



# **Institute for Advanced Sustainability Studies IASS in Potsdam**

## **Integration of distributed energy resources into the grid**

—

## **Results from a interview series with German distribution grid operators**

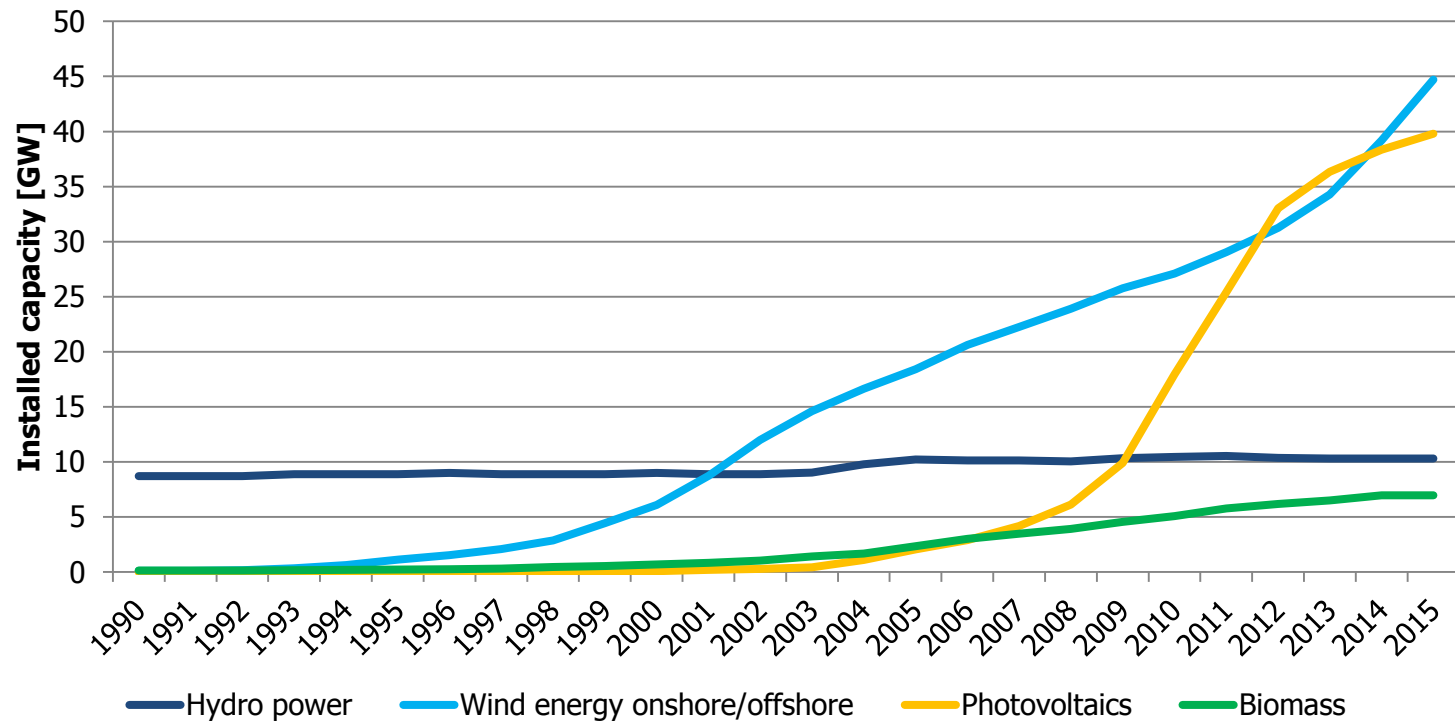
Lisboa, November 2016

**Benjamin Bayer**

1. Basic information on renewables in Germany
2. Integration of photovoltaics in the low voltage grid
3. Regulatory framework for distribution grid operators

## Basic information on renewables in Germany

# Development of renewable energies in Germany



# Structure of the electric grid



The diagram illustrates the hierarchy of the electric grid. It consists of four horizontal boxes on the left, each containing a voltage level. The top box is for the Extra high voltage grid (220 kV and 380 kV). The next three boxes (High voltage grid at 110 kV, Medium voltage grid at 20 kV, and Low voltage grid at 0,4 kV) are grouped together by a large bracket on the right, indicating they are managed by the Distribution System Operator (DSO). Each box is preceded by a circular icon: a power line tower for the high voltage levels and a sun with rays for the medium and low voltage levels. To the right of the boxes, two large brackets group them under the labels 'Transmission System Operator (TSO)' and 'Distribution System Operator (DSO)'.

