Transition to Renewable Energies
- a challenge for Research Infrastructures

Jutta Hanson

Generation

Conventional power plants

Solar power plants

Wind farms

Transmission and distribution

Consumption

Intelligent Measurement

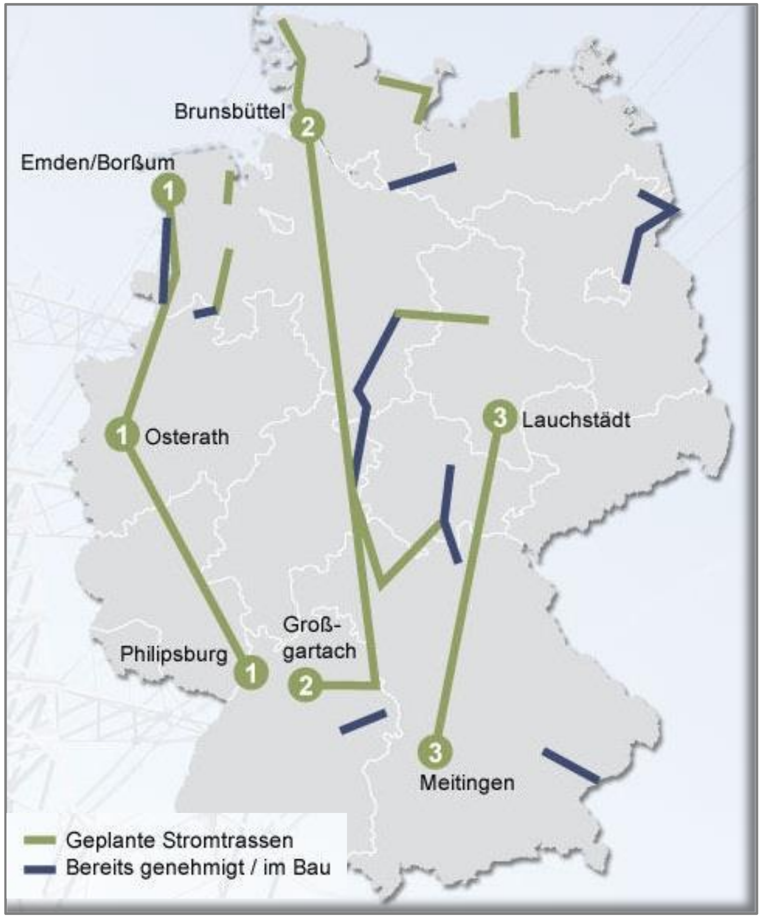
Home automation

Electromobility

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Transition to renewable energies
Agenda

TECHNISCHE UNIVERSITÄT DARMSTADT



Source: www.netzentwicklungsplan.de

- Main Goals and time frame of "German Energy Transition"
- Structure of power supply
- Goals and measures of energy management of RIs for
  - Environment
  - Power supply
  - Costs of power supply

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Main Goals of German "Energiewende"

