Elements Of A New Target Model For European Electricity Markets
Towards a Sustainable Division of Labour between Regulation and Market Coordination,
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A Cost Effective Mix of Flexibility Options for Integrating a High Share of Variable Renewables

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Outline

- Background and motivation
- Demand for flexibility
- Flexibility options and their characteristics
- Modeling approach: E2M2s
- Case study: Germany
- Conclusions

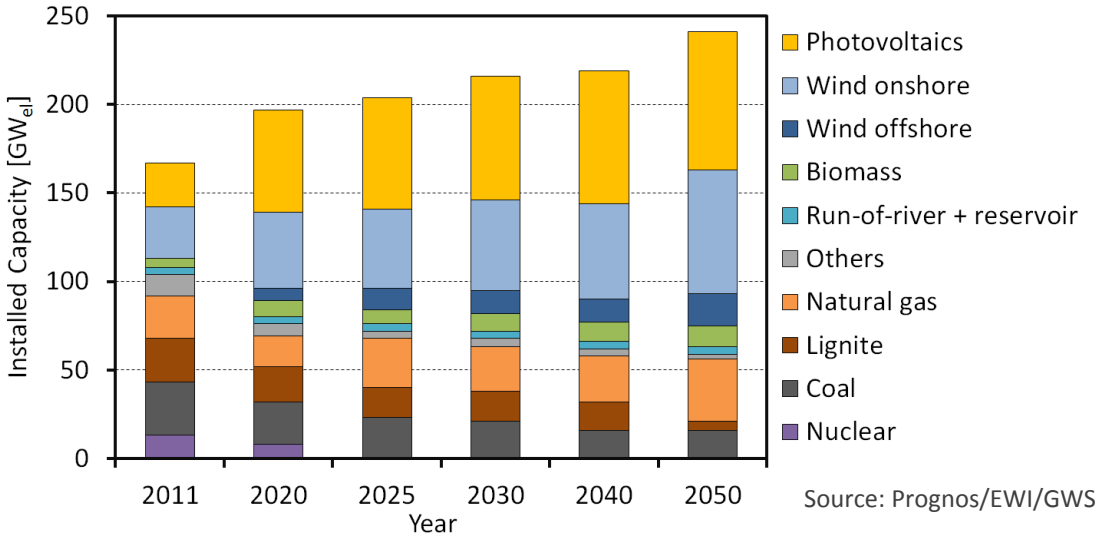
Climate and Energy Targets

on different administrative levels set the framework

	GHG reduction	Renewable energy	Energy savings
EU_1	2020: -20% 2030: -40%	2020: 20% 2030: 27%	2020: 20%$_{pe,\ ref.\ scenario}$ 2030: 27%$_{pe,\ ref.\ scenario}$
$Germany_2$	2020: -40% 2050: -80/95%	2020: 18% 2050: 60%	2020: 20%$_{pe,\ 2008}$ 2050: 50%$_{pe,\ 2008}$

1) EU Climate and Energy Package 2030, October 2014
2) Energy Concept 2011

GHG – greenhouse gas
pe – primary energy



Source: Prognos/EWI/GWS 2014, Target scenario

Challenge of a **safe and cost-effective integration** of high shares of volatile RES → demand for **flexibility** in all ranks

