TECHNISCHE UNIVERSITÄT DRESDEN

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

EE²
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How much flexibility can Demand Response applications provide the electricity system?

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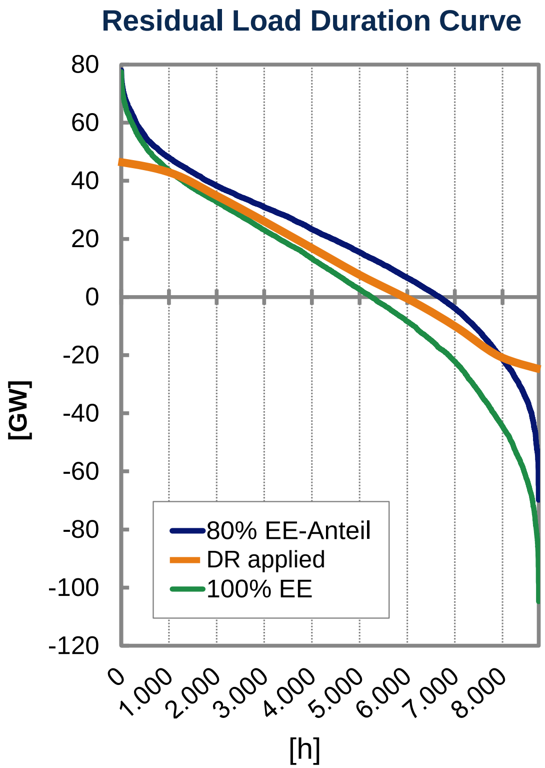
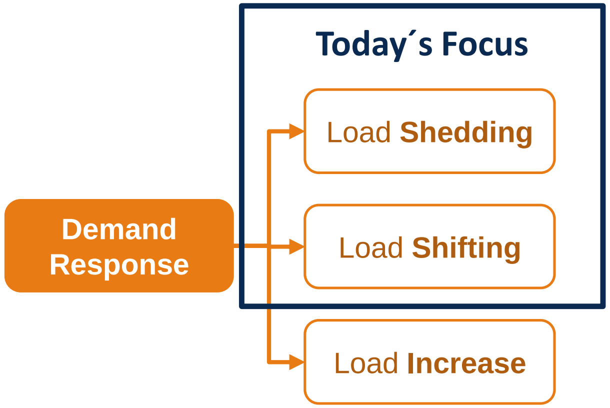
DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Demand Response flattens the residual load curve and increases the utilization of generation capacities



(Source: Own Illustration)

- System with high share of renewable energy sources (RES) is based on a high amount of overcapacities (conventional and renewable)
- To minimize curtailment of RES, investments in flexibility options are needed
  - Overcapacity increases (e.g. storages, lines)
- Demand Response (DR) helps to increase the utilization of existing plants



Several applications exist, which can provide flexible demand to the electricity system

