2015-09-10, A. Oudalov, C.Y. Evrenosoglu, A. Marinakis, O. Mousavi, ABB Switzerland Ltd. Corporate Research

Value of Demand Response

Reduction of system OPEX

Value of demand response
Outline

- Future energy transition
- DR reduces system OPEX
- Problem definition

  Model the performance of DR in a unit commitment model
- Example

  Scenarios for Germany 2015 and 2040
- Conclusions

- ABB Corporate Research project “Future Utility” investigating alternatives scenarios of electric power sector transition and assessing potential of different technologies to support these changes
- We see demand response role will grow with a need to have more flexible grids in light of growing amount of variable RES

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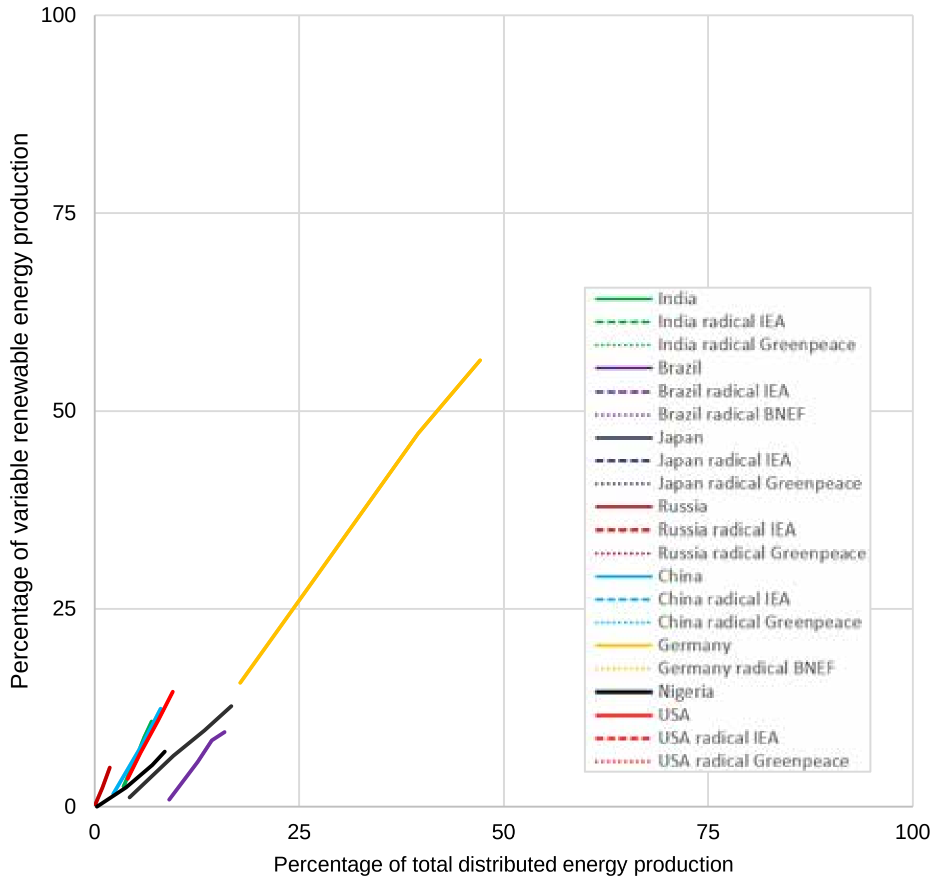
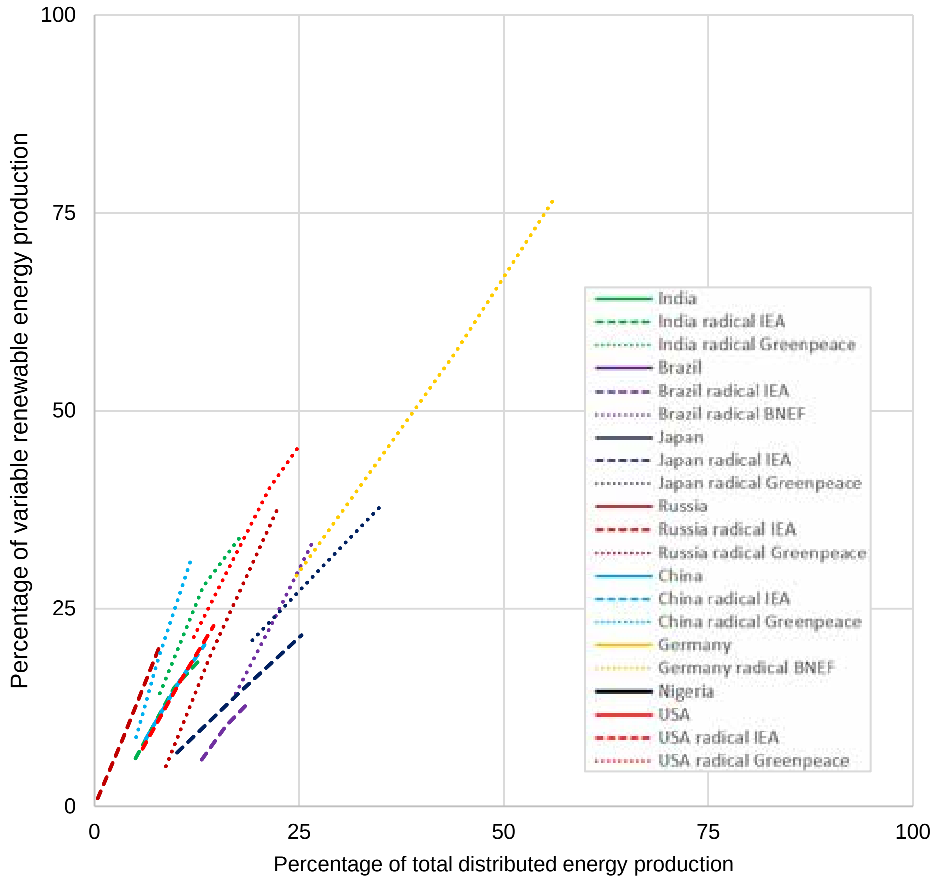
Future energy transition scenarios
Anticipated trajectories 2015-2040



