

Exploring Uncertainty in Energy System Models

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Structure



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- Open Questions on Uncertainty
- Example Application of multi-scenario analysis on European Power System
- Conclusion

Open Research Questions



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What level of complexity is appropriate in long term energy system models given the uncertainty in the inputs over time...?

What is the relationship between required complexity and inherent uncertainty?

Open Research Questions



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Is reducing complexity just getting the wrong answer quicker?

Are we trying to make models faster or trying to make them more accurate?

Improved computing power and efficiency in energy systems modelling



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Parkinson's law "work expands so as to fill the time available for its completion"

..applied to simulations

..."Simulations are only as complex as the time available to complete them"



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Are there lessons we can learn from other disciplines?

Insights from other modelling fields



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The art is to find an approximation simple enough to be computable, but not so simple that you lose the useful detail -Prof Michael Levitt

Deciding what counts as a good model [sic] depends on intense, detailed discussions between groups of experts who usually agree about fundamentals- Eric Winsberg

Within complex systems, understanding the interactions between system components can be more important than the contribution of each to disease risk-W Maziak

soft-linking has added value to our modelling



- Technique we use to better explore uncertainty in large Energy System model is Soft-linking to other sectorial models

How soft-linking has added value to our modelling



- Better insights on the ability of the power system to absorb variable renewables and better estimations of curtailment
- Our TIMES model underestimated the value of storage
- Overestimated the impact of residential electric heating (ASHP)
- Didn't capture impact of variable renewable on gas grid
- Did not do a good job of producing wholesale market electricity prices

Disadvantages to our approach



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- Only a one way flow of information (no convergence, not an optimal)
- Needs more resources to maintain more models
- Requires ‘hardwiring’ in of new constraints (not elegant)
- Interoperability between models is an issue

Sample Application of Multi Scenario Analysis to European Power System



Research Question: What uncertainty does increased renewable variable generation introduce into the power system market prices?

Research Motivation: Typical energy system models use 1 year or a limited number of renewable profiles. This may not capture inter-annual variability of wind energy.

UCC EU-28 Power and Gas Model



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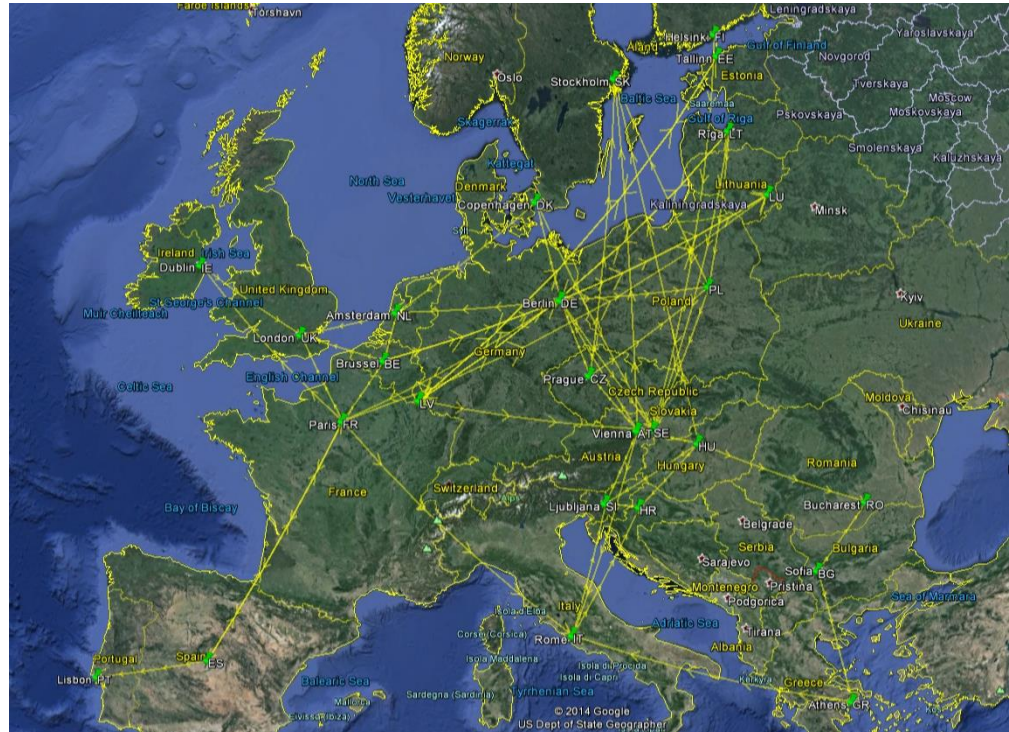
PLEXOS Integrated Gas and Electricity model soft-links to Energy system model

