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Reduction of carbon emissions due to renewables
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Methods and approaches

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Estimating carbon emission reduction of RES is not straight-forward due to dynamic effects, trade and long term effects

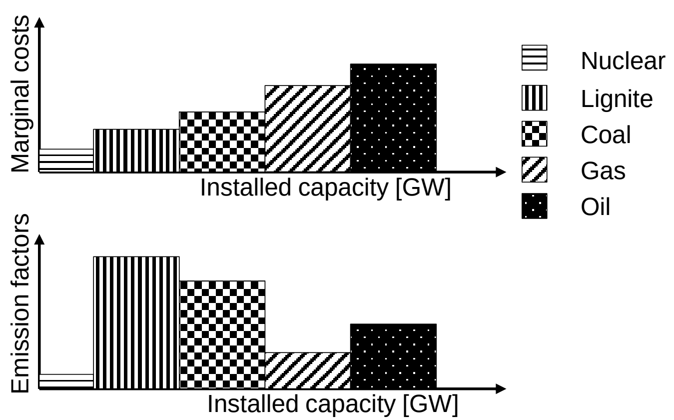
Motivation & Effects of RES

Motivation

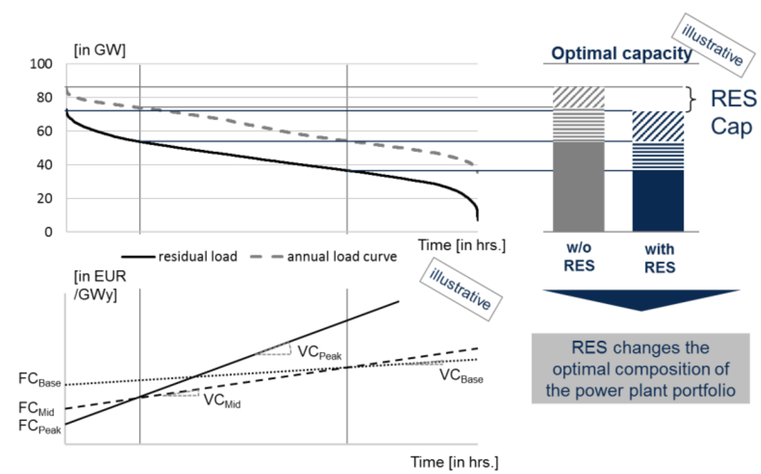
- Main measure to reduce carbon emissions in the power sector
- Complex analysis necessary in order to determine the contribution of RES on carbon emission reductions
- No uniform method for determining carbon emission reduction

Effects of RES

Short term effects of RES



Long term effects of RES



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The literature review shows that there are three types of methods to determine the effect of RES on carbon emissions

Literature review

Authors	Year	Region	Time period	Method type	Considered RES	SAE[1] of wind [kg / MWh]
Howley et al.	2014	IR	2012	Displacement	All	489
Wheatley	2013	IR	2011	Econometric	Wind	280
Di Cosmo et. al.	2014	IR	2012	Econometric	Wind	430
Oliveira et. al.	2018	IR	2013-2017	Econometric	Wind	460
Clancy et al.	2015	IR	2012	Dispatch	Wind & Biomass	460
Klobasa & Ragwitz	2005	DE	2003	Displacement	All	856
Abrell et al.	2018	DE	2010-2015	Econometric	Wind & PV	175 – 530
Klobasa & Sensfuß	‘07, ‘09, ‘11, ‘16	DE	2004-2013	Dispatch	All	669[2]
Cullen	2013	ERCOT	2005-2007	Econometric	Wind	430
Kaffine et al.	2013	ERCOT	2007-2009	Econometric	Wind	515
Novan	2015	ERCOT	2007-2011	Econometric	Wind & PV	740[3]
Lew et al.	2013	ERCOT	2020	Dispatch	Wind & PV	500 – 540[4]

1) SAE – specific avoid emissions; 2) for 2013; 3) and 4) results for a mix of Wind & PV