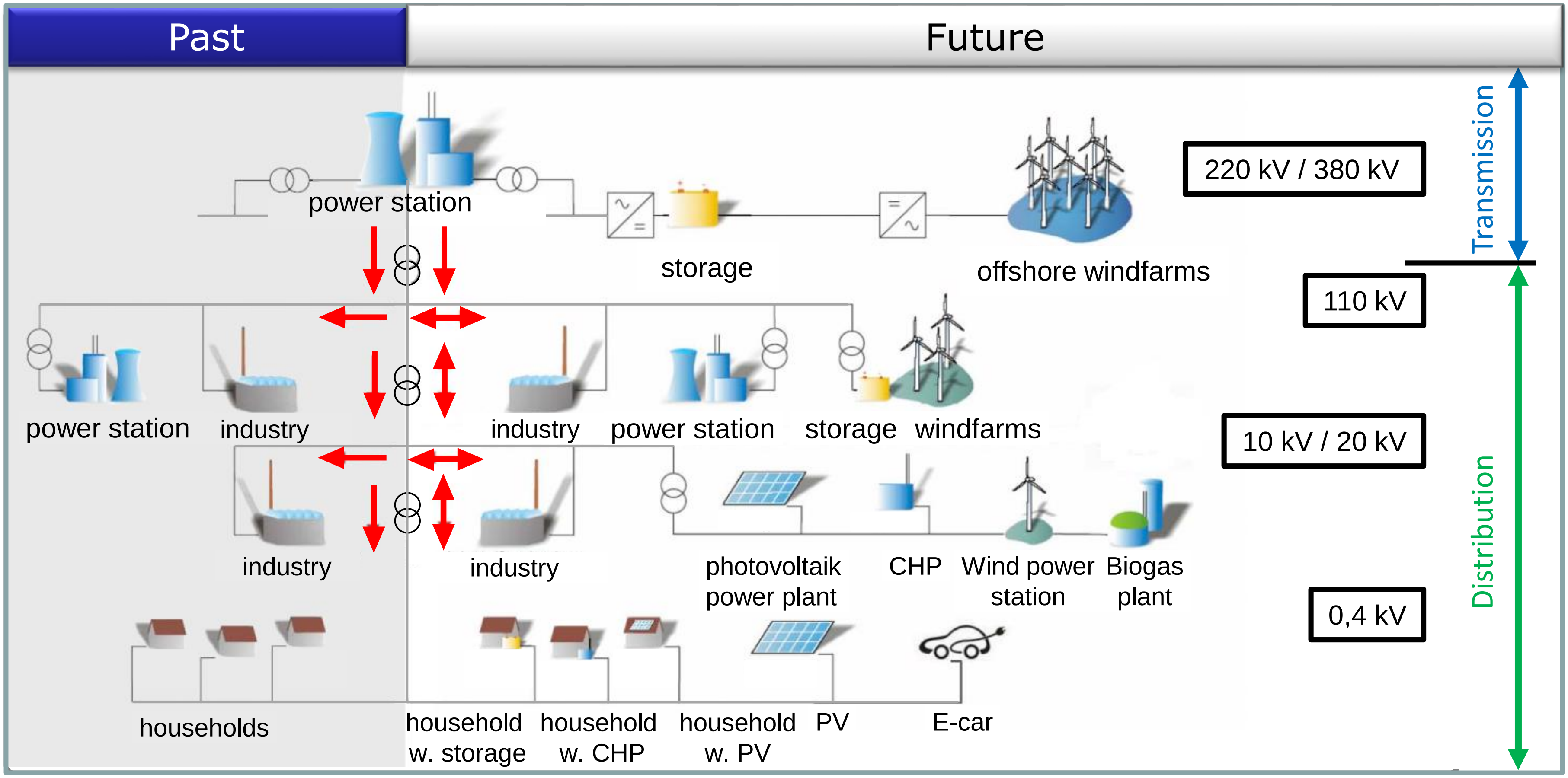
TECHNISCHE UNIVERSITÄT DARMSTADT

	2020	2050
Greenhouse gas emissions (1990)	-40 %	-80 %
Primary energy consumption (2008)	-20 %	-50 %
Heat demand in buildings (2008)	-20 %	-60 %
El. power consumption (2008)	-10 %	-25 %
Share of RE in electrical energy consumption	35 %	80 %
Share RE in energy energy consumption	18 %	60 %
E-Cars	1 Mio	5 Mio (2030)
Offshore wind energy	10 GW	25 GW (2030)

- Shut-down of nuclear power plants latest end of 2022
- Increased installation of renewable energies (80% of electrical energy consumption in 2050)
- Extension and reinforcement of electrical power system
- Increase of energy efficiency – in particular in the field of building insulation (heat)
- Decrease of energy consumption by innovative technologies

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Top-Down power supply changes to decentralized power supply



CHP – combined heat and power station

Installed power and energy consumption out of renewable energies in Germany in 2013

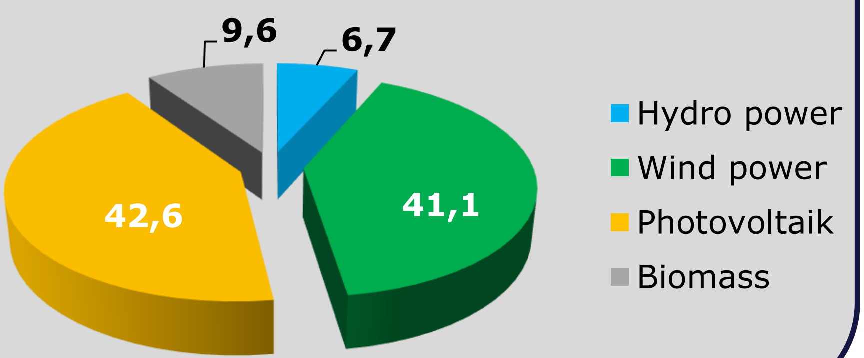
Installed power

Total	187 GW
Renewable Energies	84 GW

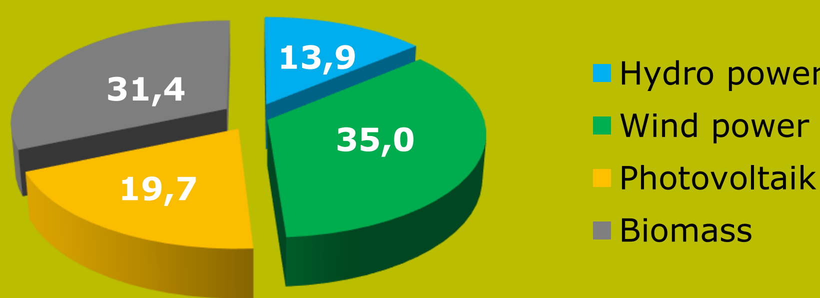
Electric Energy consumption

Gross energy consumption	600 TWh
Renewable Energies	153 TWh

Installed renewable power in %



Renewable consumption in %



Source: BMU-KI III 1 Task Force Erneuerbare Energien-Statistik (AGEE-Stat) and Federal Environmental Agency (UBA); Effective February 2014
Monitoring report German Government, June 2014, October 2013

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

New structure of generating units

TECHNISCHE UNIVERSITÄT DARMSTADT

WHERE?

- **Distributed** generation in small units
- **Increased distance between generation and consumption** in large units
  - Wind energy, in particular offshore
  - Hydro power – Alpes, Scandinavia

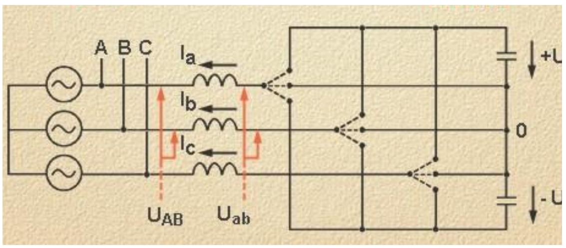
HOW?