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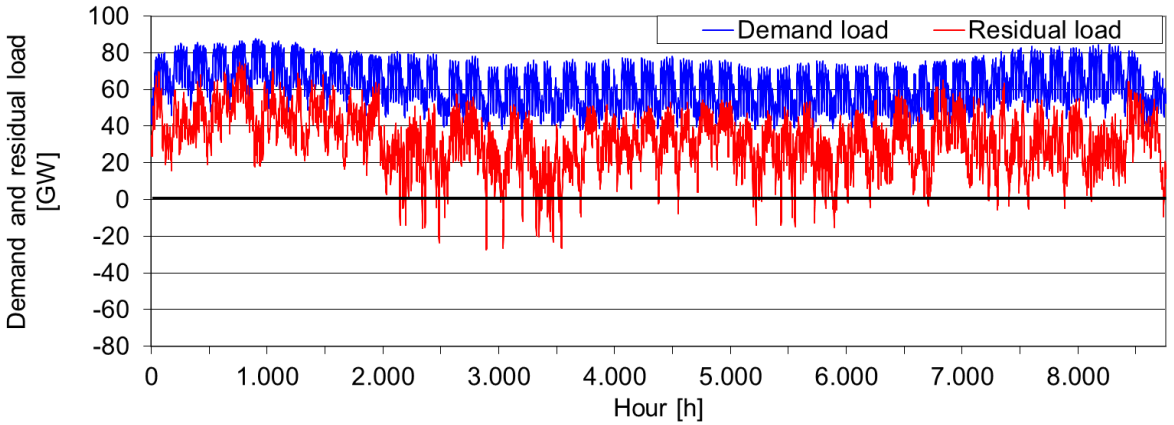
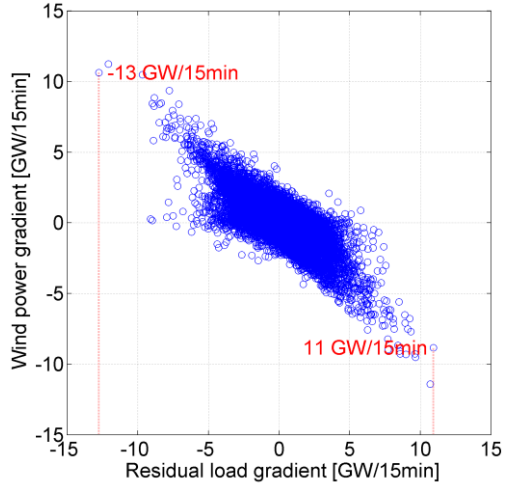
Upcoming flexibility requirements in the electricity sector

