Backup Flexibility Classes in Renewable Electricity Networks

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Forschungsinitiative der Bundesregierung

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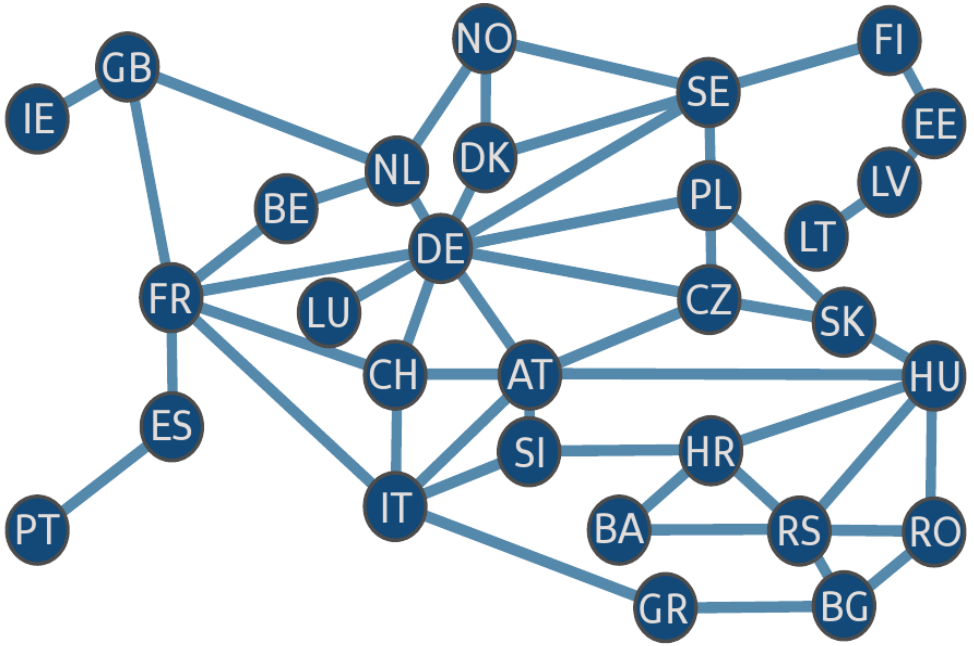
Federal Ministry of Education and Research