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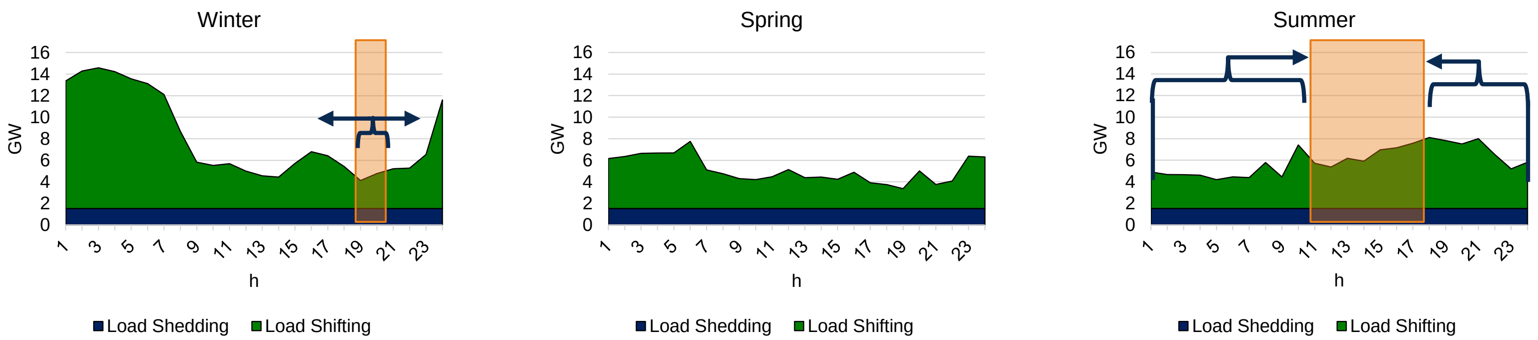
		Limits the available potential		Limits the dispatch			
Main restrictions:		Time dependency	Temperature dependency	Frequency	Duration of interfere	Shifting time	
Sector & selected applications		DR(t)	DR(ϑ)	f	t_{shed} in h	t_{shift} in h	
Industry	Electrolytic primary aluminium	-	-	40	4	-	Load shedding
	Chloralkali process	-	-	40	4	-	
	Steel (electric arc furnace)	-	-	40	4	-	
	Wood Pulp Production	-	-	24	2	4	Load shifting
	Cement mills	Season, hour	-	365	3	24	
Tertiary/Residential	Cold storage	Season, hour	-	1095	2	2	
	Warm Water Heater	hour	+	1095	12	12	
	Night Storages	hour	+	1095	12	12	
	Ventilation	hour	+	1095	1	2	
	Air conditioning	Season, hour	+	1095	2	2	

(Source: dena 2010, Klobasa 2007, VDE 2012, Gils 2014)

The (total) Demand Response potential is not necessarily available when needed

Cumulated DR potential of selected devices for an exemplary day in winter, spring and summer



(Source: Own calculation)

Total available DR potential varies with season and daytime:

1) Winter
   - Highest potential available at night → Need for load shedding is low during this time
   - Peak demand in evening hours → load shedding potential is low during this time

2) Summer
   - Load reduction potential is highest at daytime → no/small demand during this time
   - To compensate PV feed-in, load needs to be increased during these hours

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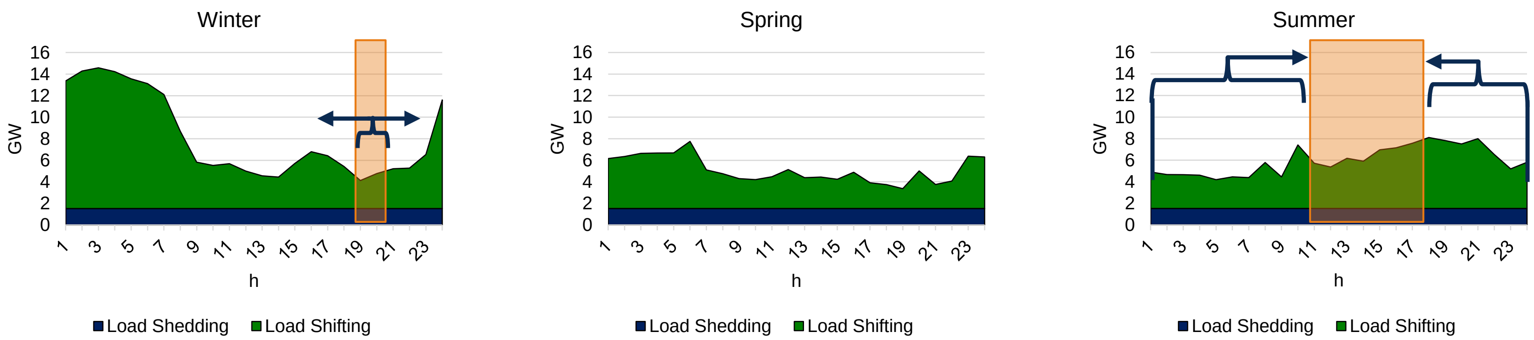

(Source: Own calculation)

How much flexibility can Demand Response applications provide the electricity system?

