# „Integration of renewable energies – flexibility options from demand side management "

## EPFL Lausanne – Workshop on Demand Side Management
## Session 1: Assessment of demand response potential and willingness and ability to participate

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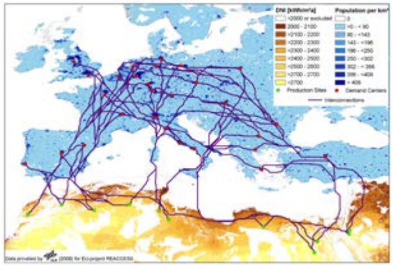
**DLR - German Aerospace Centre, Stuttgart**
*System Analysis and Technology Assessment*
Institute of Technical Thermodynamics

11. September 2015


DLR

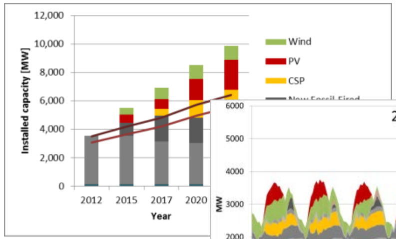
## 1. Introduction

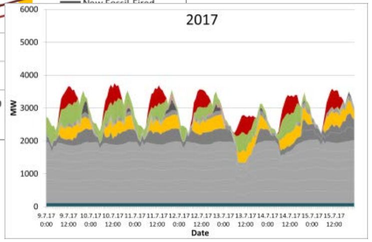
# DLR - Who we are

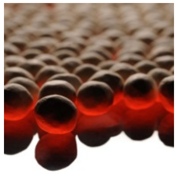


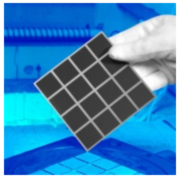
**Research Areas**

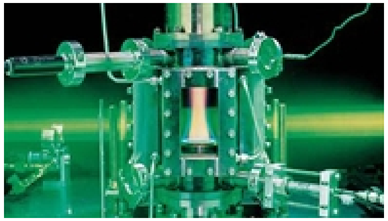
- Aeronautics
- Space Research and Technology
- Transport
- Energy
  - Solar Research
  - Wind Energy Research
  - Systems Analysis
  - Thermal & Chemical Storage
  - High & low Temp. Fuel Cells
  - Combustion & Gas Turbine Technologies
- Space Administration
- Project Management Agency



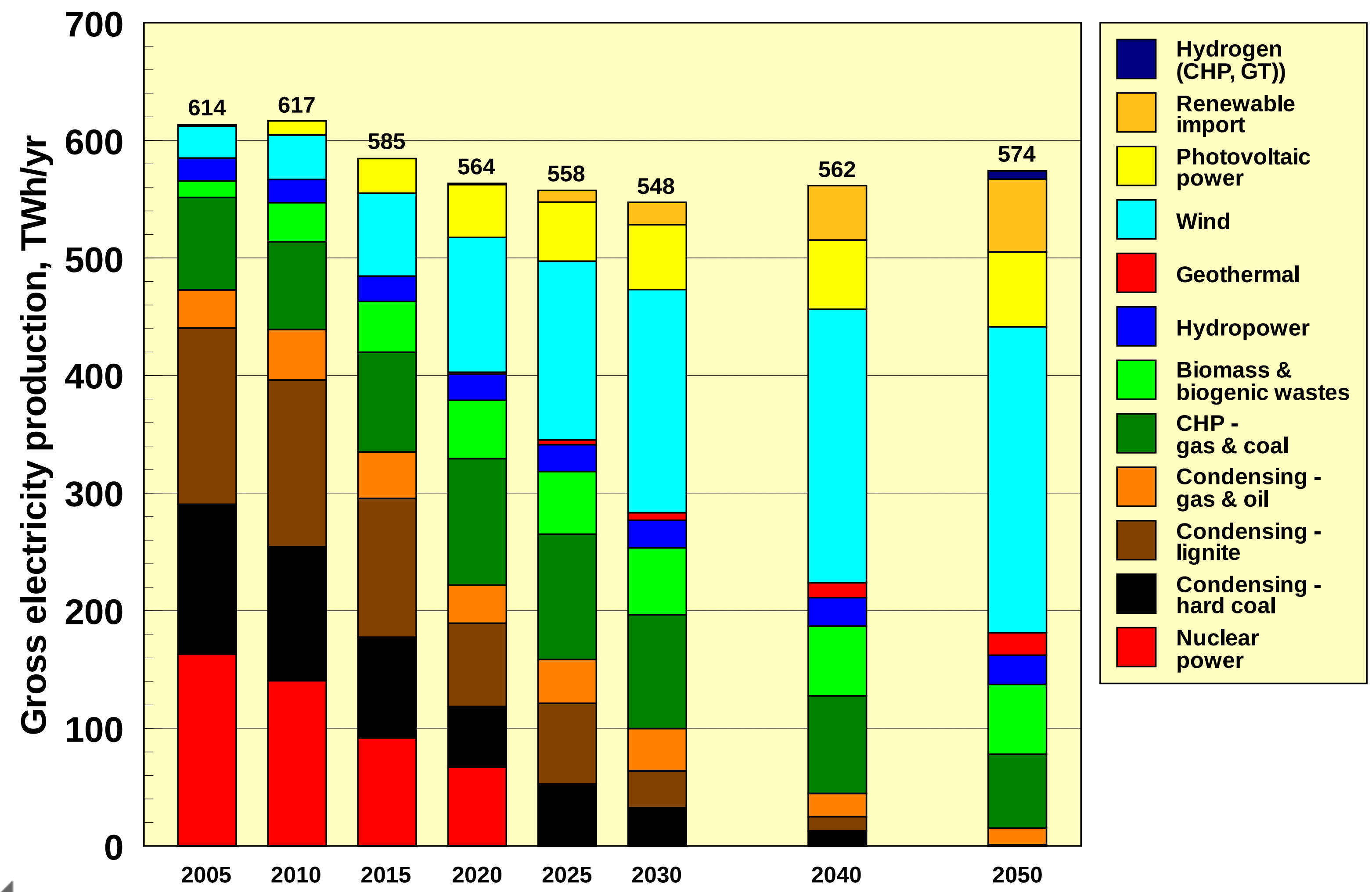







## 1. Introduction

# DLR lead study for the German government 2012

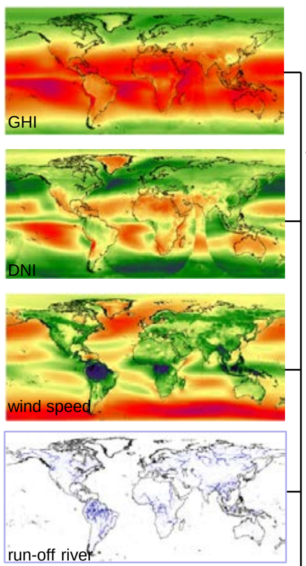


## 1. Introduction

# Energy systems model REMix:

## Validation of power supply, load balancing and flexibility demand

**Installed capacities and power generation profiles from renewables**

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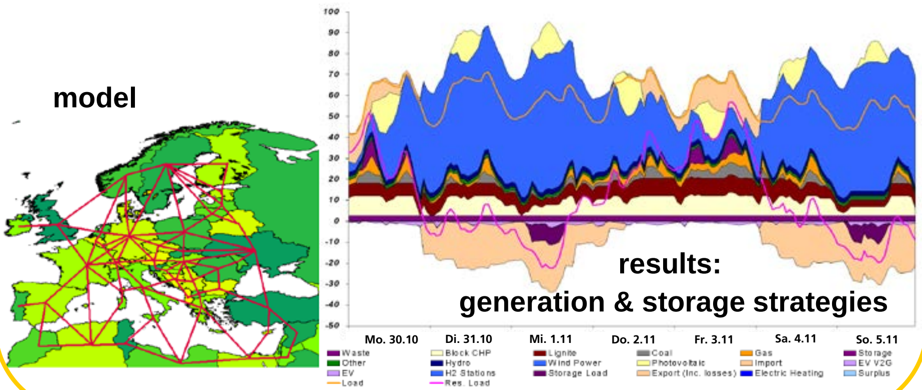
**HVDC lines**
long-range power exchange and imports

**Transmission grid**
based on current European AC grid

**Scenario analysis with model REMix**
cost minimised supply in temporal & spatial resolution



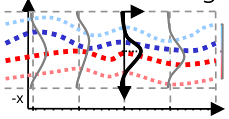

**Electricity demand**

**Heat demand**

**Flexible operation of CHP with:**
- heat storages
- peak boiler & electric heaters

**Electric vehicles (EV)**

**BEV/hybrids:** charging strategies, hourly battery capacities of the fleet connected to the grid



**FCEV:** flexible on-site $H_2$ generation

**Conventional generation**
nuclear, coal, gas power plants

**Storages**
pumped hydro
compressed air
hydrogen

**Demand side management**
industry & households, increases system efficiency

source: DLR-TT

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## 1. Introduction

# Research Questions at DLR

- What are the theoretical potentials for demand response (DR) in Europe?
- Is the exploitation of these potentials an economic alternative to other balancing options?
- What are the load balancing impact and typical operation pattern of DR?
- How is DR interacting with alternative balancing technologies?
- To what extent can DR reduce supply costs and $CO_2$ emissions?

