TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät für Wirtschaftswissenschaften, Lehrstuhl für Energiewirtschaft, Prof. Dr. Möst

Curtailment of renewables and its impact on NTC and storage capacities in 2030

EE²

www.ee2.biz

Theresa Müller, David Gunkel, Dominik Möst

Dresden, 19. April 2013

This presentation is based on analysis developed within the project Energy System Analysis Agency (ESA²)

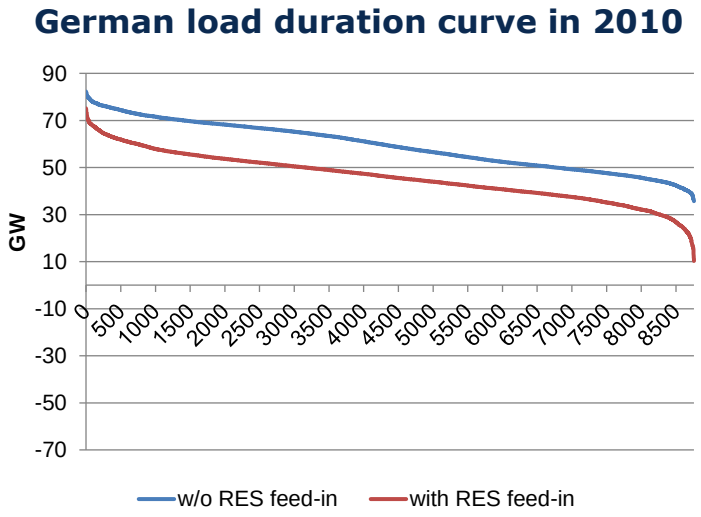
Agenda

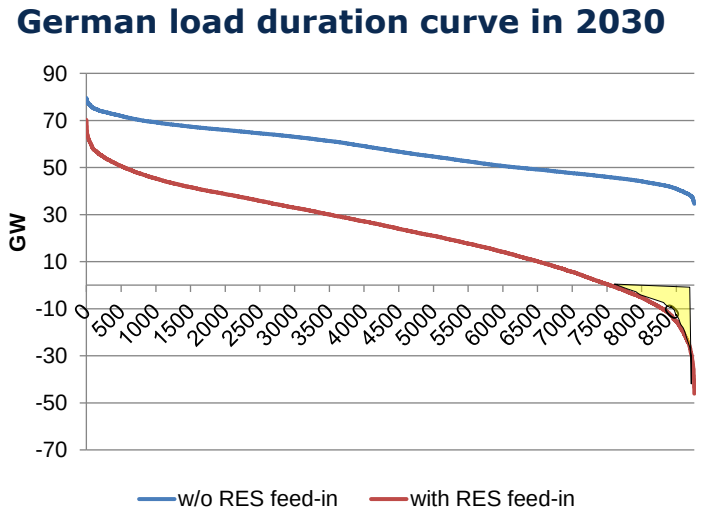
1. Motivation

2. ELTRAMOD - Model description and main assumptions

3. The impact of curtailment on NTC and storage expansion - results and outlook

Hours with surplus renewable feed-in will increase



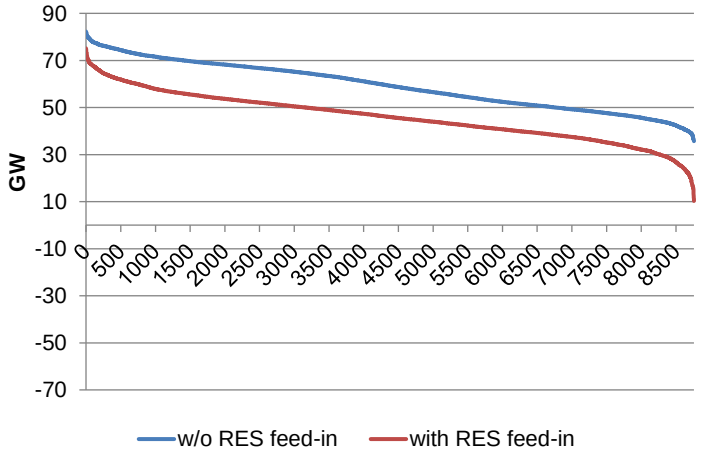


The integration of renewable energy sources (RES) significantly influences the residual load:

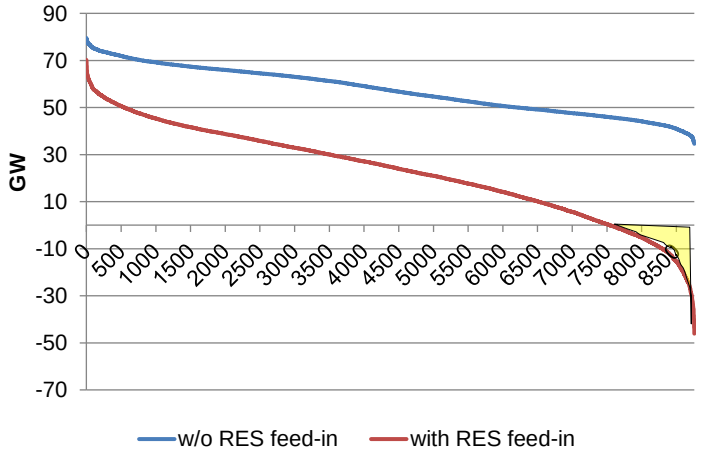
- Number of hours with negative residual load rises
- Surplus of RES feed-in increase
- Level of maximal negative residual load grows

Research Question

German load duration curve in 2010



German load duration curve in 2030



Options to handle the surplus RES feed-in:

- **Export** the overproduction to neighbouring countries
- **Store** the surplus of RES feed-in
- **Curtail** renewable feed-in

Research Questions:

1) **Are additional NTC and storage capacities needed?**
2) **What impact has RES curtailment on investments in NTC and storage facilites?**