Extra high voltage grid  
220 kV and 380 kV

Transmission System Operator  
(TSO)

High voltage grid  
110 kV

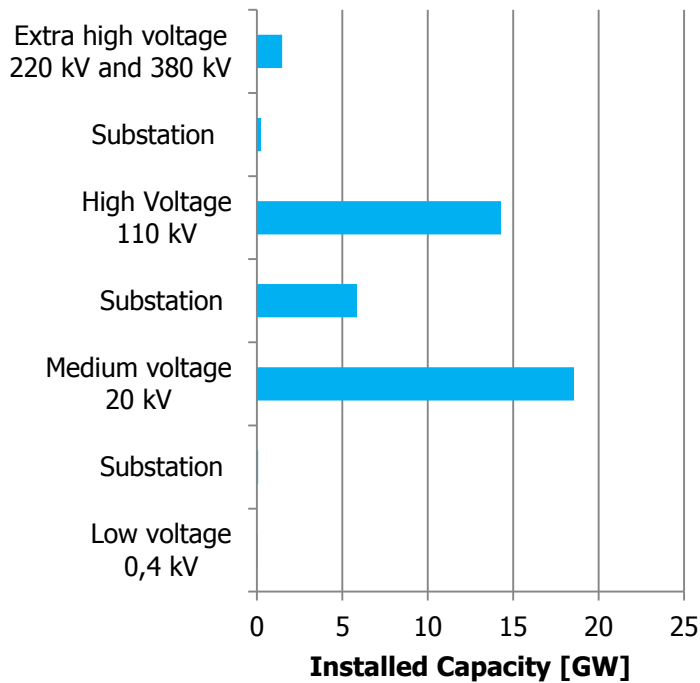
Medium voltage grid  
20 kV

Distribution System Operator  
(DSO)