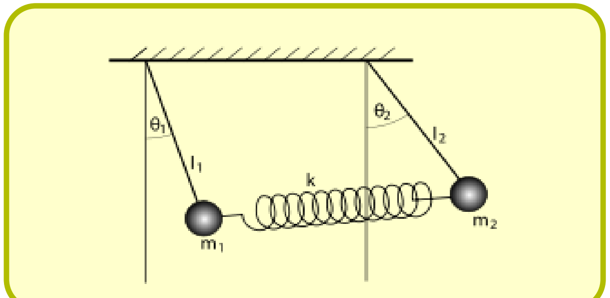
- **Fluctuating** generation
- (Additional) **impreciseness** of generation due to weather **forecast**
- Generation units with **power electronics**

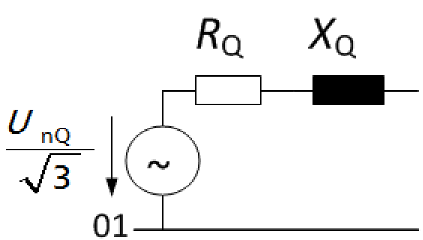



Source: BMU-AGEE-Stat

New energy mix changes network behavior







- **Power electronics** replaces synchronous generators, e.g.
  - Wind farms (doubly-fed and full-converter-fed machines)
  - Photovoltaic
  - HVDC of offshore-wind farms

A network with this **new energy mix** (less synchronous generators more power electronics) tends to be

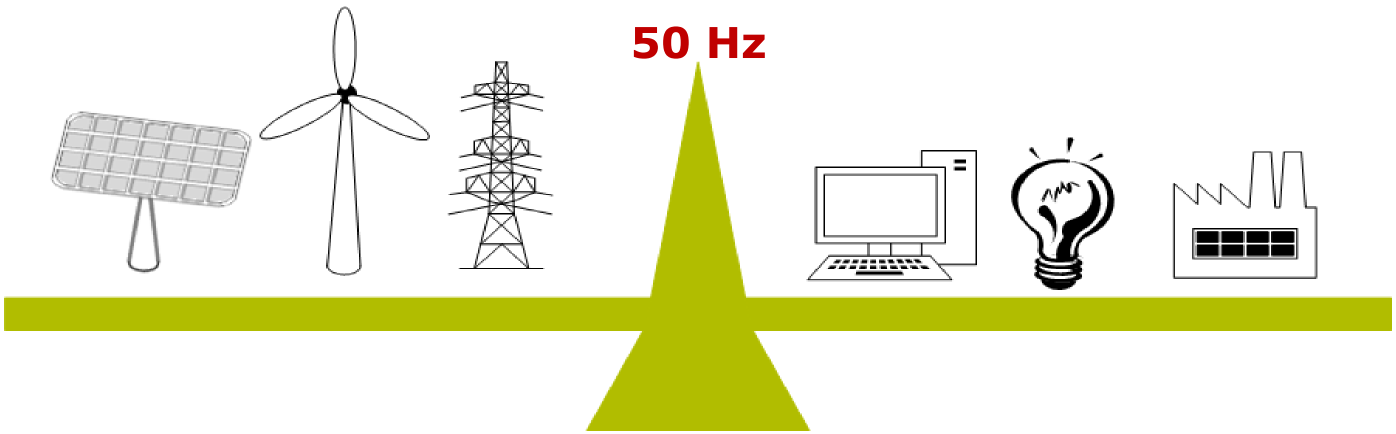
- weaker (less voltage stable)
- faster (less frequency stable)

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Challenges for the future energy systems

TECHNISCHE UNIVERSITÄT DARMSTADT

Power Generation | **Power Consumption**



Possible technical actions

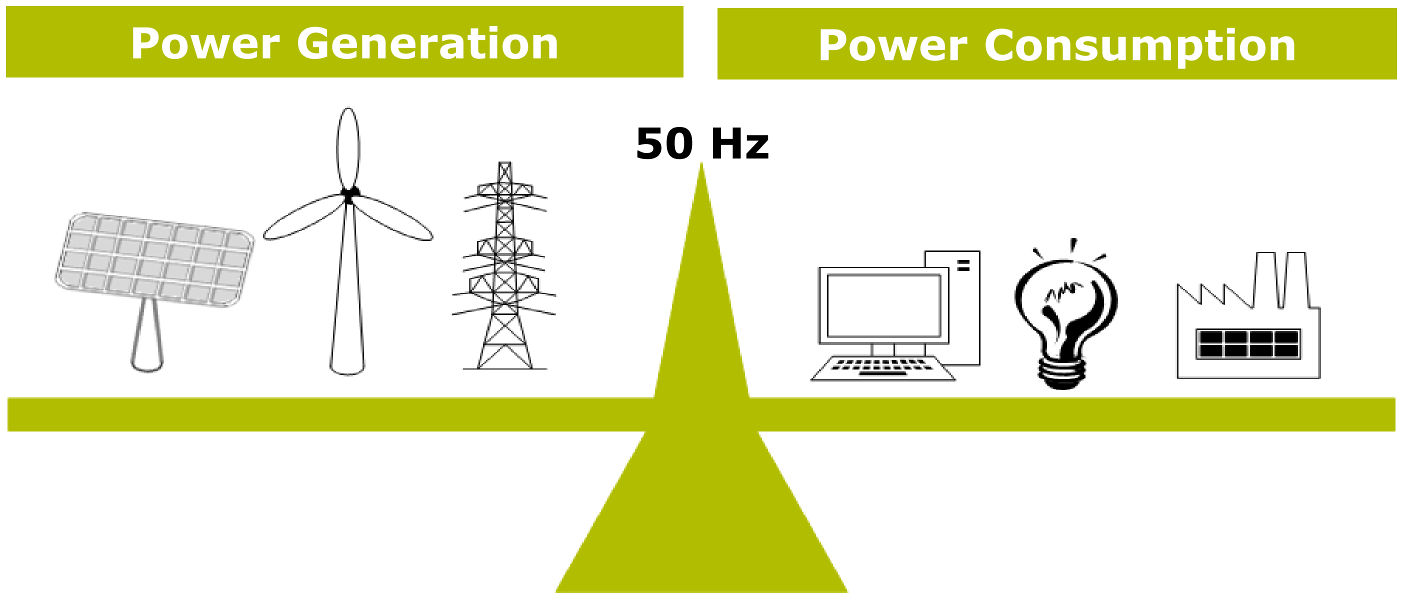
Flexible power plant operation

"Smart" technologies

Energy storage (Power-2-X)

