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Modeling Renewable Energy in Europe: Cost-Efficient System Integration

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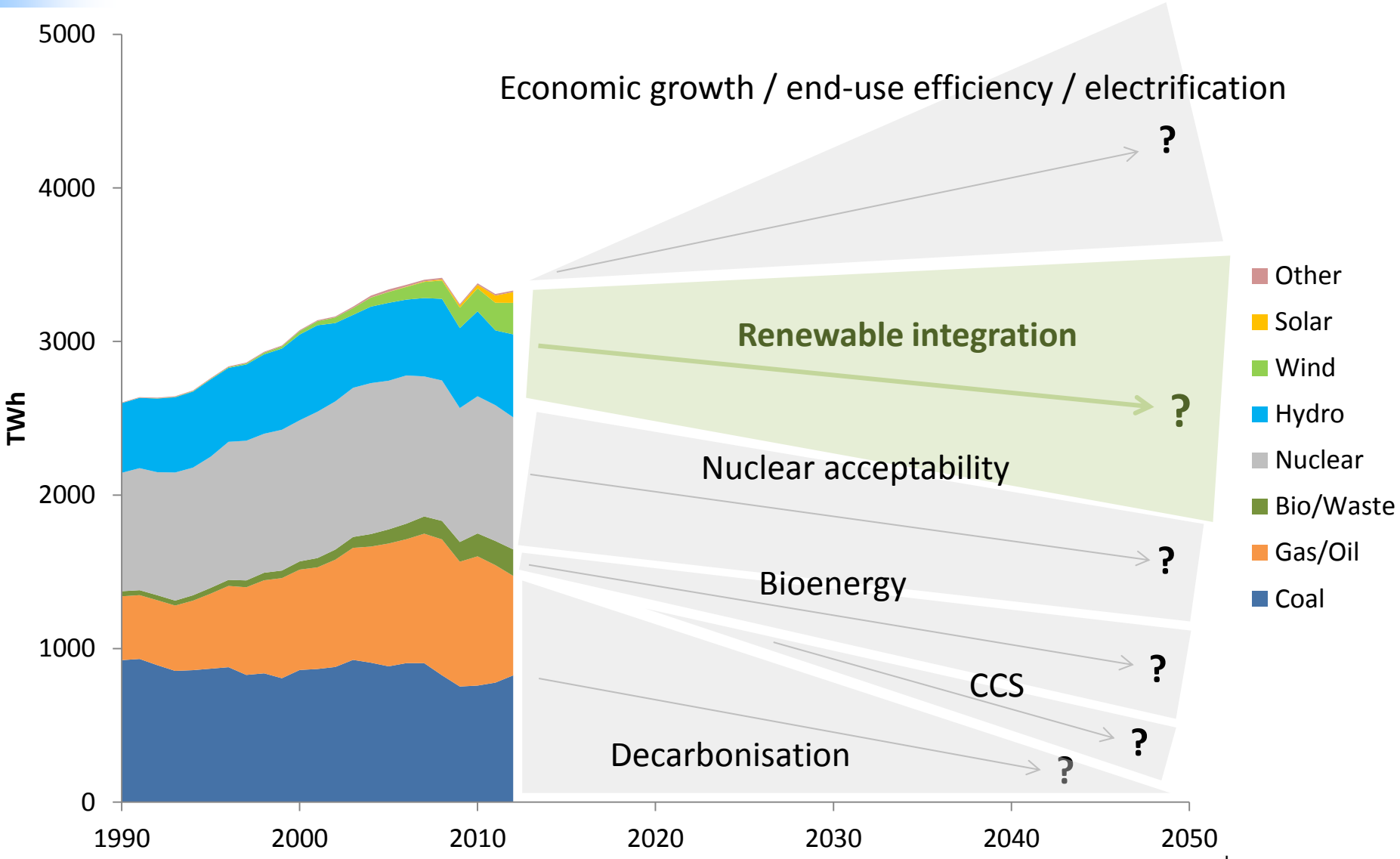
EU Electric Sector is Undergoing Rapid Change



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How should we think about renewable energy?

- Renewable energy (in this talk = wind and solar) is at the center of most scenarios for decarbonisation of electric generation
- Supported by a wide array of policy instruments
- Key characteristics are well-known:
  - Capital intensive; costs declining
  - **Intermittent**; **spatially dispersed**; **physical constraints**
- Economic implications of these traits are less well understood (e.g. many insist on LCOE-based analysis → uninformative)
- Long-term modelling of role of renewable energy must effectively capture these implications