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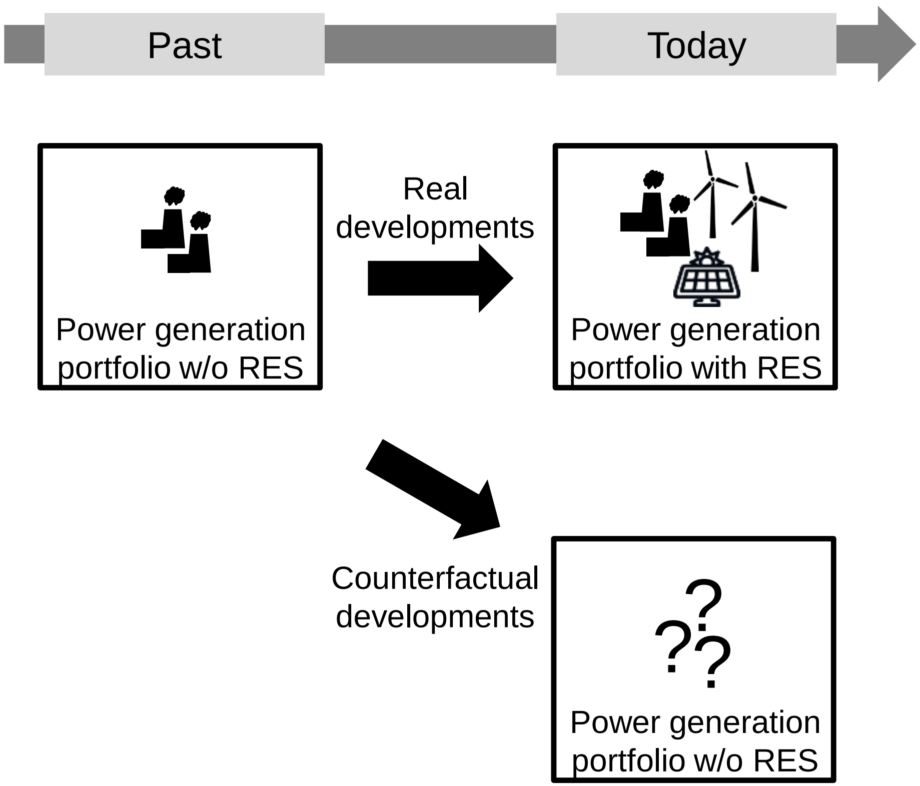
Dispatch models can integrate long-term effects of RES such as alternative investments in the power generation portfolio

Method comparison

Criteria	Displacement estimations	Econometric models	Dispatch models
Data need:	Low	Medium	High
Effort:	Low	Medium	High
Analysis period:	Ex-ante & ex-post	Ex-post	Ex-ante & ex-post
Considered RES:	All	Volatile RES	All
Consideration of:			
- Dynamic effects	No	Yes	Yes
- Trade	No	(Yes)	Yes
- Long term effects	No	No	Yes
Applications:	Country comparisons	Island networks	Integrated power systems

A counterfactual world w/o RES provides the base for deter-mining the long term effects of RES on the power markets

Development of a counterfactual world



Assumptions for the counterfactual world:

Historical power generation portfolio:

- Base year 2006
- Elimination of all existing RES

Application of the PEST-Framework:

Political assumptions:

- No alternative emission reduction measures

Economic assumptions**:**

- Price assumptions for fuel and CO_2 based on expectations

Social assumptions:

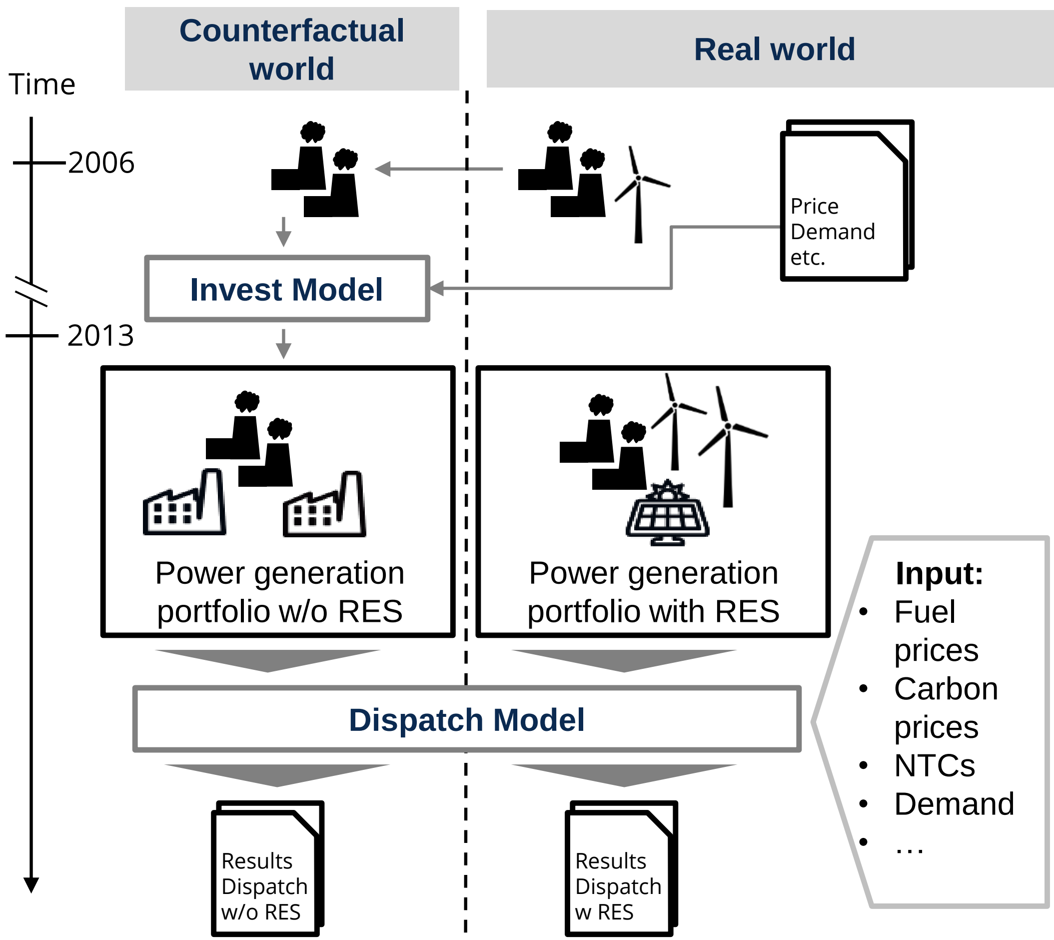
- No additional lignite or nuclear power plants

Technological assumptions:

- Substitution of Run of River power plants with coal-fired power plants

A counterfactual approach allows the calculation of a power generation portfolio without RES using an invest model

Our approach



Invest Model:

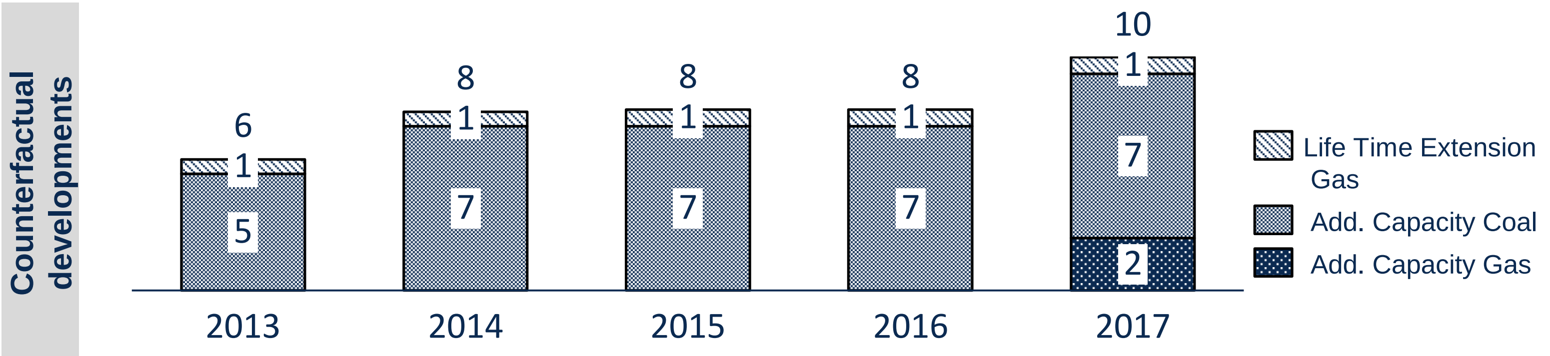
Approach:	Linear optimization
Objective:	Total system costs incl. capital costs
Timely Res.:	8760 h
Geo Res.:	Germany
Trade:	No
Gen. Techno.:	All
Invest Techno:	Coal, Gas and Oil

