Potsdam Institute for Climate Impact Research

ADVANCE activities on improving VRE representation in large-scale energy-economy and integrated assessment models

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Characteristic properties of VRE impose additional costs on the power system

VRE resource quality is **spatially variable**

→ Additional transmission is costly

VRE supply is **uncertain** and **short-term variable**

→ Short-term output adjustments are costly

VRE supply is **variable over time**

→ Costs for temporal matching of VRE supply and demand

„Grid-related costs“

„Balancing costs“

„Profile costs“ (incl. adequacy costs)

Integration costs

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Ueckerdt 2013, Hirth&Ueckerdt 2014 (forthcoming). Similar cost divisions can be found in Milligan et al. 2009, Holttinen et al. 2011, SRREN 2011, Borenstein 2012,

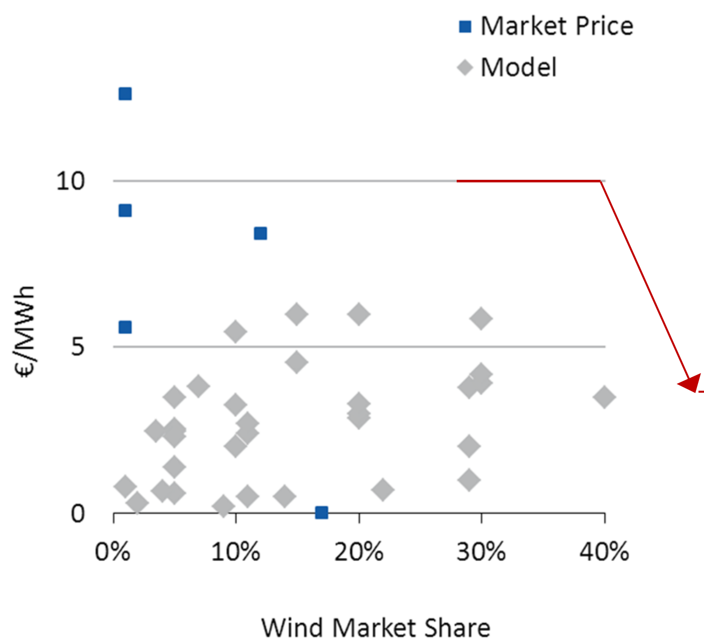
Quantification for wind: profile costs are most important at high VRE shares

Grid-related costs

- Scarce and inconclusive data
- **2-13 €/MWh$_{VRE}$**
  (shares of 15-40%, dena 2010, NREL 2012, Holttinen et al. 2011, Schaber et al. 2012)