Source:
Gils, Hans Christian (2015) *Balancing of Intermittent Renewable Power Generation by Demand Response and Thermal Energy Storage.* Dissertation, University of Stuttgart.
Gils, H. C. (2015). Assessment of the theoretical demand response potential in Europe. Energy, 67(0):1 – 18.

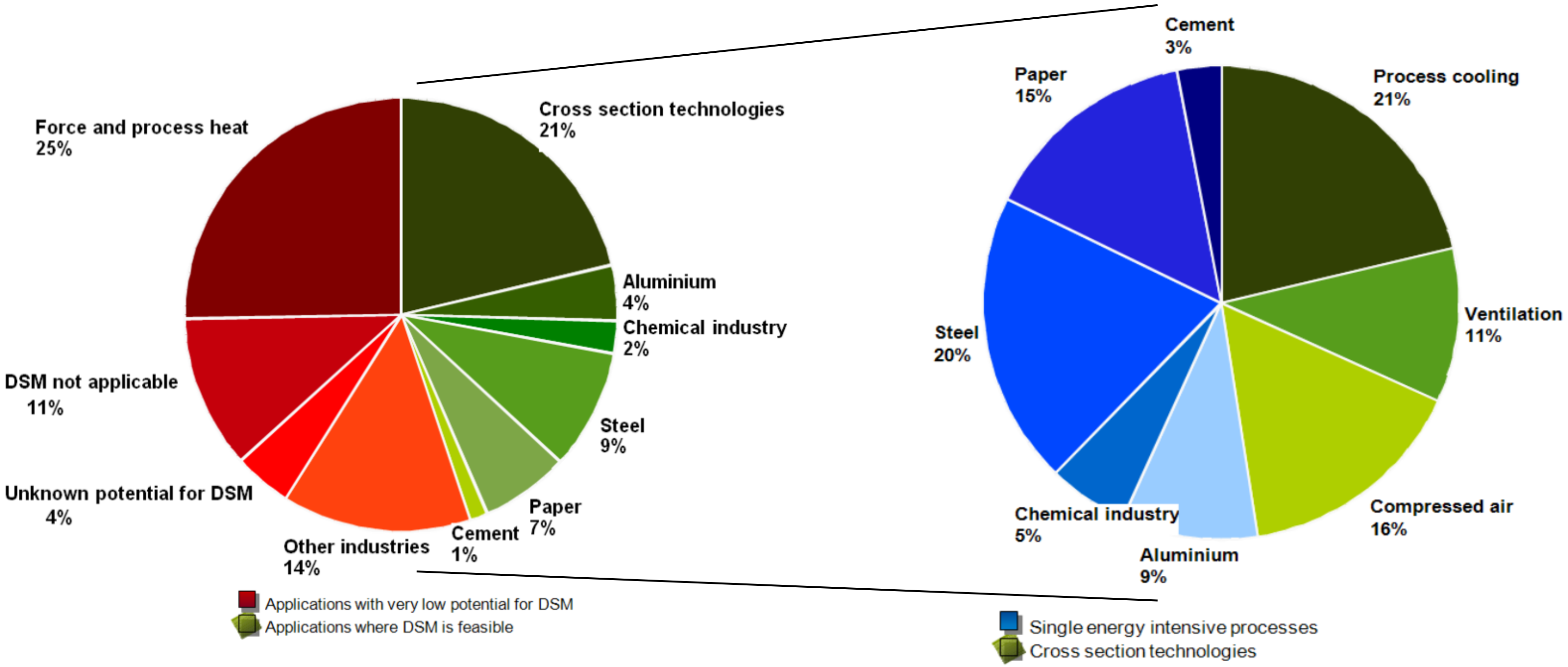
## 1. Agenda

# Today‘s presentation

1. What is the **technical potential** for Demand Side Management?
2. Investigating the **myth**: How will DSM be used? And how not?
3. What are potential **game changers** in this analysis?
4. Conclusion

## 2. Technical potential

# Overview of DSM in industry

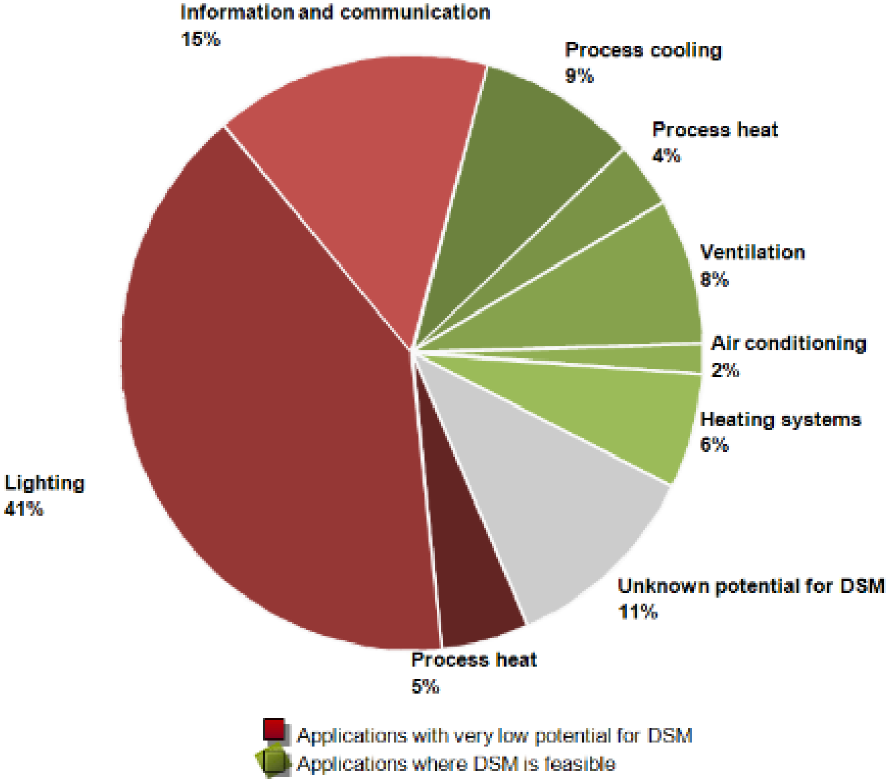



Source:
**DENA (2010)**: "*dena Grid Study II - Integration of Renewable Energy Sources in the German Power Supply System from 2015 – 2020 with an Outlook to 2025*". German Energy Grid Agency (DENA) November 2010

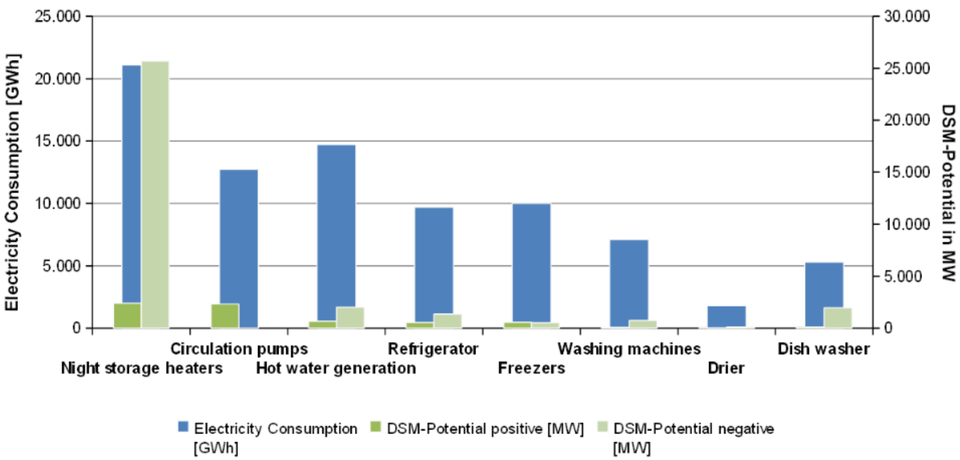
## 1. Technical potential

# Overview of DSM in the service sector and households

### Trade & service sector




### Households

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## 2. Technical potential

# Top-down and bottom-up: Technical potential in industry is 2,6 GW

| area | | Electricity intensity [kWh/t] | productionoutput [Mil. t] | Full utilisation hours | Ratio being flexible usable | potential [TWh] | DSM capacity [MW] | Storage dimension [MWh] |
|---|---|---|---|---|---|---|---|---|
| Cement production: Raw- and cementmills | | rawmills: 26 kWh/t cementmills: 45 kWh/t | 33,58 Mil. t | 7.500 h | 100,00% | 2,38 TWh | 318 MW | - |
| Chlorine-alkali electrolysis | membrane-method | 2.850 kWh/t Chl. | 2,38 Mil. t | 7.400 h | 30,00% | 2,04 TWh | 275 MW | 138 MWh |
| | diaphragm method | 3.500 kWh/t Chl. | 1,10 Mil. t | 7.400 h | 30,00% | 1,16 TWh | 156 MW | 78 MWh |
| | Amalgam-method | 3.400 kWh/t Chl. | 1,29 Mil. t | 7.400 h | 30,00% | 1,32 TWh | 178 MW | 89 MWh |
| aluminiumelektrolysis | | 15.000 kWh/t Al | 0,61 Mil. t | 8.760 h | 25,00% | 2,27 TWh | 295 MW | - |
| electric arc furnace | | 525 kWh/t | 13,70 Mil. t | 6.500 h | 70,00% | 5,03 TWh | 775 MW | - |
| Paper production: preperation of mechanical wood pulp | | 1.850 kWh/t | 1,38 Mil. t | 7.500 h | 65,00% | 1,66 TWh | 222 MW | 333 MWh |
| sum | | | | | | 19,86 TWh | 2.669 MW | 802 MWh |