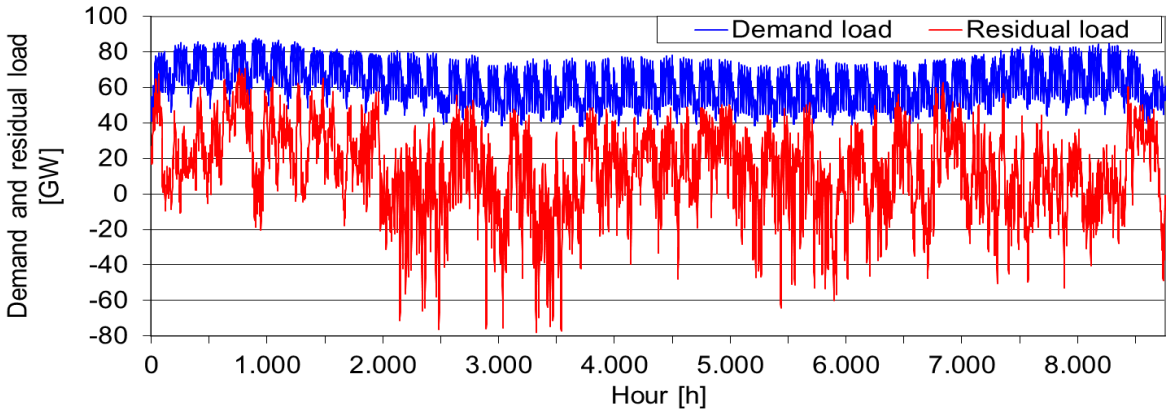
the case of Germany

50% RES





80% RES



RES share	Max. excess power	Surplus production
50%	27 GW	2 TWh
80%	78 GW	43 TWh