Agenda

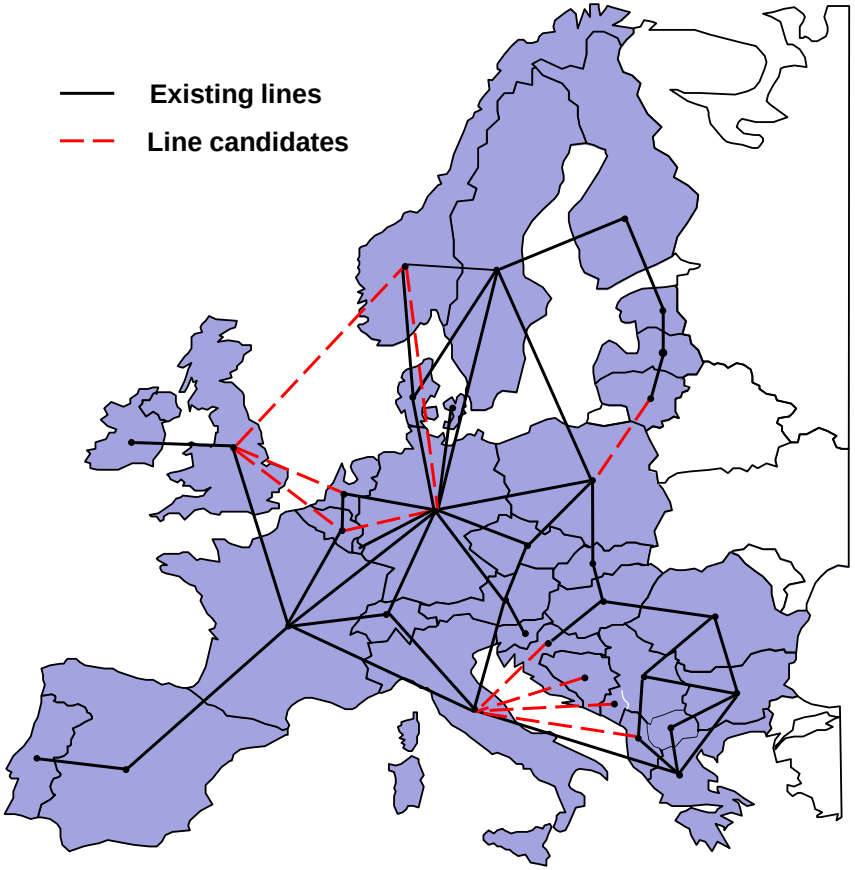
1. Motivation

2. ELTRAMOD - Model description and main assumptions

3. The impact of curtailment on NTC and storage expansion - results and outlook

ELTRAMOD – a European investment and dispatch model

- Bottom-up electricity market model
- EU 27 states plus Norway, Switzerland and Balkan region
- Temporal resolution of 8760 h
- Calculation of the cost-minimal generation dispatch and investments in additional transmission lines and storage facilities
- Considering Net Transfer Capacities (NTC)
- Modelled storage facilities: pump storage plants (PSP)



Considered countries and lines in ELTRAMOD

Objective function and main restrictions

Objective Function: $Min \sum_t TC = I_{PSP} + I_{NTC} + OC_{t,u} + CurtC_{t,c} + VOLL$

Focus: Storage expansion vs. NTC expansion vs. RES curtailment

Energy Balance: $DP_{t,u} + Imp_{t,cA,cB} = RL_{t,c} + Pump_{t,u} + Exp_{t,cA,cB} + Curt_{t,c}$

Main storage restricitons:

1) PSP-level

$$PSP\_l_{t,u} = Pump_{t,u} - DP_{t,u} + PSP\_l_{t-1,u}$$

2) Maximum PSP-level

$$PSP\_l_{t,u} \leq \left(C_{PSP_u} + C_{add_{PSP_u}}\right) * \mathrm{ST}$$

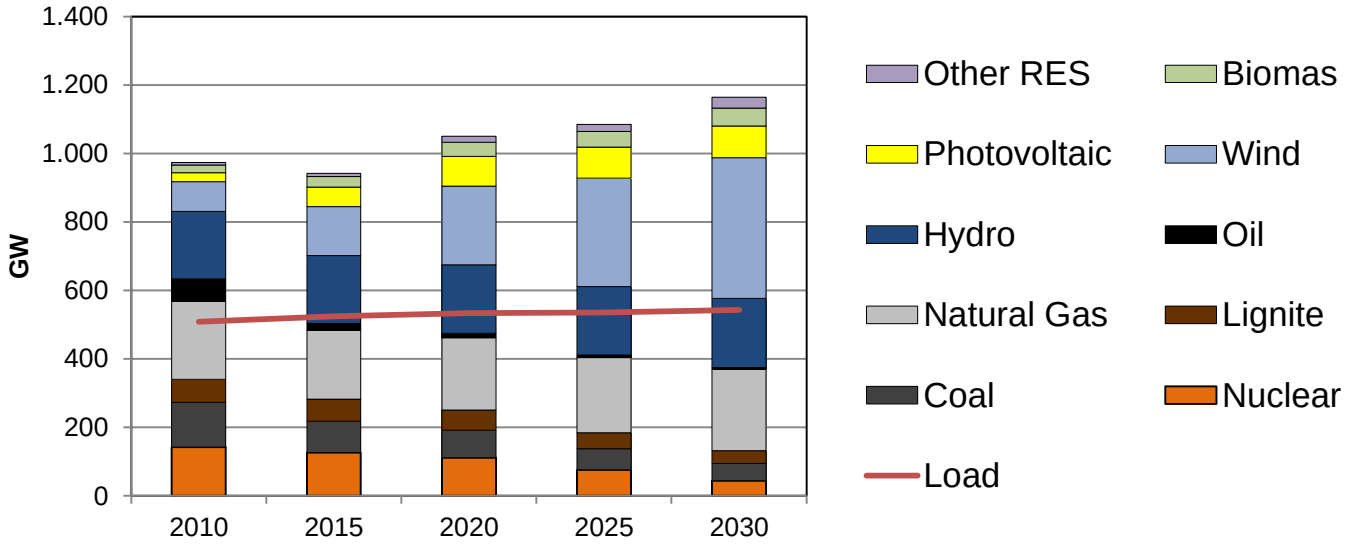
Main grid restrictions:

$$Imp_{t,cA,cB} \leq NTC_{cA,cB} + NTC_{add_{cA,cB}}$$

$$Exp_{t,cA,cB} \leq NTC_{cA,cB} + NTC\_add_{cA,cB}$$

Input data and main assumptions

Net generation capacity and net electricity demand from 2010 till 2030 in EU25+3*