Power System Model Provides:

- Detailed analysis of energy system model results using soft-linking techniques⁺
- High temporal resolution (15min-1 hr)
- High technical detail, reserve modelling, hydro modelling, multi-stage stochastic UC
- Ramping costs, flexibility metrics

EU 28 Model- 3,000 generators, 22 PHES Units, 53 IC Lines

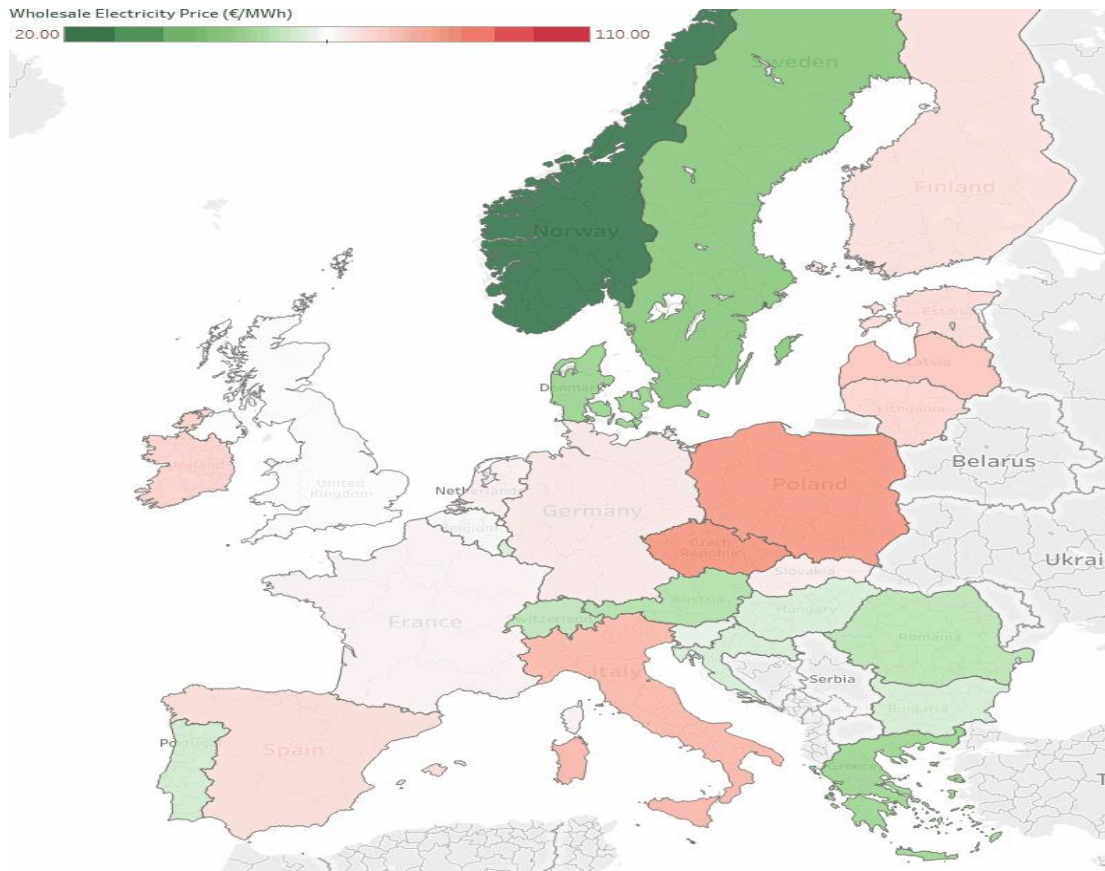
+ Deane, J.P., Chiodi, A., Gargiulo, M., Ó Gallachóir, B.P., 2012. Soft-linking of a power systems model to an energy systems model. Energy 42, 303–312. doi:10.1016/j.energy.2012.03.052