Backup Flexibility Classes in Renewable Electricity Networks

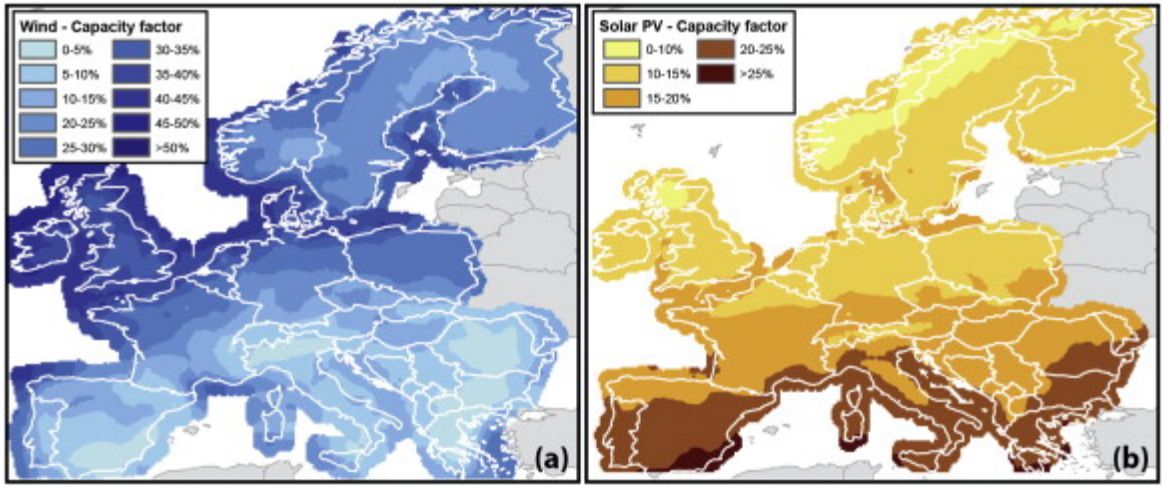


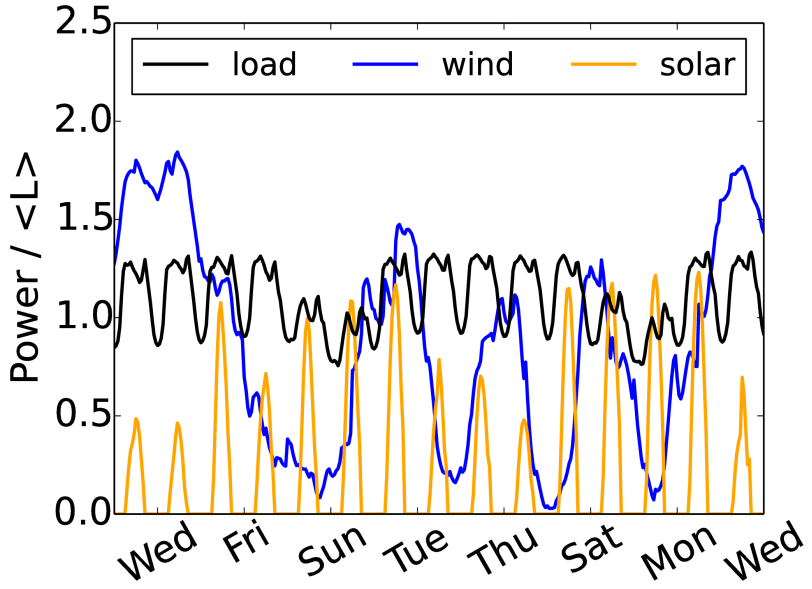
$$G_n^R - L_n = B_n + P_n$$

$$B_{i,n}$$

- Extreme cases of transmission:
  - Isolated
  - Aggregated
- 3 backup flexibility classes

Power System: Wind, Solar + Backup





Andresen et al., 2014 (Fig. 1), Energy, 76

- Weather-based generation data
- Europe, 50x50 km²
- 2000-2007, hourly
- Historic load data

Sources: ISET, 2008; Heide et al., 2010

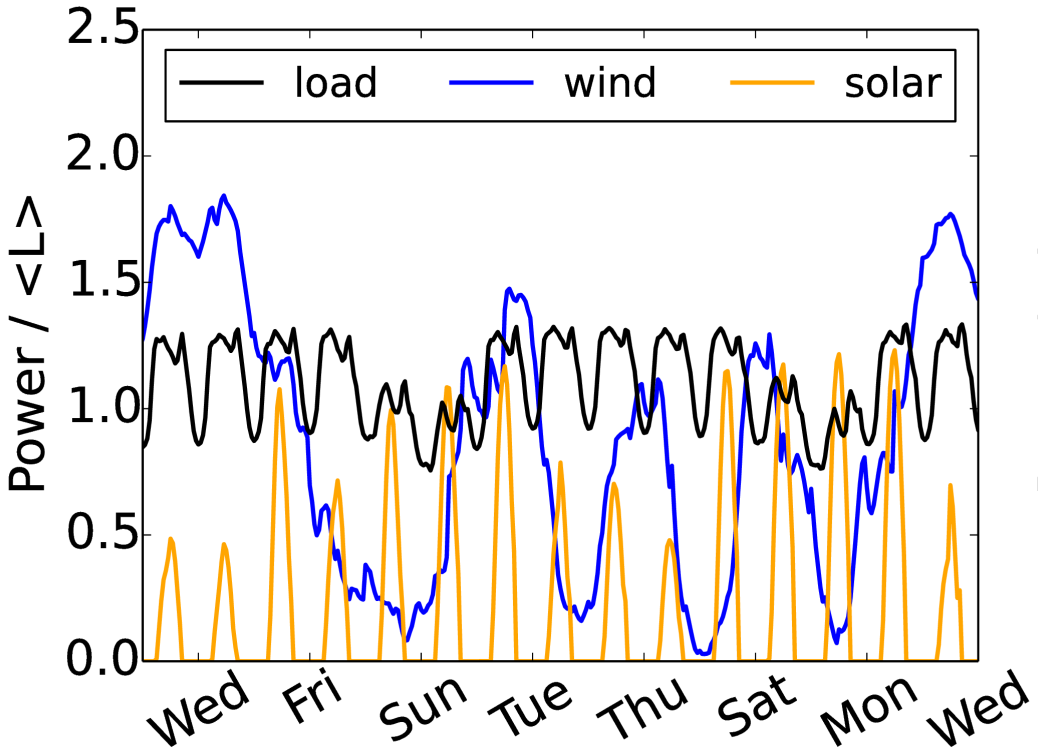
Fluctuations in Wind, Solar:

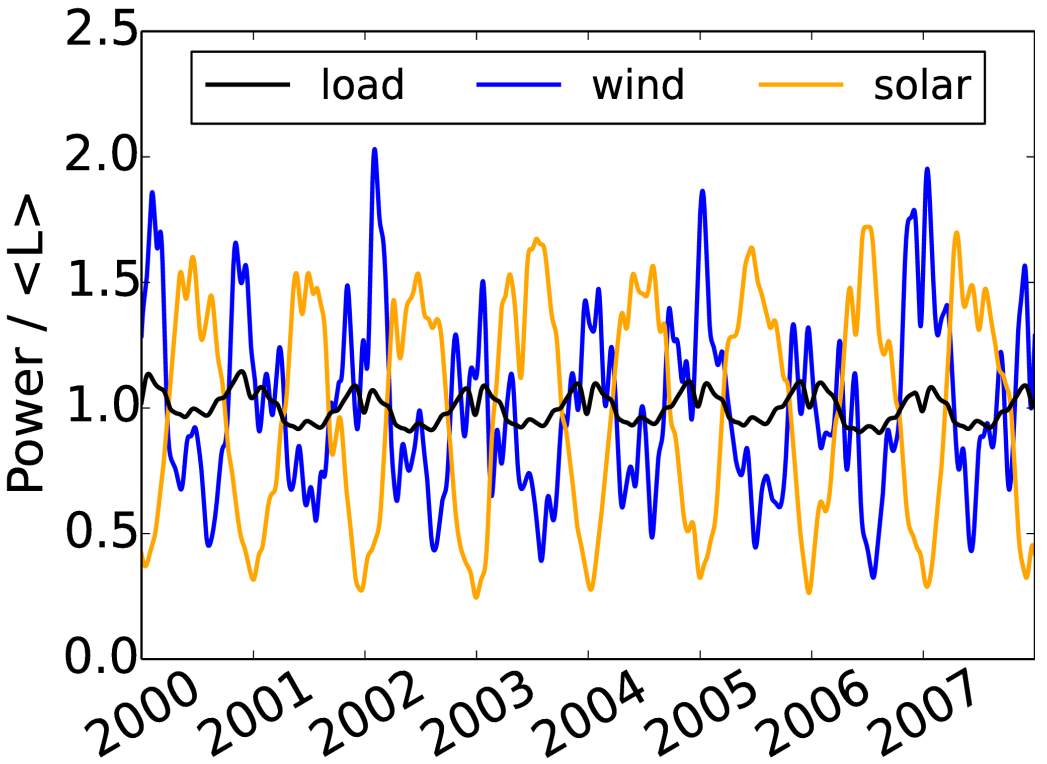
→ Residual load

→ Flexible backup needed

$$L_R = \{ L - \gamma [\alpha W + (1-\alpha) S] \}_+$$

Timescales for load and VRES