Expansion of electrical networks

Challenges for the electrical power systems



Distribution networks

- Integration of volatile decentralized electrical energy

➔ Flexibilisation of system operation "Smart Grids"

Transmission networks

- Transmission with low losses over long distances (HVDC)
- Operation without large generating units

Operation of Research Infrastructures
Technical challenges of electrical power supply

The network connection point may have different behavior in the future

- Voltage Stability ("stiffness") esp. for pulse operation
- Reliability
- Demand Side Management ("Power to Cryo")
- Request for System Services
- Voltage Quality (harmonics)

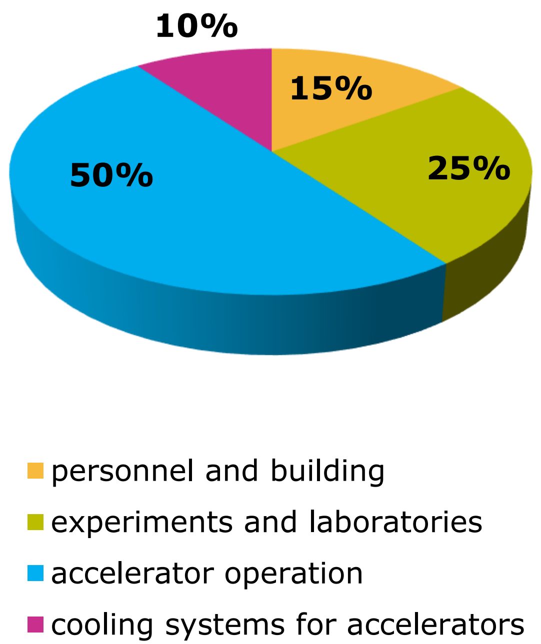
Operation of Research Infrastructures
Costs of electrical power supply

"Design of electricity market"
(Whitebook, July 2015):
Integration of renewable energies, storage and flexibility are exposed goals of the future electricity market.

Costs for electrical power supply will most probable be dependent on

- Active Power
  (peak power and energy per year)
- Reactive Power esp. for pulse power
  (power factor)
- Voltage Quality
- Flexibility of consumption
  (Storage ⇔ Time shift of loads)

Electrical Energy Consumption of RIs
Status Quo



Saving potential is located in different areas

Personnel and Building

- Building technologies
  - Lighting
  - Ventilation
- Energy efficiency of data center (e.g. Green Cube, GSI)
- Computers

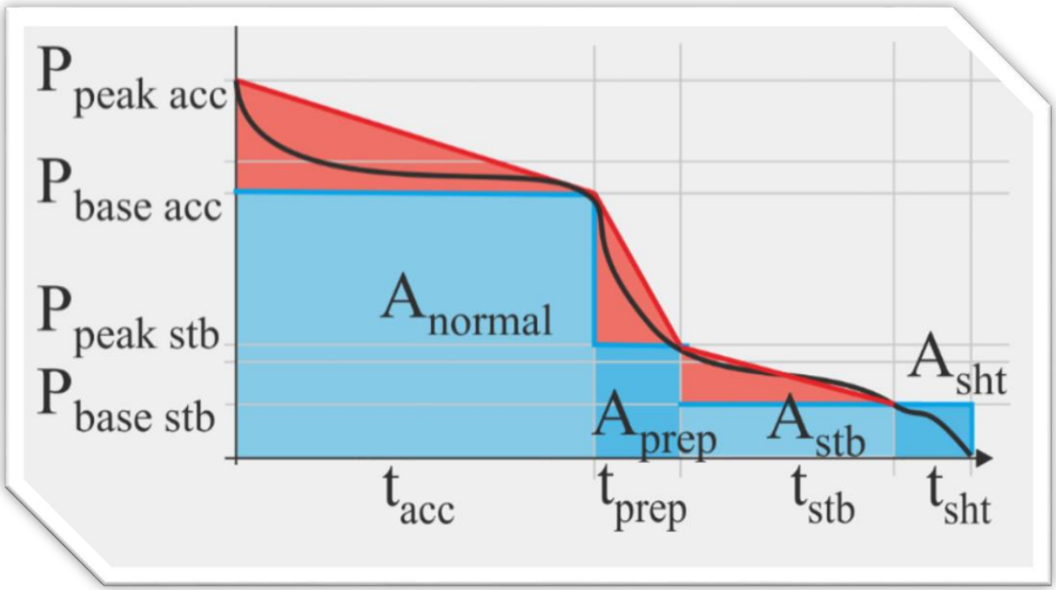
Investigations show that the share can be reduced from 15 % to 5 %

Cooling Systems (Cryo)

- Optimization of technology
- Changed positioning of plants (load shifting potential)
- Operation time and power

Analysis of saving potential via the power distribution curve

TECHNISCHE UNIVERSITÄT DARMSTADT



Identify areas of operation in electrical power consumption:

- Shut-down time
- Stand-by time
- Preparation time
- Acceleration and experiment time

- Power consumption during stand-by and shut-down times causes losses.
- The steeper the curve in every stage the more inefficient the unit is.
- The number and time period of shut-downs throughout one year has an influence on energy efficiency -depending on the energy consumption of the start-up process.