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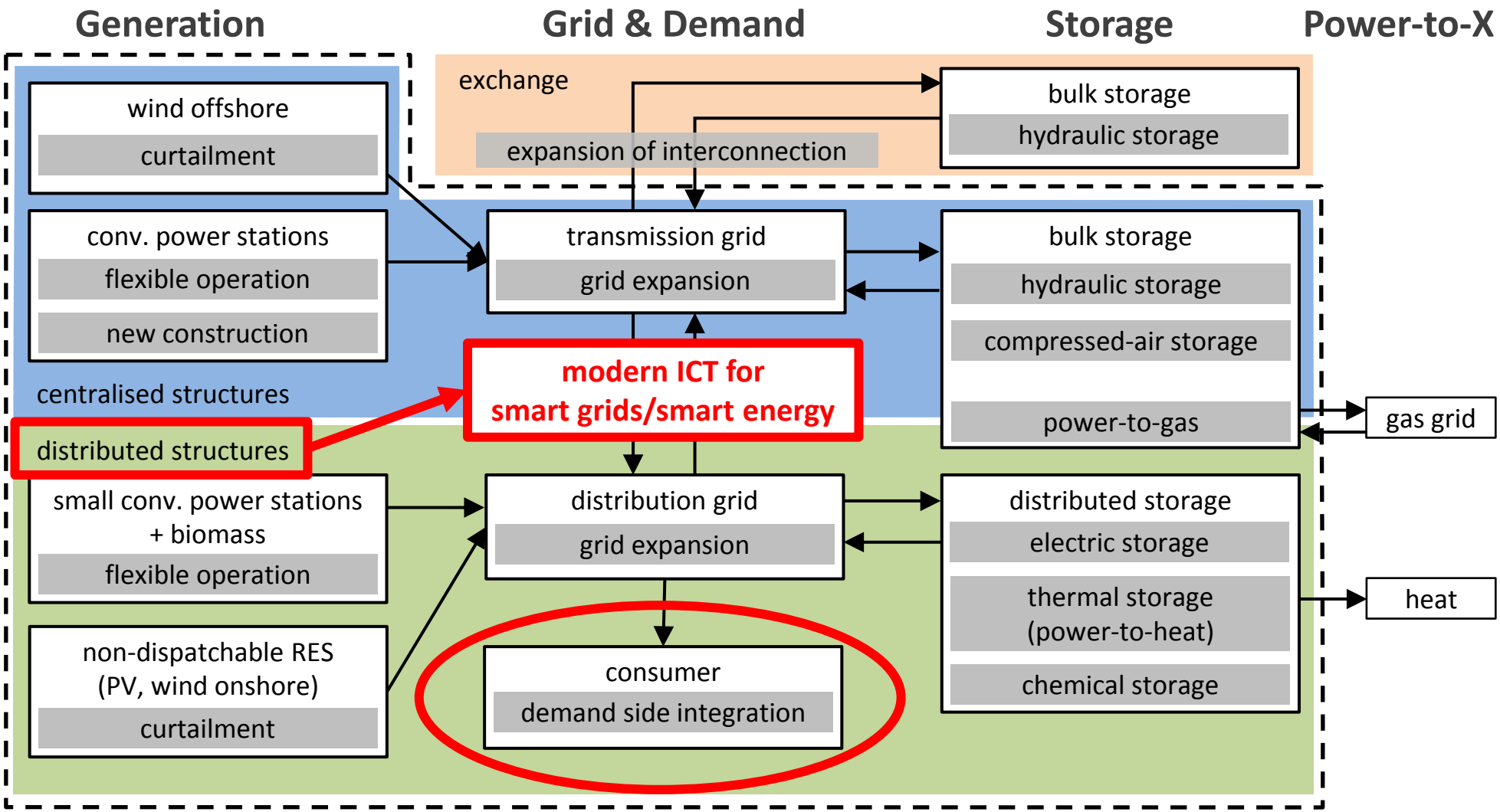
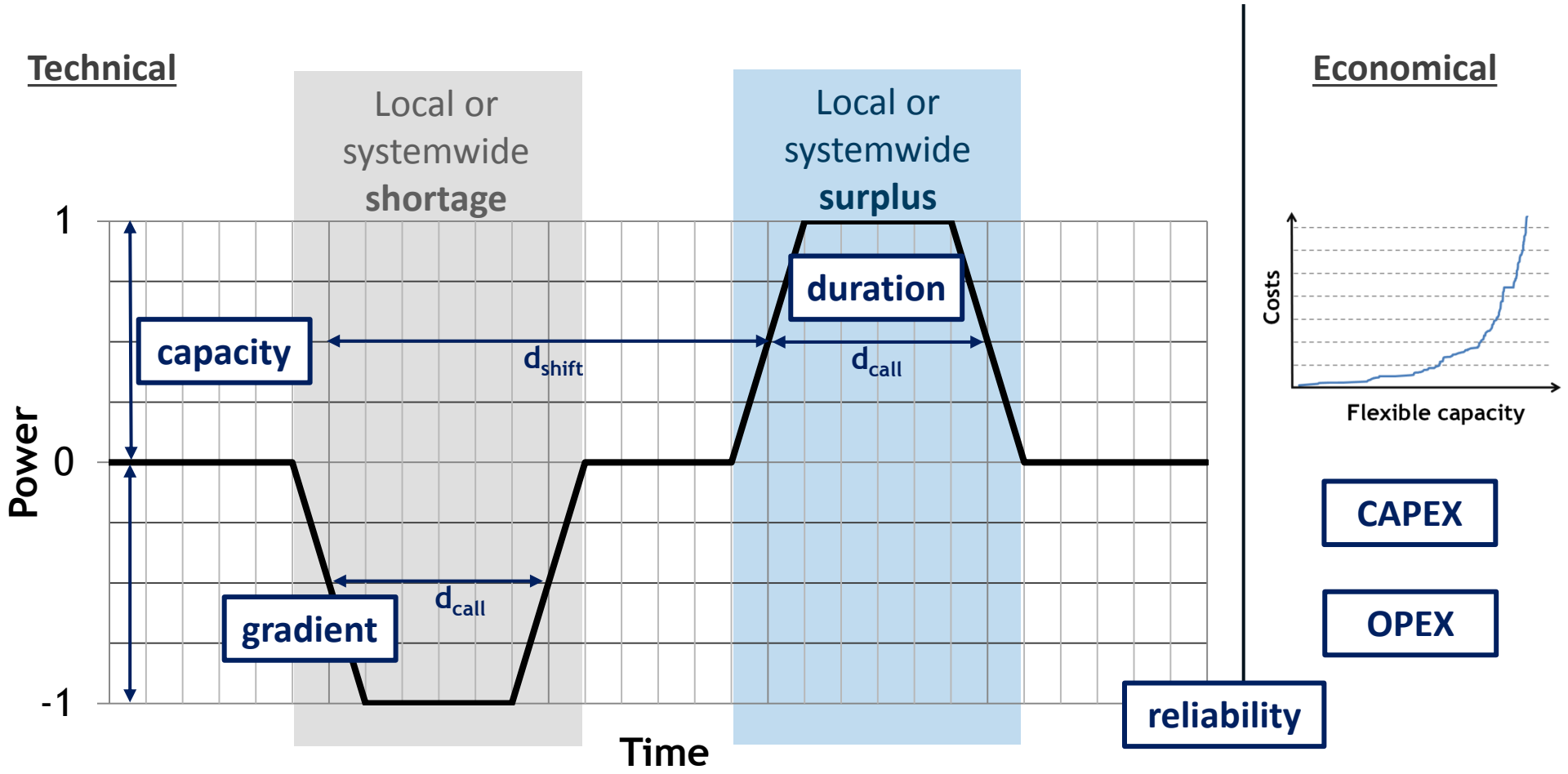
Overview: flexibility options in the electricity market