Data: Energy System Analysis Agency (ESA²); www.esa2.eu

- Power plant capacities (based on technology classes) and electricity demand from model coupling within ESA²
- Share of RES at overall electricity demand: 60% in 2030
- Country specific time series of wind and PV feed-in

* EU27-states (without Cyprus and Malta) plus Norway, Switzerland and Balcan Region

Agenda

1. Motivation

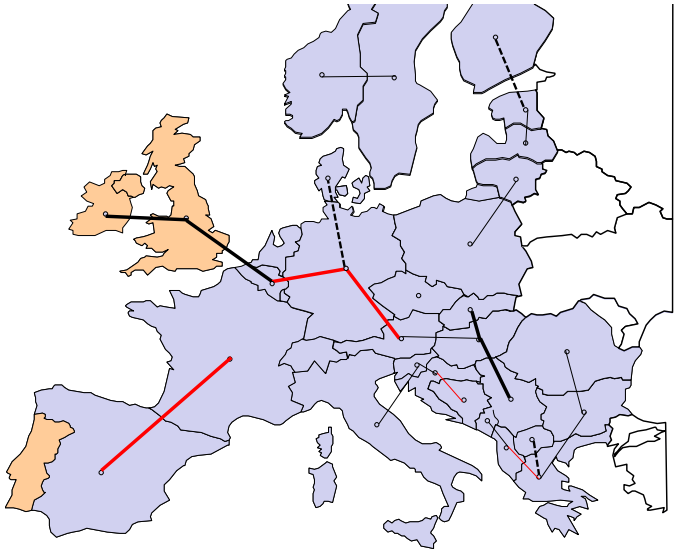
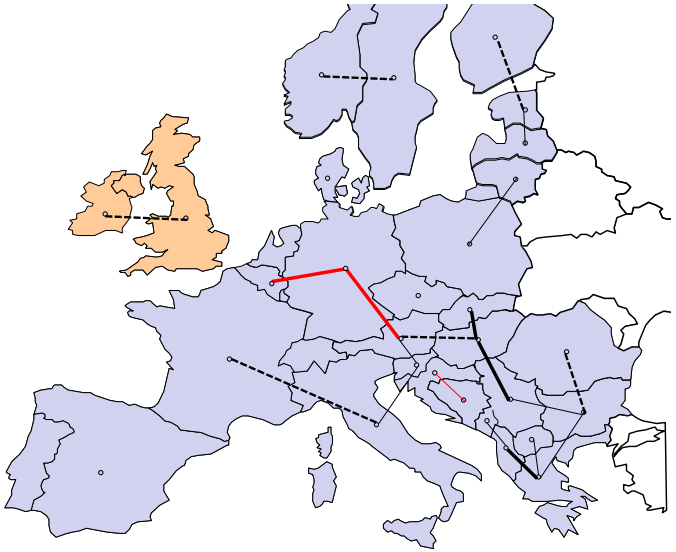
2. ELTRAMOD - Model description and main assumptions

3. The impact of curtailment on NTC and storage expansion - results and outlook

Four scenarios: w/w.o. curtailment combined with NTC and storage expansion

	RES feed-in obligation	RES curtailment
	• All RES feed-in needs to be integrated into the electricity system ➢ Curtailment costs: 600 €/MWh	• The surplus of RES feed-in can be curtailed ➢ Curtailment costs: 0 €/MWh
Base	**No NTC or storage expansion**	
Exp	**With NTC and storage expansion**	

NTC and storage expansion by 2030 with and without RES curtailment

RES feed-in obligation	RES curtailment	Legend
		< 500 MW < 1000 MW < 1500 MW < 2000 MW > 2000 MW No storage expansion Storage expansion

- Additional NTC and storage capacities in both settings
- Feed-in priority for renewable energy influences investments in NTC and storage capacities

