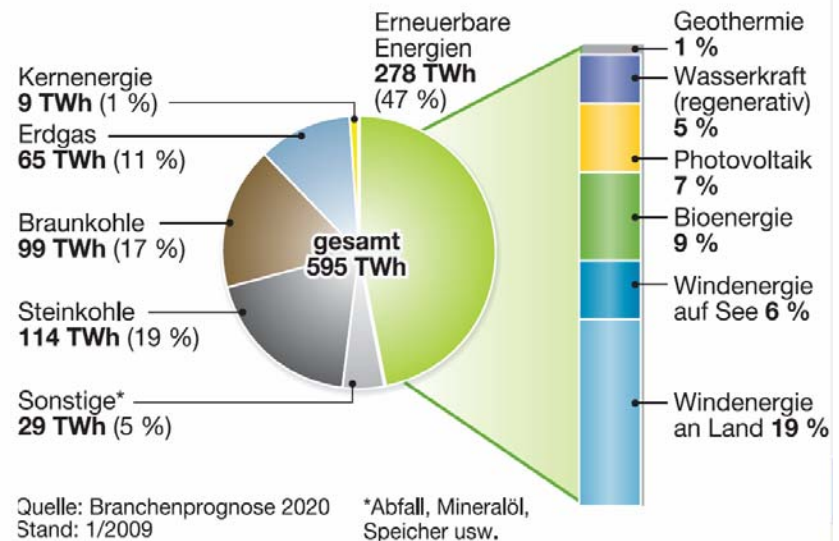
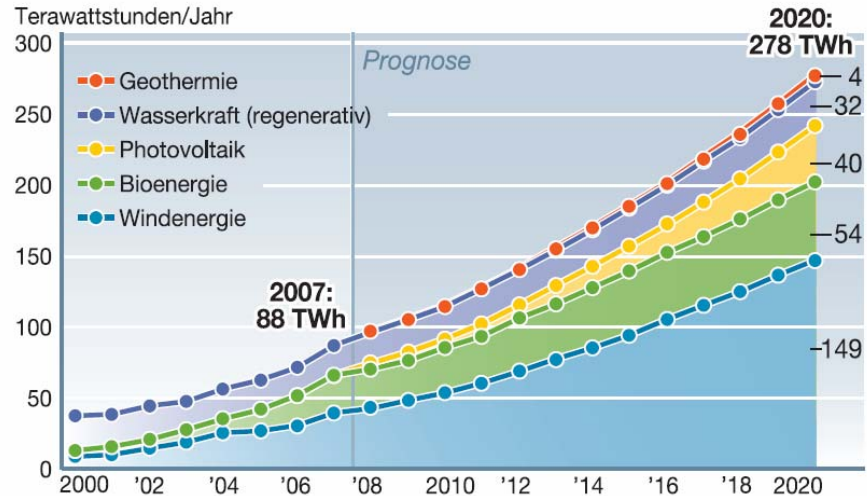
## Das Regenerative Kombikraftwerk

Considering the time availability of the fluctuating RES, a power system with a high share of RES is feasible.

→ The transformation of the current power system to a high-RES supply needs anticipation for adaptating the current structure.

→ Need for roadmaps and scenarios

# The way to a high share of RES - Case study: BEE Scenario

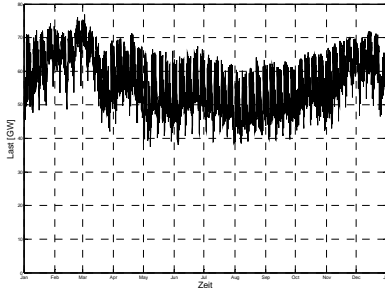




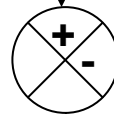
# The way to a high share of RES - Case study: BEE Scenario

No consideration of:

- Issues related to the security of supply
- Grid related issues
- Economical issues

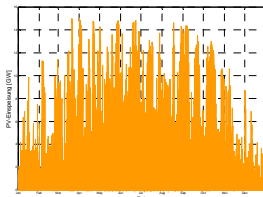
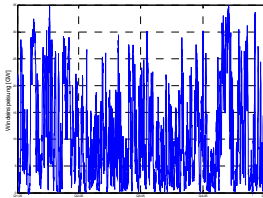