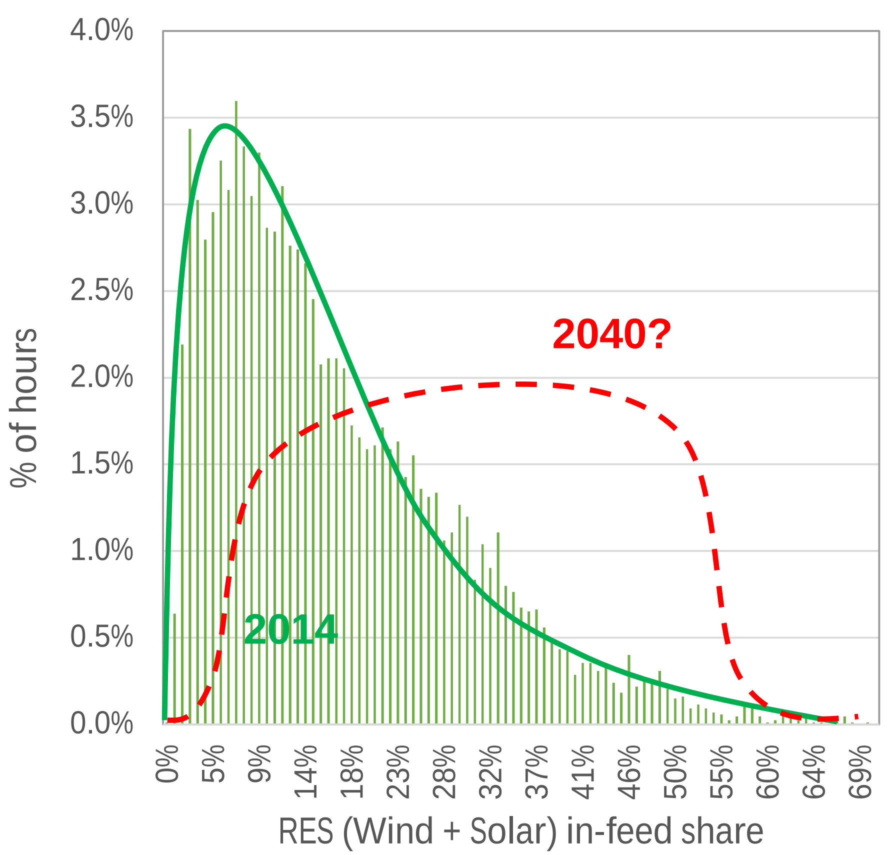
- **Plausible scenarios:**
  - V-RES < 15%
  - Distributed-ness <15%

Future energy transition scenarios
Anticipated trajectories 2015-2040



- **Plausible scenarios:**
  - V-RES < 15%
  - Distributed-ness <15%
- **More ambitious scenarios**:
  - V-RES < 25%
  - Distributed-ness <25%
- **Radical scenarios**:
  - V-RES < 45%
  - Distributed-ness <35%
- Germany shows exceptional progress on V-RES but as part of ENTSO-E the global European figures are at the same levels as above