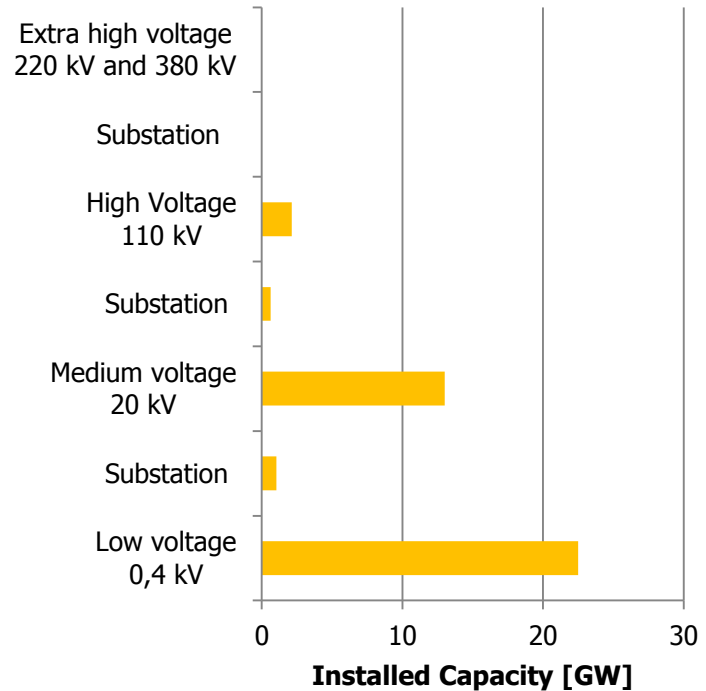
Low voltage grid  
0,4 kV

# Grid connection of wind energy and photovoltaics

## Wind energy



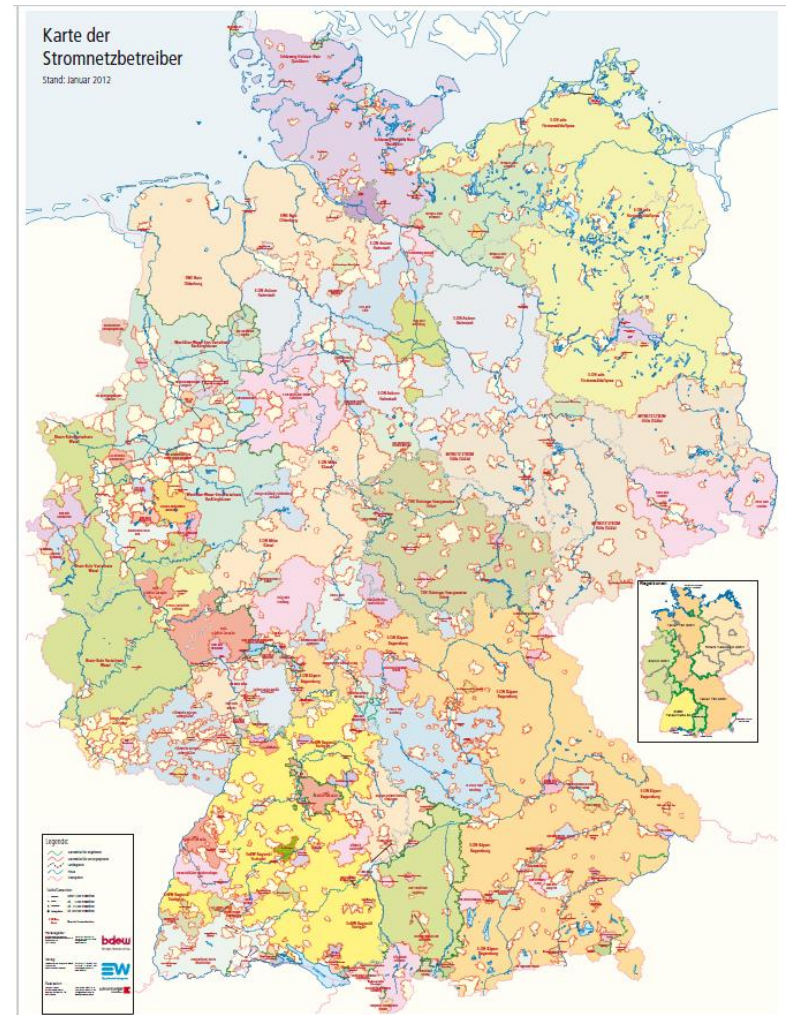
## Photovoltaics



## Integration of photovoltaics into the low voltage grid

# Interview series with distributions system operators

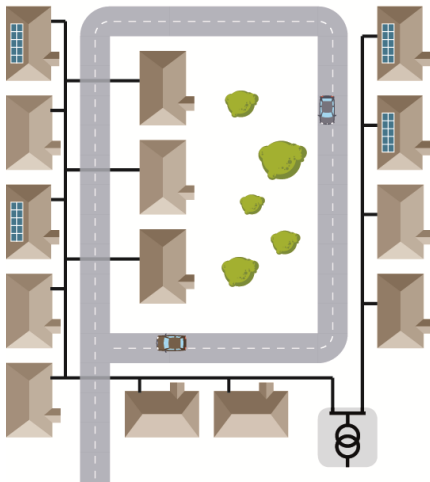
- 881 DSOs operate the low, medium and high voltage grid
- We conducted 10 interviews with the largest DSOs