Typical Monthly Price Analysis



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Typical mean wind production in Germany (GWh)



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Region "DE" Generators "Wind Onshore-DE"

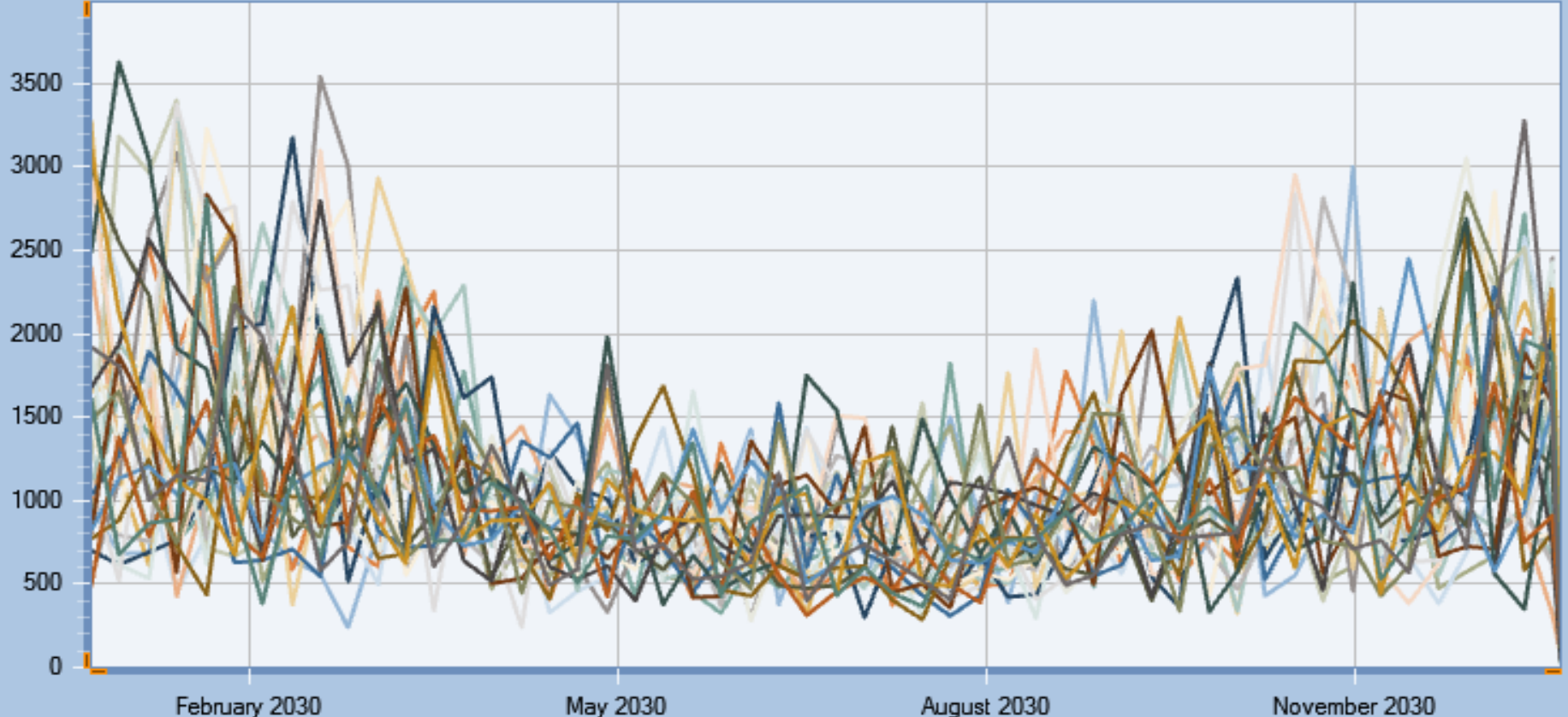


Wind Onshore-DE, Generation (GWh)