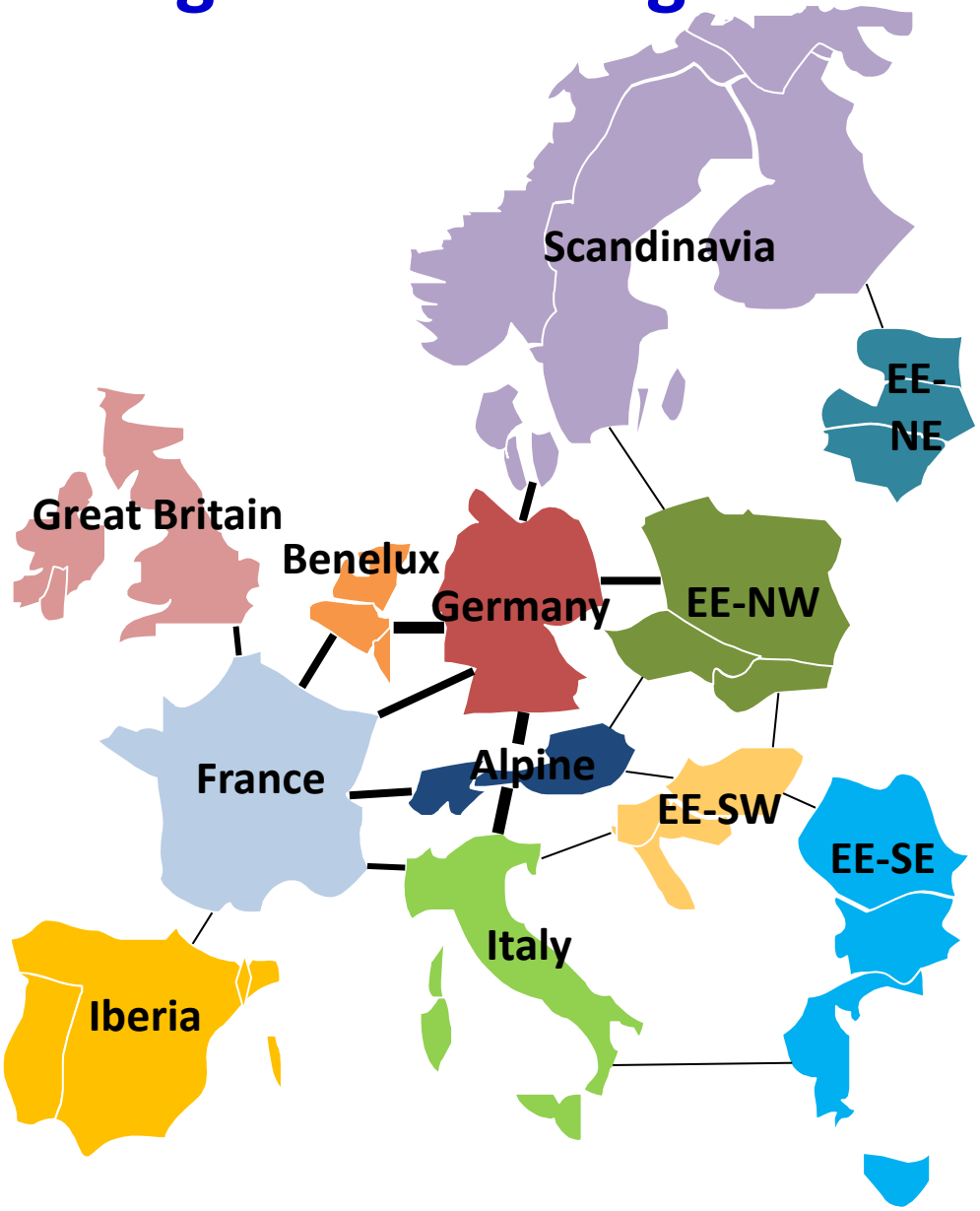
How should we think about renewable energy?

- Renewable energy exhibits decreasing returns to scale, i.e.:
  The ***value*** of wind or solar capacity declines as more is added
- The three factors potentially driving this are:
  - Intermittent (time profile is “inconvenient”, storage is costly)
  - Spatially dispersed (transmission is costly or constrained)
  - Physical constraints on resource base
- In most electricity models, focus is on resource constraints; but the time profile is the main driver of decreasing returns
- Illustration with **marginal value curve** model calculation

EU-REGEN Model

- Jointly developed by EPRI and Ifo Institute, Munich
- Selected model characteristics:
  - Optimized investment/rental with high-resolution dispatch
  - Renewable resources and load based on hourly shapes
  - Continental scope with country-specific detail and cross-border power flows
- Built on EPRI experience:
  - US-REGEN model developed with 13 US member companies
  - Wide range of applications energy and environmental policy and technology issues

12 Model Regions Covering the EU28 + EFTA



EE = Eastern Europe

Net Transfer Capacities (ENTSO-E)