Characterization of flexibility supply



Actual flexibility demand depends on variable RES penetration, target market, …

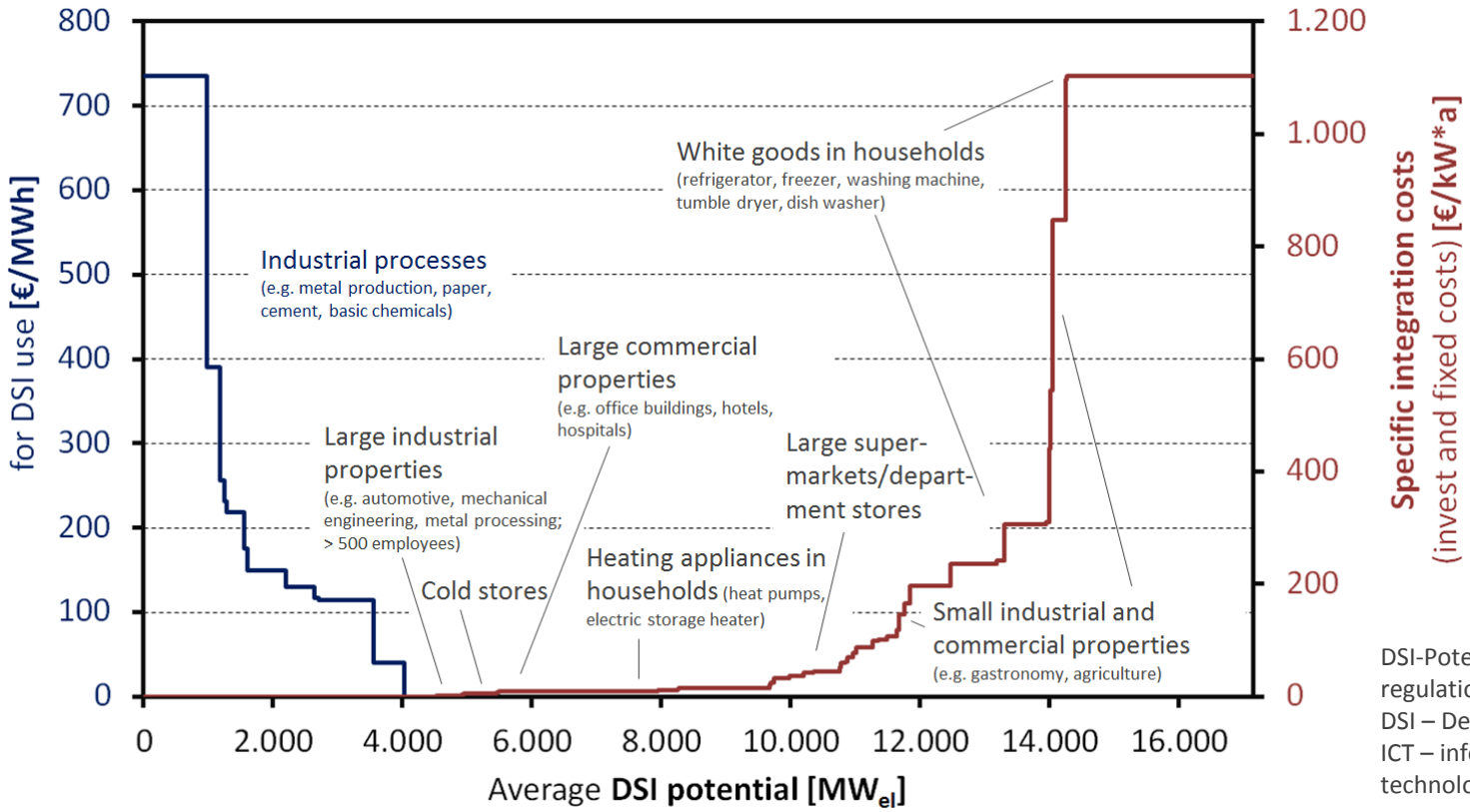
RES – Renewable Energy Systems

The example of Demand Side Integration (DSI) in Germany

Type of application	Field of application	Capacity (technical potential)		Availability	CAPEX	OPEX
		total	per site			
Process technology	**Energy intensive industry** (e.g. metal production, paper, cement, basic chemicals)	3 - 5 GW_{el}	Very high	Usually high (3-shift-operation)	Usually high (3-shift-operation)	Process disturbance
	Other industry (e.g. municipal economy, food industry)		High	Depending on operation mode	Relatively low specific effort	Process disturbance
Cross-sectional technology (e.g. ventila-tion, aircondi-tioning, heat pump, cooling)	**Large plants** in industry and commerce (e.g. automotive industry, mechanical engin.)	11 - 14 GW_{el}	High	Depending on operation mode, weather	Relatively low specific effort	Ideally no disturbance
	Medium size plants in industry and commerce (e.g. office buildings, hotels)		Rather low	Depending on operation mode, weather	Today relatively low specific effort	Ideally no disturbance
	Small plants in industry and commerce, **households**		Small sections	Depending on operation mode, weather	Today relatively low specific effort	Ideally no disturbance

Technical DSI potential – potential for down-regulation of the load with later recovery; DSI – Demand Side Integration
green – favorable; orange – conditionally favorable; red – unfavorable for DSI Use

Cost-potential curve for Demand Side Integration in Germany



DSI-Potential – potential for down-regulation of the load with later recovery
DSI – Demand Side Integration
ICT – information and communication technology

Methodology:

Bottom-up for process technology: extensive inquiry of companies and associations of all relevant industries, service providers

Top-down for cross-sectional technologies: analysis of energy balances and sector statistics, identification of required ICT components for each industry and size range