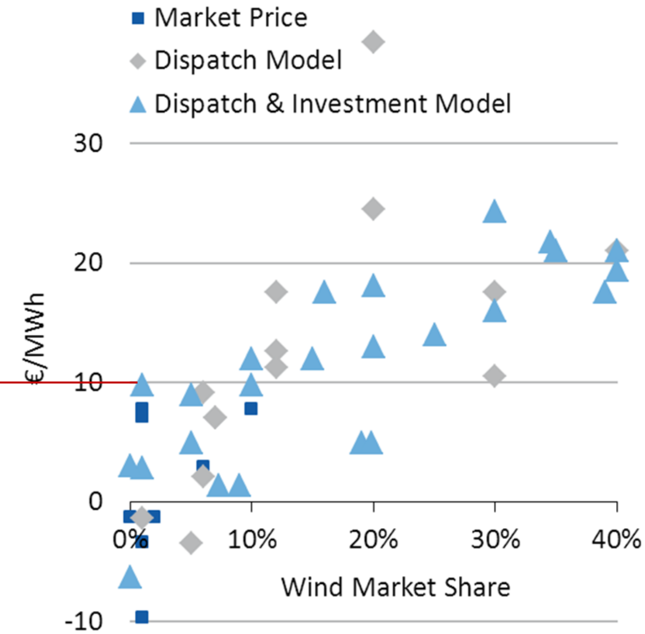
Balancing costs

~5 €/MWh$_{VRE}$



Profile costs

~10–25 €/MWh$_{VRE}$ at 30% share



All figures are
- **in marginal terms per MWh of VRE**

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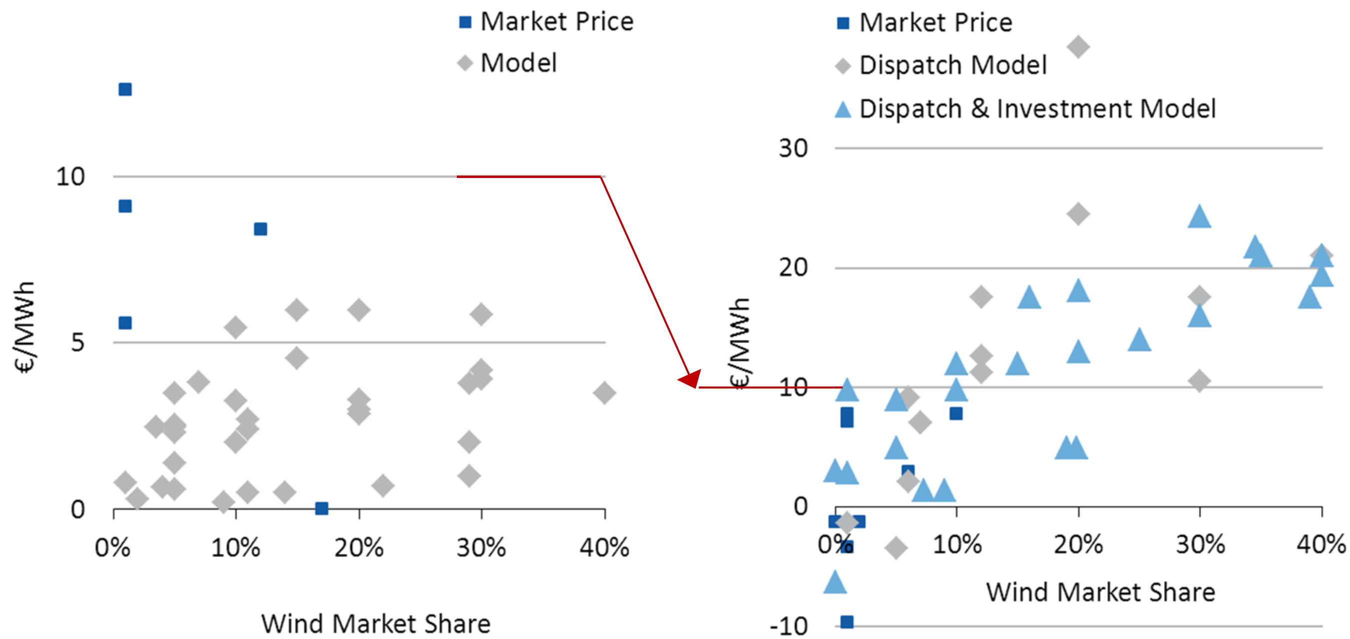

Costs can be different in developing countries due to

- Higher infrastructure requirements → increasing effect
- Lower reliability level → decreasing effect

All figures are
- **in marginal terms per MWh of VRE**
- **for power systems in developed countries**

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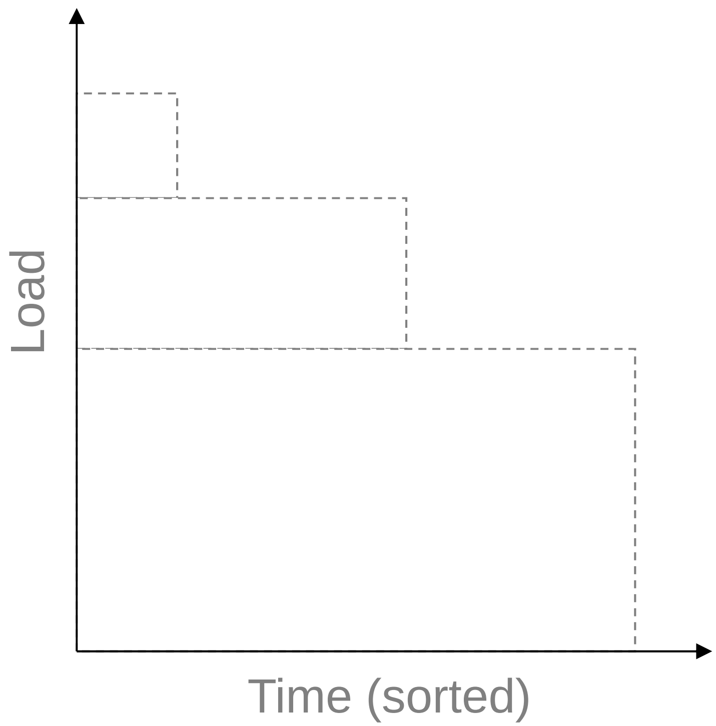
Hirth&Ueckerdt&Edenhofer 2014 (forthcoming)