- To what extent does the dispatch of DR-applications change the residual load curve?
- Is the available DR-potential completely exploited for offsetting the fluctuations in the electricity system?

Agenda

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1 **Demand Response Potential: Temporal Availability and Technical Restrictions**

2 **Modelling the (In-) Flexibility of Demand Reponse Applications**

3 **Case Study: Flexibility of Demand Response Applications in the Elelctricity System**

Main restrictions:		Time dependency	Temperature dependency	Frequency	Duration of interfere	Shifting time	
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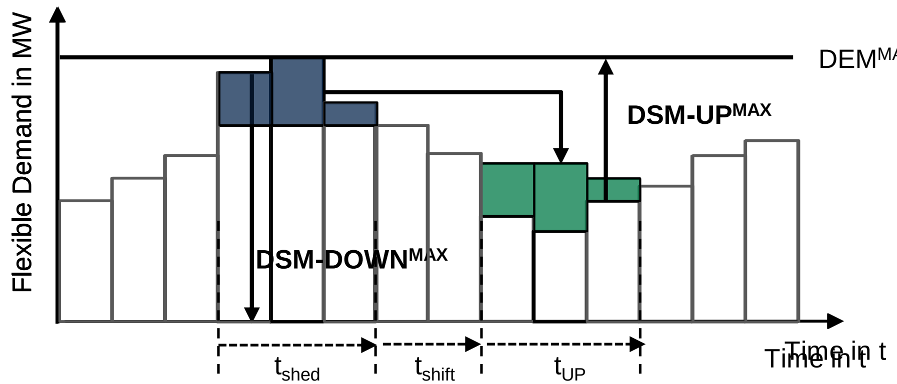
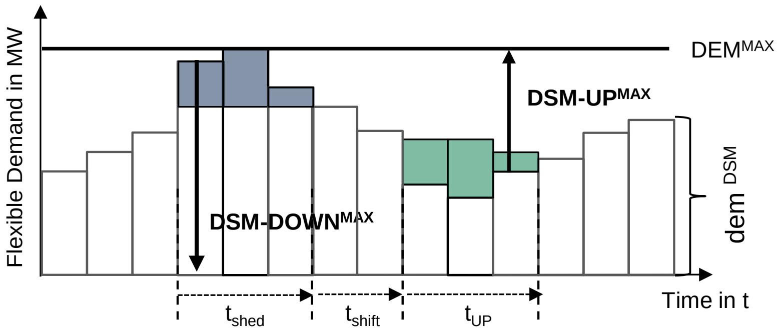
Tertiary/ Residential	Cold storage	Season, hour	-	1095	2	2	Load shifting
	Warm Water Heater	hour	+	1095	12	12	Load shifting
	Ventilation	hour	+	1095	1	2	Load shifting
	…	Season, hour	+	1095	2	2	Load shifting

Several restrictions needed to be considered when modelling Demand Responds



Limits in…	Parameter needed to be considered:	
(Max.) Amount	• Reduced demand • Increased demand	$DSM\text{-}DOWN^{MAX}$ $DSM\text{-}UP^{MAX}$
(Max.) Duration	• Duration of interfere • Shifting time • Raising time	t_{shed} t_{shift} t_{up}
Frequency	• Per day, month, year, …	
Total consumption	• The total consumpation doesn´t change for load shifting	■ = ■