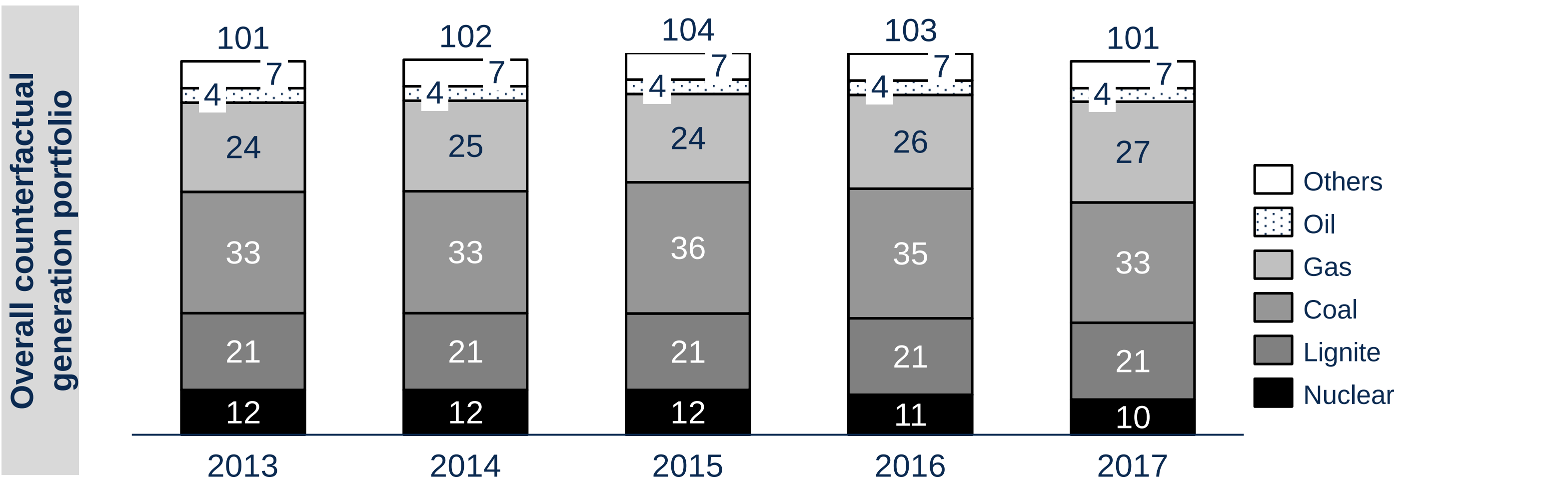
Dispatch Model:

Approach:	Linear optimization
Objective:	Total system costs excl. capital costs
Timely Res.:	8760 h
Geo Res.:	EU27 + NO + CH + …
Trade:	NTC
Gen. Techno.:	All
Invest Techno:	None

The impact of the counterfactual scenario rises steadily and is responsible for 10 % of installed capacity in Germany 2017