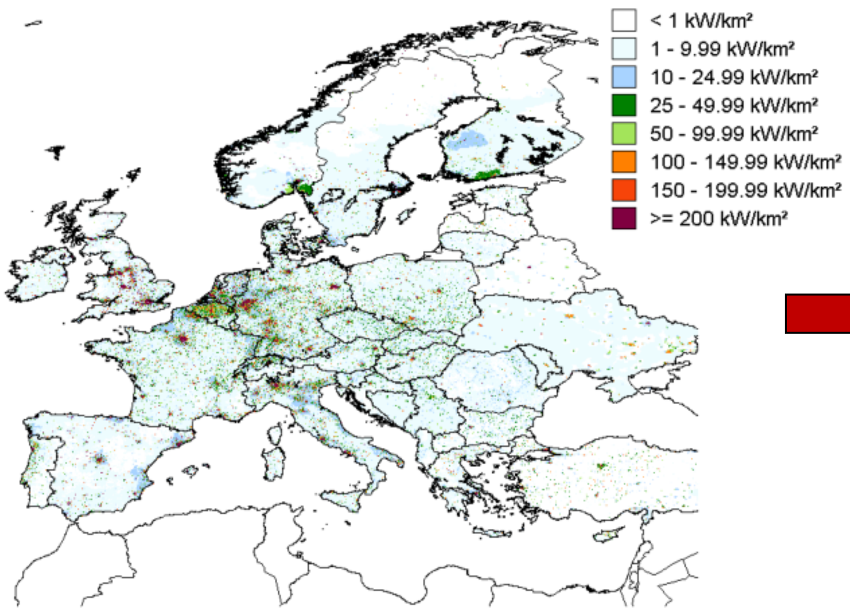
*Source: EWI (2010).*

Source:
**DENA (2010)**: "*dena Grid Study II - Integration of Renewable Energy Sources in the German Power Supply System from 2015 – 2020 with an Outlook to 2025*". German Energy Grid Agency (DENA) November 2010

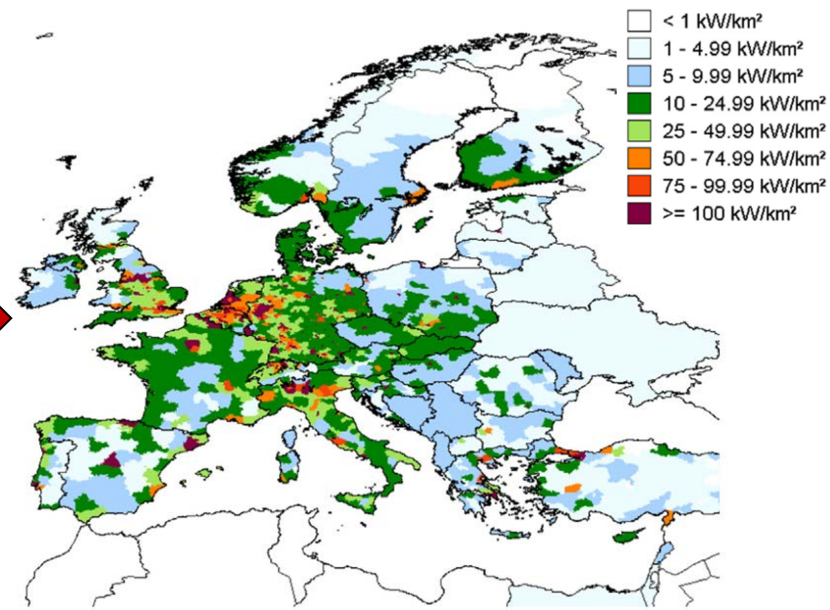
## 2. Technical potential

# Estimating technical DSM potential in Europe based on GIS analysis

- Consideration of 30 flexible electric loads across all demand sectors
- Derivation of hourly load profiles
- Geographic disaggregation to 1 km² raster




Theoretical potentials, values of 2010




Average theoretical potentials, nuts 3, values of 2010

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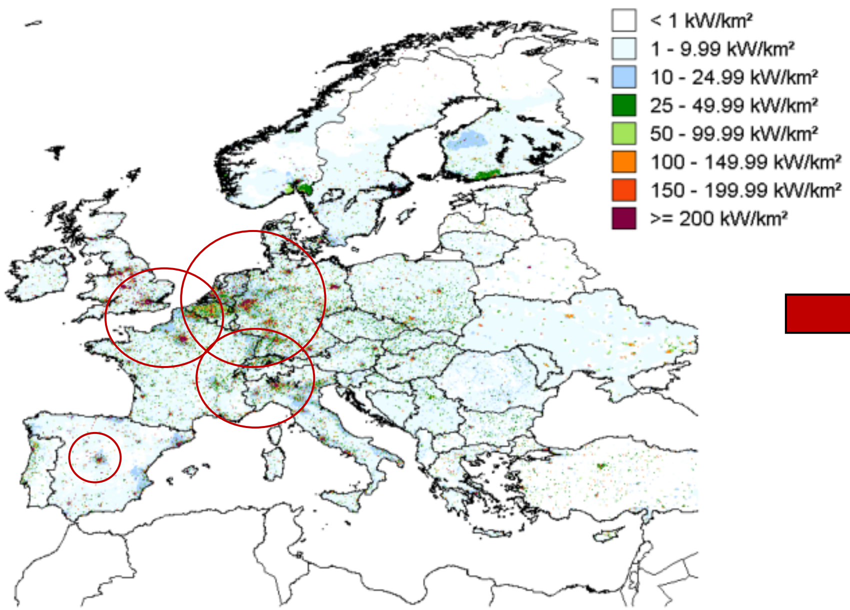


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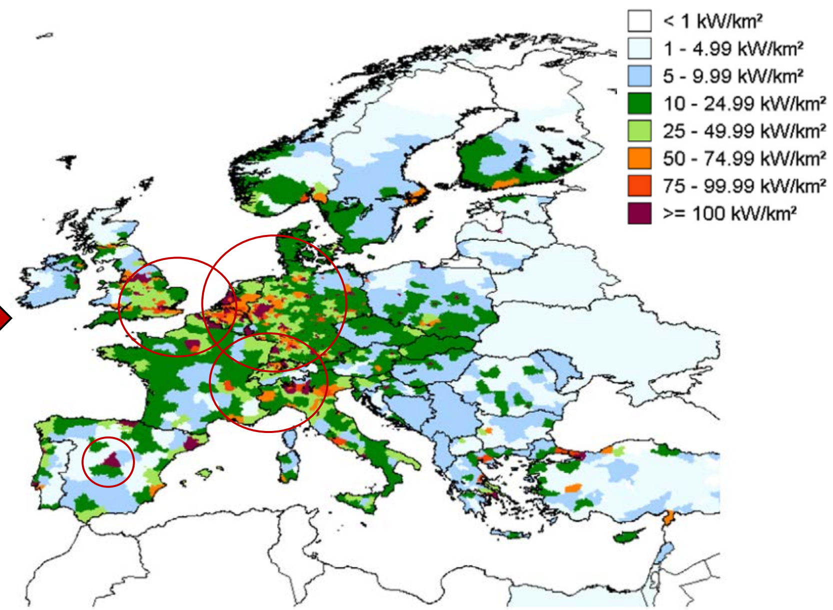


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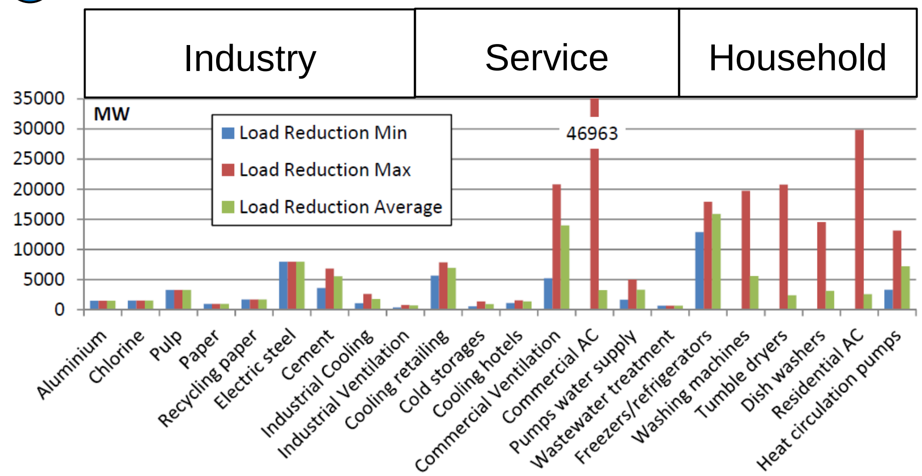
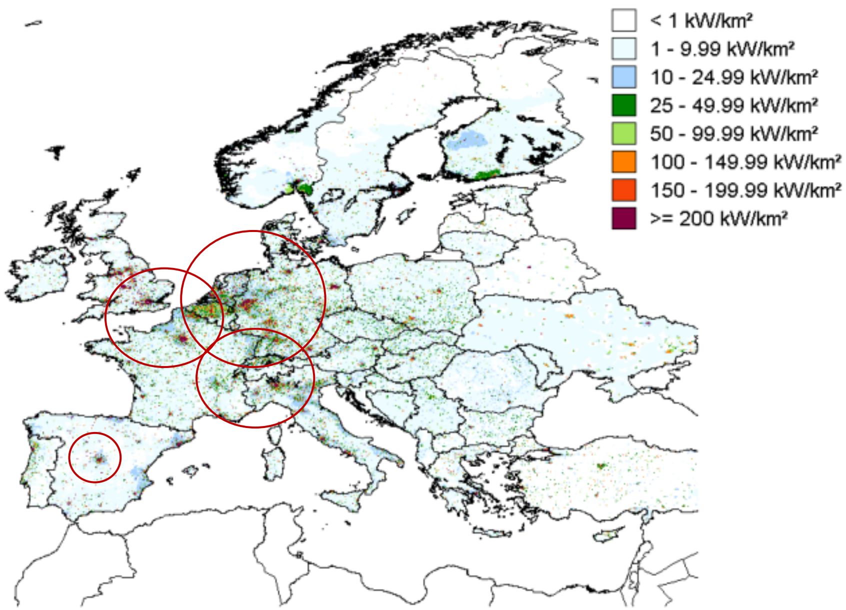
Decrease