3 Timescales:
- Intra-day
- Intra-week
- Seasonal

→ 3 backup classes: “ramp rates” from maximum slopes of load

Ramps:
- 100%/h
- 54%/d
- 42%/wk

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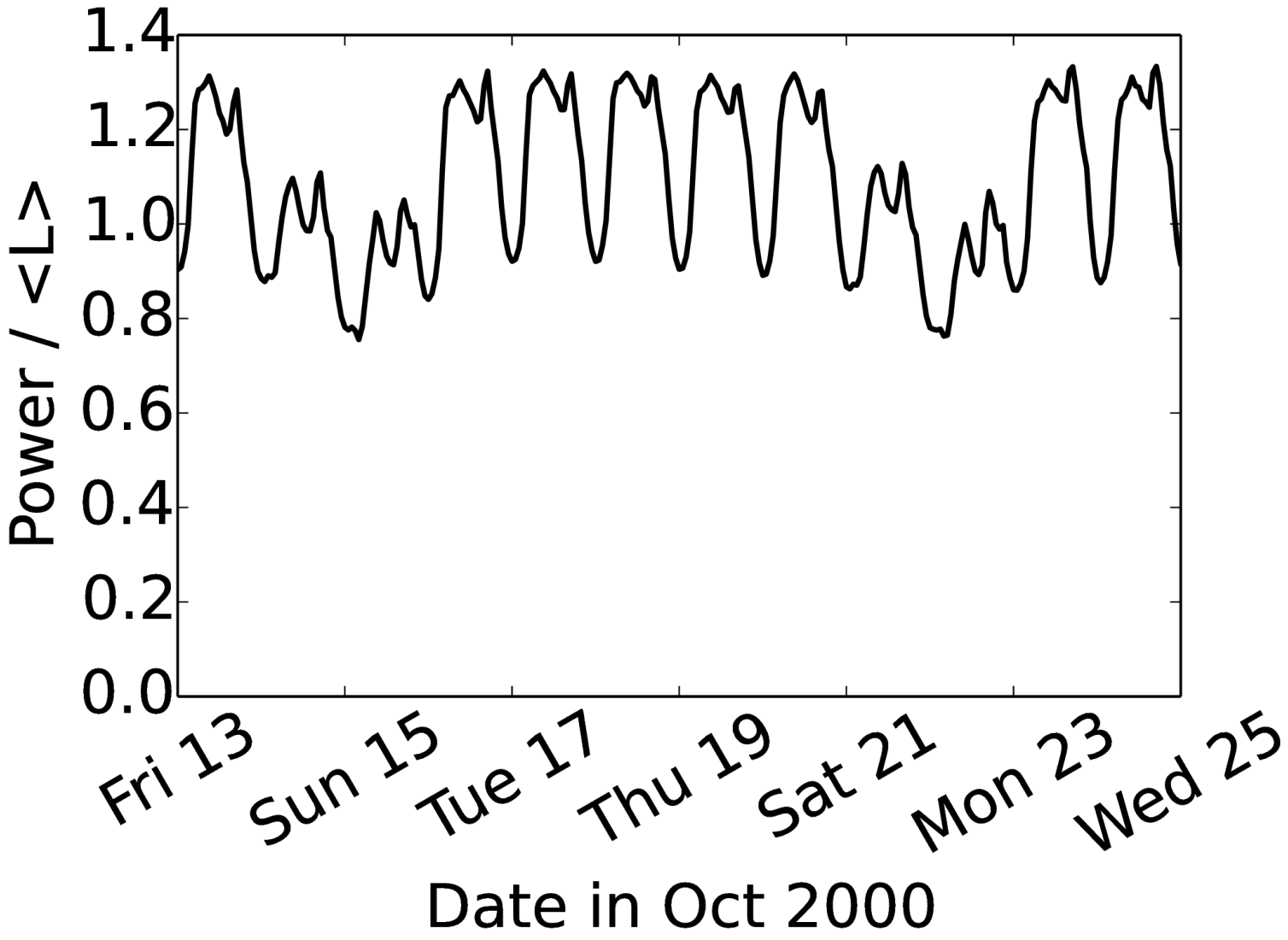
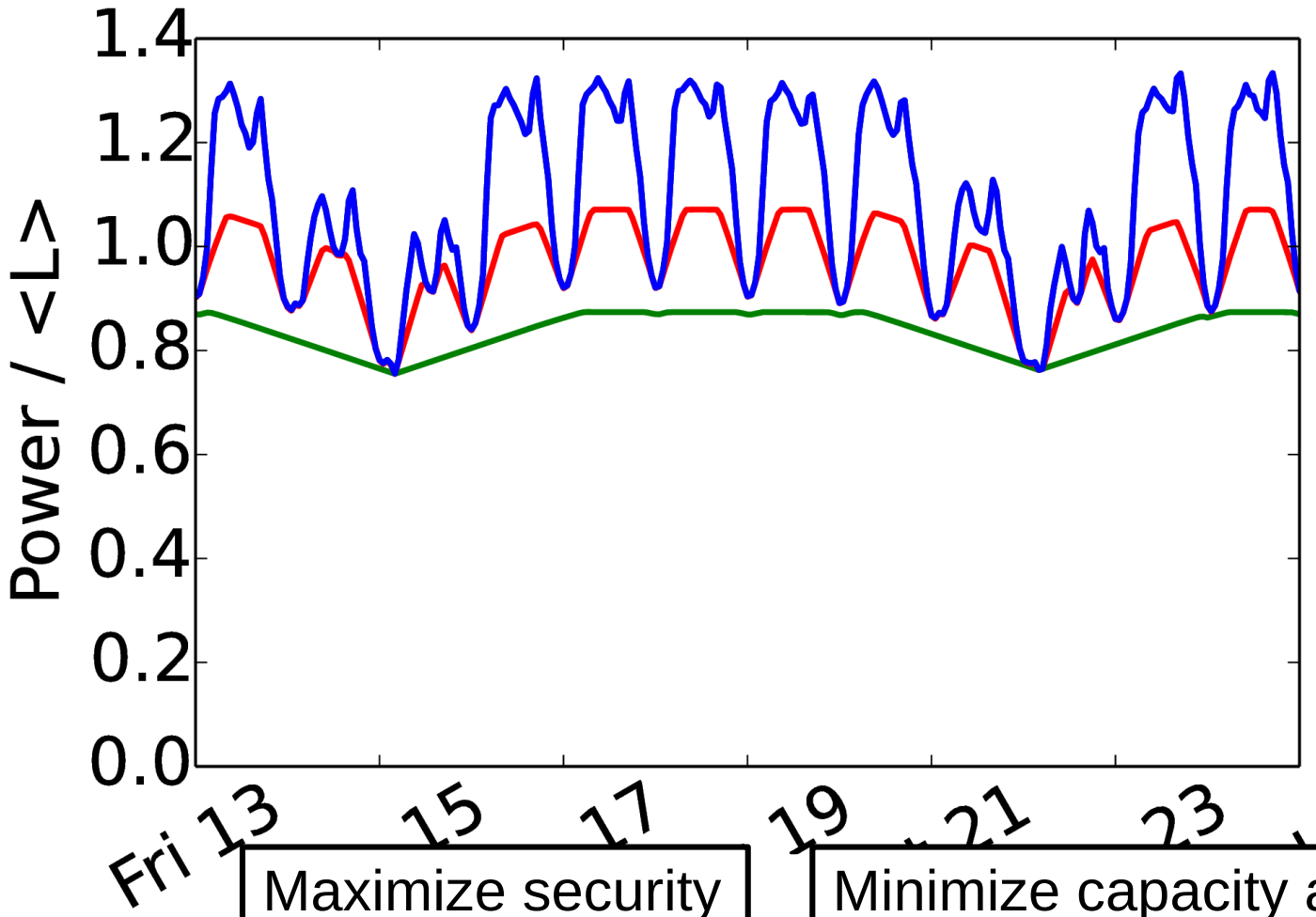
Residual load – isolated Germany