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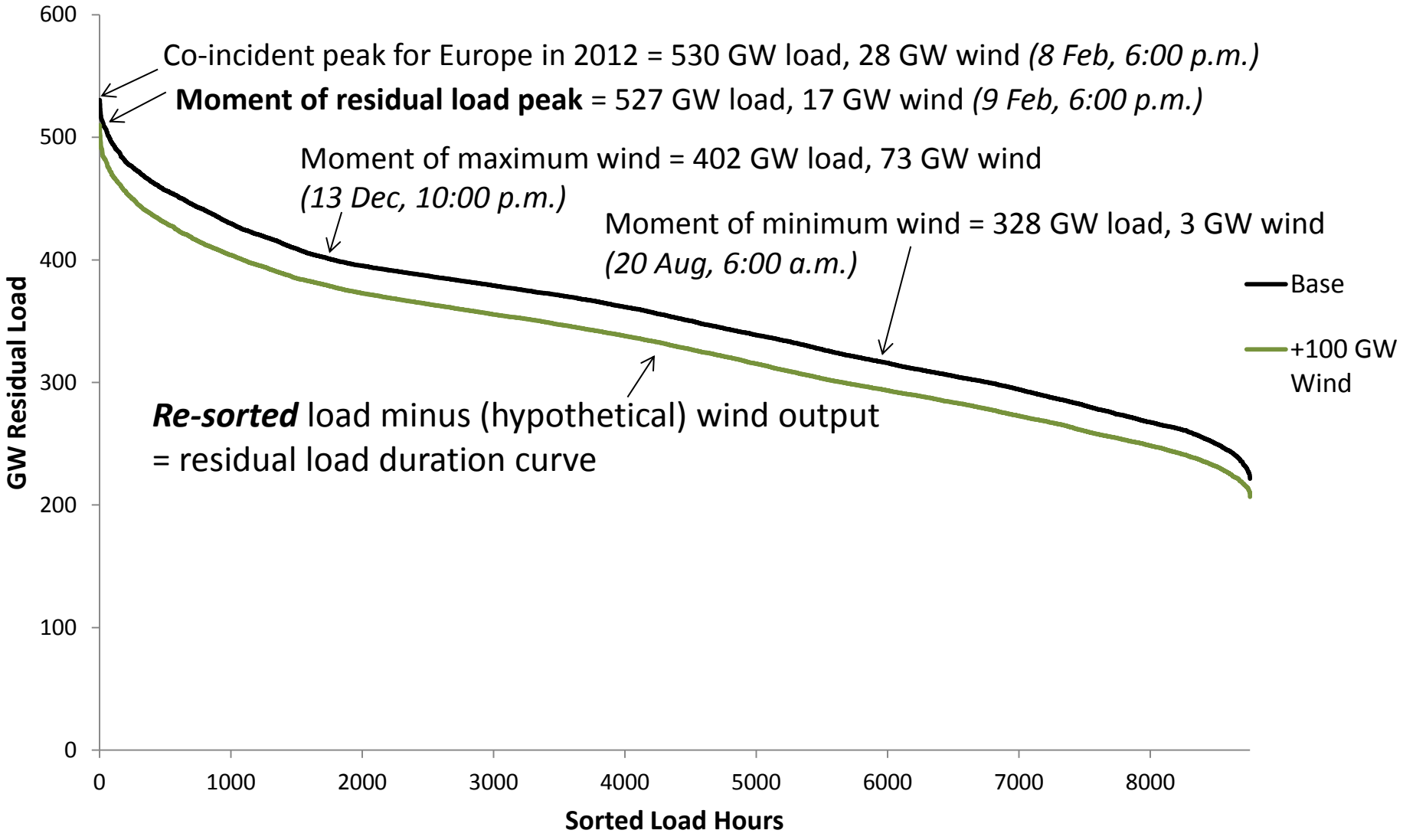
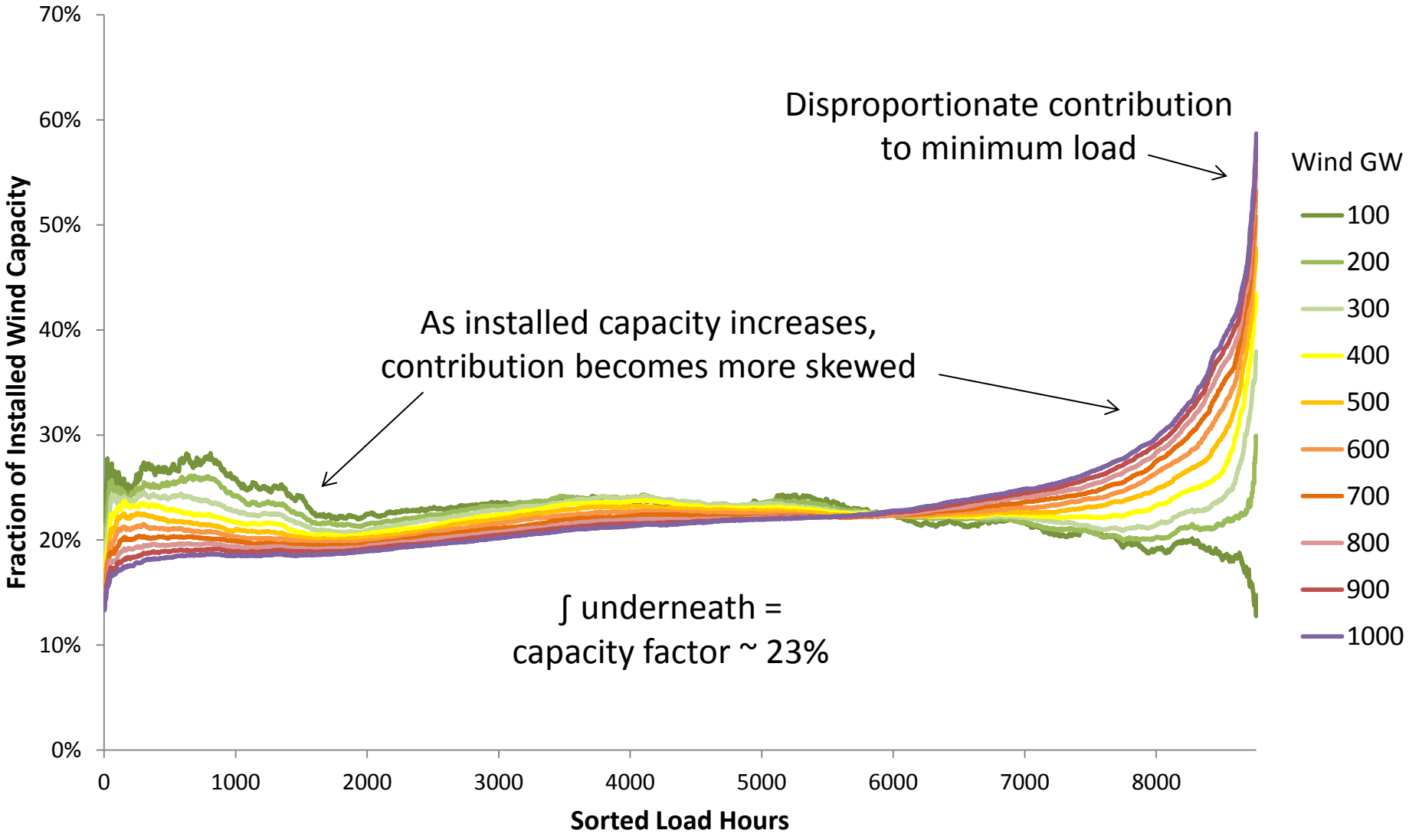
Hourly Data