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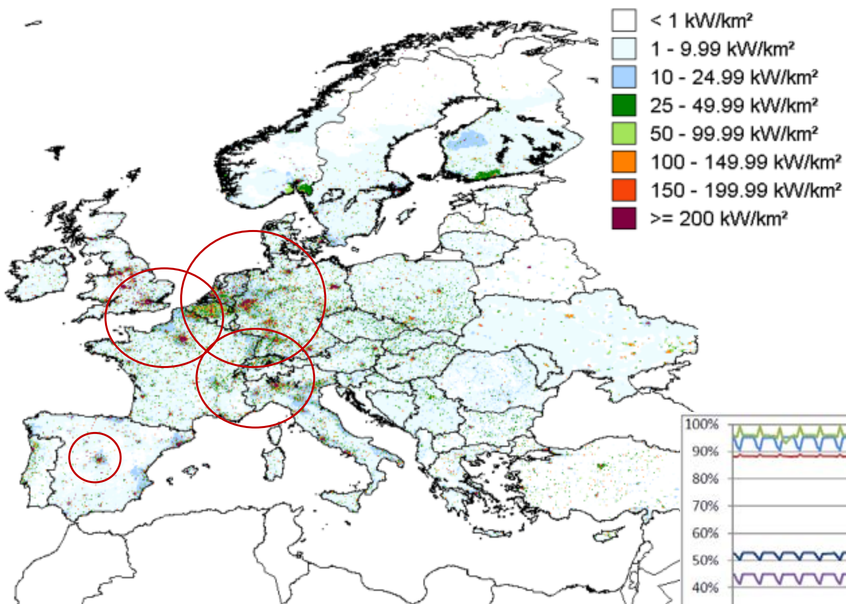
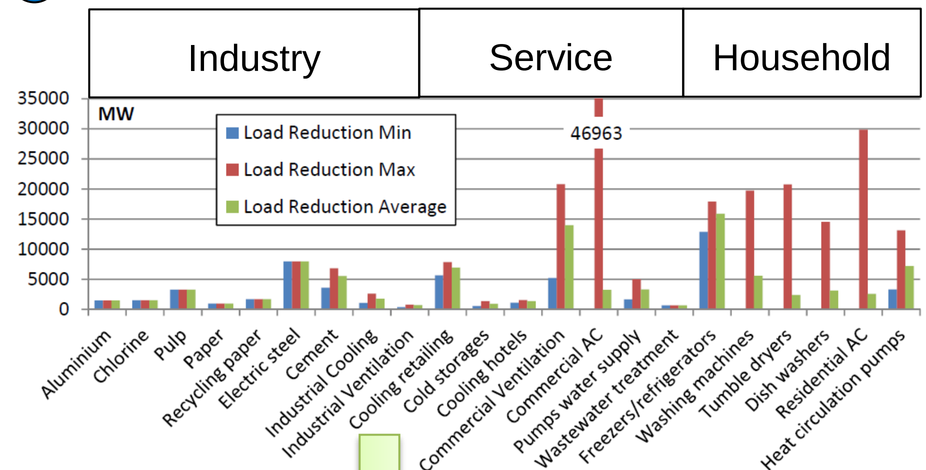
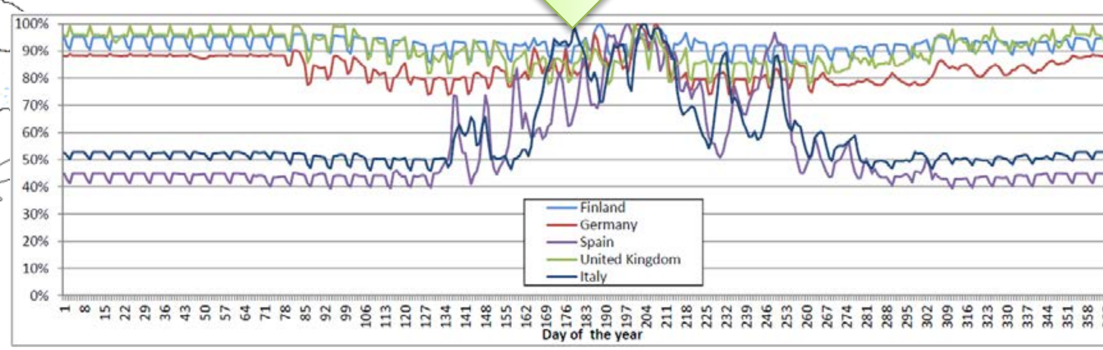



Theoretical potentials, values of 2010

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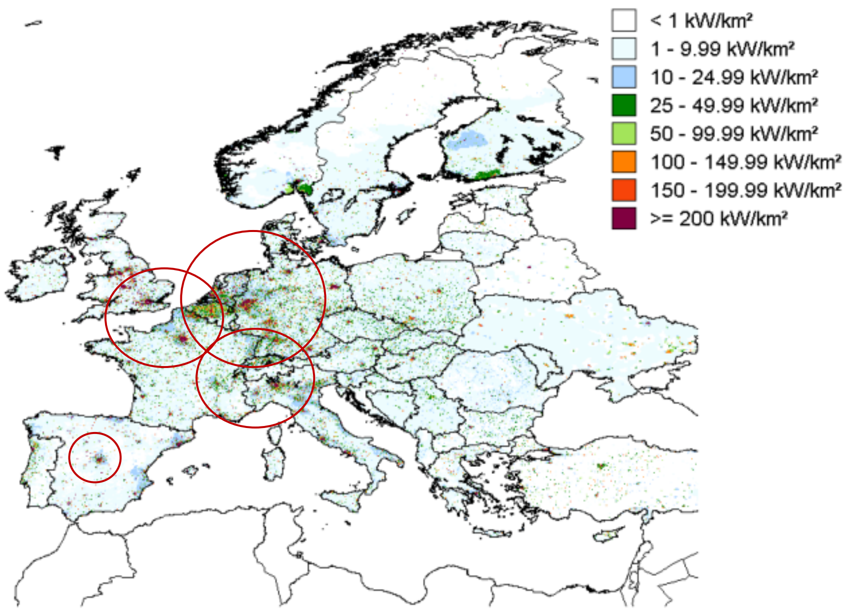


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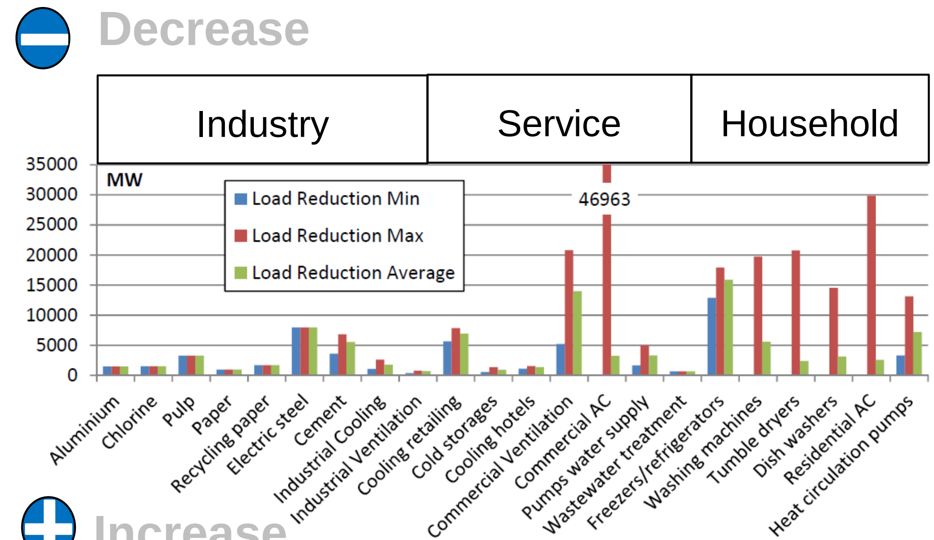


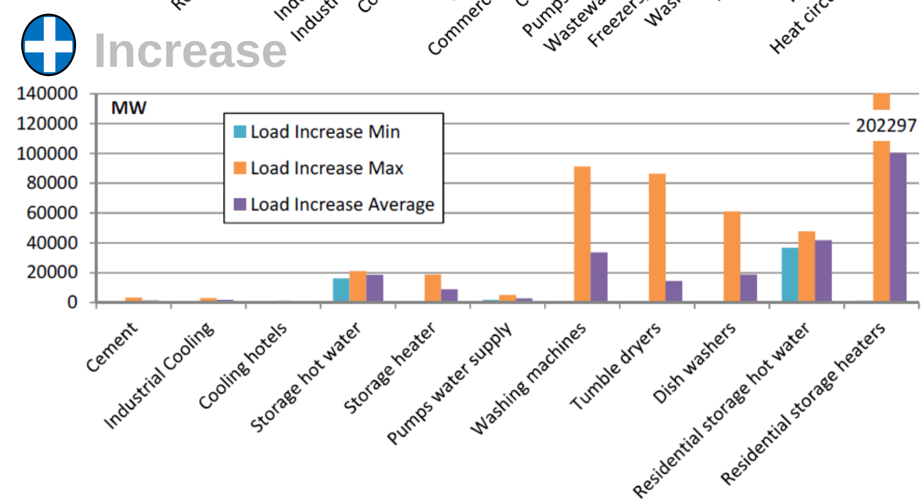


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2. Investigating the myth: Potential for DSM

# Potential for demand side management to integrate large shares of REN-E

a. Contribution to efficient renewable feed-in?
b. Contribution to supply security?
c. Increasing potential in Balancing and real time market?
d. Increasing potential in intraday markets?
e. Hourly load management?
f. Reducing grid investments?