0% VRES

→ = total consumption

Modelled Power Plant Dispatch



Variation timescales:

- Intra-day
- Intra-week
- Seasonal

→ ramp rates

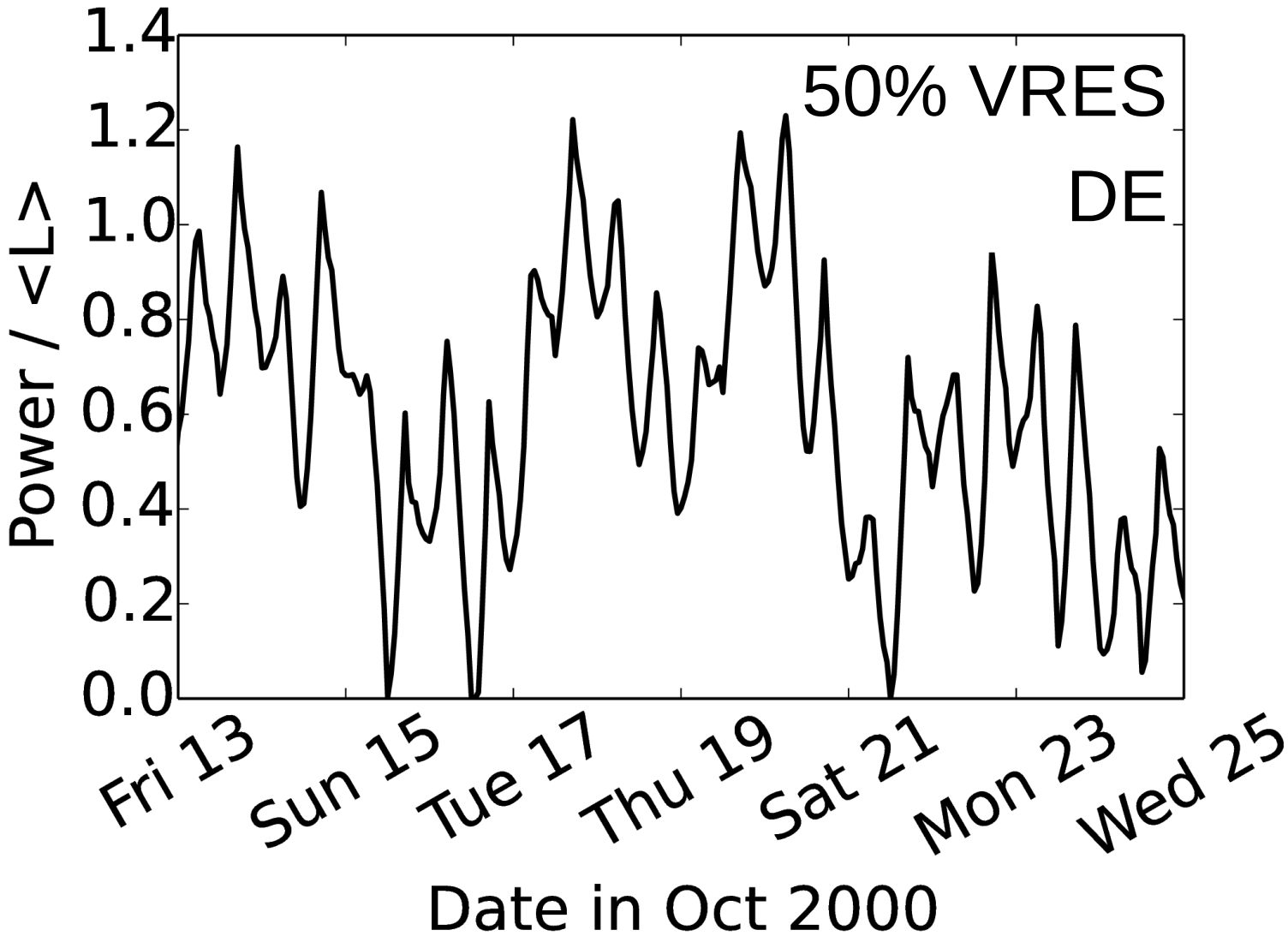
Maximize security of supply

Minimize capacity and usage of fast systems

Ramp rates

$$min\ A = \left|\left| L_R(t) - \sum_i B_i(t) \right|\right|^2 + \sum_i w_i K_i - \sum_{t,i} u_i B_i(t)\ ;\ \text{s.t.} \left|\partial_t B_i\right| < m_i$$