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Goals and measures of Energy Management for optimized power and energy consumption

TECHNISCHE UNIVERSITÄT DARMSTADT

Sustainability (environment)

- **Goals:**
  - Reduction of carbon dioxide
  - "Green" generation
  - Be part of the transition
  - Less consumption
- **Measures:**
  - Increase energy efficiency of cooling, heating and the whole electrical power supply system
  - Erection of renewable generation

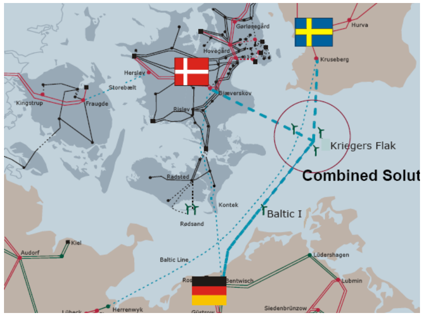
Reliability (Technical power supply)

- **Goals:**
  - Ensure a reliable and safe power quality of the power system
- **Measures:**
  - Erection of own power generation
  - Network analysis
  - Enable voltage control
  - Asset Management
  - System Services (e.g. reactive power)
  - Combine energy systems (heat, steam, electrical power)
  - Energy efficiency

Profitability (Costs of power, energy)

- **Goals:**
  - Decrease costs of power and energy
- **Measures:**
  - Implementation of an energy management system
  - Technical aspects of contracts
  - Demand side management
    - Planning of production (experiments)
  - Management of change process

Conclusions



Quellen: Dii, Stattnet, energienet.dk, Svenska Kraftnet, Vattenfall, Airtricity

The energy transition requires a change of paradigm of the existing energy systems (electrical power, heat, gas, etc.).

Research infrastructures are consumers with a potential to increase the share of renewable energies in power supply with the goal to reduce carbon dioxide:

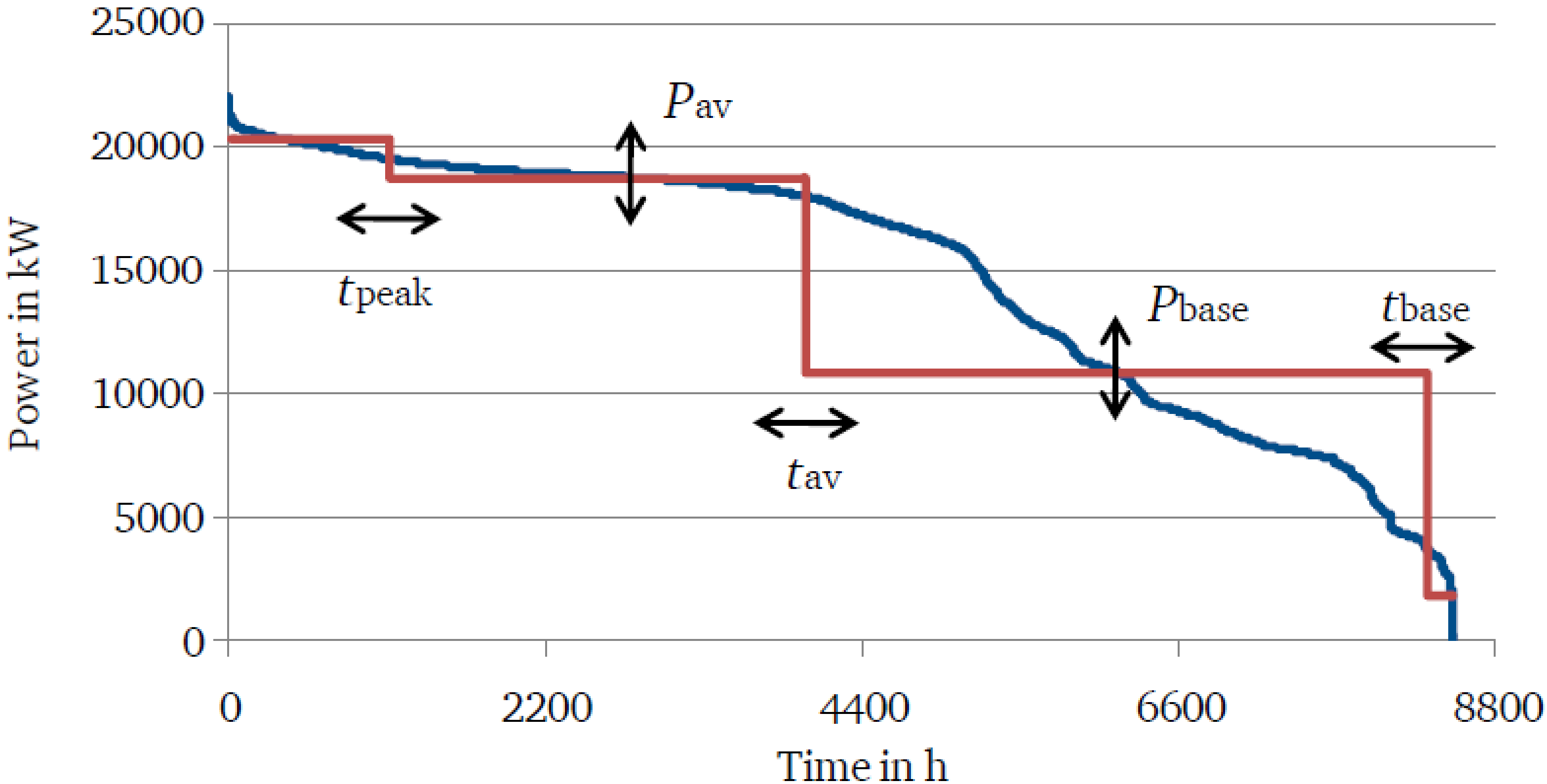
- increase energy efficiency
- optimize energy and power consumption with help of an energy management system
- make use of and combine more than one energy system (electrical power, heat, coldness) – if advantageous.
- reduce "carbon footprint".