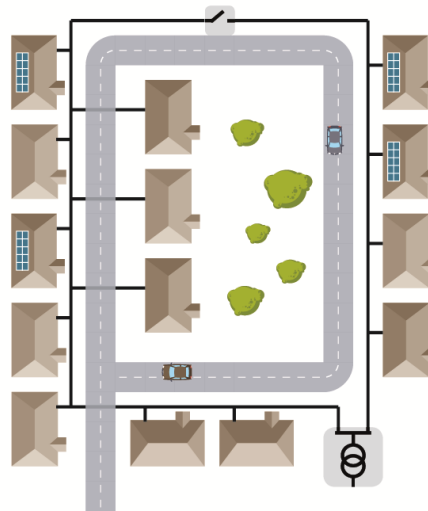


# Grid structure

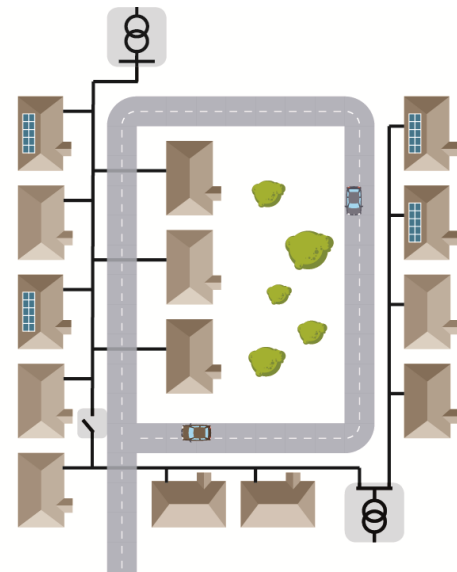
Radial distribution



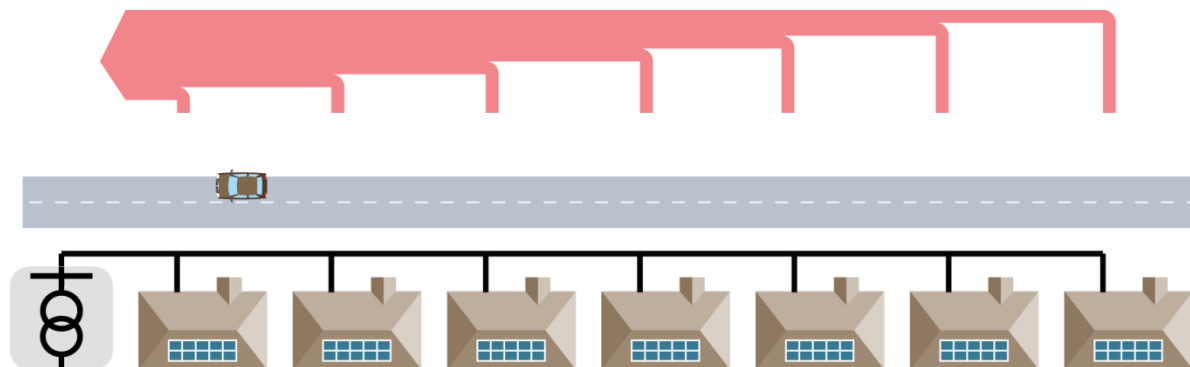
Loop distribution



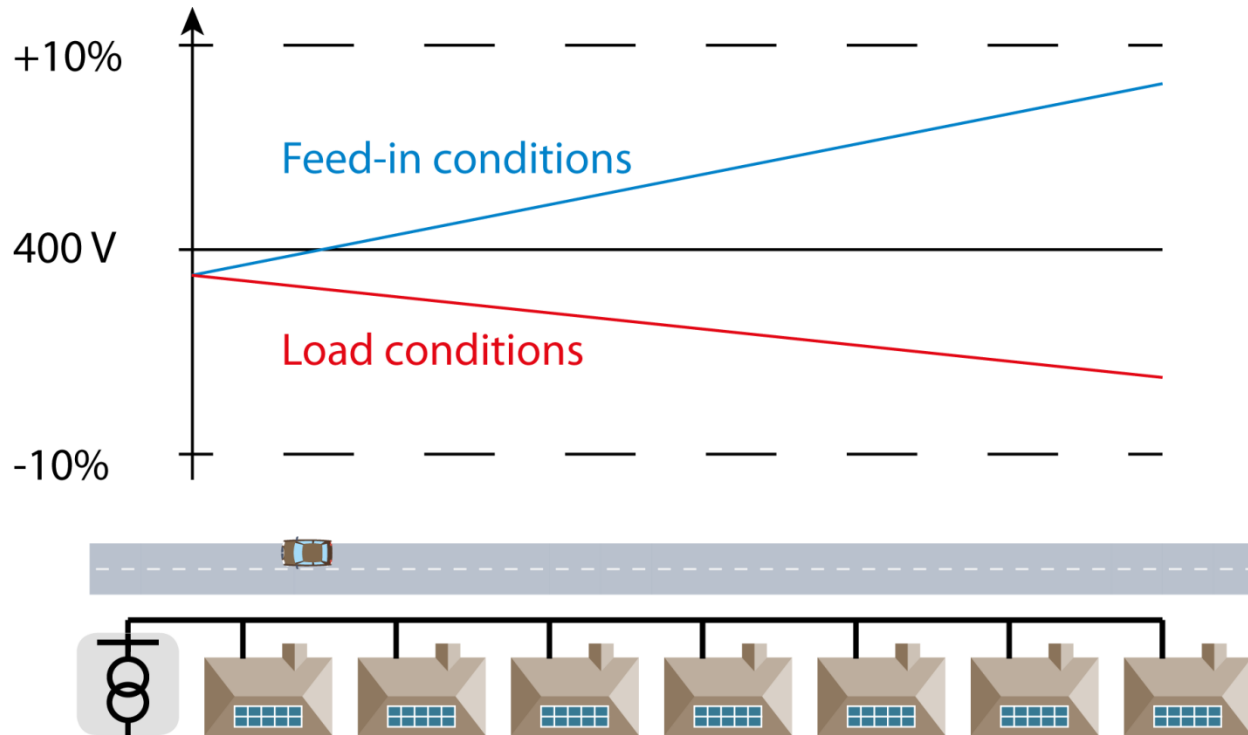
Meshed grid



# Impact of PV systems on amperage

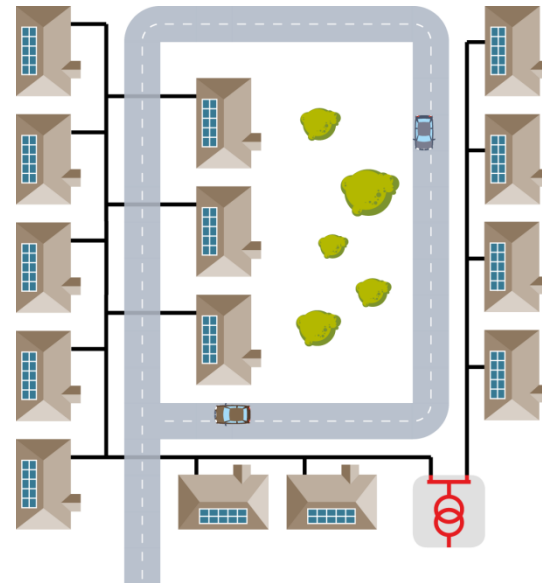


# Impact of PV systems on voltage



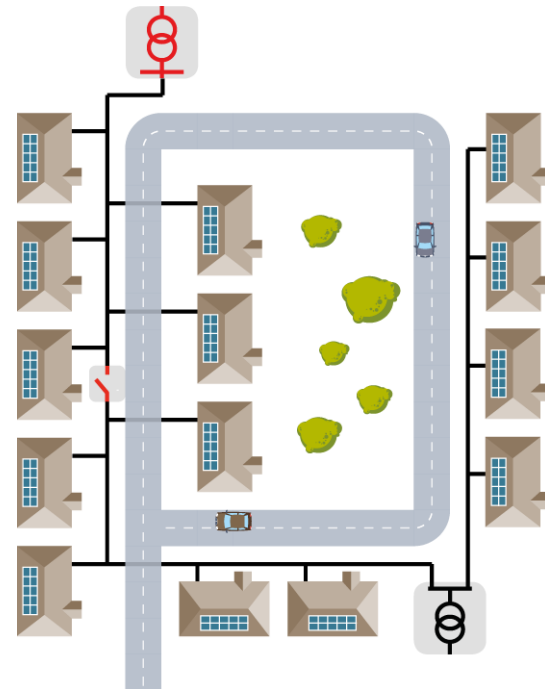