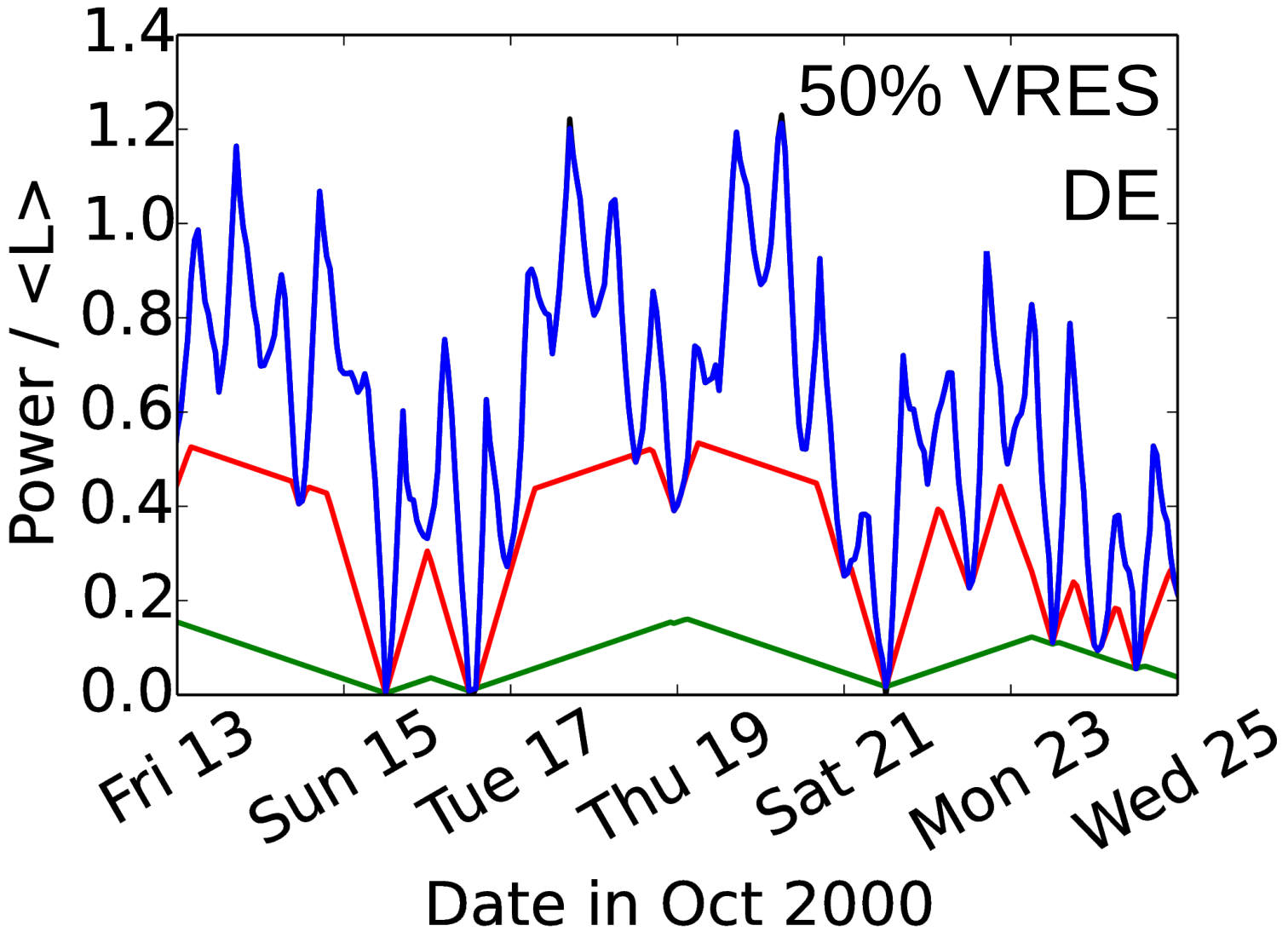
Residual load at 50% VRES (gross)