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Elektrische
Energieversorgung
unter Einsatz
Erneuerbarer Energien

Analysis of saving potential via the power distribution curve

6000 hours of beam operation



Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

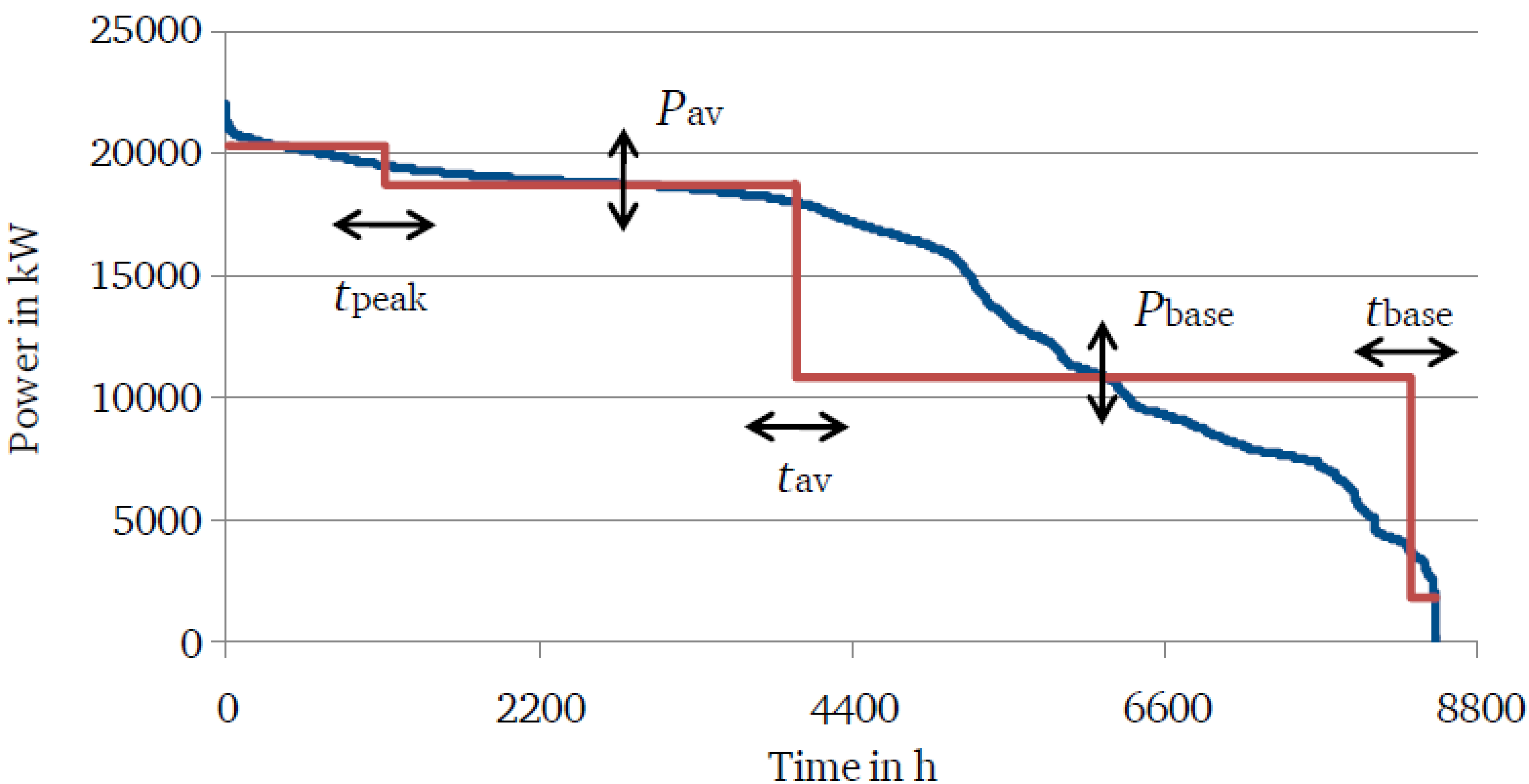
General saving potentials and Green Generation

Contribution to Stability by consuming energy depending on the current status in the grid	Implementation of own generating plant, especially from renewable energy sources	Using the full capacity
Intelligent control system/ coupling system	Increase of energy efficiency of one plant may lead to less need of cooling devices	Increase of voltage quality, Decrease of harmonics

Analysis of saving potential via the power distribution curve

TECHNISCHE UNIVERSITÄT DARMSTADT

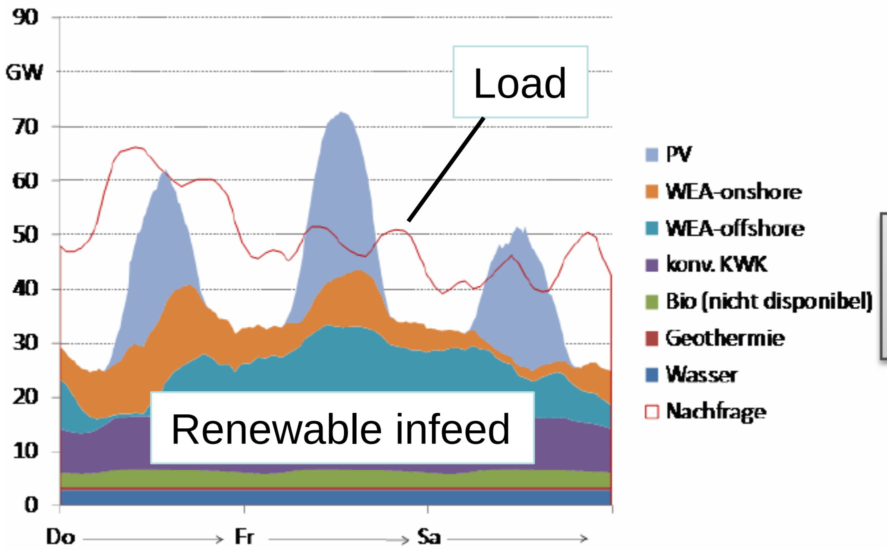
Identifying the different stages helps to differentiate between the different areas of operation:

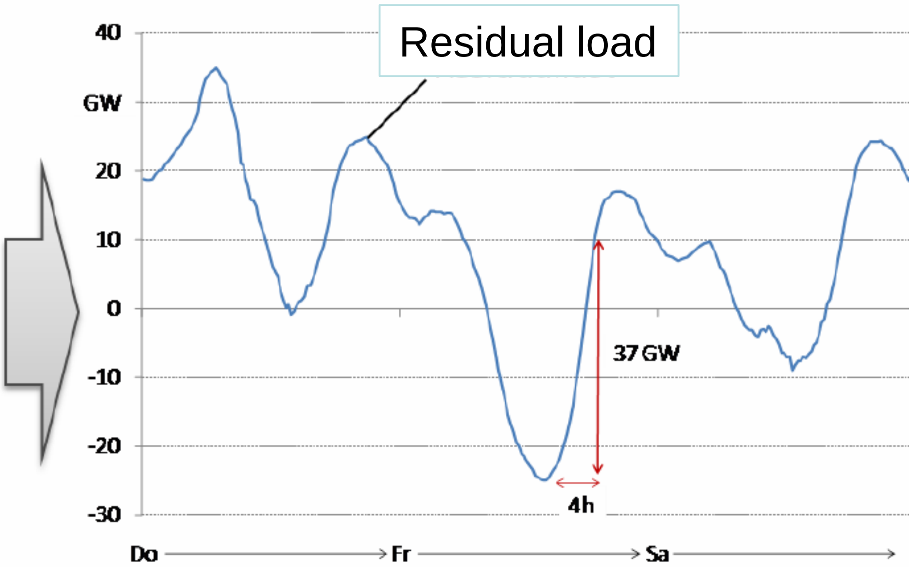


ne
e

Challenges for conventional power plants

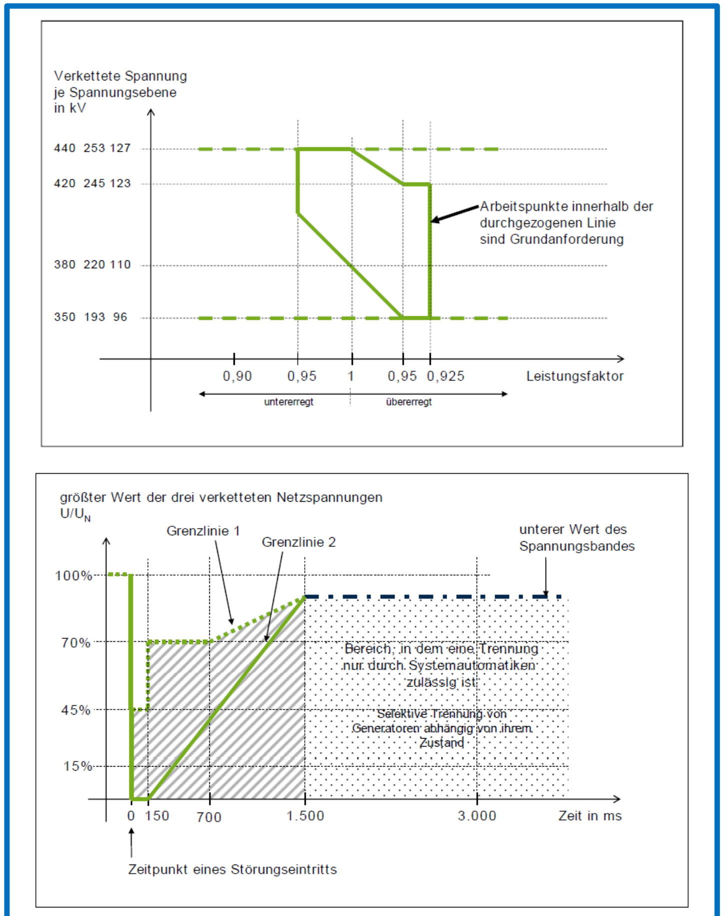
- High gradients of renewable power & residual load
- Minimisation of "must-run" capacity desired
- Frequent start-ups and shut-downs require flexibility
- High efficiency for partial load





Source: Report Consentec, 2011

Challenges for renewable energies



Source: TenneT TSO GmbH

Grid Codes to comply with to enable electrical power infeed

- Reactive power infeed/consumption, voltage band/control
- Behavior during and after disturbances
  - "Low Voltage Ride Through"
  - Voltage support
- Voltage quality (harmonics, flicker)
- Neutral point treatment
- Network protection

Vorträge
www.vde.com/cigrecired2015

- Lastkappung, Lastflexibilität
- Hermann:
  Integration von Erneuerbaren Energien, Speicher und Lastflexibilität sind erklärte Ziele des Strommakrtdesigns.