## Options

- Replace transformer
- Install additional transformer(s)
- Replace cable
- Lay additional parallel cable(s)
- Change grid topology



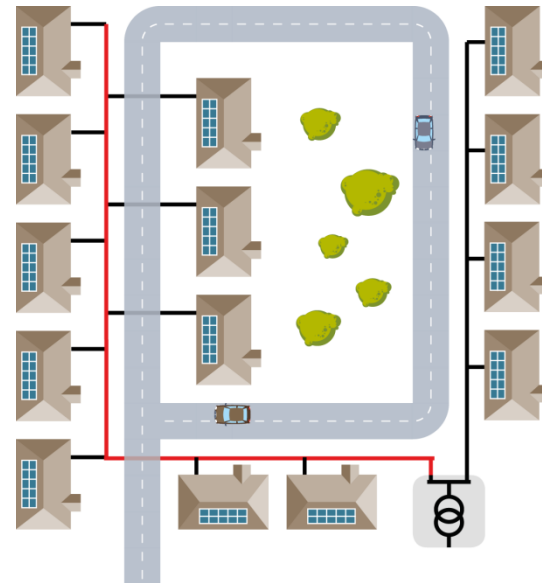
## Options

- Replace transformer
- Install additional transformer(s)
- Replace cable
- Lay additional parallel cable(s)
- Change grid topology