Future energy transition scenarios
Growing need for system flexibility

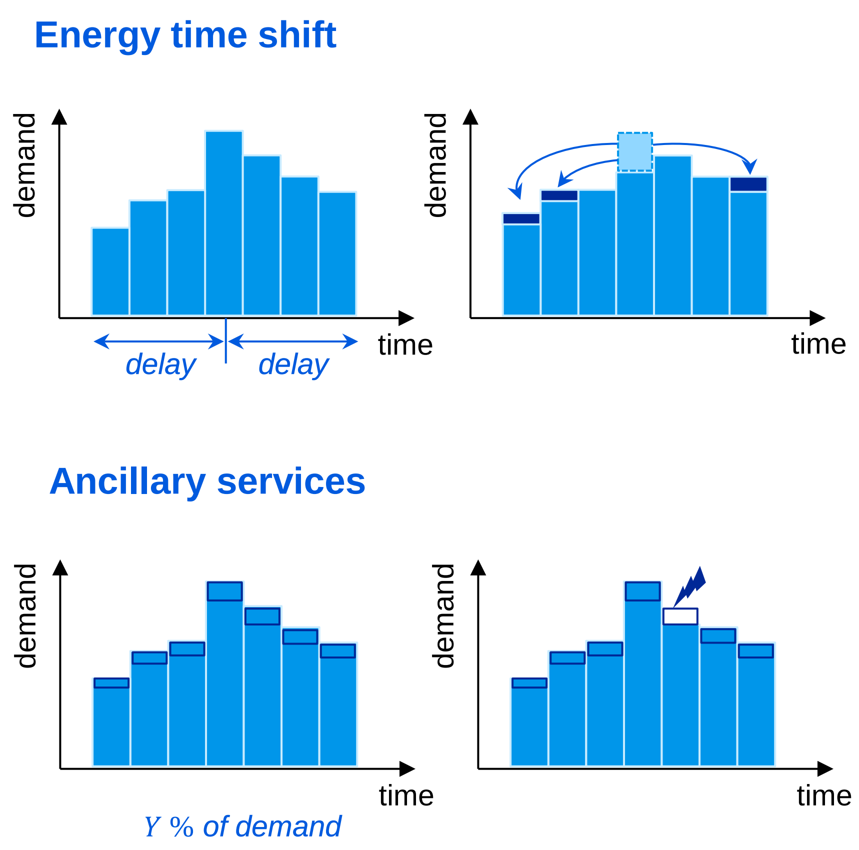


- Wind and solar supply in 2014:
  - up to 15% of load feed-in for half of the time
  - >50% of load feed-in was reached 1.6% of the time (140 hours)
  - record maximum of 71% of load feed-in was reached once on Sunday, May 11th at 2 pm, when the demand was 52 GW
  - 1.8% of load feed-in at the highest demand, 79 GW, was on December 3rd at 6 pm
- In the future the V-RES in-feed share will grow and create a need for more system flexibility

Despite the 74 GW of installed capacity, wind and solar do not present challenges yet due to low feed-in

Value of demand response
Types of demand response

- Demand Response (DR) is defined as the change in the electricity use in response to the electricity price changes or the system operator's control signal
- Energy time shift: a percentage of demand can be anticipated or postponed within a given time delay
- Ancillary services (e.g. frequency regulation): a percentage of demand can be changed by the system operator in case of contingency
- We focus on OPEX (production cost) savings: avoided fuel, startups, shutdowns, ramping, CO2 emission cost, etc.



Integration of demand response to unit commitment
Mathematical formulation for energy time shift

$$P_t = P_t^0 - P_t^- + \sum_t P_{t,\tau}^+$$ change in demand

P_t: modified demand after demand response.

P_t^0: initial demand

P_t^-: reduction of demand

$P_{t,\tau}^+$: compensation of reduced demand

$$P_t^- = \sum_\tau P_{t,\tau}^+$$ reduced demand should be compensated within time delay

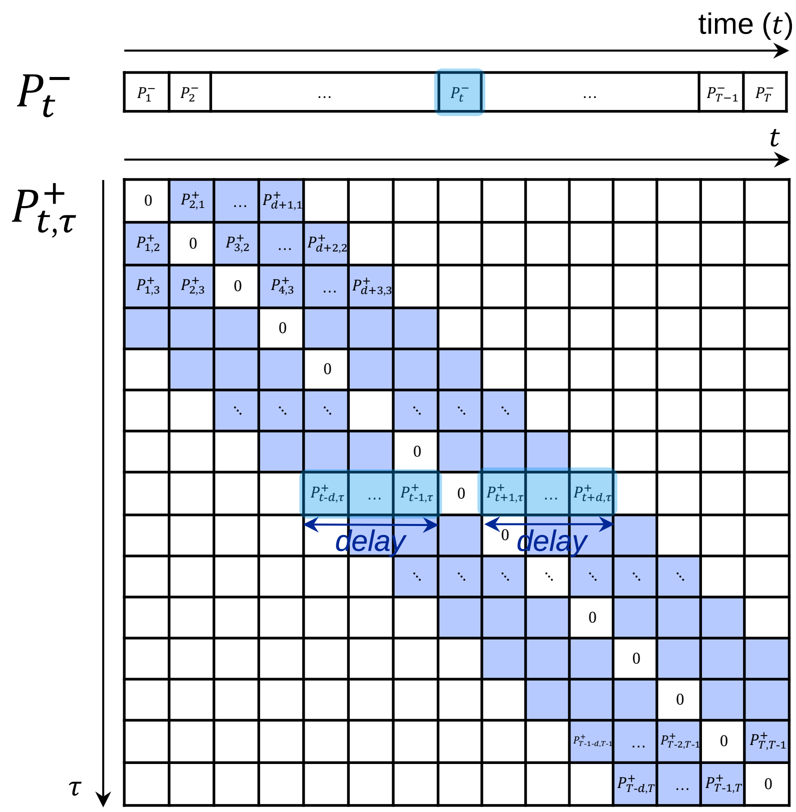
$$P_t^- \leq u_t\, X\%$$ limit for change of demand

$u_t \in \{0,1\}$: deciding between the reduction of demand ($u_t = 1$) and its compensation ($u_t = 0$)