To model ***Load Shifting*** no storage is needed



Level of detail	DSM-applications are clustered (profile, shifting time, …)
Shifting time, balance	$\sum_{t}^{t+t^{bal}} \mathrm{DSM}_{\mathrm{t,app}}^{\mathrm{Down}} = \sum_{t}^{t+t^{bal}} \mathrm{DSM}_{\mathrm{t,app}}^{UP}$ $t^{bal} = t^{shed} + t^{shift} + t^{up}$
Maximum Amount	$DSM_{t,app}^{Down} \leq dem_{t,app}^{DSM}$
	$DSM_{t,app}^{UP} \leq dem_{app}^{max} - dem_{t,app}^{DSM}$

Load shedding is modelled with binary variables

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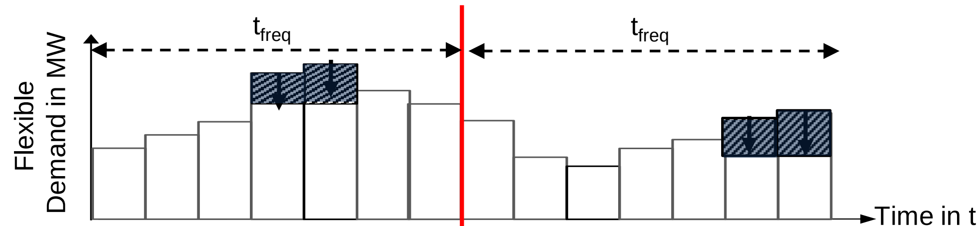

DSM^{ON}	0	0	0	1	1	0	0	0	0	0	0	0	1	1
DSM^{SU}	0	0	0	1	0	0	0	0	0	0	0	0	1	0

Binary modelling:

Implementing the binary variable „online":

$$DSM_{t,app}^{Down} \leq dem_{t,app}^{dsm} * DSM_{t,app}^{ON}; \qquad DSM_{t,app}^{Down} \geq DSM_{t,app}^{ON}$$

Implementing the binary variable „Start-Up" :

$$\mathrm{DSM}_{\mathrm{t,app}}^{SU} - \mathrm{DSM}_{\mathrm{t,app}}^{SD} = \mathrm{DSM}_{\mathrm{t,app}}^{ON} - \mathrm{DSM}_{\mathrm{t-1,app}}^{ON}$$

Duration of interfere

$$\sum_{t}^{t+t^{freq}} \mathrm{DSM}_{\mathrm{t,app}}^{ON} \leq t_{app}^{down}$$

Frequency:

$$\sum_{t}^{t+t^{freq}} \mathrm{DSM}_{\mathrm{t,app}}^{SU} \leq 1$$

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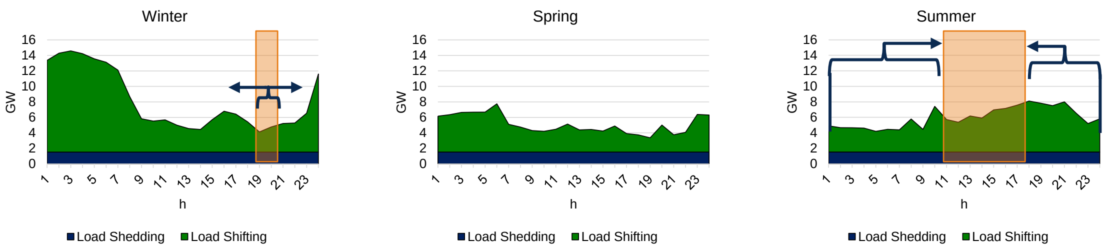
Cumulated DR potential of selected devices for an exemplary day in winter, spring and summer



How much flexibility can Demand Response applications provide the electricity system?