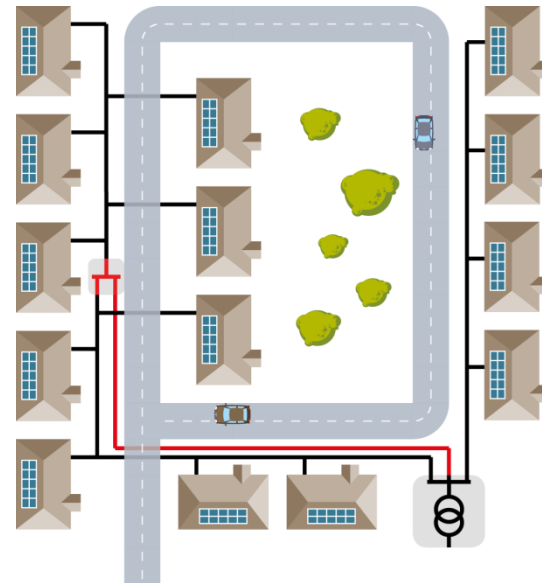
## Options

- Replace transformer
- Install additional transformer(s)
- Replace cable
- Lay additional parallel cable(s)
- Change grid topology



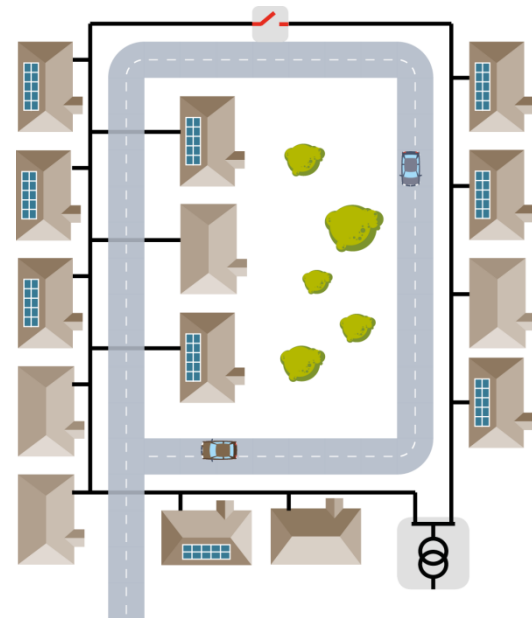
## Options

- Replace transformer
- Install additional transformer(s)
- Replace cable
- Lay additional parallel cable(s)
- Change grid topology



## Options

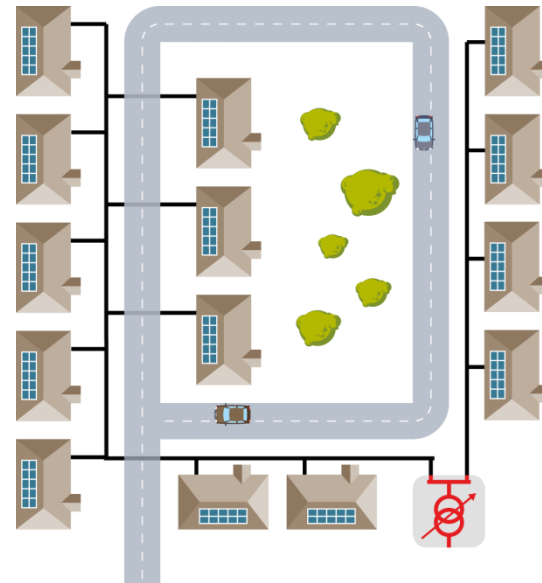
- Replace transformer
- Install additional transformer(s)
- Replace cable
- Lay additional parallel cable(s)
- Change grid topology