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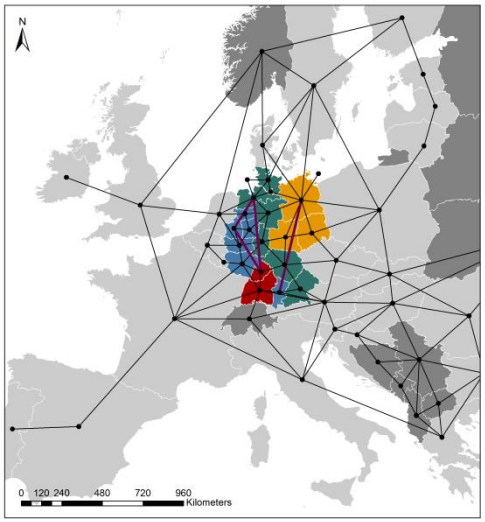
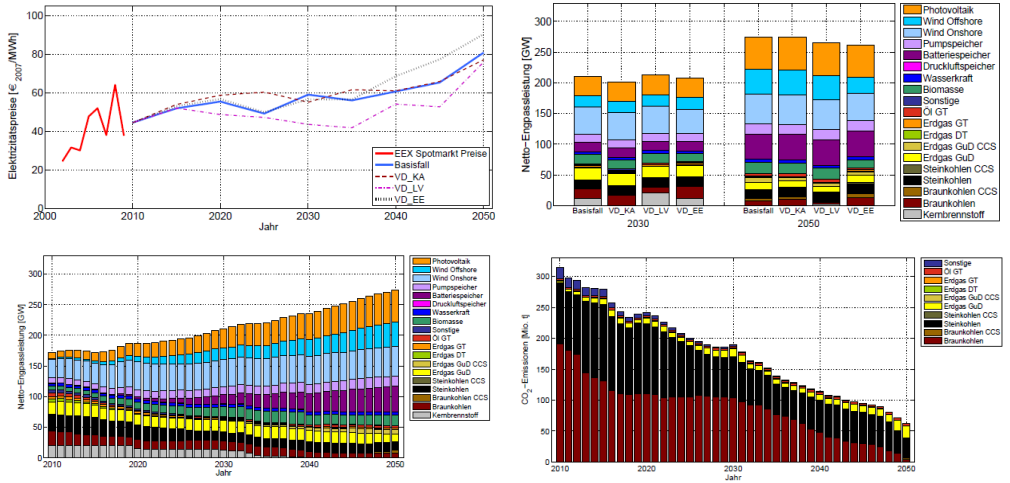
Tool: investment and dispatch model E2M2s





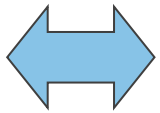
European Electricity Market Model E2M2s

- Fundamental linear electricity market model for Europe
- **Investment** in power stations, storage, grid and further flexibility options with **simultaneous dispatch optimization**
- Myopic optimization on a yearly base with an **hourly resolution**
- For this study simplification to keep the optimization problem solvable with many flexibility options and high temporal resolution: only Germany, one price zone

E2M2s: Model structure and restrictions

Minimization of the system cost

- Variable generation cost
- Start-up cost
- Annuity of investment
- Fixed cost



Security of supply

- Hourly demand coverage
- Provision of balancing power (spinning and non-spinning)

Technical restrictions

- Admissible power range
- Maximum load change rates
- Start-up times

Others

- Exogenous renewable feed-in based on real weather years
- Broad variety of flexibility options

E2M2s: Representation of flexibility options

Electricity storage

- Generic aggregation of different types of storage (pump storage, compressed-air, battery)
- Typical fixed ratio between input and output capacity per technology
- Different withdrawal times for short- (2h), medium- (7h) and long-term storage (200h)

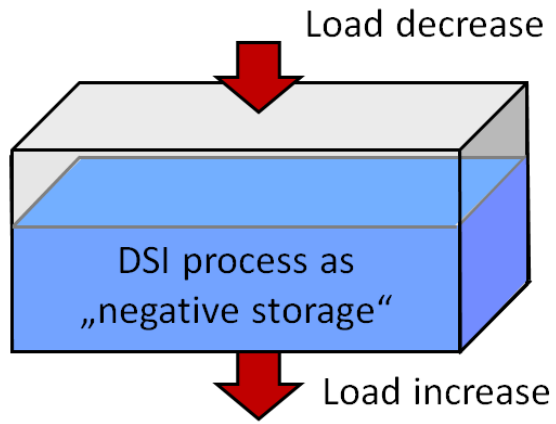
Demand Side Integration

DSI Cluster 1

DSI Cluster 2

…

$P_{up}(t)$, $P_{down}(t)$
E_{shift}, d_{shift}
c_{inv}, c_{fix}, c_{var}
η



Feed-in management

- Curtailment of surplus feed-in from variable renewable sources
- Amount of unused renewable feed-in limited to 5%
- Additionally necessary renewable capacity to reach political targets is considered

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E2M2s: Example scenario framework