Discussion based on results from 2014 study funded by the ministry of economics:

- How will flexible technologies be used and to what extend competition might arise between these technologies?
- What characteristics define an efficient electricity mix for the integration of large shares of renewables?

Degree of flexibility

| | |
|---|---|
| o | Reference scenario: No additional flexibility options |
| + | Flexible CHP based on thermal storage, conventional and electric peak load boiler |
| ++ | Additional load managment options<br>Heat pumps<br>Electric vehicles - flexbile charging |
| +++ | Additional construction of electricity storages (CAES- Storages) |

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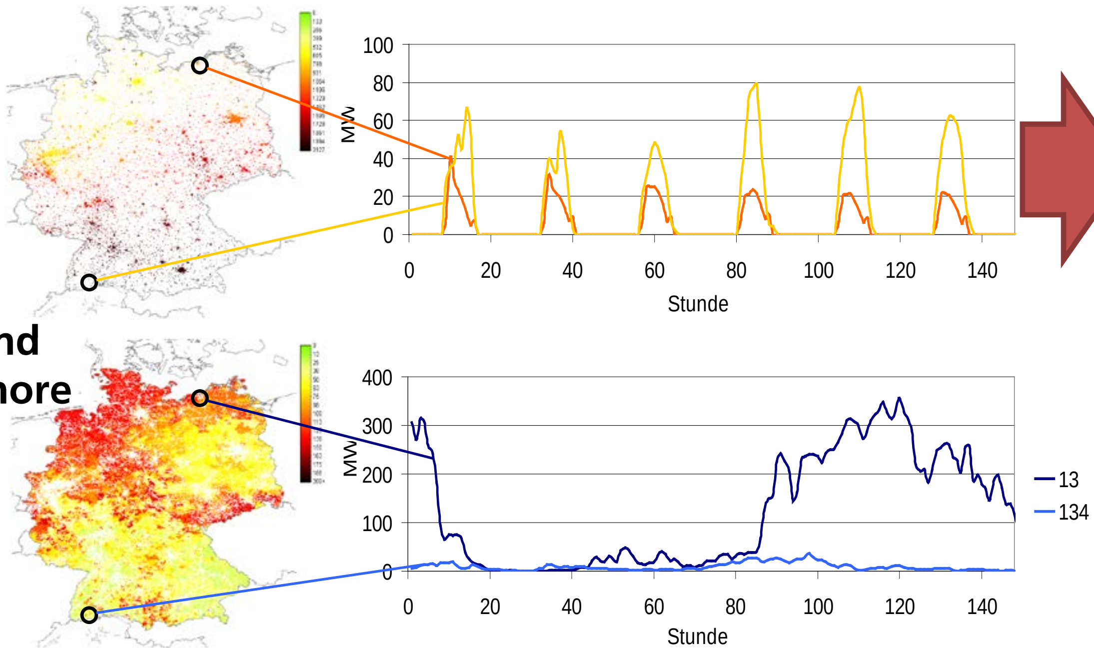
## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

PV

Wind onshore




**Degree of flexibility**

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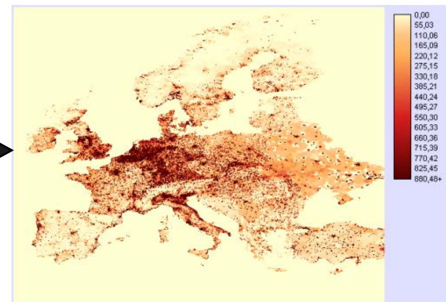
**DLR study on „Load balancing" for the German Federal Ministry of Economic Affairs and Energy:**
Scholz, Y., Gils, H. C., Pregger, T., Heide, D., Cebulla, F., Cao, K.-K., Hess, D. and Borggrefe, F. (2014)
*Möglichkeiten und Grenzen des Lastausgleichs durch Energiespeicher, verschiebbare Lasten und stromgeführte KWK bei hohem Anteil fluktuierender erneuerbarer Stromerzeugung.* Project report.

## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

Demand per capita

Density of heat suppy



District heating

- 23 technologies
- Potential district heating areas
- Annual demand
- Heat density
- Costs

- GIS-based method with 1 x 1 km² area pixel
- Upper bound for district heating grids

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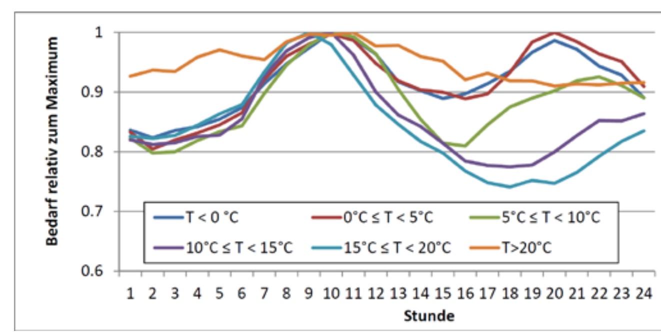


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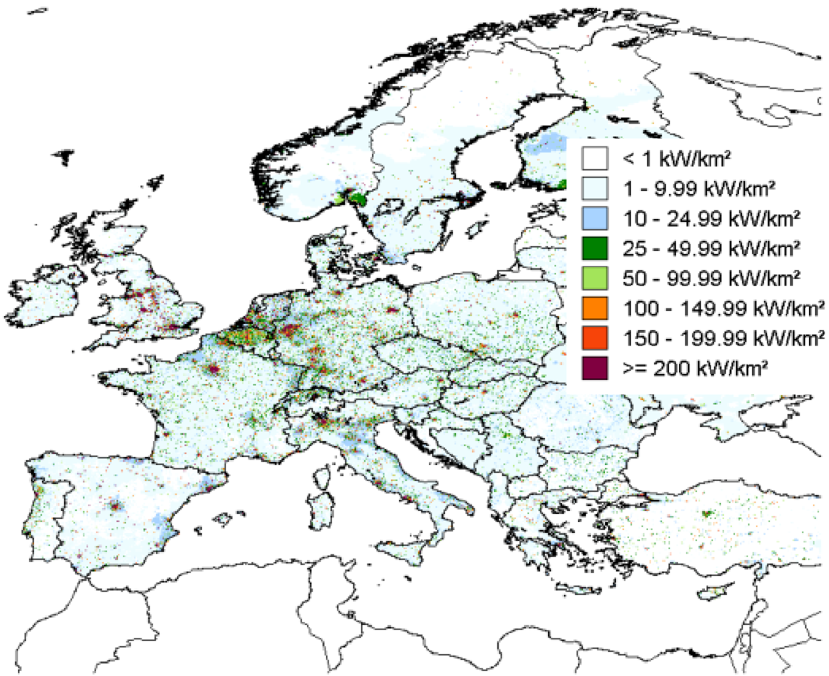
## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

**Theoretic potential for DSM in 2010**




- 30 different endusers with the ability for load shifting and load shedding

Degree of flexibility

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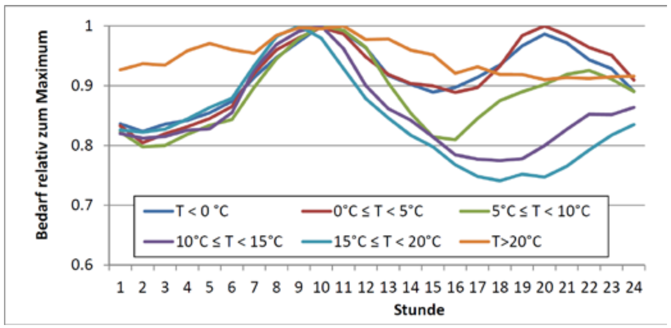