- We have synchronized regional series for:
  - Load
  - Wind output
  - Solar output
- Load data by country available from ENTSO-E
- Hourly wind and solar data constructed to match current feed-in and spatial distribution
  - Publicly available gridded weather data in combination with turbine / panel power functions
- Results here based on 2012 shapes

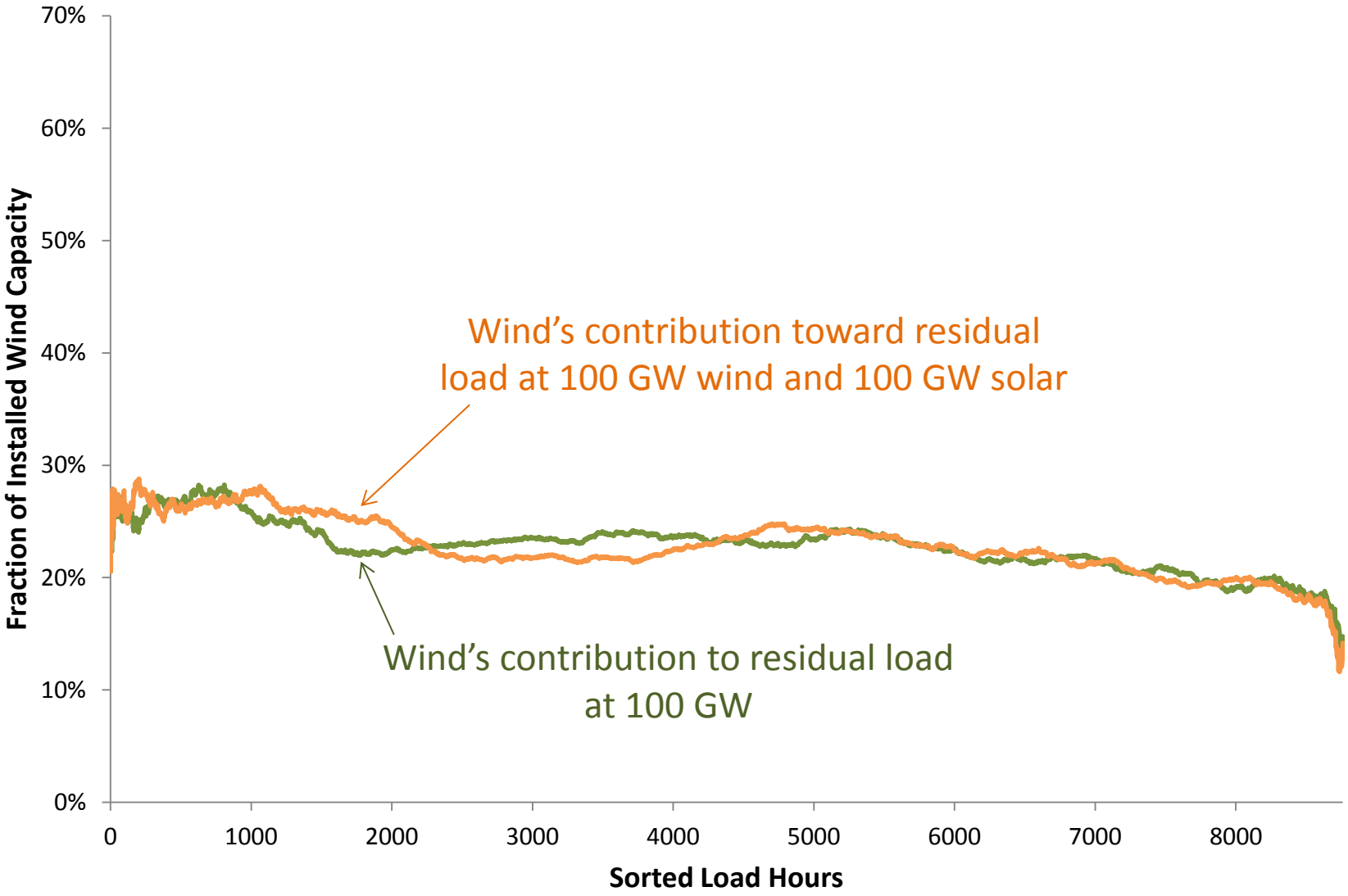
Residual Load Duration Curve Illustration