30 samples of wind production in Germany (GWh)



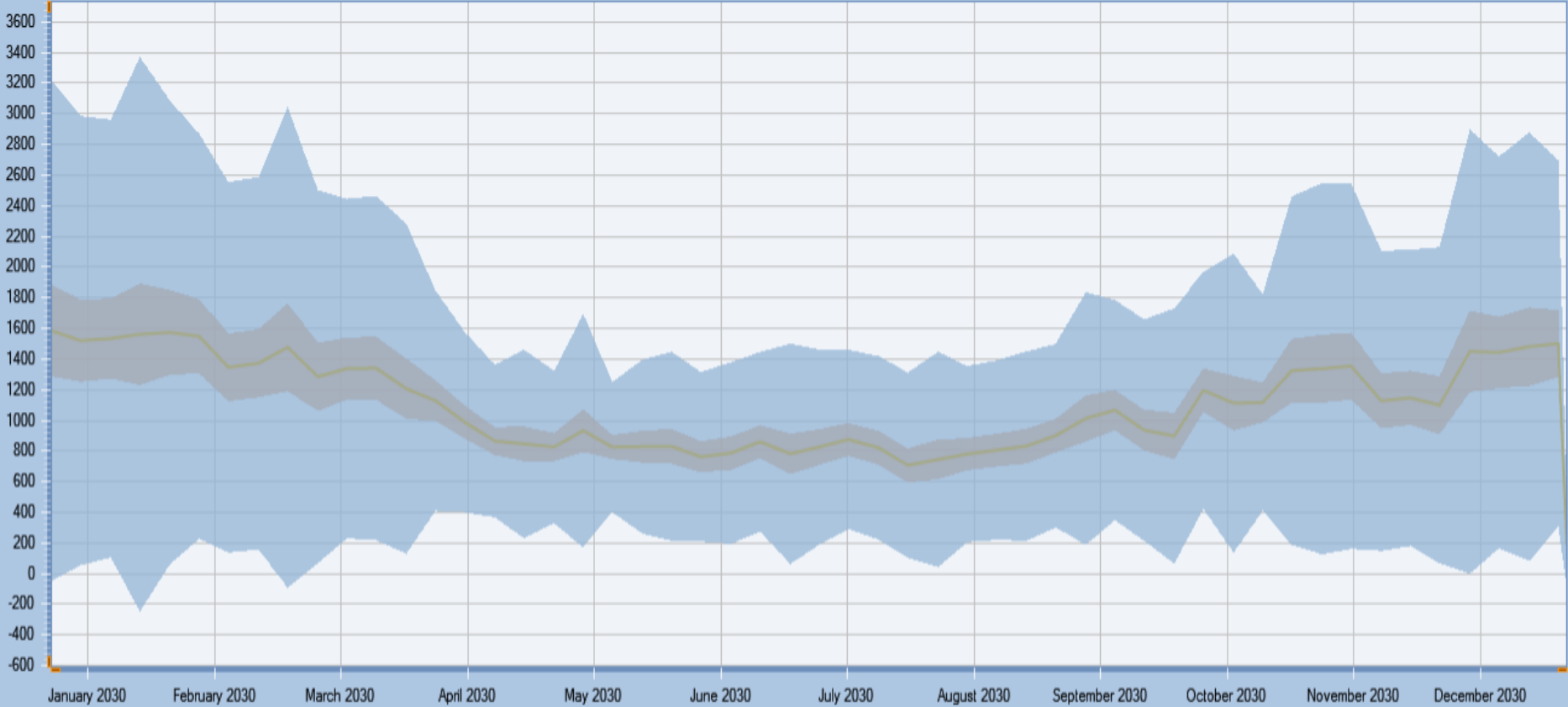
Region "DE" Generators "Wind Onshore-DE"



30 samples of wind production in Germany (GWh)