**Energy  
consumption  
time series**

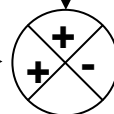


**Must-run RES**

**Wind  
PV  
Hydro  
Biomass**

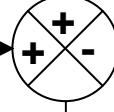


**Export**



**Import**

**PSW pump**



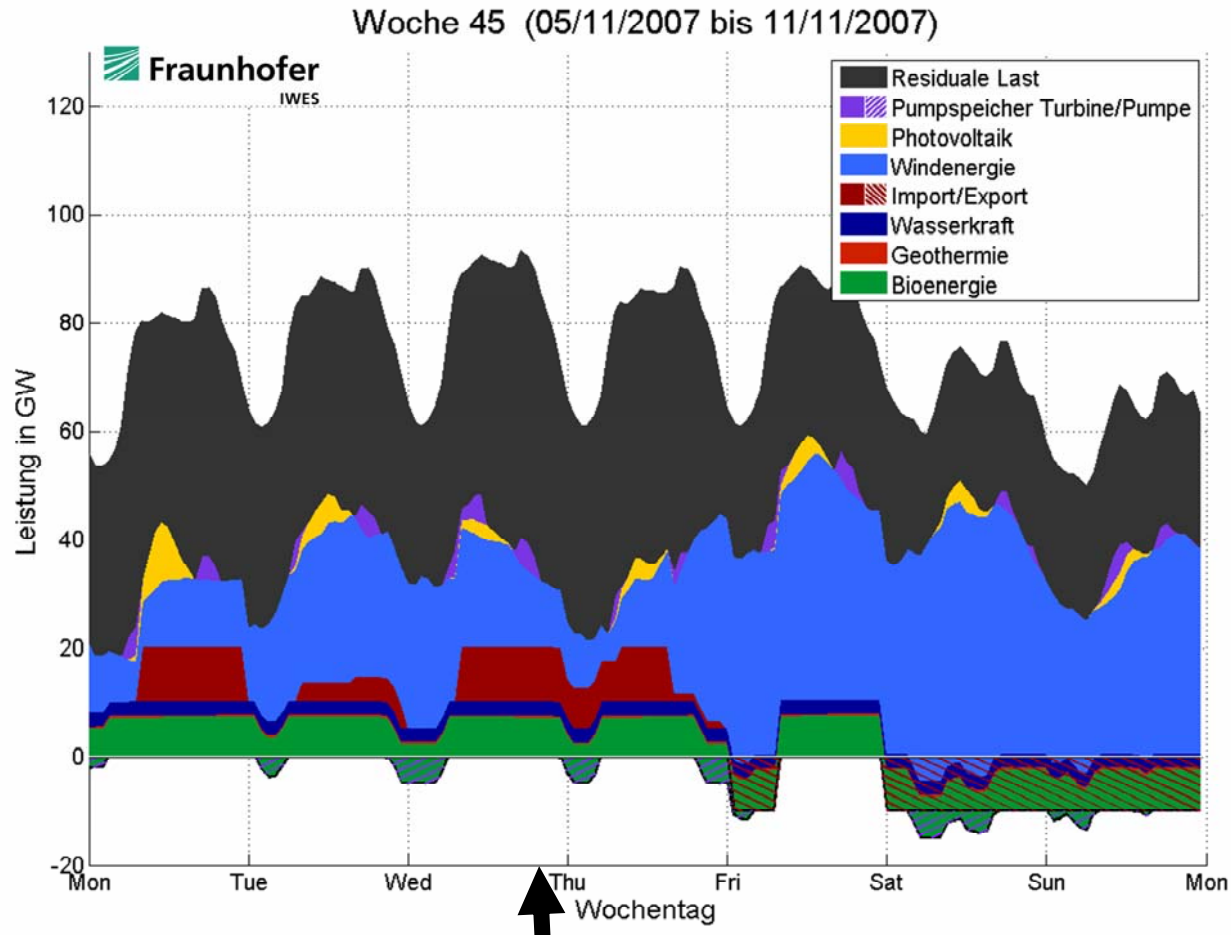
**PSW turbine**

**Driven to bring the residual load as close as possible to a base load.