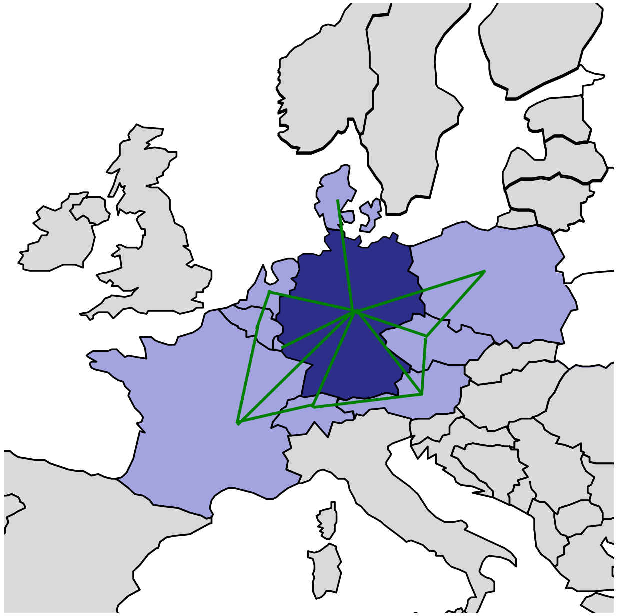
- To what extent does the dispatch of DR-applications change the residual load curve?
- Is the available DR-potential completely exploited for offsetting the fluctuations in the electricity system?

Scope of the Study

- Research Year: 2030
- Share of RES feed-in in Germany: ~ 60%
- Model-based analysis with ELTRAMOD
  - Bottom-up electricity market model
  - Temporal resolution of 8760 h
  - Calculation of the cost-minimal generation dispatch and commitment of DR applications
- 11 DR applications are considered:

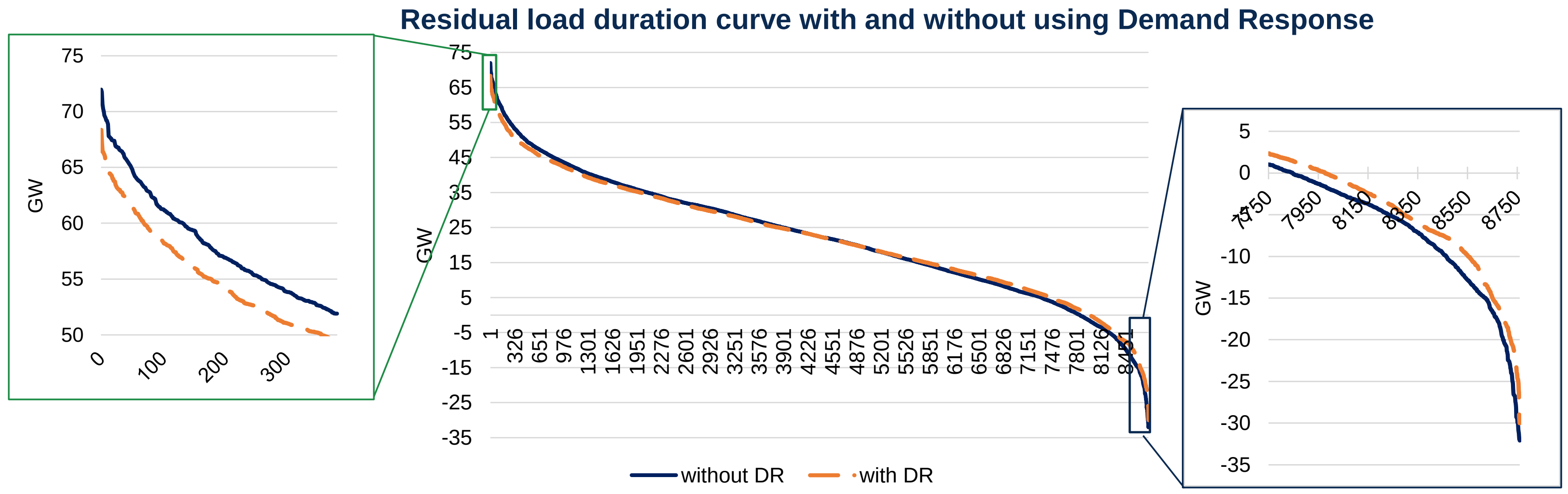
Industry Processes	• Electrolytic Primary Aluminium • Chloralkali Process • Electric Arc Furnace • Wood Pulp • Cement Mills
Heat Supply	• Night Storage Heater • Heat Pump • Warm Water Heater
Cold Supply	• Air Conditioning • Ventilation • Cold Storage