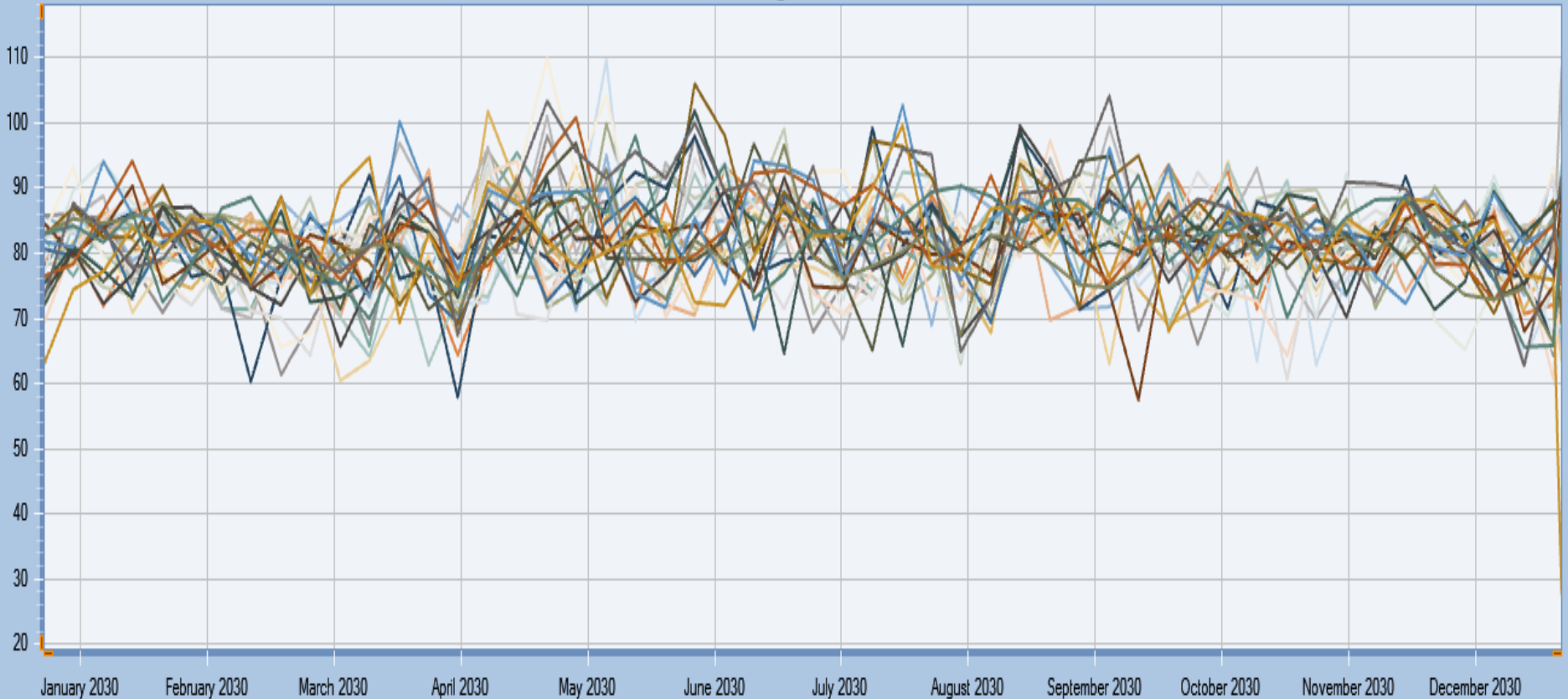
Generator "Wind Onshore-DE"



Germany Resultant Wholesale Prices (€/MWh)