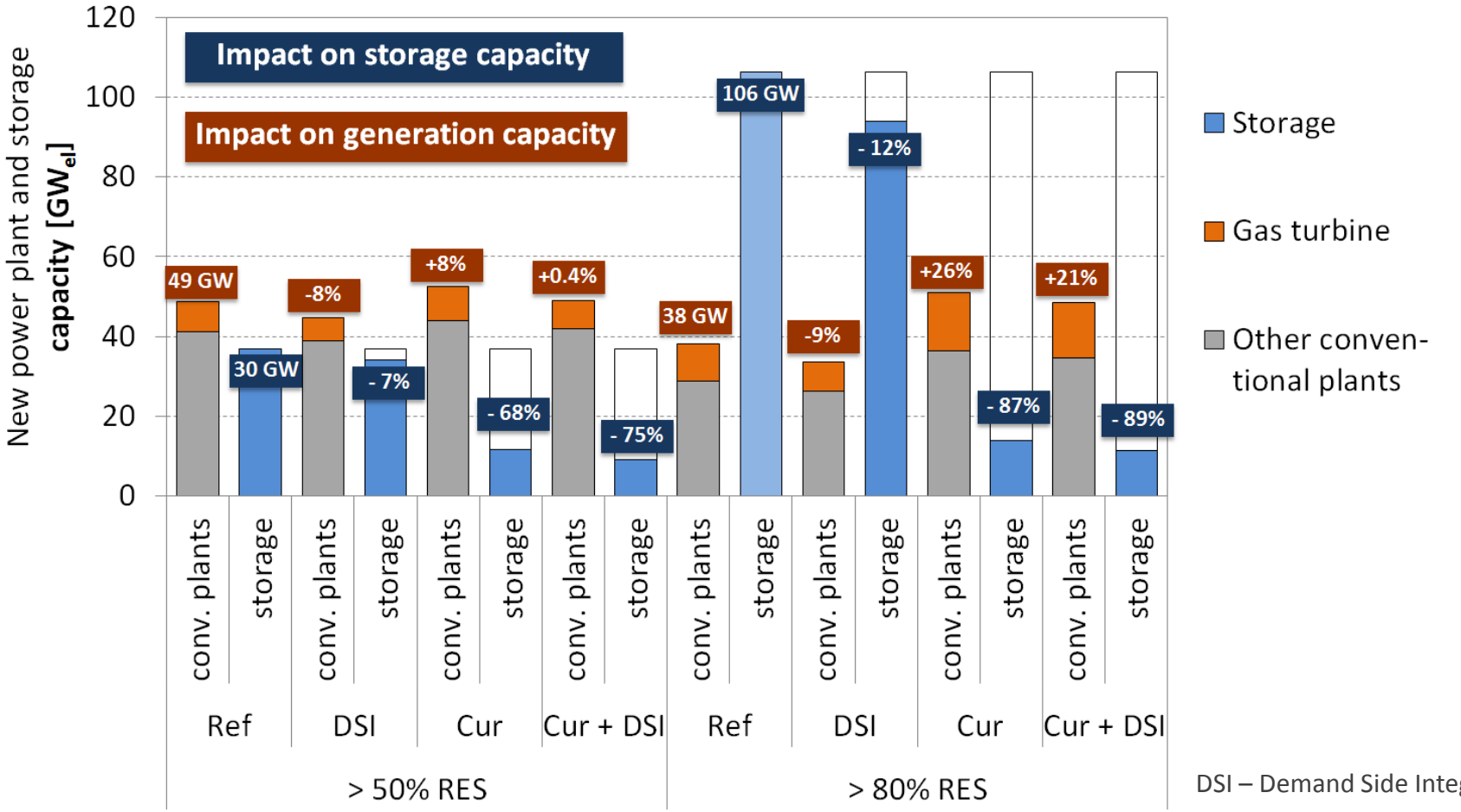
- German electricity system as one region without bottlenecks and no interconnections to neighboring countries
  - Increases demand for flexibility
  - Relaxes model complexity
- Optimization of investment and dispatch in hourly resolution
- Scenario framework: variation of RES penetration (according to the official German energy reference forecast) and available flexibility options:

Scenario	RES share	Electricity storage	Demand Side Integration (DSI)	Feed-in management (curtailment)
Ref	> 50% and > 80% respectively	X	-	-
DSI		X	X	-
Cur		X	-	X
Cur + DSI		X	X	X