**

**Residual load**

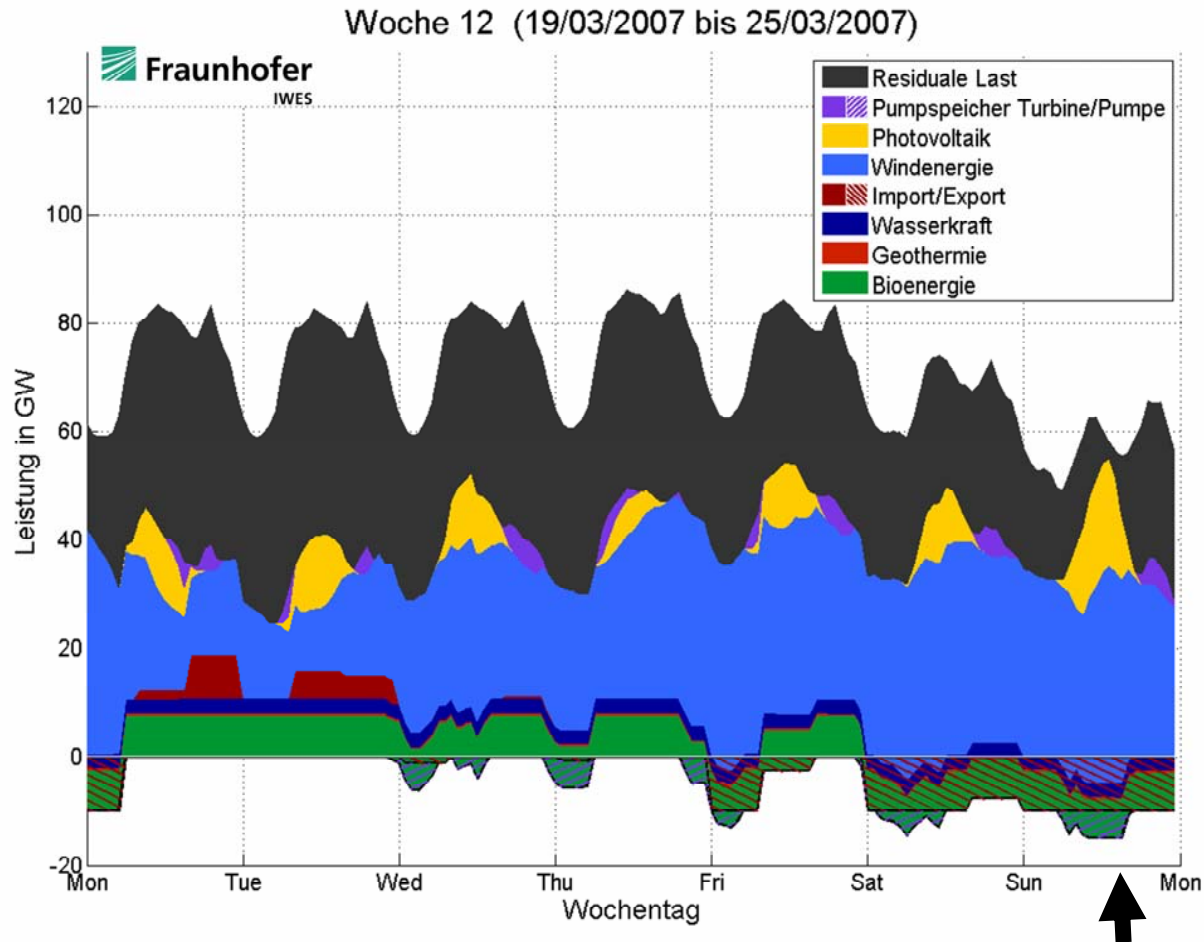


# The way to a high share of RES - Case study: BEE Scenario



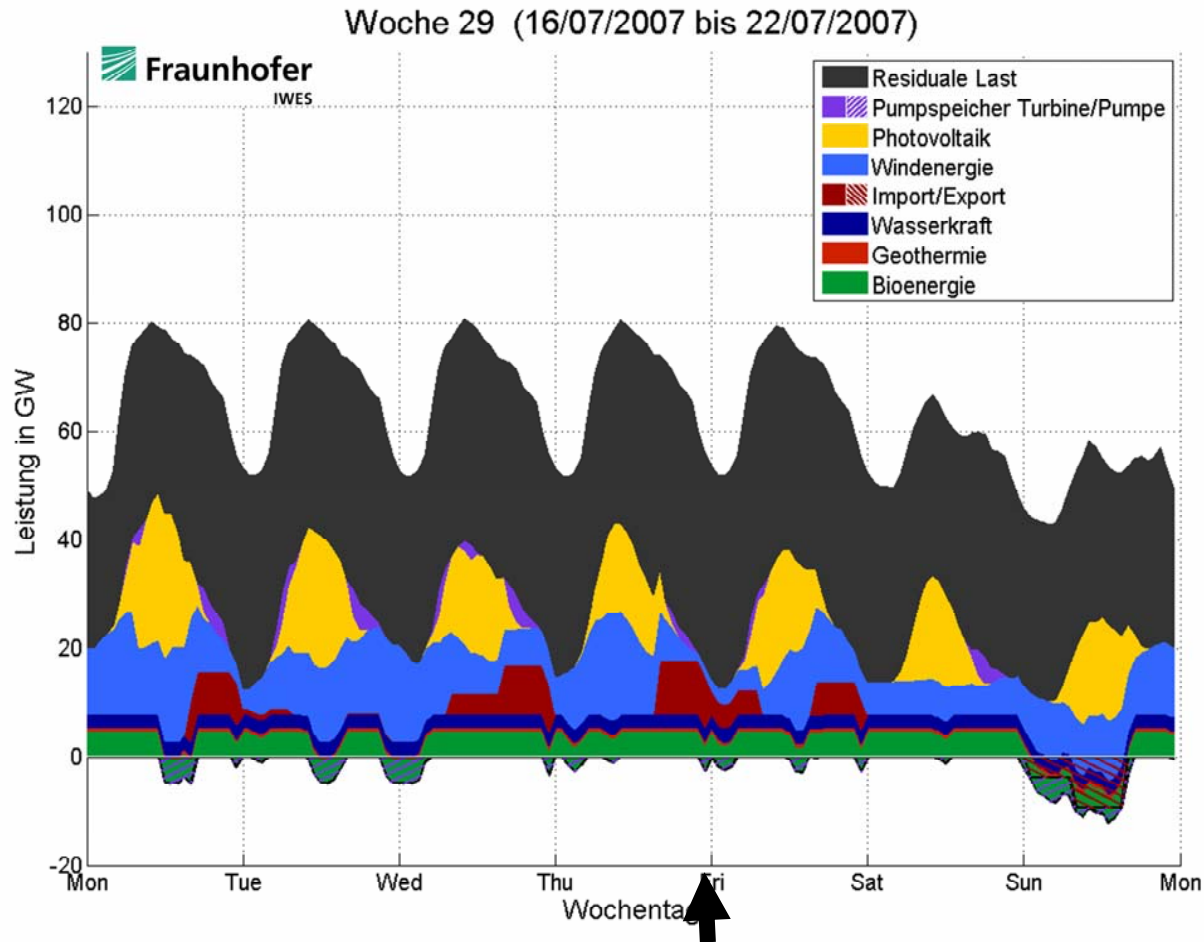
*Week of the maximal load*