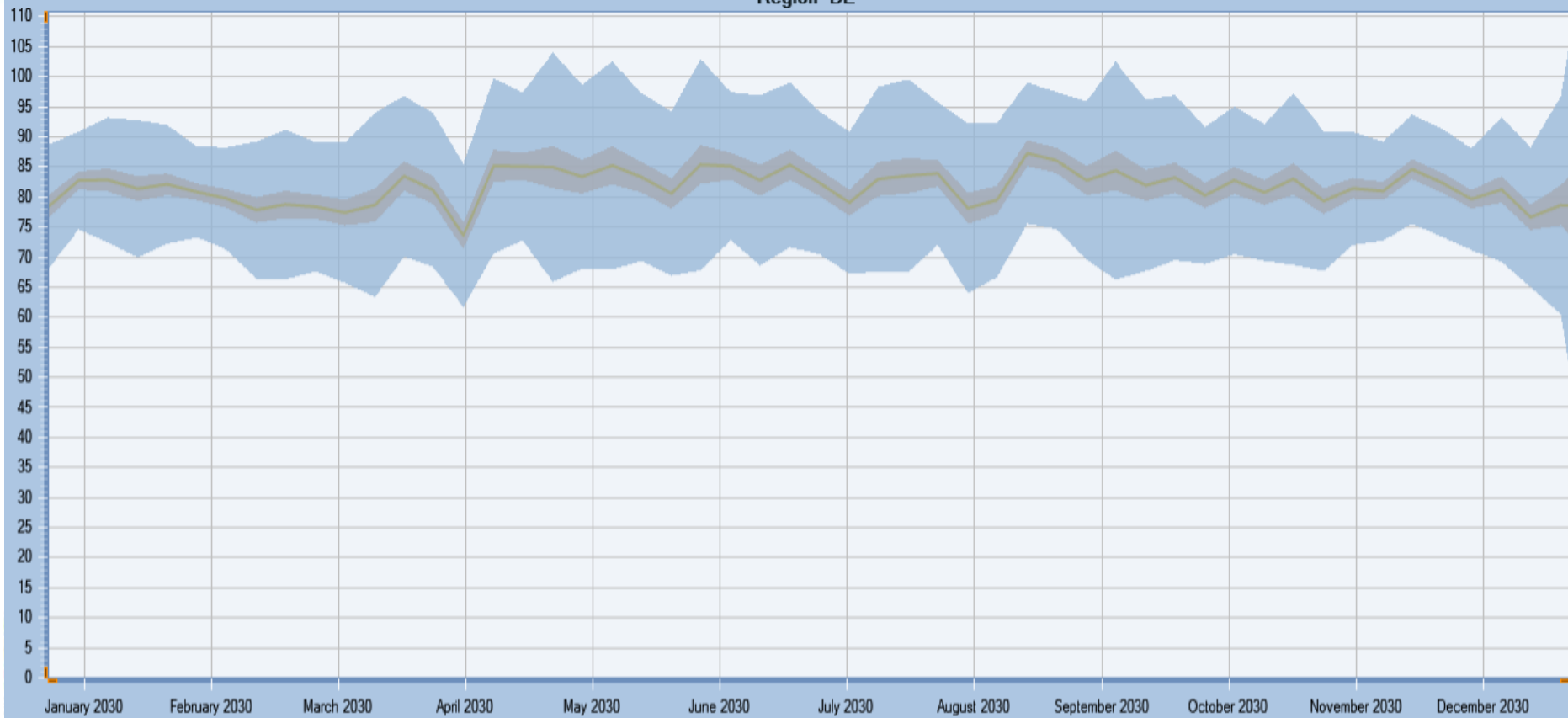
Region "DE"