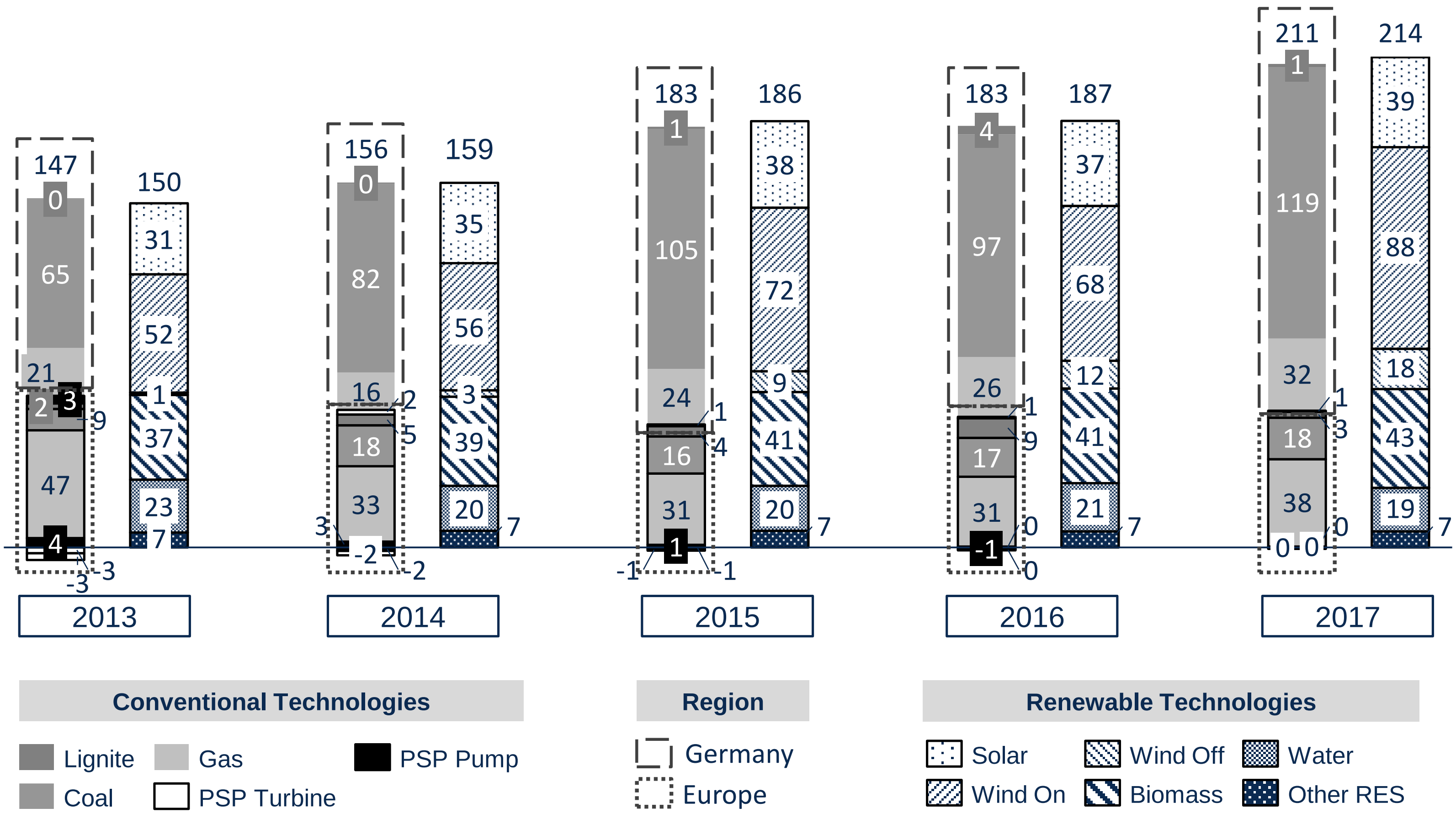
Development of the counterfactual power generation portfolio in GW