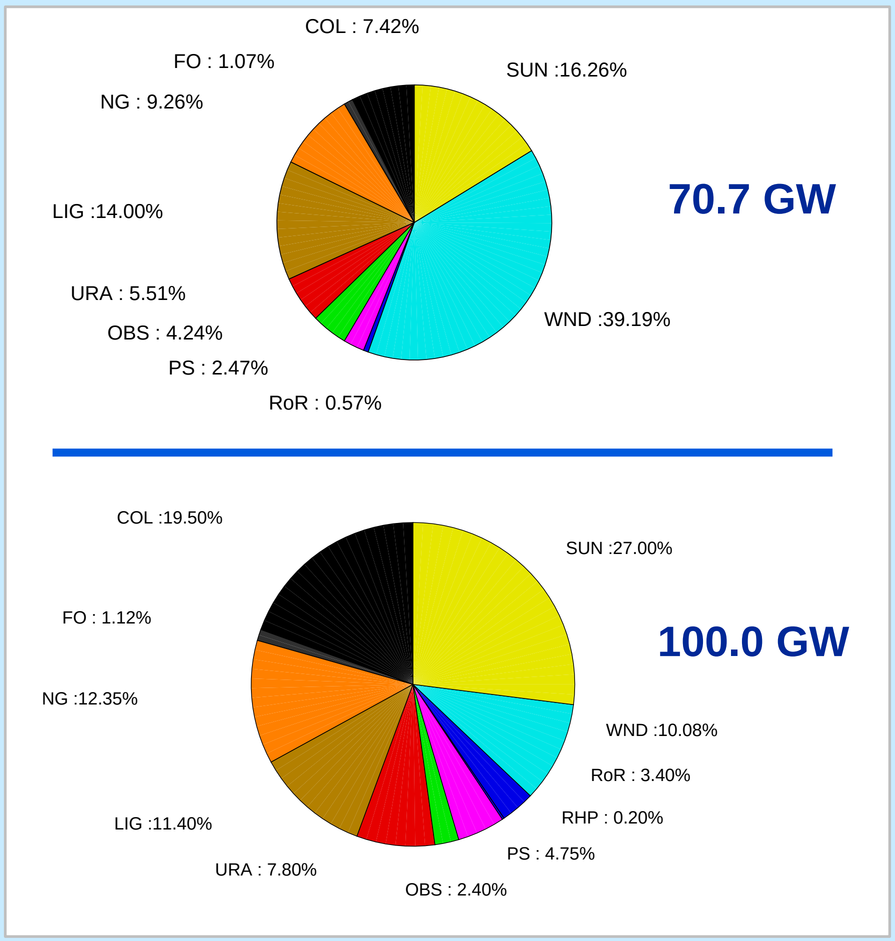
$X\%$: percentage of demand participating in demand response

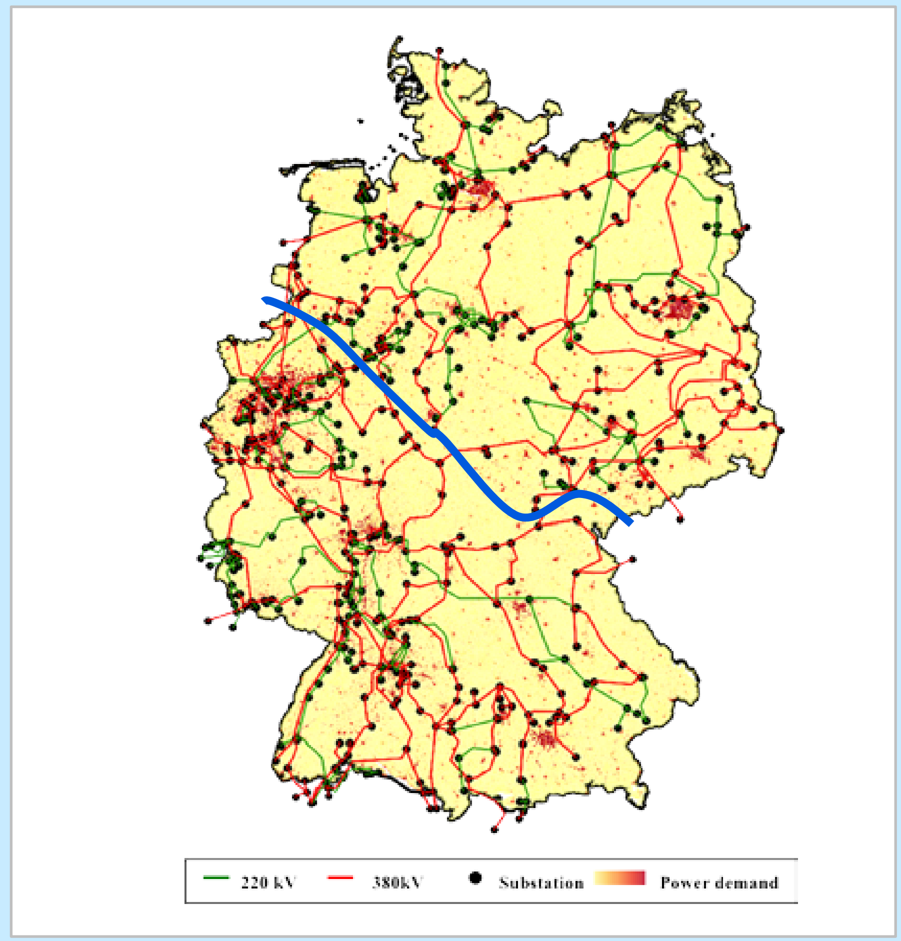
$$\sum_t P_{t,\tau}^+ \leq (1 - u_t)\, X\%\, K$$ compensation is allowed if there is no demand reduction