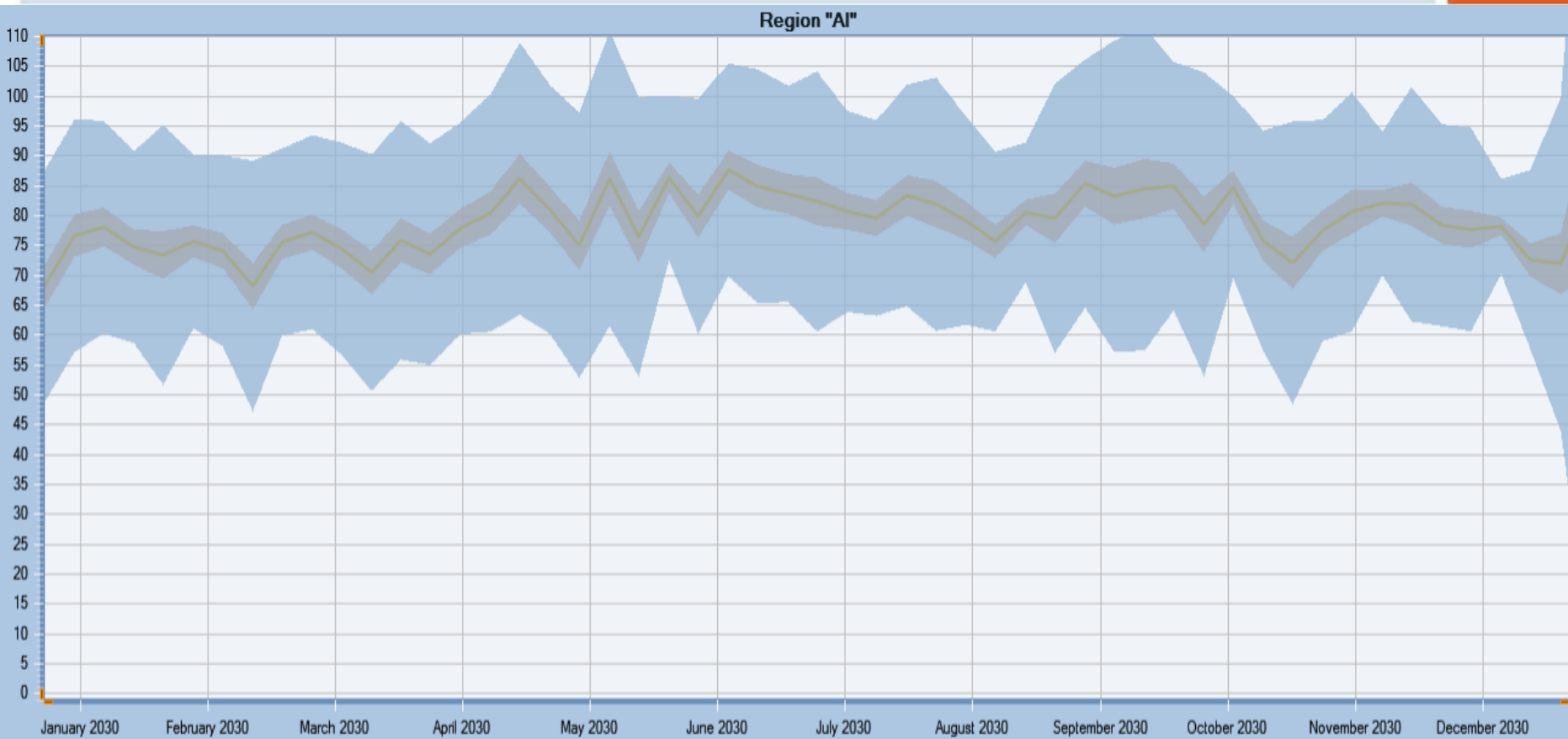
Germany Resultant Wholesale Prices (€/MWh)



Region "DE"



Ireland Resultant Wholesale Prices (€/MWh)



Lessons Learned



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- Countries with limited Interconnection have a greater exposure to uncertainty in inter-annual variability
- Countries with smaller geographical spread of variable renewable resources have greater exposure to uncertainty in inter-annual variability

Uncertainty



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- Uncertainty can be quantified with large multi scenario analysis, but may not be warranted in all cases
- Uncertainty is amplified in some cases/regions depending on location and infrastructure
- Multi-scenario analysis is a useful method but comes at high computational time budgets

Thank You



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Conclusions



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The importance of temporal\technical resolution depends on the question being asked

- appears to have limited impact on costs

- important for technology choice especially storages/batteries

- using a number of models from different users has important broad benefits

- Research should focus on getting the right balance between complexity and uncertainty.



- System wide approach is beneficial.
- Importance of where the boundaries of energy system are drawn
- Multiple models approach has benefits
- Importance of temporal resolution for power system ([5 Minute Simulations vs Hourly](#))
-but all of these have tradeoffs..☹️