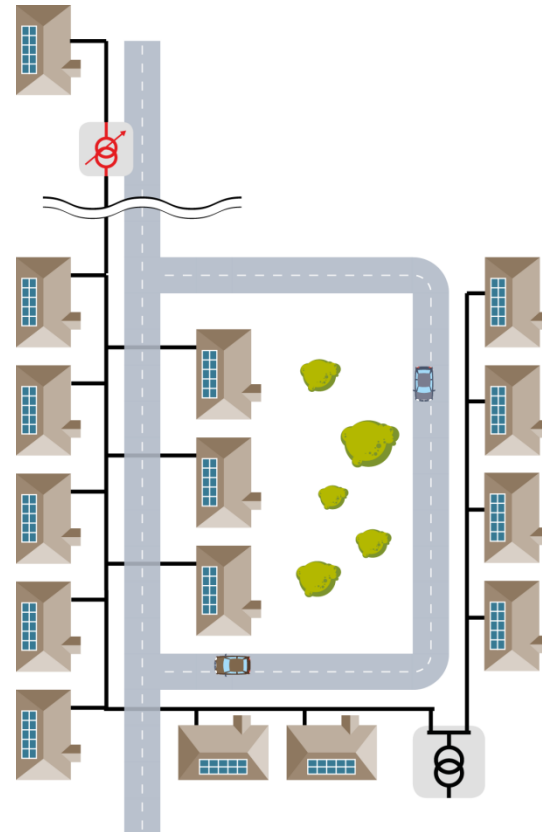
## Options

- Variable transformer
- Booster
- Wide area control
- Reactive power feeding



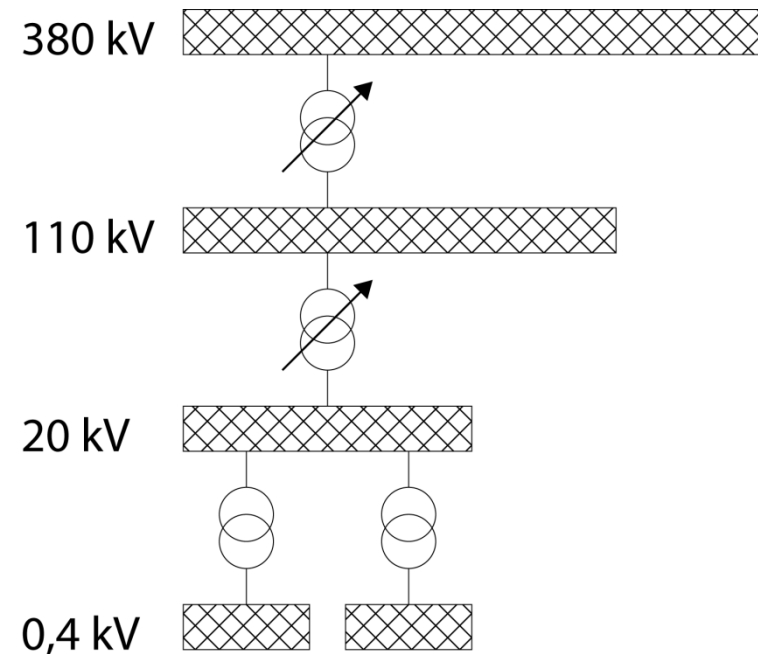
## Options

- Variable transformer
- **Booster**
- Wide area control
- Reactive power feeding