# The way to a high share of RES - Case study: BEE Scenario



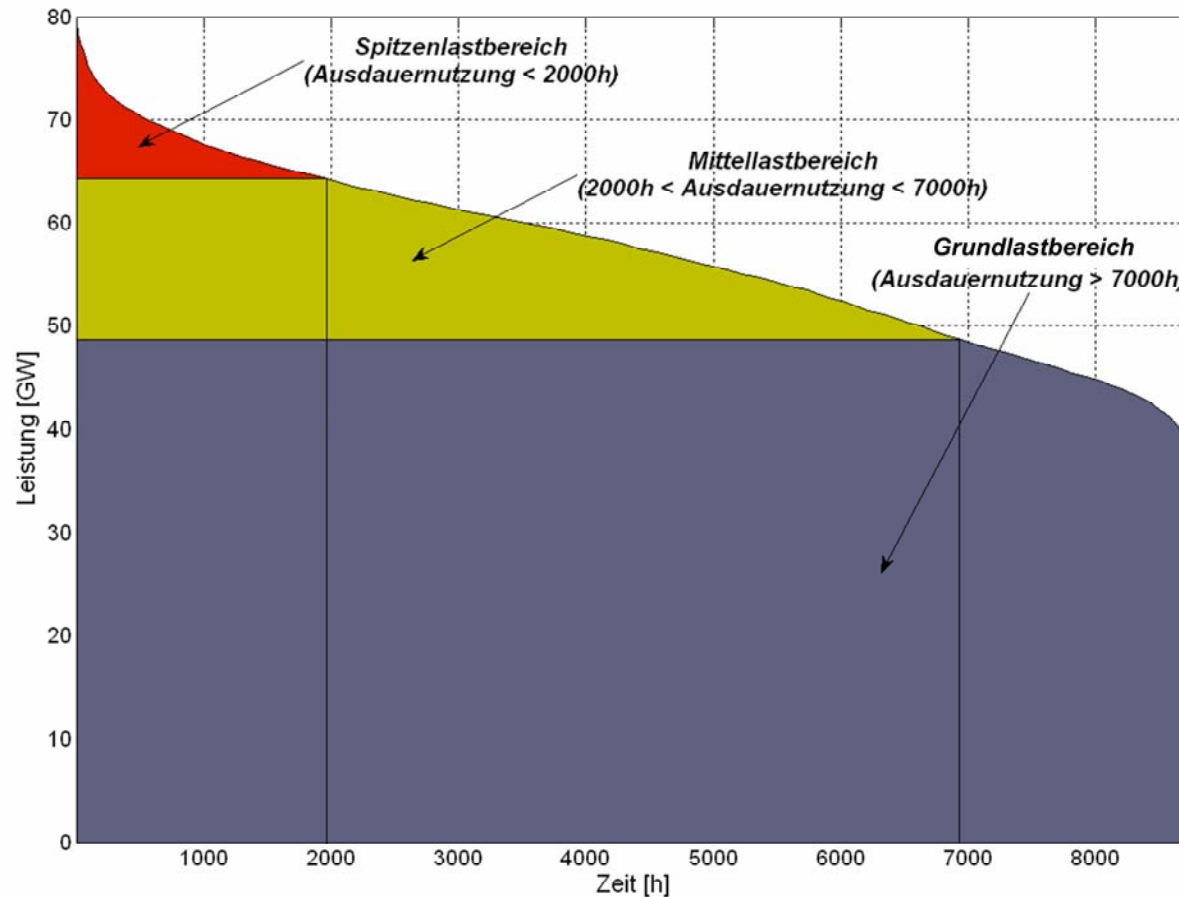
*Week of the maximal RES generation*

# The way to a high share of RES - Case study: BEE Scenario