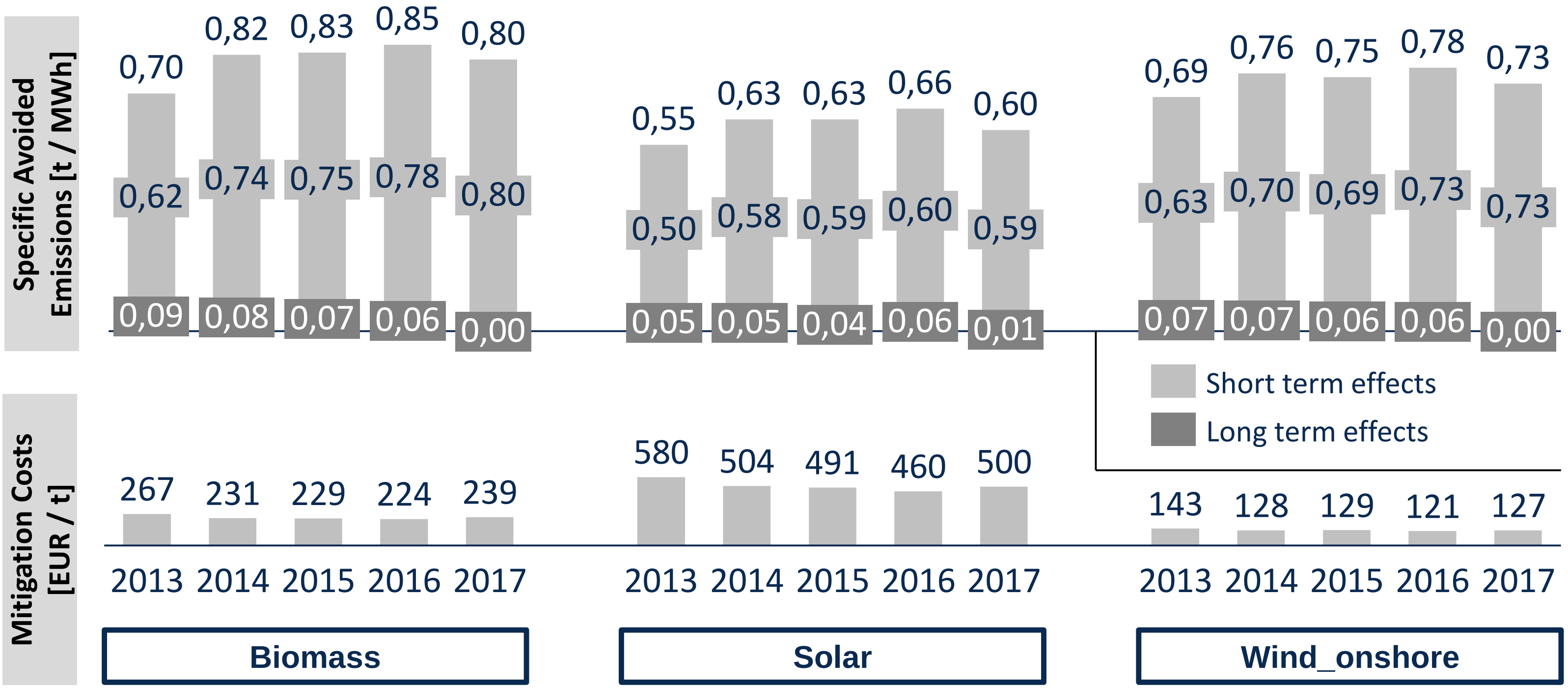
The increase in wind generation is accompanied by an increasing displacement of coal generation

Displaced power generation from 2013 to 2017 in TWh



The RES expansion increases the specific avoided emissions for all technologies due to an increased displacement of coal

Specific Avoided Emissions & Mitigation Costs for Biomass, Solar and Wind



- **Increased displacement of coal raises the specific avoided emissions**
- **Fuel and carbon prices can compensate effects of capacity expansion**
- **High correlation to load decreases specific avoided emissions**
- **High impact of governmental support on carbon mitigation costs**

Dispatch models are suitable to integrate long term effects of RES – the specific avoided emissions increase up to 10%

Summary & next steps

Summary

- Methods for estimating carbon emission reduction by RES:

	Pros	Cons
Displacement estimation	easy & little data	limited effects considered
Econometric models	dynamic effects	no long term effects
Dispatch models	all effects	High effort & data

- Presented approach for integrating long term effects suitable
- Considering trade is essential as about 30% of the displacement effects take place abroad
- Long term effects can further increase the specific avoided emissions up to 10%

Next steps

- Implementation of an econometric model
- Publication of a paper

»Wissen schafft Brücken.«