- Energieeffizienz,
- Jennes:
  Wärme Elektro, heizung
- Nachfrage regelt den Marktpreis

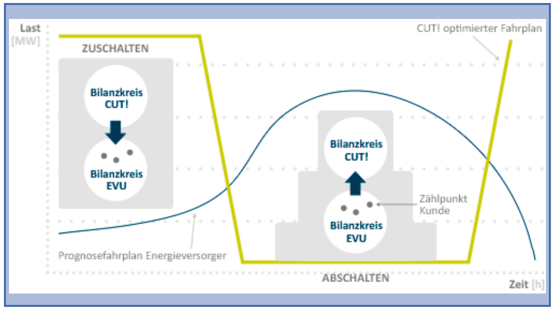
Measures to increase electrical energy efficiency of Research Infrastructures

TECHNISCHE UNIVERSITÄT DARMSTADT

Reduction of average load P_{av}

Reduction of base load P_{base}

Reduction of average operation time t_{av}



Increase of energy efficiency

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Overview of Research Areas (1/2)

TECHNISCHE UNIVERSITÄT DARMSTADT

- **Generation**
  - Structure of power systems with 100 % renewable energies
  - Centralized and decentralized power infeed
  - How to come from the power system of today to the future power system?

- **Power Systems**
  - Change in power infeed leads to change in power system
  - DC technologies
  - Distribution networks with high degree of renewable infeed
  - System behavior:
    - Stability (frequency, voltage, transient)
    - Voltage Quality
  - Network control/management

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Overview of Research Areas (2/2)

TECHNISCHE UNIVERSITÄT DARMSTADT

Future mix in power supply

- How much inertia is needed by the power system?
- Power electronics in transmission and distribution networks
- Requirements of storage devices
- Renewable energy and system services
- Optimization of conventional power plants' dynamics
- Voltage quality and volatile renewable generation

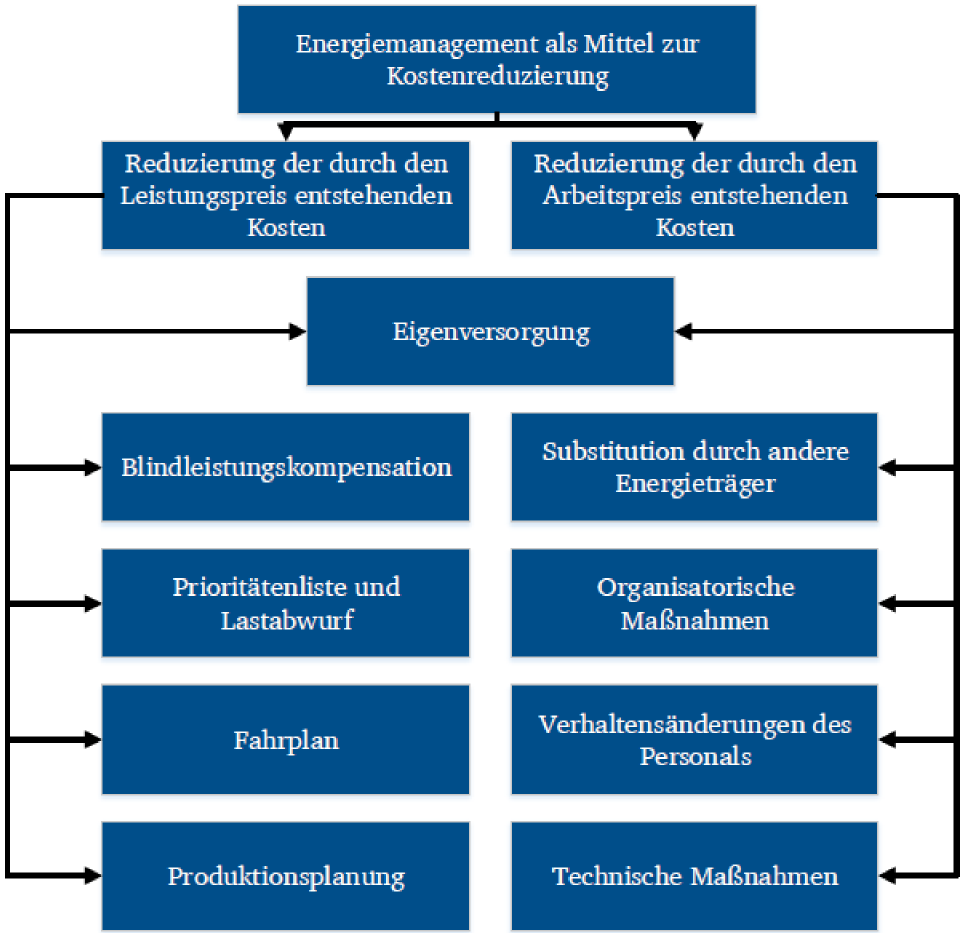
DC networks and the future of AC-networks

- Control concepts for DC networks
- Coordination and control of AC and DC networks
- Smart grids and Overlay networks
- Stand-alone and islanded networks
- Network control for central and decentralized power infeed

Elektrische Energieversorgung unter Einsatz Erneuerbarer Energien

Energy Management as mean for cost reduction

TECHNISCHE UNIVERSITÄT DARMSTADT



Quelle: Volker Hessel, Energiemanagement, 2008

Energiemanagement als Mittel zur Kostenreduzierung

Reduzierung der durch den Leistungspreis entstehenden Kosten

Reduzierung der durch den Arbeitspreis entstehenden Kosten

Eigenversorgung

Blindleistungskompensation

Substitution durch andere Energieträger
Prioritätenliste und Lastabwurf
Organisatorische Maßnahmen
Fahrplan
Verhaltensänderungen des Personals
Produktionsplanung
Technische Maßnahmen