Curtailment compared to NTC and storage expansion in all scenarios in 2030

	scenario	RES feed-in obligation	RES curtailment	Difference
Relative curtailment of RES	Base	5.00 %	5.85 %	**- 0.85 %**
	Exp	0.12 %	0.52 %	**- 0.40 %**
Added NTC by 2030	Exp	24.4 GW	18.4 GW	**6.0 GW (+ 25 %)**
Added storage capacity by 2030	Exp	14.5 GW	12.1 GW	**2.4 GW**

- Curtailment of RES feed-in occurs in both cases
- Difference between both settings is low
- With higher grid and storage capacities curtailment decreases
- Lower investments with RES curtailment

  → Difference in the amount of RES curtailment is minor

Conclusion

EE²

1) **Regardless of the presence of feed-in obligation investments in NTC and storage facilities are needed**
   - Upgrading of the grid infrastructure dominates the construction of new pump-storage plants
   - Grid expansion is mandatory for the integration of RES
   - By 2030 additional storage capacities are only needed at periphery EU-countries

2) **Feed-in priority for renewable energy influences investments in NTC and storage capacities**
   - RES feed-in obligation strongly effects investments in NTC
   - The impact on storage expansion is low (compared to NTC expansion)
     - ➢ It is expected that the impact increases with a higher penetration of RES

From an economical perspective:

Curtailment is an important measure for RES integration in the middle- to long-term

Outlook

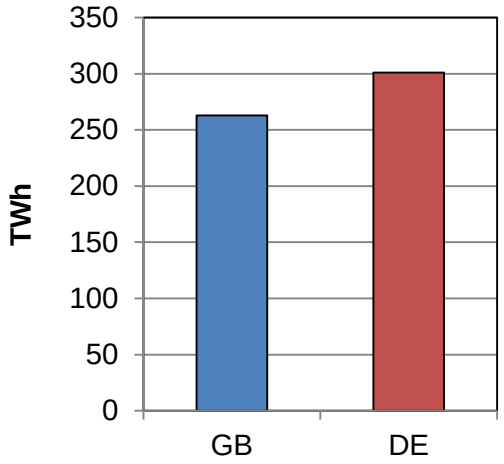
- Model results give first insights in the topic
- Further research is necessary, e.g. concerning the following aspects:
  - Increasing penetration of RES (long term perspective)
  - Varying curtailment costs
  - Impact on conventional power plants
  - Impact on electricity prices
  - …

EE²
www.ee2.biz

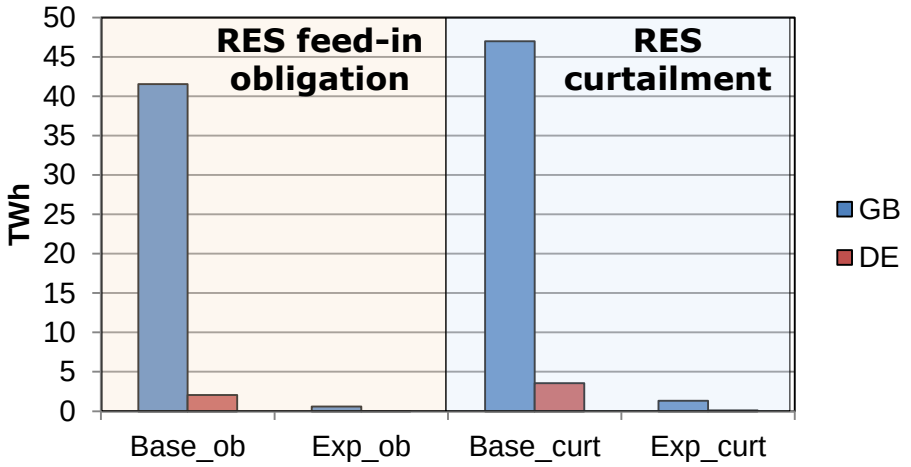
Thank you!

Regional differences in RES curtailment

Available RES feed-in (2030)



Curtailed RES feed-in (2030)



Higher RES penetration in Germany

Higher curtailment in Great Britain in all scenarios

- Curtailment depends on:
  - RES penetration
  - Connection to neighbouring countries
- Curtailment more important in peripheral areas than in Central Europe
- Impact on NTC/Storage Expansion higher in peripheral areas