Contribution of wind to EU residual load curve



Interaction effect of solar on wind



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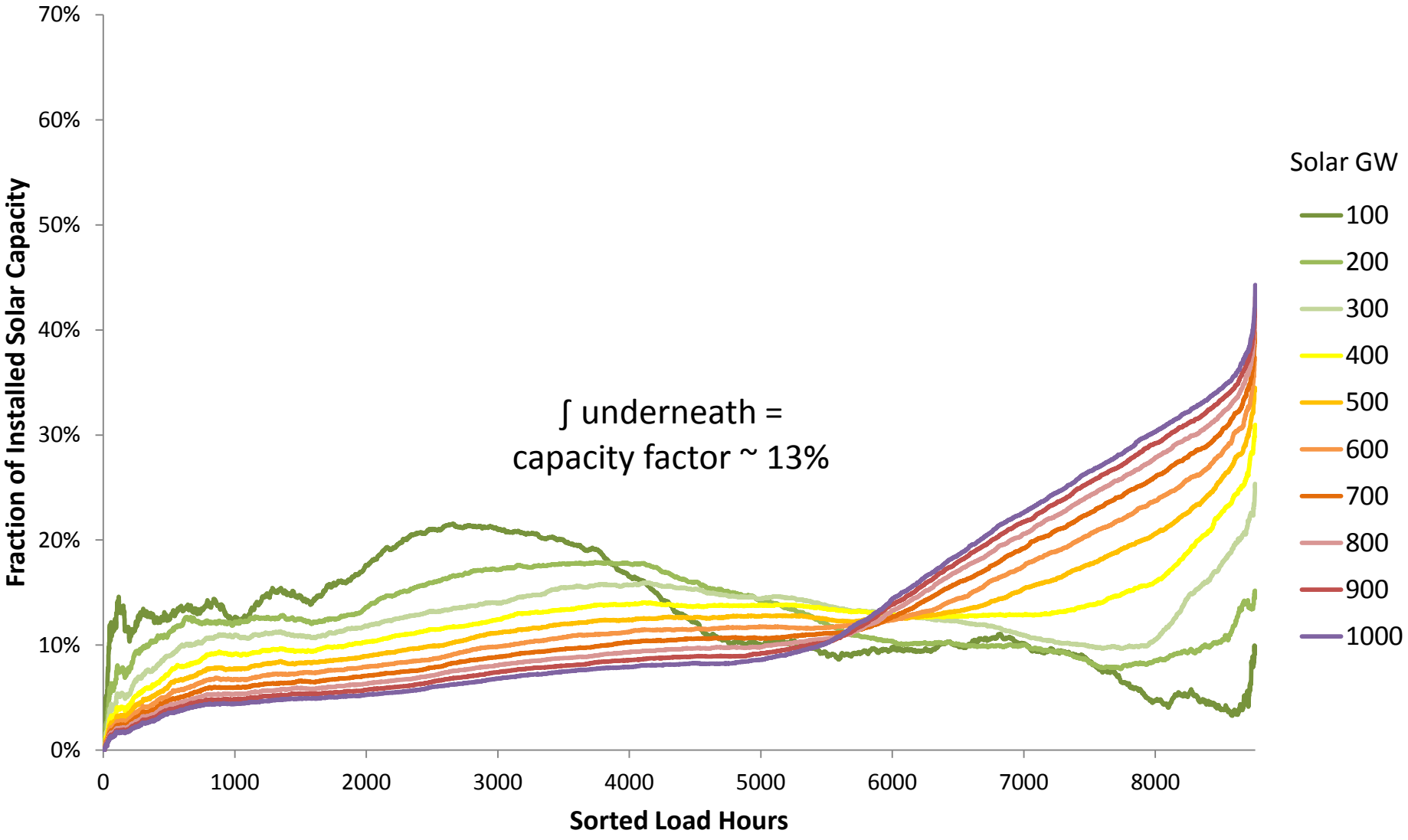