RES = Renewable Energy Systems

E2M2s: example model results

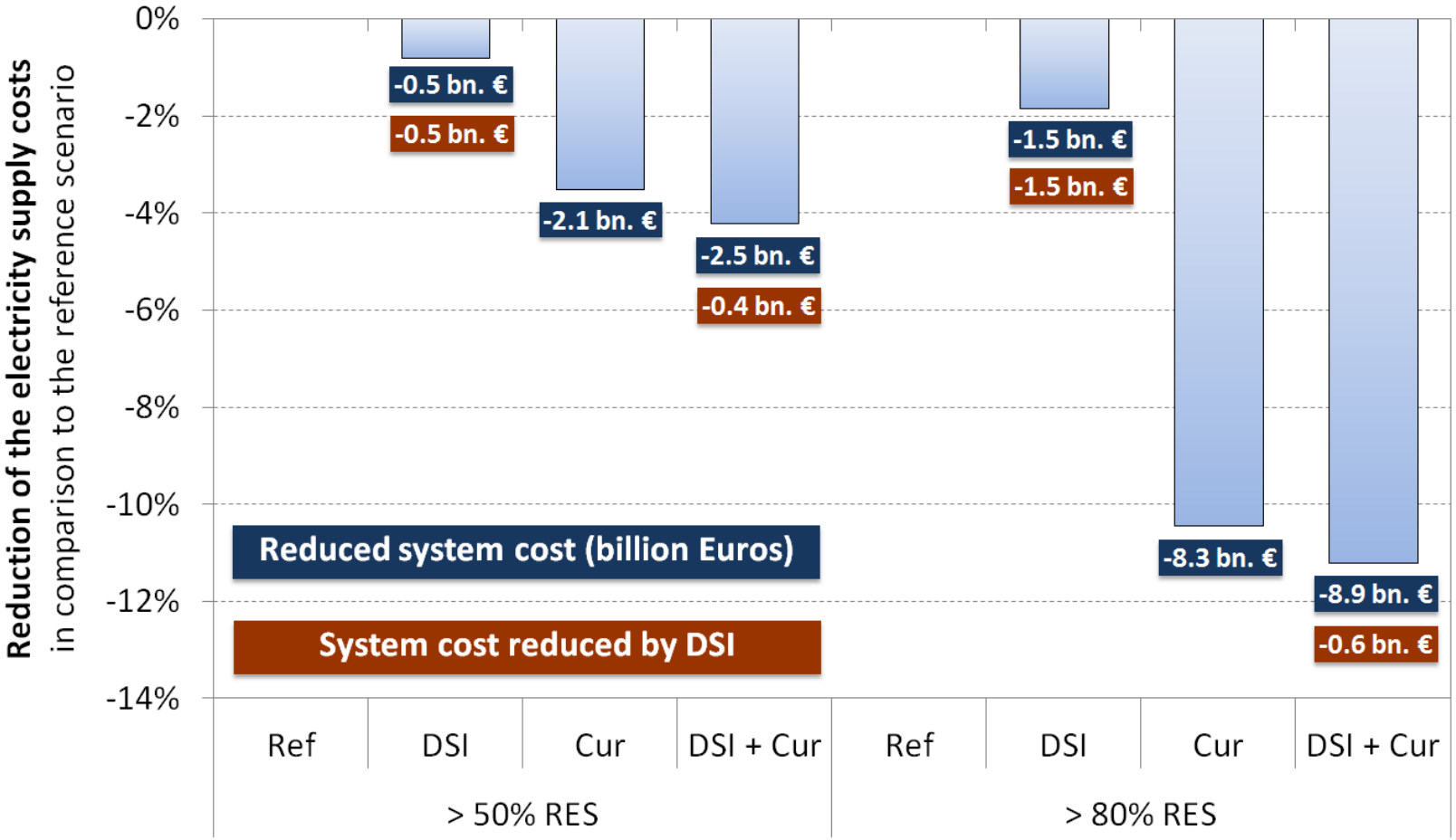
impact of flexibility options on storage and generation capacity



DSI – Demand Side Integration

E2M2s: example model results

yearly system cost savings



DSI – Demand Side Integration

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Conclusions

- For cost-effective management of high shares of renewables an **efficient mix of flexibility options** is required
- Beside electricity storage especially **feed-in management (curtailment)** and **flexibilization of the demand side** discloses efficient potential
  - Installing more variable RES capacity and curtailing some of its output in peak times is more efficient considering the overall cost
  - Demand Side Integration provides an economically interesting potential of several gigawatts for balancing renewables in the **short term**
  - For the **long term** Power-to-X, electricity storage and back-up generation are appropriate options

The case of Germany:

- Combining feed-in management and demand side integration can lead to a reduction in electricity supply cost of 2.5 bn. € p. a. at > 50%RES and 9 bn. € p. a. at > 80%RES by especially cutting investments in energy infrastructure

Outlook

Electricity market model:

- European context in hourly resolution
- Transmission grid in Germany (18 regions)
- Heat market for more detailed cogeneration and power-to-heat

Market mechanism for an efficient embedding of DSI options:

- Consideration of both grid and energy
- E.g. “grid traffic light” concept

Thank you!

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