Regional Scope



- Research Area with detailed power plant portfolio
- Aggregated power plant portfolio
- Not considered
- Hourly NTC-Value

Result (I): Demand Response commitment (slightly) flattens the residual load duration curve



(Source: Own calculation)

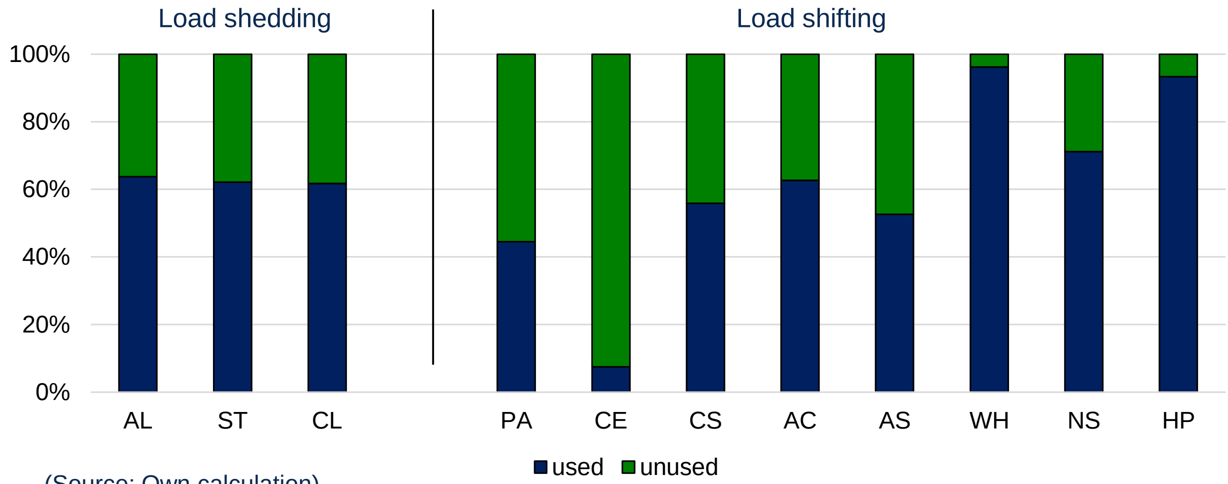
	w/o DR	With DR
Load Max [GW]	72.0	68.4
Load Min [GW]	-32.1	-30.0
RES Surplus [GWh]	733	140
Hours with RES surplus	913	782

- The maximum load peak decreases and the minimum increases
- Changes of maximum load peak are more considerable
- DR commitment leads to less RES surplus

➢ **The entire RES surplus cannot be compensated completely by DR commitment**

Result (II): The available Demand Response potential is not completely exploited

(Un-) used Demand Response potential per application



(Source: Own calculation)

- The exploitation of the DR potential varies between the applications
- The characteristics of each application (temporal availability, shedding and shifting time, …) strongly effects the usable DR potential

➢ **It is not cost-efficient to exploit the entire DR-potential from a system perspective but to focus on selected applications**

Conclusion

Demand Response supports the integration of RES into the electricity system

- Reduces the need for back-up capacity by minimizing maximum load
- Increases the utilization of RES plants

Demand Response commitment is strongly restricted by the temporal availability and characteristics of the underlying applications

- DR potential is overestimated when only cumulated numbers are considered
- (Full) DR potential is not necessarily available when needed
- Total available DR potential is not exploited completely, because it is not always needed when available and due to technical restrictions

Thank you!

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»Wissen schafft Brücken.«

Sources

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