K: sufficiently big number



Unit commitment analysis
Germany: regional installed capacity 2014

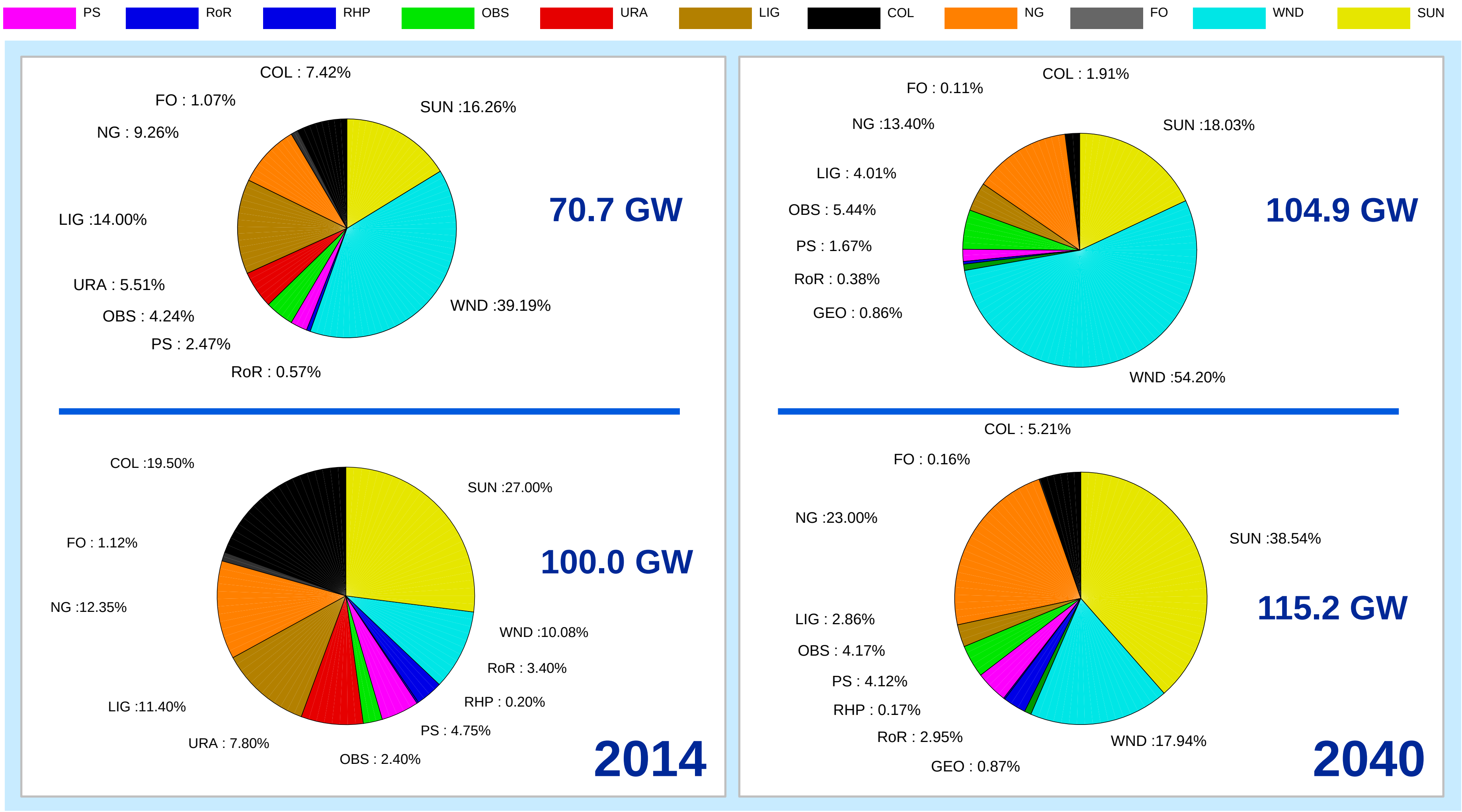




Source: Velocity Suite, Bundesnetzagentur

Germany is divided in 2 zones: north is dominated by wind, the south is by solar

Unit commitment analysis
Germany: regional installed capacity 2014 & 2040



Source: Energiewende, Fraunhofer

The capacity of RES increases, nuclear phase-out, and coal capacity decreases

Unit commitment analysis

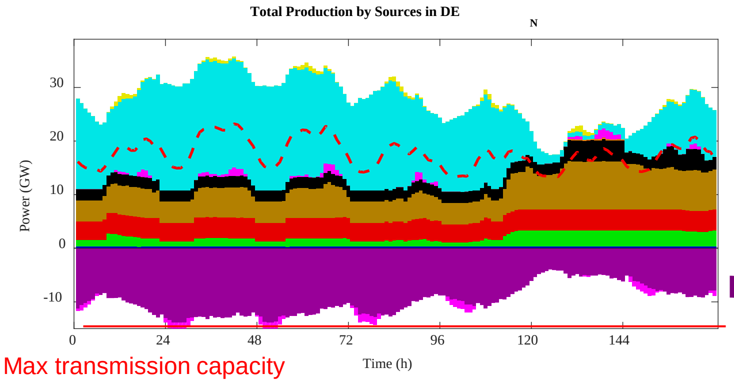
Germany: results for a week in December 2014

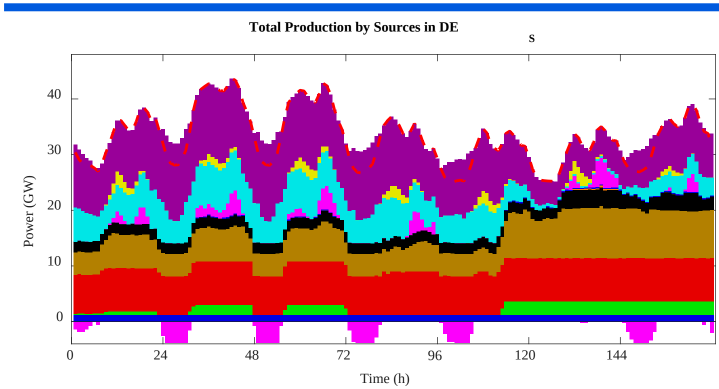
demand curve w/o demand response — demand curve with demand response