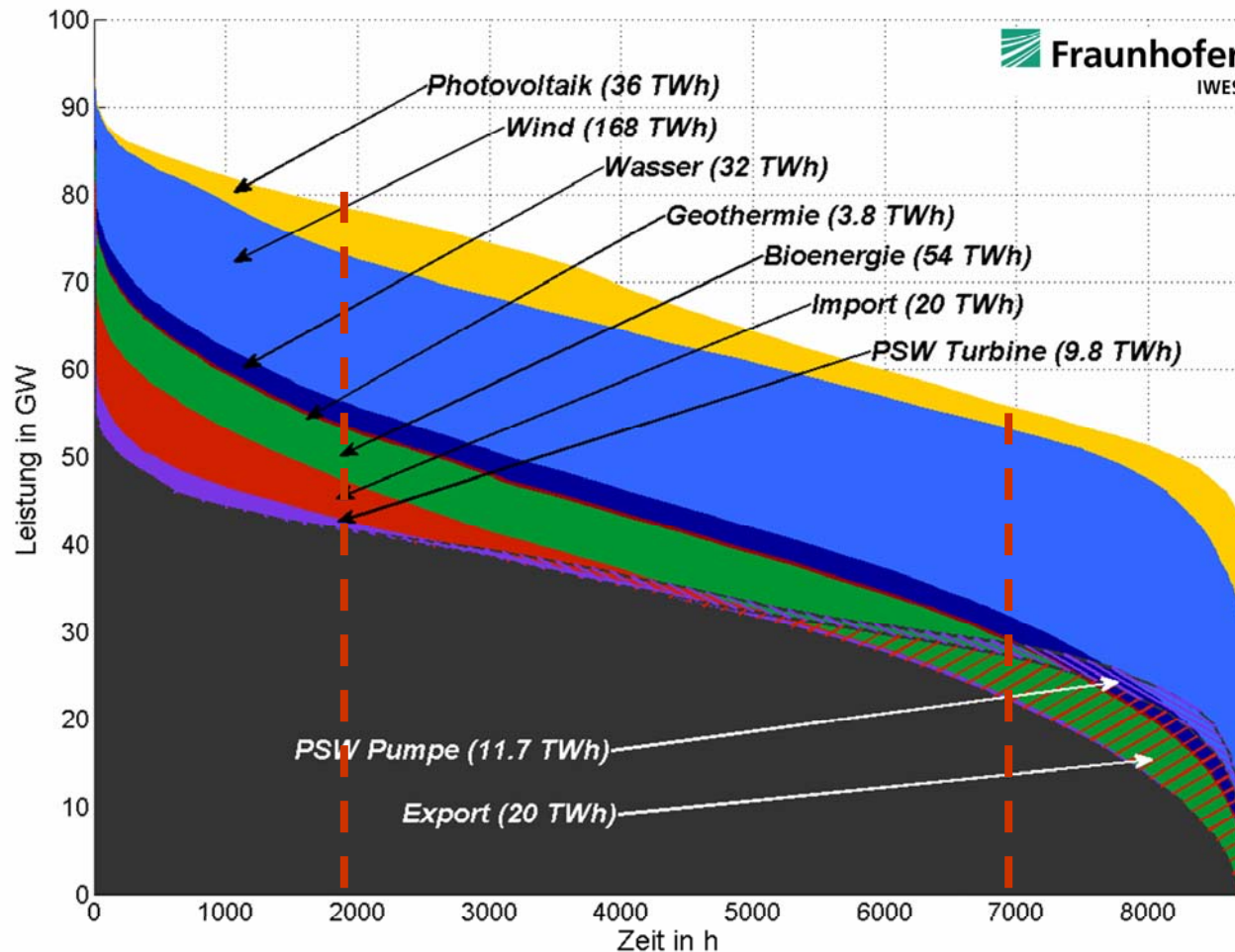


*Week of the minimal RES generation*

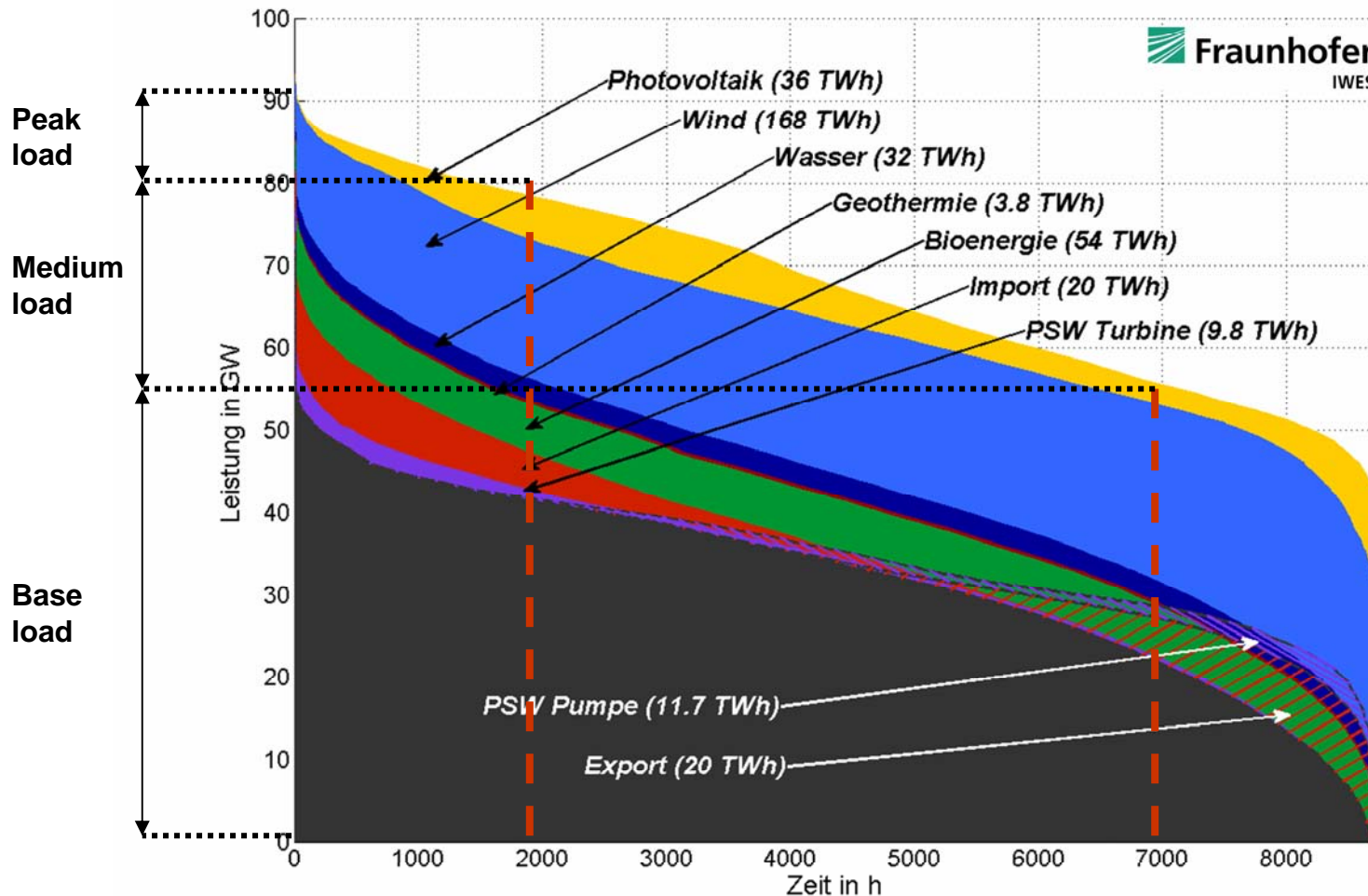
# The way to a high share of RES - Case study: BEE Scenario