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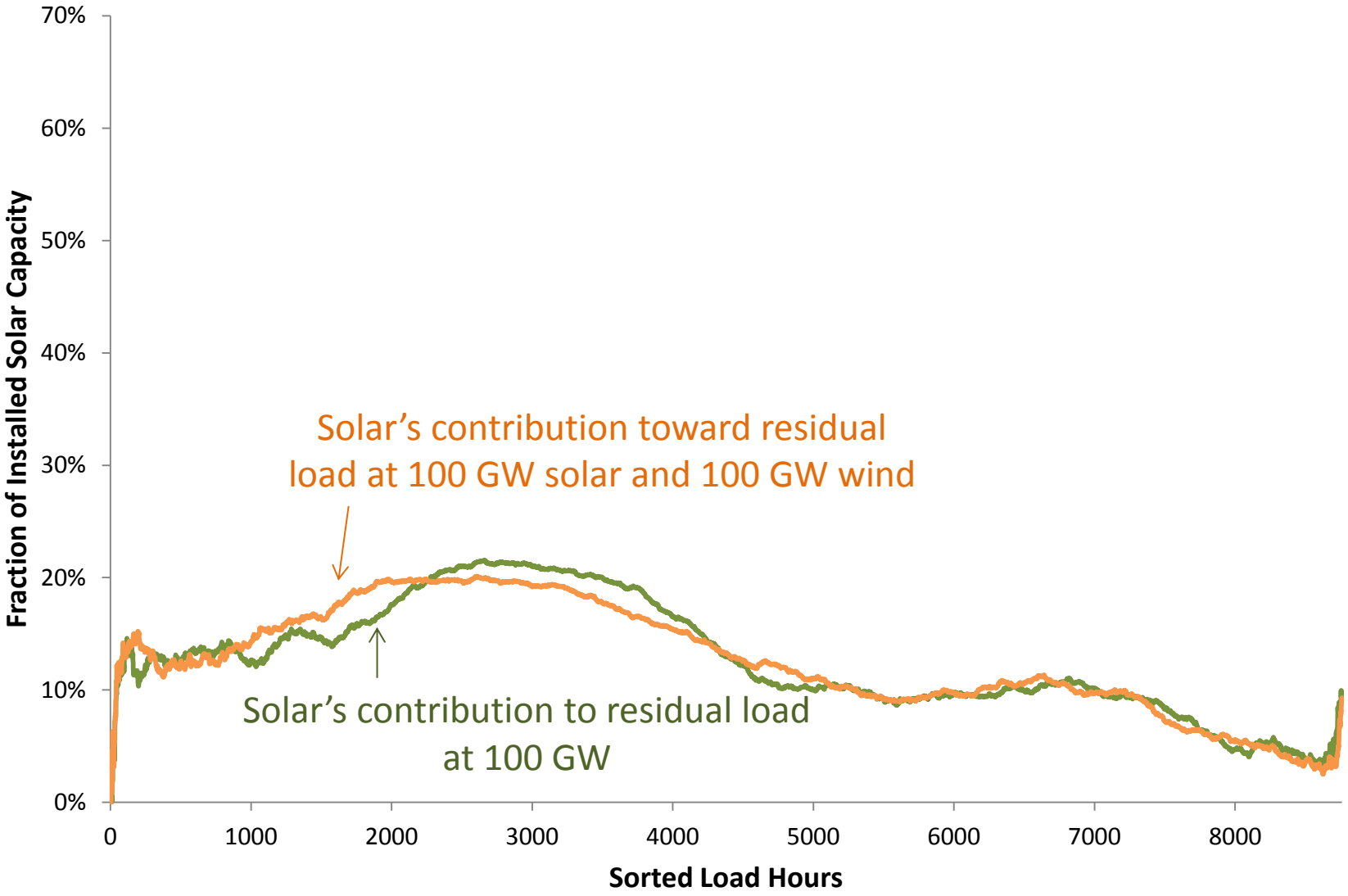
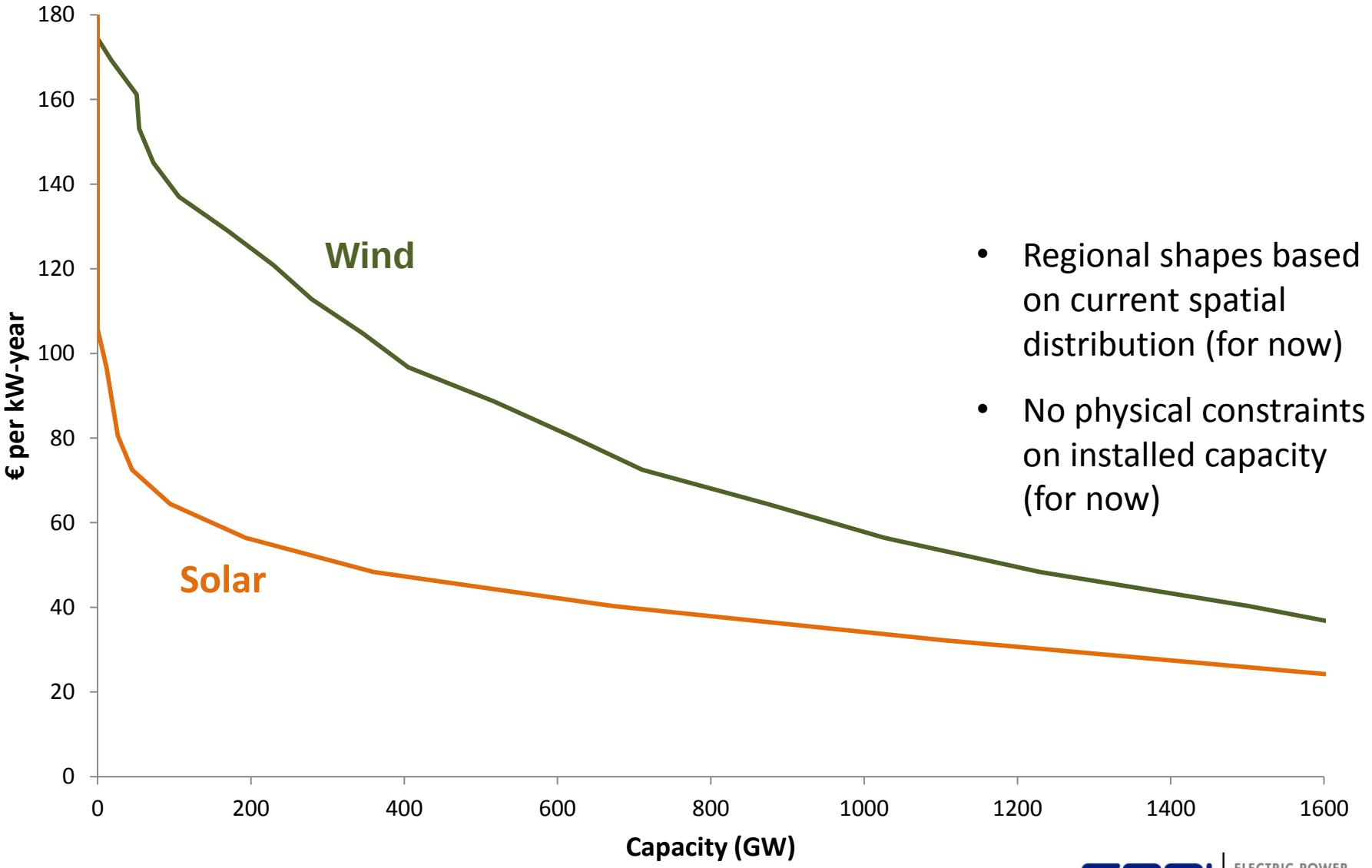
Interaction effect of wind on solar



