On the economics of electrical storage for variable renewable energy sources

Alexander Zerrahn, Wolf-Peter Schill, Claudia Kemfert
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An outlier topic in this session:

How much electrical storage does the integration of variable renewable energy sources require?
Our answer to Sinn (2017)

Paper by Hans-Werner Sinn (European Economic Review 2017)

• Increasing vRES shares would require excessive storage
• Reason: volatility of (onshore) wind power and PV
• Stylized analysis for Germany:
  • 17% variable RES share → No storage required
  • 30% variable RES share → 40 GWh storage required (roughly as PHS today)
  • 50% variable RES share → 2,100 GWh
  • 68% variable RES share → 5,800 GWh (more than European PHS potential)
  • 89% variable RES share → 16,300 GWh
• Somewhat lower in (stylized) European interconnection
• Sinn’s conclusion: storage needs limit the transition to RES

Our answer

• Open-source rebuttal, addressing questionable implicit assumptions
• We illustrate the effects of flexible sector coupling (power-to-x)
Sinn vs. literature

The graph illustrates the relationship between storage energy capacity in percent of total yearly energy demand and the share of variable renewable energy sources. Different studies are represented by various symbols and legends, indicating the percentage values at different points on the graph. The present analysis is highlighted with a specific line connecting points across different studies, showing a trend in the data.
How does Sinn derive such large figures?

**Stylized general approach**

- Hourly time series on demand and a combined (onshore) wind and PV capacity factor (2014 German data)
- Scale up RES capacity until desired annual RES share is reached
- Minimum storage capacity (GWh) to integrate all variable renewables

**Storage heuristic**

- Store hourly renewable surplus generation
- Release energy as soon as residual demand is positive again
Questionable implicit assumptions

- Full RES integration by electrical storage, no curtailment
- No economic objective function
- Heuristic storage strategy (w.r.t. both dispatch and investment)
- No flexible power-to-x
- Others:
  - No dispatch of other plants
  - No other flexibility options
  - No endogenous combinations of renewables
  - No offshore wind
  - ...
We can replicate it!

- Open input data (OPSD), open Excel tool (https://doi.org/10.5281/zenodo.1170554)
Intuition: What drives Sinn’s results?

Full integration of all vRES drives storage requirements

- Residual load duration curve (here 80% vRES)
Intuition: What drives Sinn’s results?

Full integration of all vRES drives storage requirements

- Residual load duration curve: storage shifts surplus from A to B
We introduce *power-oriented* curtailment (storage loading restriction)

- Same Excel tool, but renewable surplus curtailed if larger than threshold (D)
Renewable curtailment strategy 1: power-oriented

Result: storage needs substantially lower

[Graph showing the relationship between storage energy in TWh and maximum allowed renewables curtailment in percent for different variable renewables proportions (40%, 50%, 60%, 70%, 80%).]
Slightly increased renewable capacities

If some renewable energy is curtailed, necessarily higher renewable capacities
We introduce *energy-oriented* curtailment (storage energy restriction)

- Same Excel tool, but renewable surplus curtailed if storage full
Result: storage needs even lower than under strategy 1

→ Nothing new. Sinn should have seen my presentation at Strommarkttreffen in June 2013: „Residuallast, EE-Überschüsse und Speicherbedarf“ … and respective *Energy Policy* paper 2014

http://dx.doi.org/10.1016/j.enpol.2014.05.032
Endogenous storage and curtailment: still moderate storage capacities

Alternative approach: optimization with stylized cost minimization model and same input data
Flexible use of (additional) vRES for „X“

- Heat, mobility, hydrogen, ...
- This triggers both
  - additional renewable capacity expansion
  - and additional demand flexibility
- Stylized parameterization:
  - 50 GW
  - 2,000 full-load hours (i.e. 100 TWh)
  - perfectly flexible
Effects of (generic) power-to-x

Result: substantially lower storage and curtailment

- Renewable surplus as a valuable resource
Electrical storage needs for different P2X settings for 70% vRES
Conclusions

- Sinn’s findings on storage needs deviate strongly from the literature
- We replicate and extend the analysis with open data and open-source tools
  - [https://doi.org/10.5281/zenodo.1170554](https://doi.org/10.5281/zenodo.1170554)
  - [http://arxiv.org/abs/1802.07885](http://arxiv.org/abs/1802.07885) (just accepted for publication in *EER*).
- Main point: assumption of full vRES integration (no curtailment)
- More suitable: cost minimization approach
  - More detailed analysis desirable
- Flexible sector coupling further decrease storage needs
  - Especially those triggered by right-hand side of residual load curve
Shorter German version: DIW Aktuell 11

http://www.diw.de/documents/publikationen/73/diw_01.c.591369.de/diw_aktuell_11.pdf

News coverage: Tagesspiegel Background, EUWID, PV magazine...

Reply by Hans-Werner Sinn and re-reply by us

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Thank you for listening