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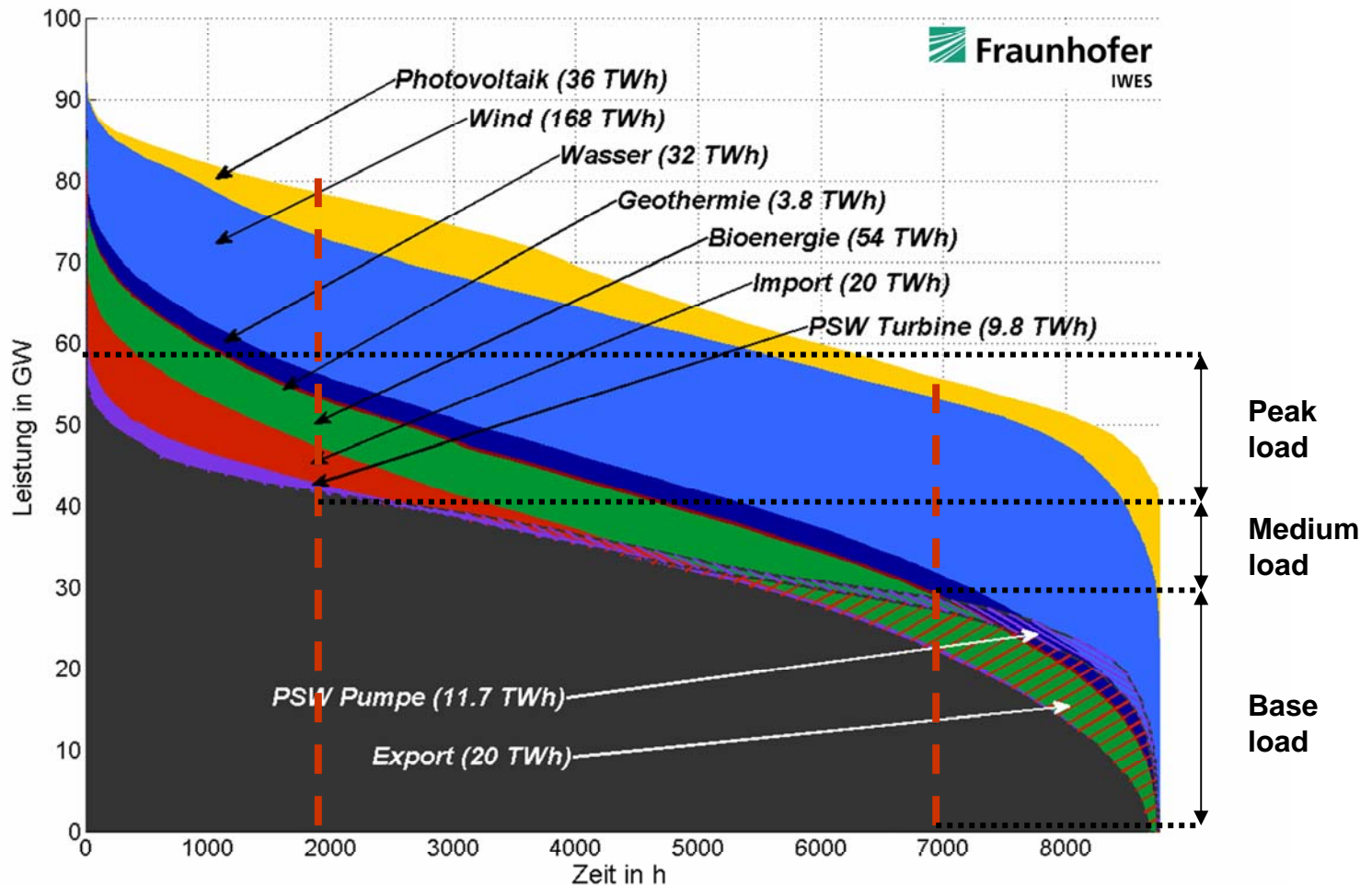