Marginal Value Curve Analysis

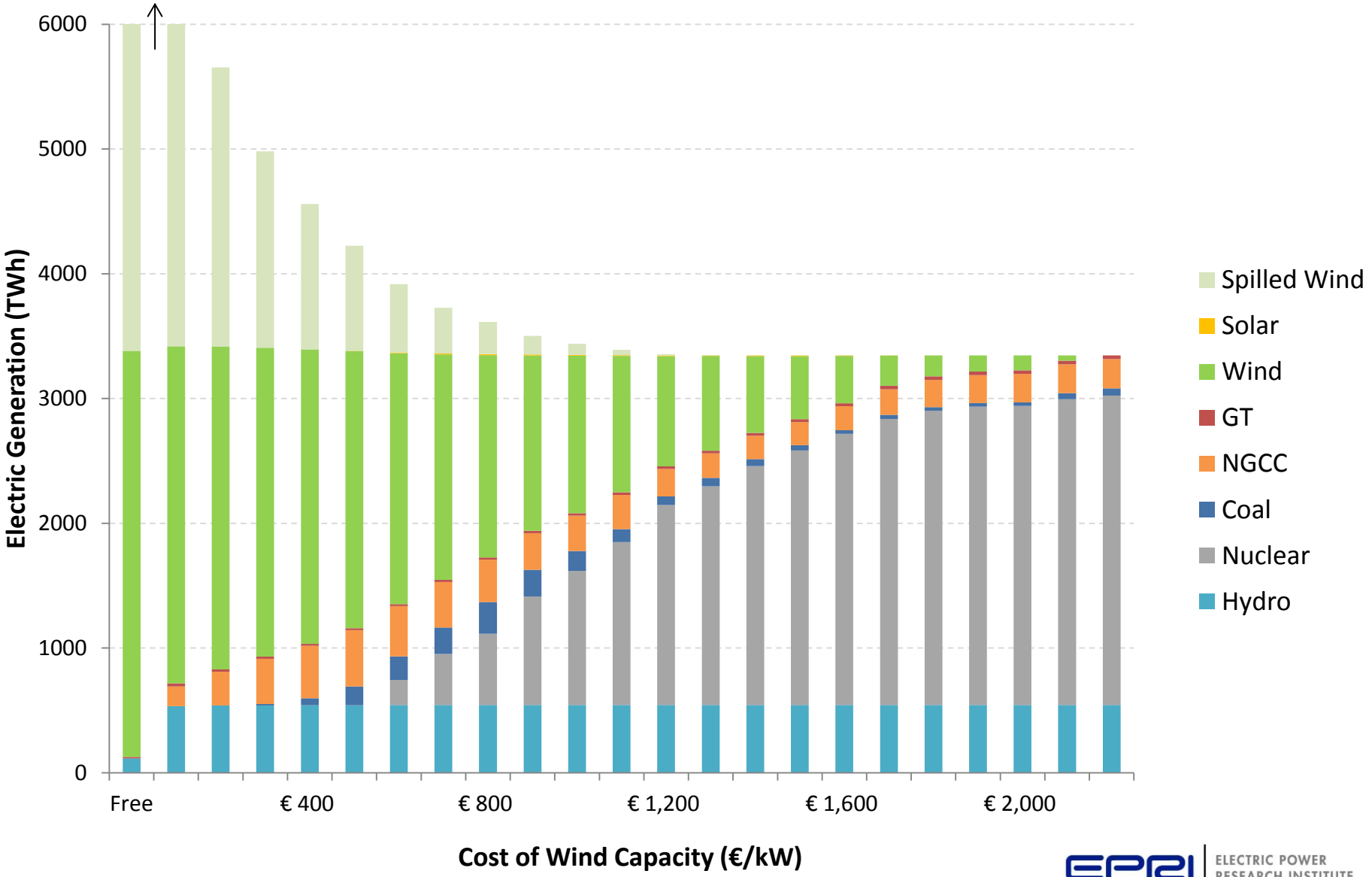
- Run a static instance of EU-REGEN (single year ~ 2012)
- Fixed capacity for hydro, pumped storage, and transmission
  - All other capacity is rented and dispatched to meet load at minimum cost → long-run equilibrium
- Systematically vary the cost of wind and solar and plot rented capacity at each cost level → marginal value curve
- Sensitivity to new transmission (at a cost)

Marginal Value Curve for Wind and Solar in EU



- Regional shapes based on current spatial distribution (for now)
- No physical constraints on installed capacity (for now)