Representing residual load duration curves (RLDC) in IAMs

- A step-function approximates the (R)LDC data

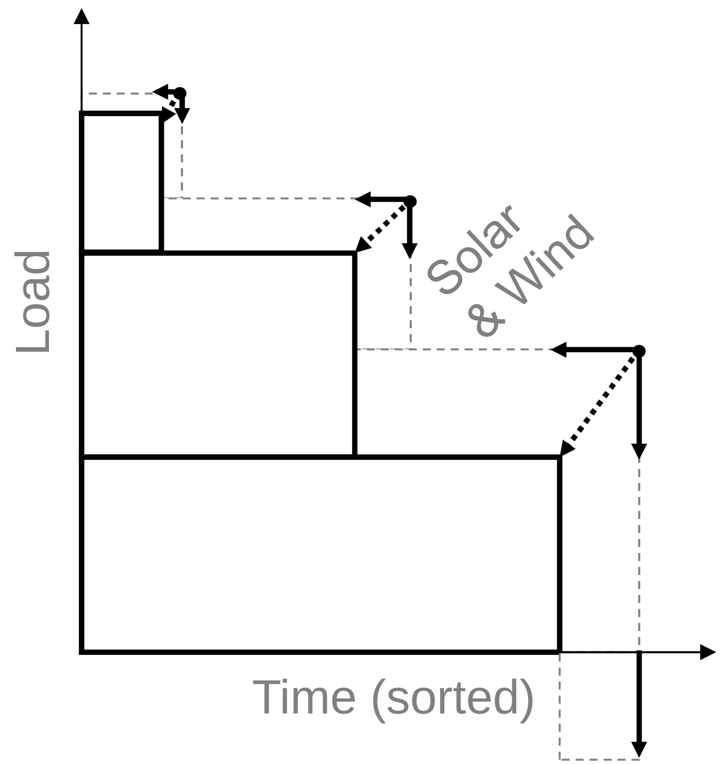
RLDC approach



Ueckerdt et al. “Representing power sector variability and the integration of variable renewables in long-term climate change mitigation scenarios: A novel modeling approach”. (submitted)

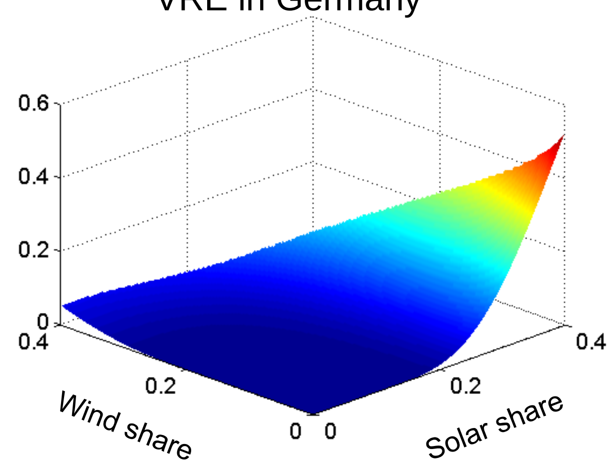
Representing residual load duration curves (RLDC) in IAMs

RLDC approach



- A step-function approximates the (R)LDC data
- The RLDC endogenously changes within the optimization
- These changes depend on VRE share, solar/wind mix, and region
- Dispatchable power plants cover residual load with an endogenous capacity factor
- Important flexibility options can be endogenously represented

Curtailment rate of VRE in Germany



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Merits and limitations of the RLDC approach

Merits: The RLDC approach is…

1. **Comprehensive**: captures most important aspects of VRE/load variability.
2. **Robust:** parameterization is valid for a range of energy system configurations.
3. **Flexible:** endogenous choice of different integration options, including adjustments of the non-VRE part of the energy system.

Limitations and outlook

1. The approach is **non-linear**.
2. DSM and short-term storage induce complex changes of the RLDC → it needs a **high-resolution model for a parameterization**
3. Grid- and balancing costs need to be implemented as **exogenous cost functions**

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Global perspective: Derive the mid- and long-term role of VRE for climate mitigation

Requires an improved representation of VRE in Integrated Assessment Models (or long-term planning tools in general).

Three activities support this:

1) **Renewable initiative (lead by JISEA / NREL):**
   - On-going since 2009
   - Focus mostly on VRE resource potentials
   - Some initial work on VRE integration challenges

2) **EMF27:** Overview of status quo in global model approaches to VRE*

3) **ADVANCE project (EU FP7):**
   - Dedicated task on system integration of VRE in IAMs
   - Additional resource data sets from individual modeling teams

*Luderer et al (2014): "The role of renewable energy in climate stabilization: results from the EMF27 scenarios", Climatic Change 123(3-4)

Activities of the ADVANCE project on VRE integration

- Improve integration mechanisms in different IAM families
  - identify most relevant real-world integration challenges
  - revisit methodologies in models
  - Compare IAM results to bottom-up models with greater spatial detail

- Identify main drivers of VRE deployment through a set of coordinated IAM scenarios

- Current status:
  - Model improvements under way
  - Results will be published early 2015

Open points for further activities

- Connecting global and national perspectives:
  - Validate and parameterize IAMs with detailed bottom-up models
  - Inform national system planners about potentially high future VRE shares required for climate mitigation
  - Requires high-detail bottom-up models to derive the system specific investments in infrastructure such as grid lines or plants for balancing

- Exchanging time series data of VRE supply and load on a data platform (started in ADVANCE, input welcome, especially for developing countries!)

- Analysing the role of flexibility options and the interaction between electricity, heat, and transport systems

References

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