# The way to a high share of RES - Case study: BEE Scenario



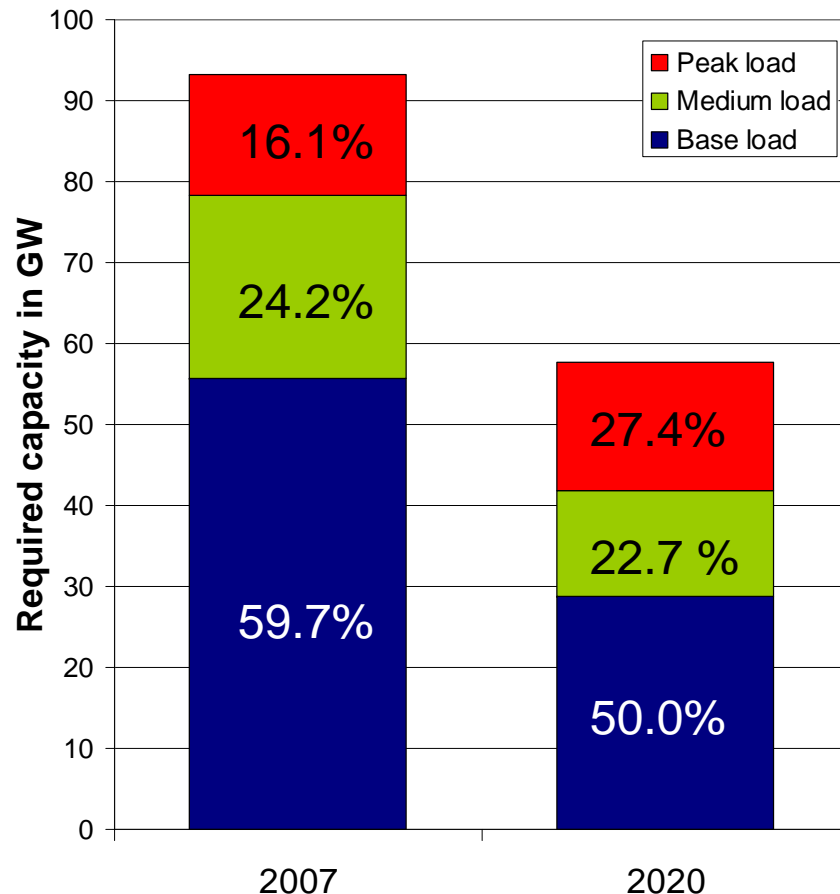


# The way to a high share of RES - Case study: BEE Scenario





# The way to a high share of RES - Case study: BEE Scenario



→ The base load energy needs decrease significantly

→ Increase of the peak load energy needs

Results to be taken into account for the choice of new conventional power plants !

# Conclusions

- PV fluctuations have a positive impact on the power system due to the correlation of PV feed-in with the energy demand
- PV and wind have a seasonal complementarity which offers a source of energy available all over the year (on a monthly basis)
- A 100% RES supply is technically feasible
- Through RES generation, the base load is drastically reduced
- RES time series can follow the energy demand
- The use of biogas power plant as regulating power can enhance the integration of RES

Thank you for your attention.

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