PS | RoR | RHP | OBS | URA | LIG | COL | NG | FO | WND | SUN

Base case: no DR

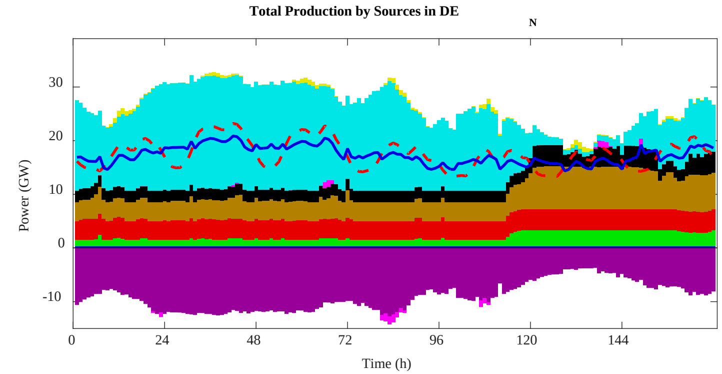
OPEX: 167.47 M€
CO_2: 0.34 tonne/MWh

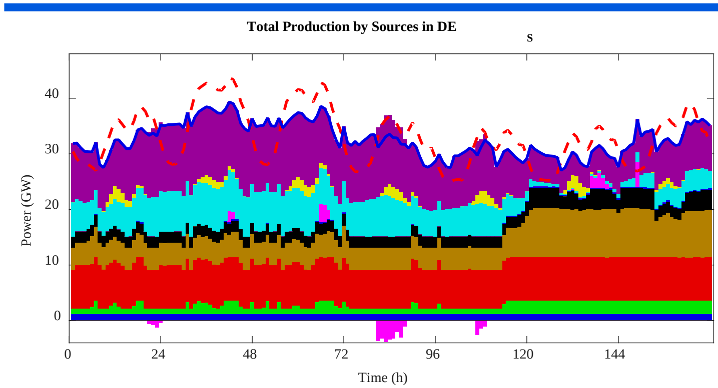




With DR

OPEX: 161.29 M€
CO_2 : 0.31 tonne/MWh





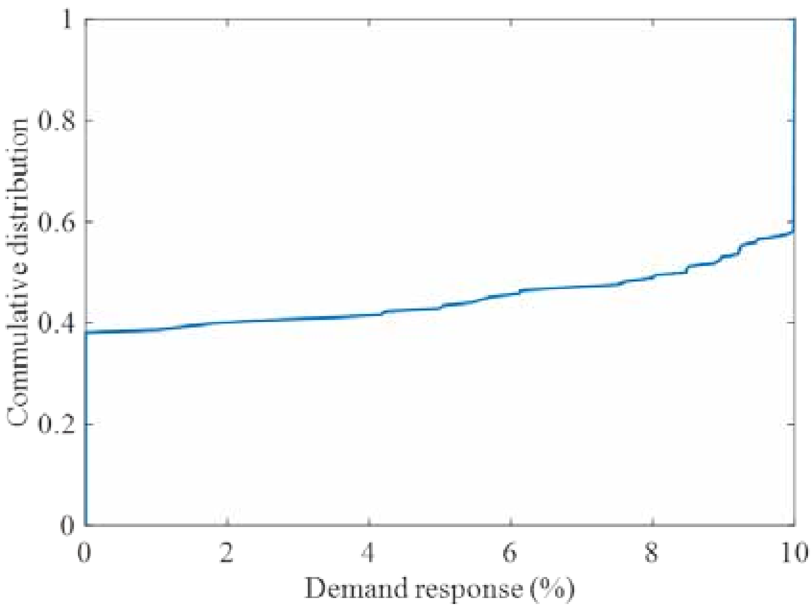
Maximum 10% DR and 8 hour delay is allowed

Unit commitment analysis
Germany: results for a week in December 2014

demand curve w/o demand response — demand curve with demand response

PS · RoR · RHP · OBS · URA · LIG · COL · NG · FO · WND · SUN

- A maximum DR of 10% is activated about 40% of time and values between 0-10% are activated for another 20% of time
- 40% of time the disconnected demand is compensated (compensation can be above 10%)