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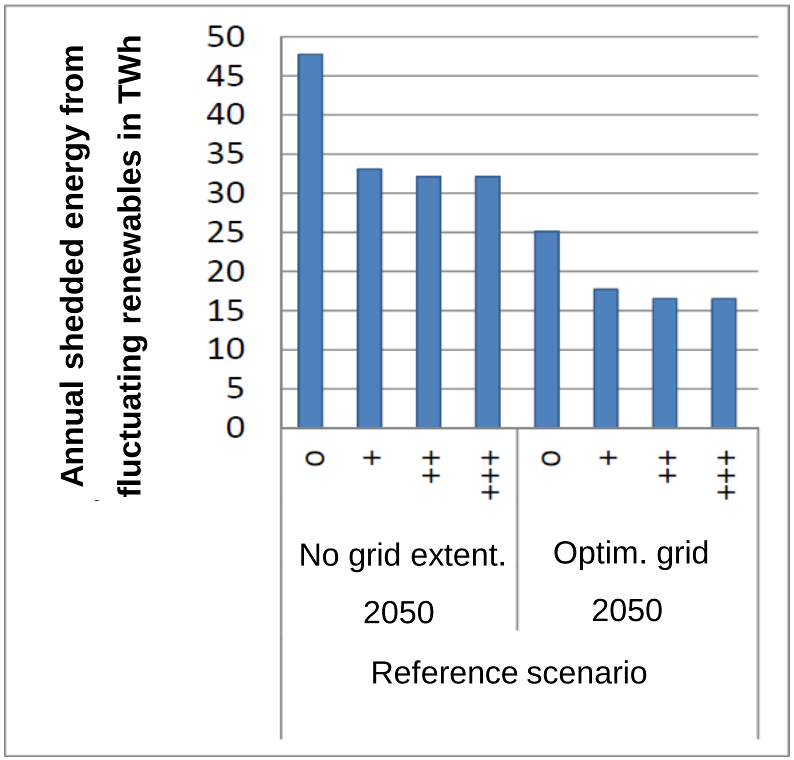
## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

**Results of study:**

### Indicator 1 - annual shedded energy

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## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

**Results of study:**

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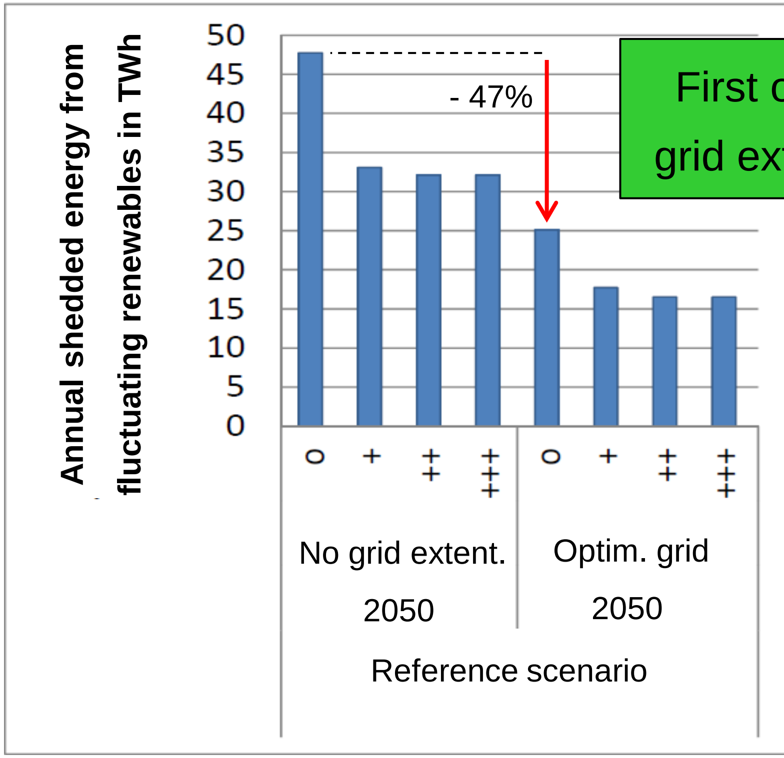


First option: grid extension

Degree of flexibility

| | |
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| **+++** | **Additional construction of electricity storages (CAES- Storages)** |

Result: Importance of the grid - Model endogenous grid extension significantly reduces demand for storage

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**Results of study:**

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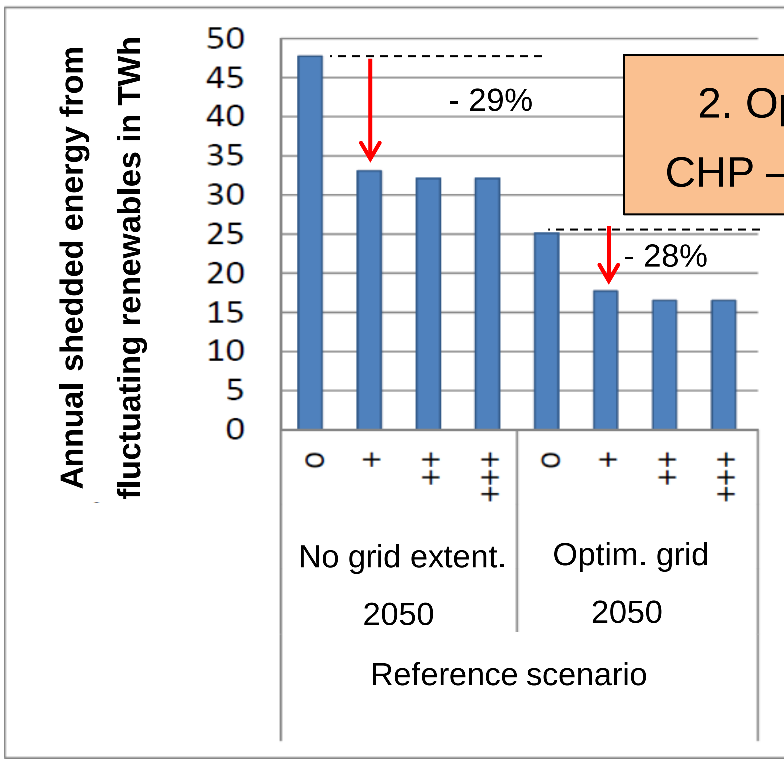


2. Option: CHP – plants

**Degree of flexibility**

| | |
|---|---|
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| + | Flexible CHP based on thermal storage, conventional and electric peak load boiler |
| ++ | ~~Additional load managment options~~<br>~~Heat pumps~~<br>~~Electric vehicles - flexbile charging~~ |
| +++ | Additional construction of electricity storages (CAES- Storages) |

Result: Felixbilisation of CHP plants appears supperior option with regards to integration of renewables compared to additional load management options

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## 2. Investigating the myth: Potential for DSM

# a.) Contribution to efficient renewable feed-in?

### Results of study:

### Indicator 2 – additional capacity in peak load hours

**Concept:** Model can endogenously build gas turbines and H2-storage to cover peak hours - if flexibility is not sufficient.

| | |
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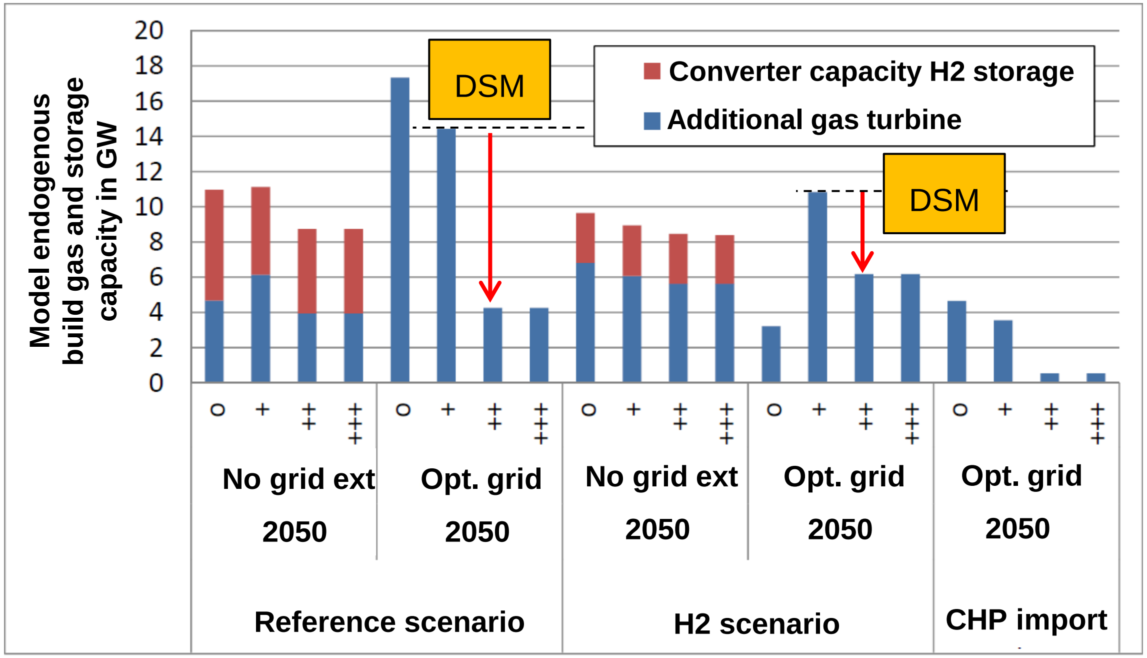


Result: DSM can reduce additional investments in peak hours!
Instead DSM will significantly be used to cover peak hours.
-> Additional results: Valuable primarily in combination with grid extensions!

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## 2. Investigating the myth: Potential for DSM

# Potential for demand side management to integrate large shares of REN-E

- (−) Contribution to efficient renewable feed-in?
- (+) Contribution to supply security?

c. Hourly load management?

d. Increasing potential in balancing and real time market?

e. Increasing potential in intraday markets?

f. Reducing grid investments?