Generation mix as a function of wind cost



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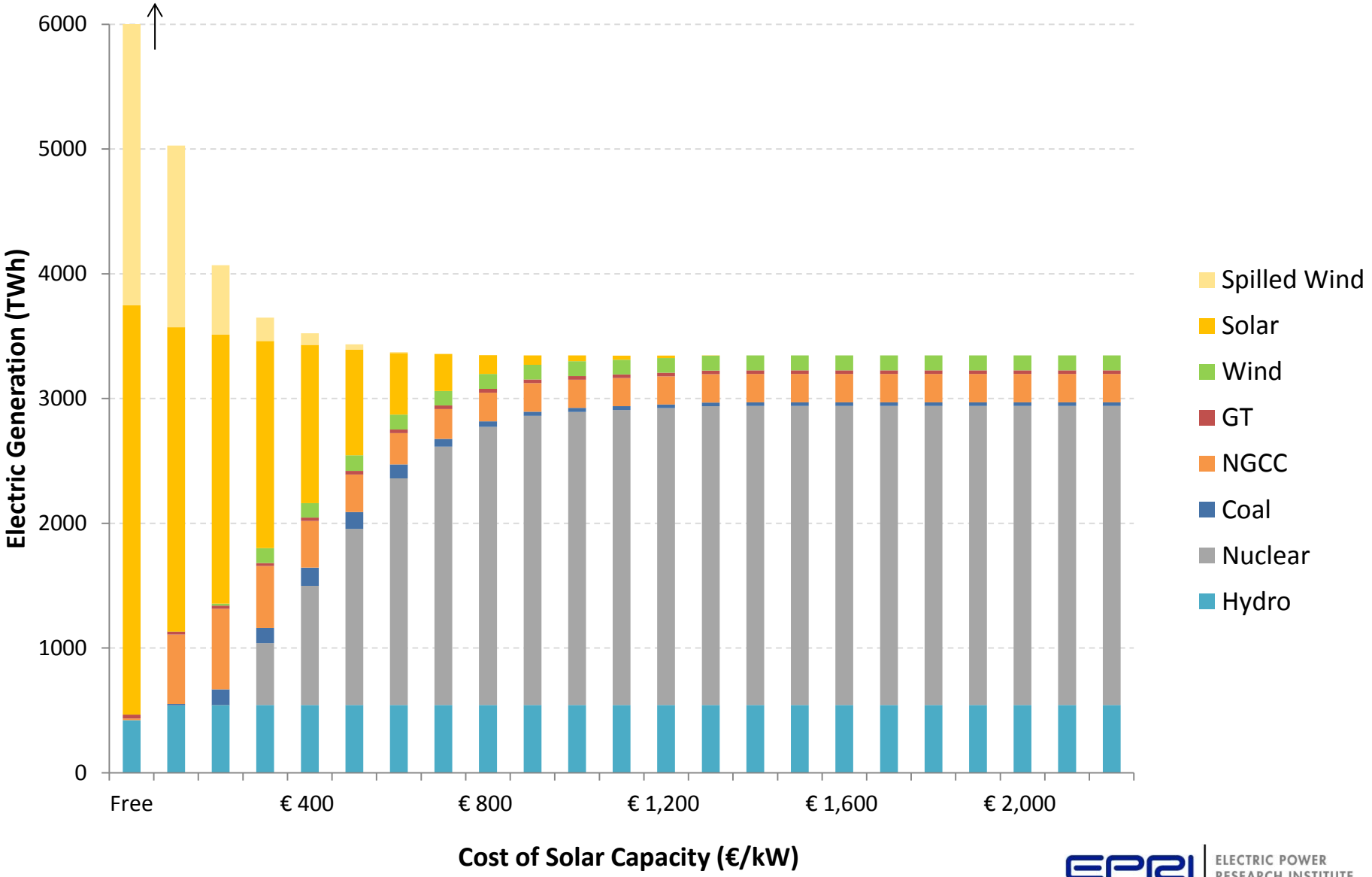
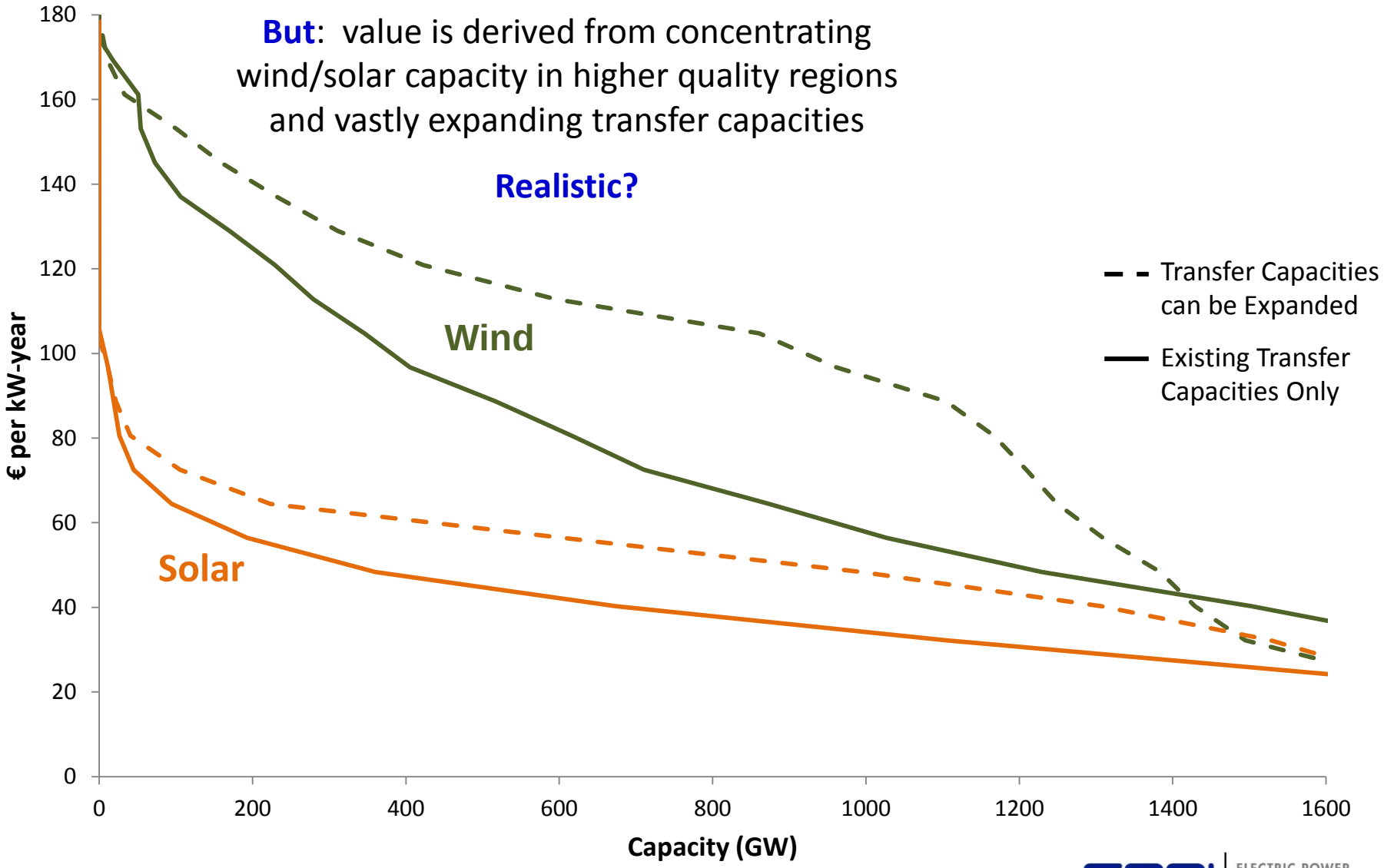
Generation mix as a function of solar cost



New transmission increases value



Key Takeaways

- Co-variation of load and renewable energy is the fundamental driver of the **economic** potential of renewable technologies
- Achieving “grid parity” on LCOE-basis is not meaningful
- Policies, investments, market design should keep DRTS in mind
- Role of renewables in future scenarios should be:
  - Cost efficient with respect to other options (market-driven)
  - Consistent with reliability constraints (back-up capacity)
  - Developed with a system perspective (cross-country)
- Models like EU-REGEN can demonstrate this role

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