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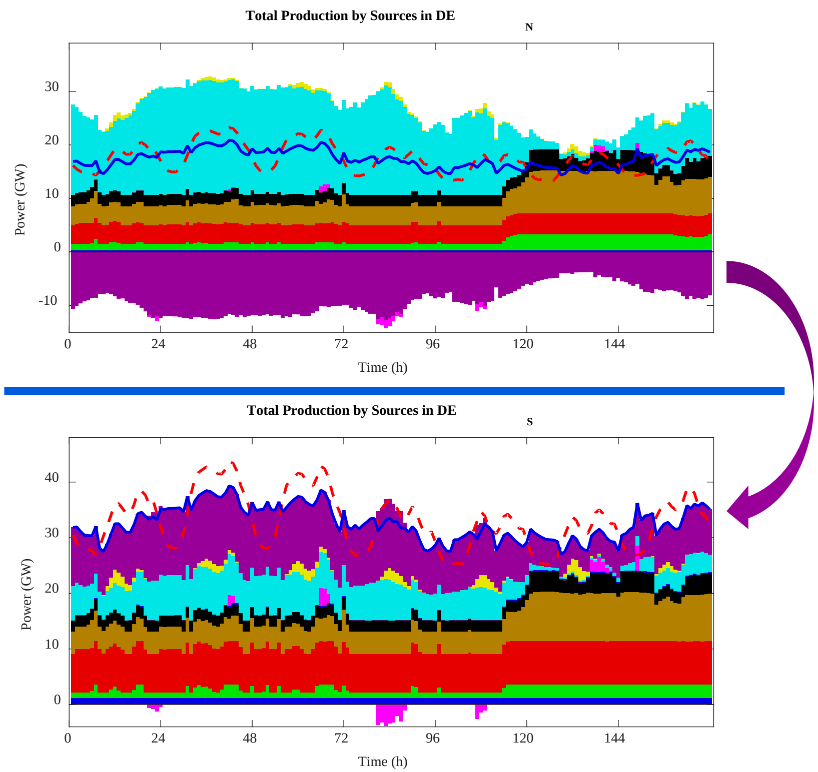

Maximum 10% DR and 8 hour delay is allowed

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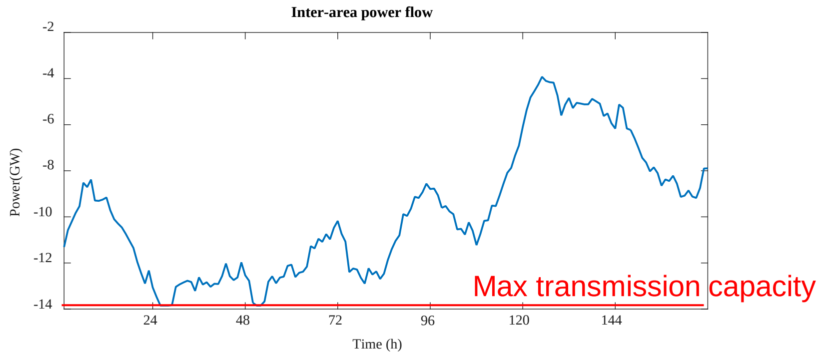
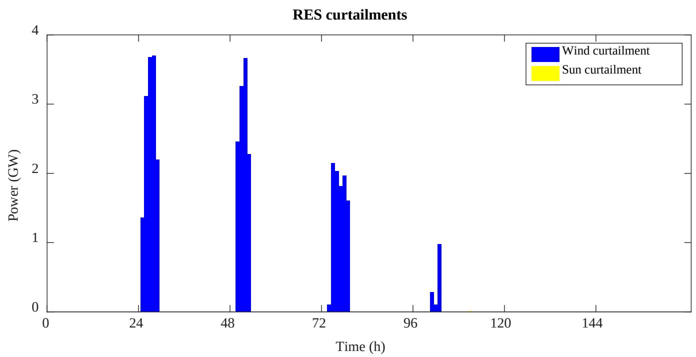
Congestion relief and RES curtailment reduction
Germany: results for a week in December 2014