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## 2. Investigating the myth: Potential for DSM

# Potential for demand side management to integrate large shares of REN-E

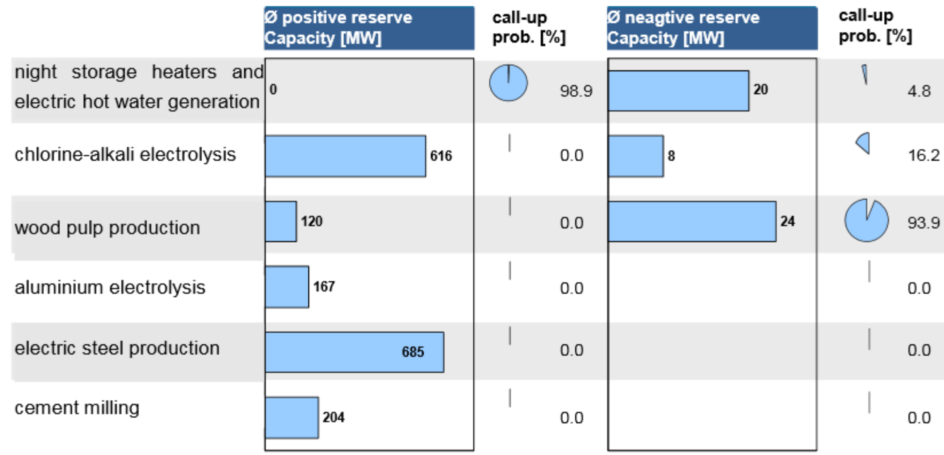
- Contribution to efficient renewable feed-in?
- Contribution to supply security?
- Hourly load management?

d. Increasing potential in balancing and real time market?

e. Increasing potential in intraday markets?

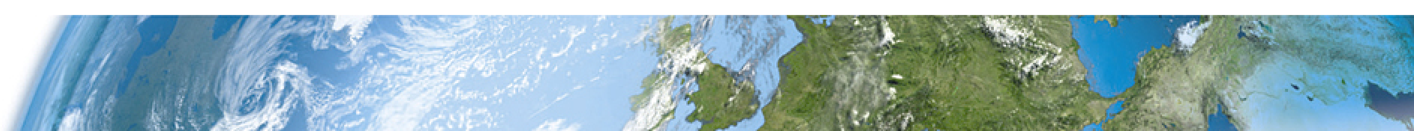
f. Reducing grid investments?

**Balancing power: Average Reserve capacity supplied by DSM processes in 2020 and probability of call-up**




*Source: EWI (2010).*

Source:
**DENA (2010)**: "*dena Grid Study II - Integration of Renewable Energy Sources in the German Power Supply System from 2015 – 2020 with an Outlook to 2025*". German Energy Grid Agency (DENA) November 2010



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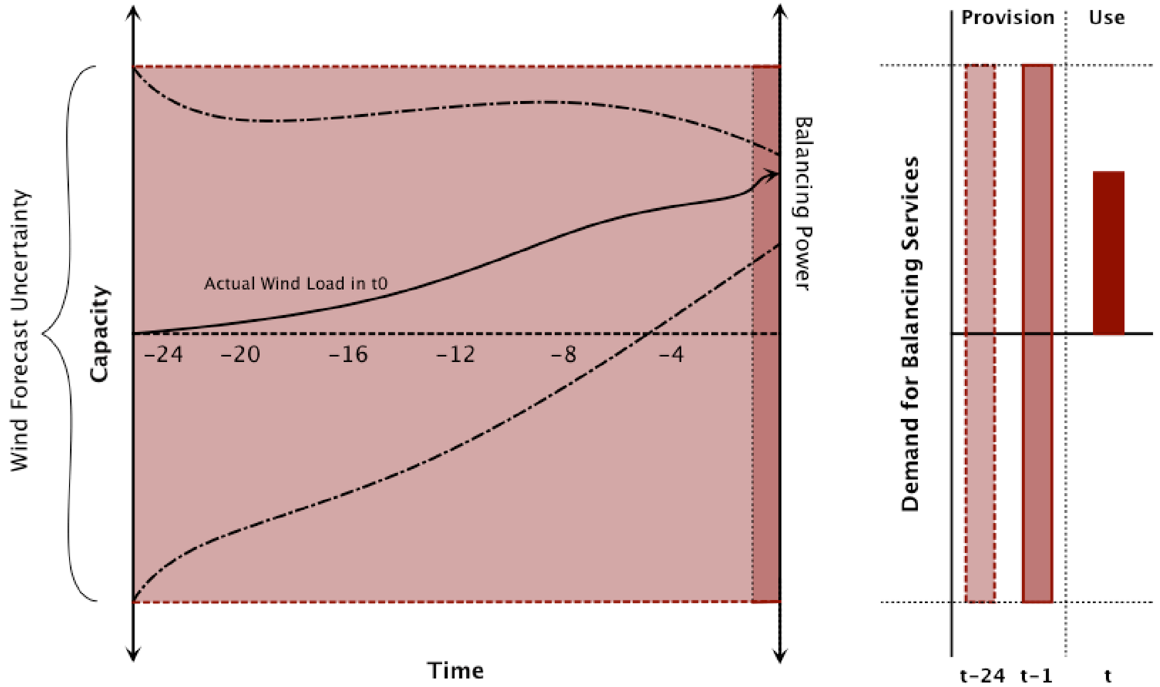
## 2. Investigating the myth: Potential for DSM

# DSM-Potential in intraday and balancing markets

**Example 1:** Balancing ***without*** intraday

Wind forecast uncertainty, actual wind feed-in and

No intraday trading real-time




**Borggrefe**, F. and **Neuhoff** K. (2011) : "*Balancing and Intraday Market Design: Options for Wind Integration*" DIW Discussion paper 1162, Oktober 2011

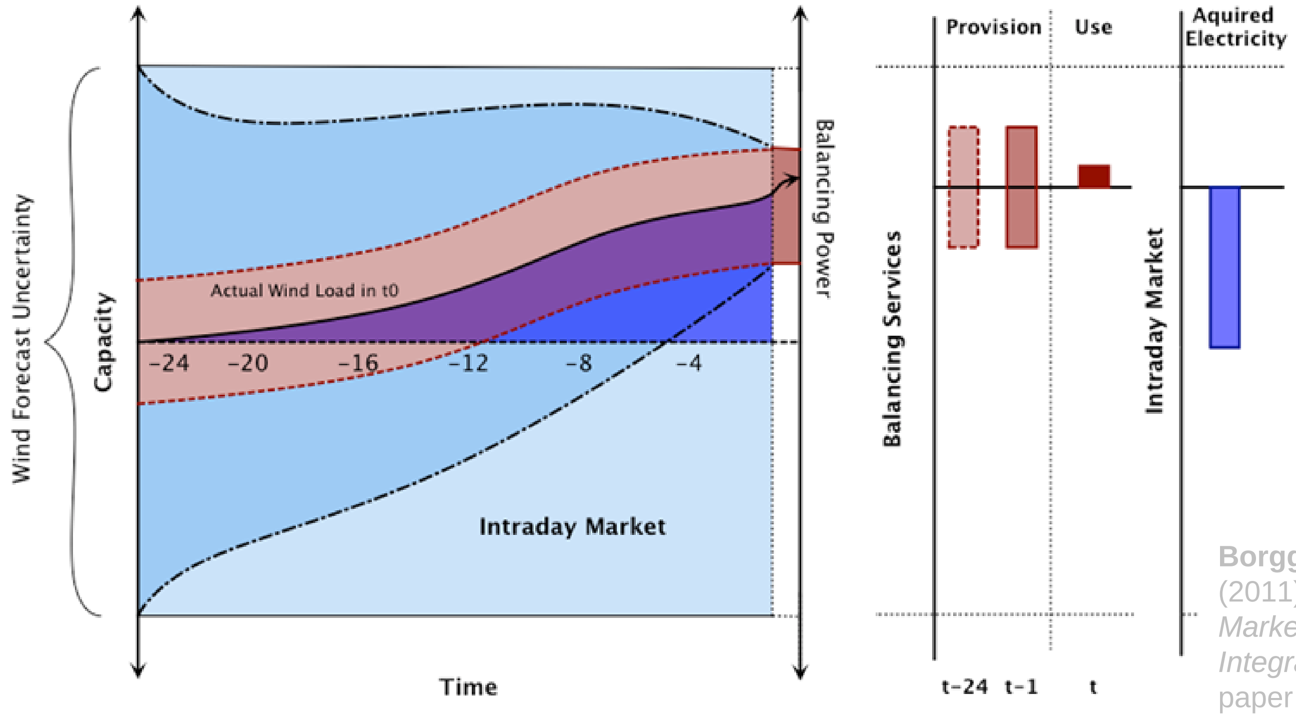
## 2. Investigating the myth: Potential for DSM

# DSM-Potential in intraday and balancing markets

**Example 2:** Balancing *and intraday*

Wind forecast uncertainty, actual wind feed-in and

Intraday trading real-time




**Borggrefe**, F. and **Neuhoff** K. (2011) : *"Balancing and Intraday Market Design: Options for Wind Integration"* DIW Discussion paper 1162, Oktober 2011