## Options

- Variable transformer
- Booster
- Wide area control
- Reactive power feeding



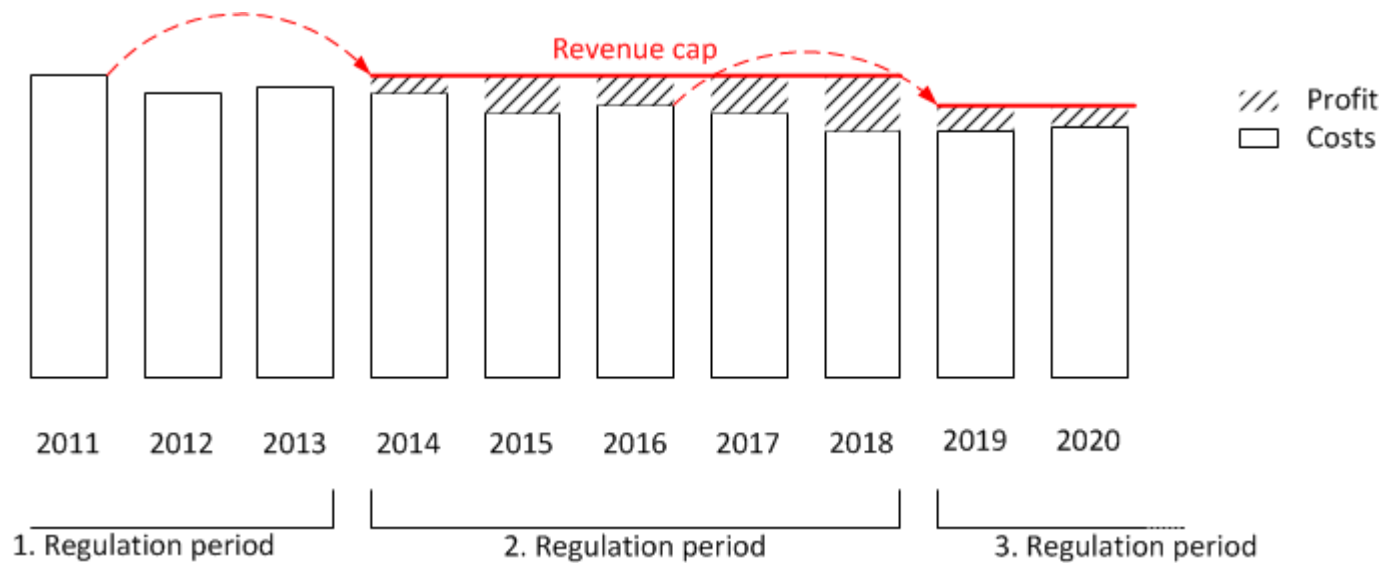
## Options

- Variable transformer
- Booster
- Wide area control
- Reactive power feeding

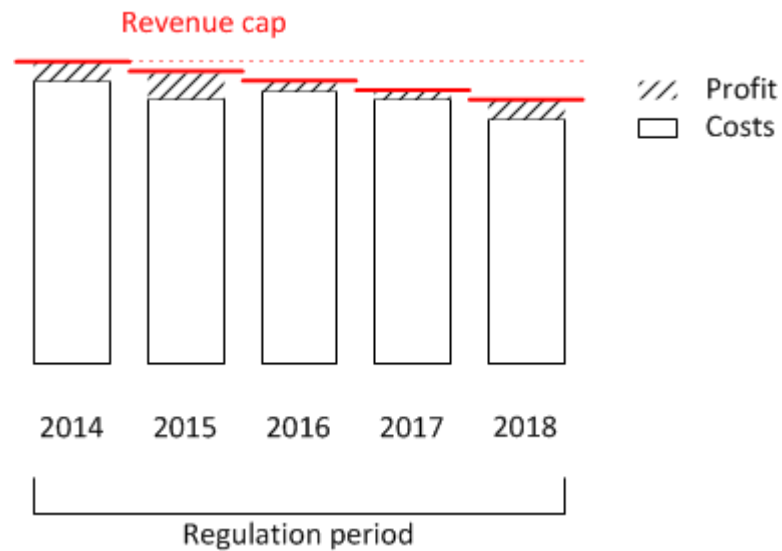
## Germany's incentive-based regulation

- Germany's regulator determines a revenue cap (budget) for each operator.
- This revenue cap is primarily based on past costs of grid operators.
- Grid operators calculate the grid fees according to the revenue cap.
- The regulator established two incentive mechanisms to keep costs low.

# Incentives through budget approach



# Incentives through efficiency comparison





- Germany's incentive-based regulation is technology neutral.
- Grid operators could implement the desired solutions in the past.
- There are no restrictions regarding the use of new technologies.
  
- Strong incentive for capital intensive solutions as there's an grid operators receive an return on equity of 9%.

- Grid integration of distributed energy is a challenge but there are several technical solutions available.
- Conventional grid extensions were in most cases the most efficient solution.
- In economic terms, grid operators in Germany are not affected negatively by the development of distributed energy resources.

Obrigado pela atenção!

Benjamin Bayer  
Research Associate  
Institute for Advanced Sustainability Studies  
[benjamin.bayer@iass-potsdam.de](mailto:benjamin.bayer@iass-potsdam.de)