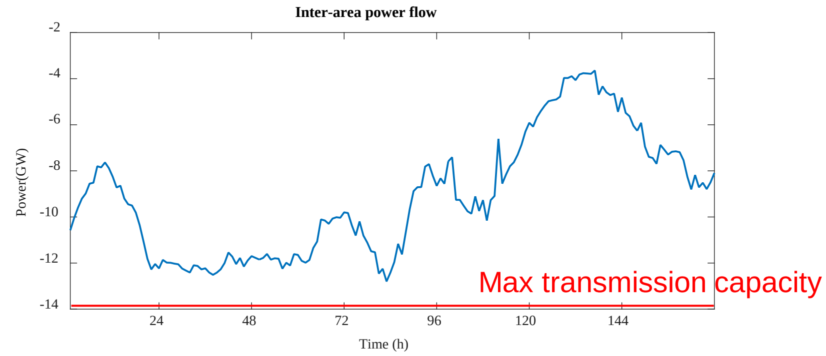
Base case: no DR

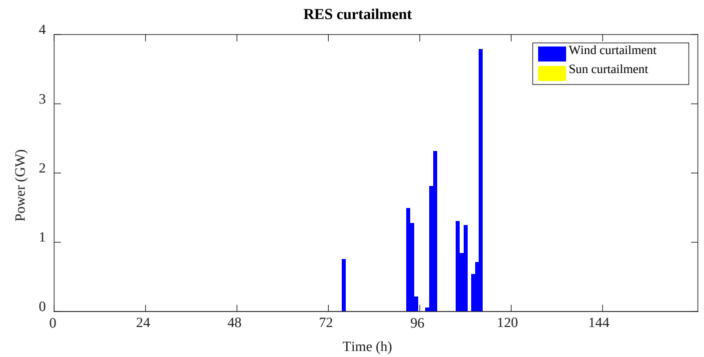




$$P_w^{curtail} = 36.76\ GWh$$
$$P_s^{curtail} = 0.01\ GWh$$

With DR





$$P_w^{curtail} = 16.34\ GWh$$
$$P_s^{curtail} = 0\ GWh$$

Maximum 10% DR and 8 hour delay is allowed

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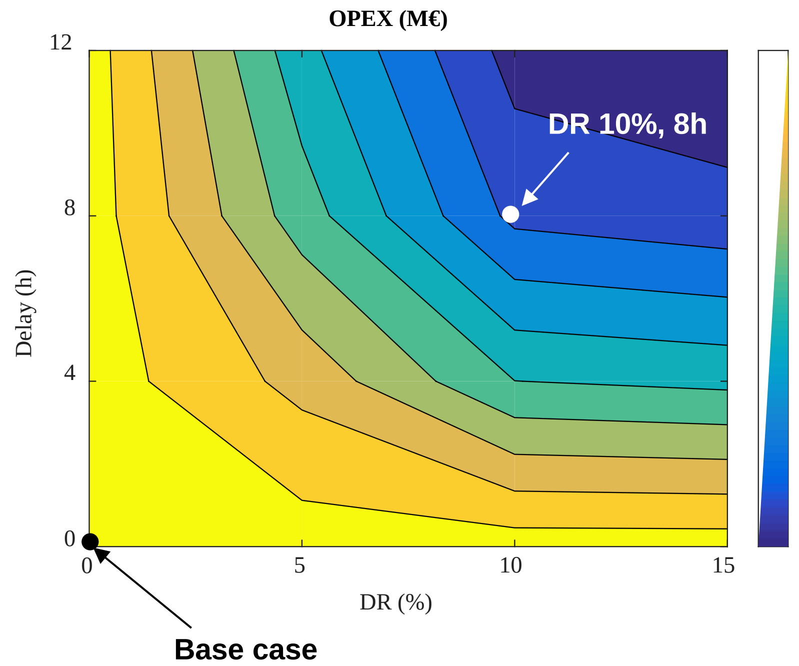
Unit commitment analysis
Germany: results for 2014

Cost, M€	Base case	DR 10%, 8 h	Savings, M€
Fuel & VOM	11650.3	11330.7	319.6
CO_2	1500.3	1451.3	49.0
Start/stop	18.7	4.2	14.5
Reserve	256.4	251.1	5.3
Total cost	13425.7	13037.3	388.4

- Dividing 388.4 M€ in production cost savings by the peak DR capacity enabled, 7.7 GW, yields a value of **50.6 €/kW-y**
- Dividing 388.4 M€ in production cost savings by the total energy DR provided to the system, 34’810.3 GWh, yields a value of **0.01 €/kWh**
- In order to estimate profit we need to include the cost of enabling a demand response service



For any given conditions OPEX savings are always saturated when percentage of DR and compensation delay are increased

Unit commitment analysis
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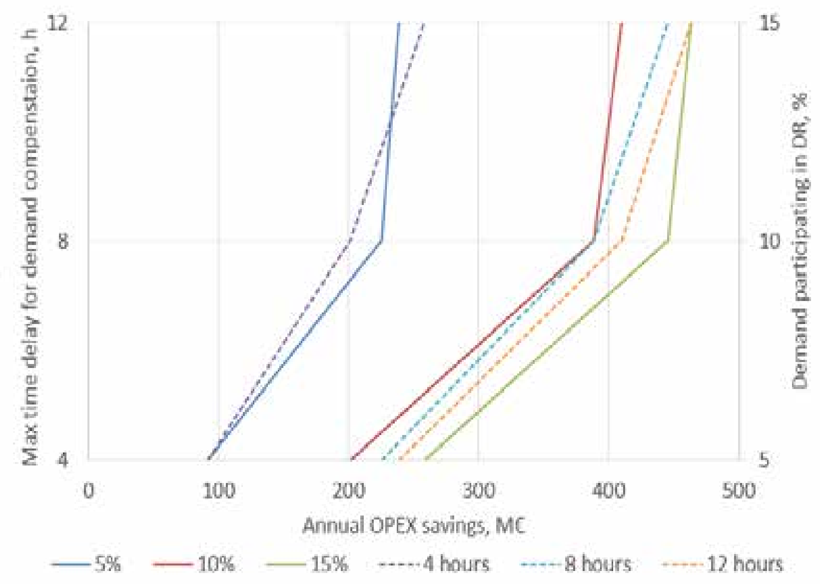

For any given conditions OPEX savings are always saturated when percentage of DR and compensation delay are increased

Unit commitment analysis
Germany: results for 2040 and comparison with 2014

Cost, M€	Base case	DR 10%, 8 h	Savings, M€
Fuel & VOM	16513.1	15905.6	607.5
CO2	6185.7	6021.7	164.0
Start/stop	144.2	104.5	39.7
Reserve	537.1	524.9	12.2
Total cost	23380.1	22556.7	823.4

- Dividing 823.4 M€ in production cost savings by the peak DR capacity enabled, 7.7 GW, yields a value of **107 €/kW-y**
- Dividing 823.4 M€ in production cost savings by the total energy DR provided to the system, 30'960.6 GWh, yields a value of **0.026 €/kWh**
- The absolute growth is mainly due to increase in fuel and CO2 emission costs
- Start/stop and reserve cost savings grow significantly

For any given conditions OPEX savings are always saturated when percentage of DR and compensation delay are increased

Value of demand response
Recap

- Future power systems with a significant amount of variable RES will create a need for more flexible operation
- Demand response is one of key technologies which can provide this flexibility
- Use of demand response results in production cost savings
- Sensitivity analysis across different sizes shows that for each set of system conditions there are optimal parameters of demand response
- With increase in variable RES feed-in a higher percentage of demand response will be economic
- We have to include costs of enabling demand response to estimate a profit

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