## 2. Investigating the myth: Potential for DSM

# DSM-Potential in intraday and balancing markets

**Example 2:** Balancing *and intraday*

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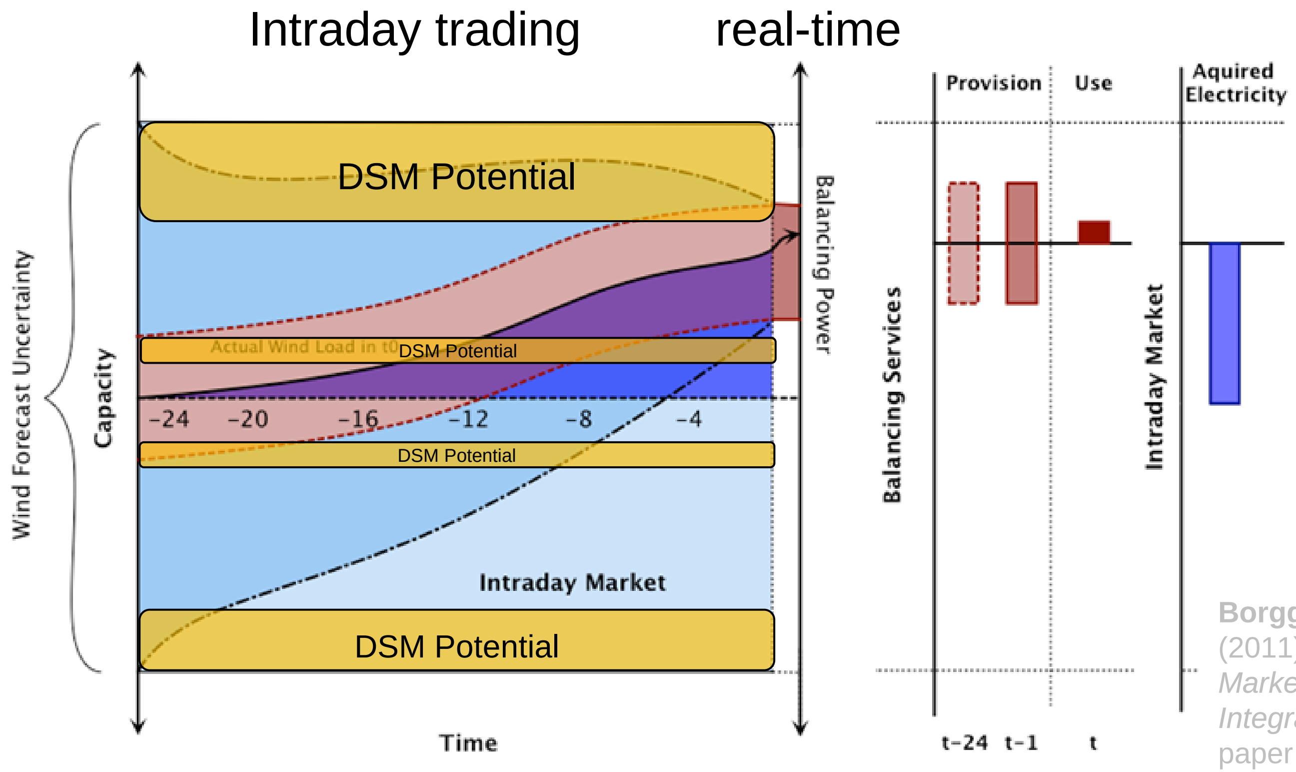


**Borggrefe**, F. and **Neuhoff** K. (2011) : "*Balancing and Intraday Market Design: Options for Wind Integration*" DIW Discussion paper 1162, Oktober 2011

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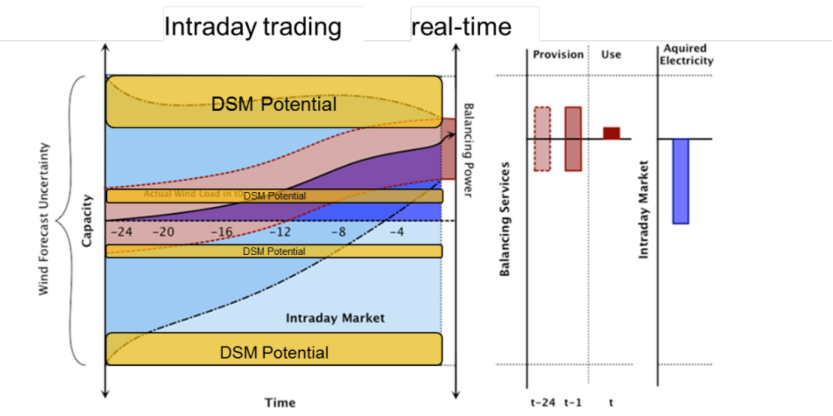
- Increasing potential in intraday markets?
- Reducing grid investments?



## 1. Agenda

# Today‘s presentation

1. What is the **technical potential** for Demand Side Management?
2. Investigating the **myth**: How will DSM be used? And how not?
3. What are potential **game changers** in this analysis?
4. Conclusion

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# What are potential game changers for DSM?

- Delayed grid extensions (within Germany and at borders)
- Power plant closure due to competition
- Ambititious CO2 targets in Paris

- Large renewable invesments in PV
- Technologial advances in storages
- Market barriers to intraday and balancing market

# What are potential game changers for DSM?

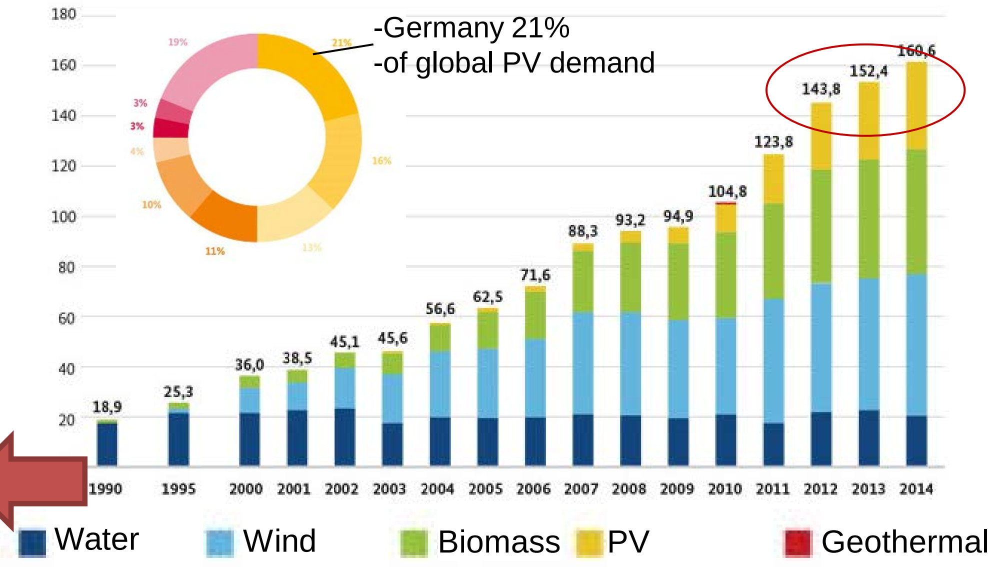
## Increasing Potential for DSM

- Delayed grid extensions (within Germany and at borders)
- Power plant closure due to competition
- Ambititious $CO_2$ targets in Paris

## Decreasing Potential for DSM

- Large renewable invesments in PV
- Technologial advances in storages
- Market barriers to intraday and balancing market

Diverging invesments in renwables (PV)



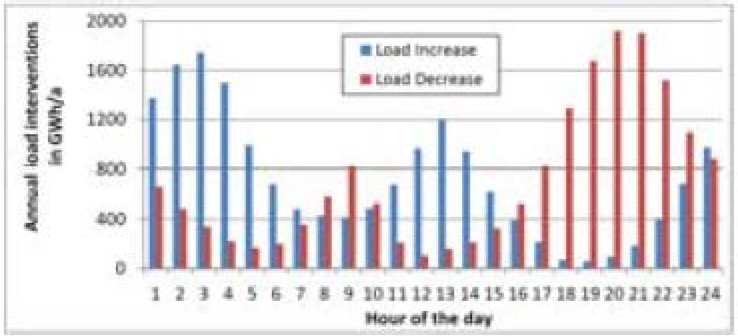




Figure 6: Hourly demand response operation

## 1. Agenda

# Today‘s presentation

1. What is the **technical potential** for Demand Side Management?
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## 4. Conclusion

# Competition in the market for flexibility – the stage is set!

-Flexibility of konv. power plants

-Grid extension (Transmission-, distribution grid)

-Power-to-Heat (Heating networks)

-Extension CHP + Heat storage

-El.short term storage (Pump storage, battery, E-Mobility)

-Demand Side Management (Households, industry)

-Wide use of el. heat pumps

-Hydrogen to gas grid

-Synth. fuels in transportation

- Synth. Fuels in electricity and heating

**Today** → **2050**

**Henning**, H.-M., **Palzer**, A. **Pape**, C., **Borggrefe**, F., **Jachmann**, H. and **Fischedick** M. "*Phasen der Transformation des Energiesystems*" (Phases of transformation of the energy system), et - Energiewirtschaftliche Tagesfragen, Issue 1-2 2015 Essen, February 2015

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## Apendix

# References

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**Gils**, H. C. (2015): *"Balancing of Intermittent Renewable Power Generation by Demand Response and Thermal Energy Storage"*. PhD thesis, University of Stuttgart.

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**Luca de Tena**, D. (2014) *"Large Scale Renewable Power Integration with Electric Vehicles"*. PhD thesis, University of Stuttgart.

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