- Stronger fluctuations
- zero load → dispatch cycling

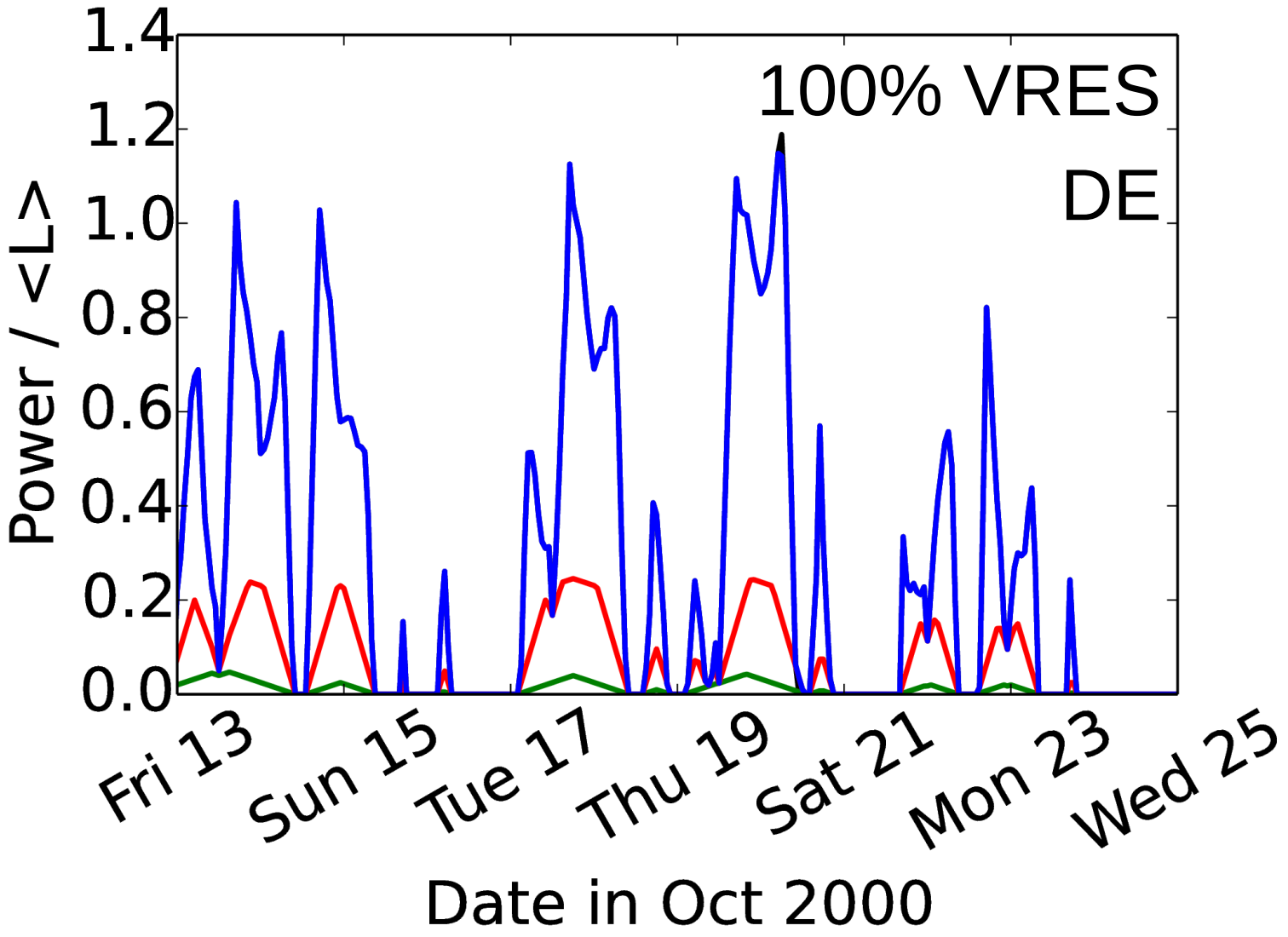
$$L_R = \{ L - \gamma [\alpha W + (1-\alpha) S] \}_+$$

Modelled Dispatch at 50% VRES



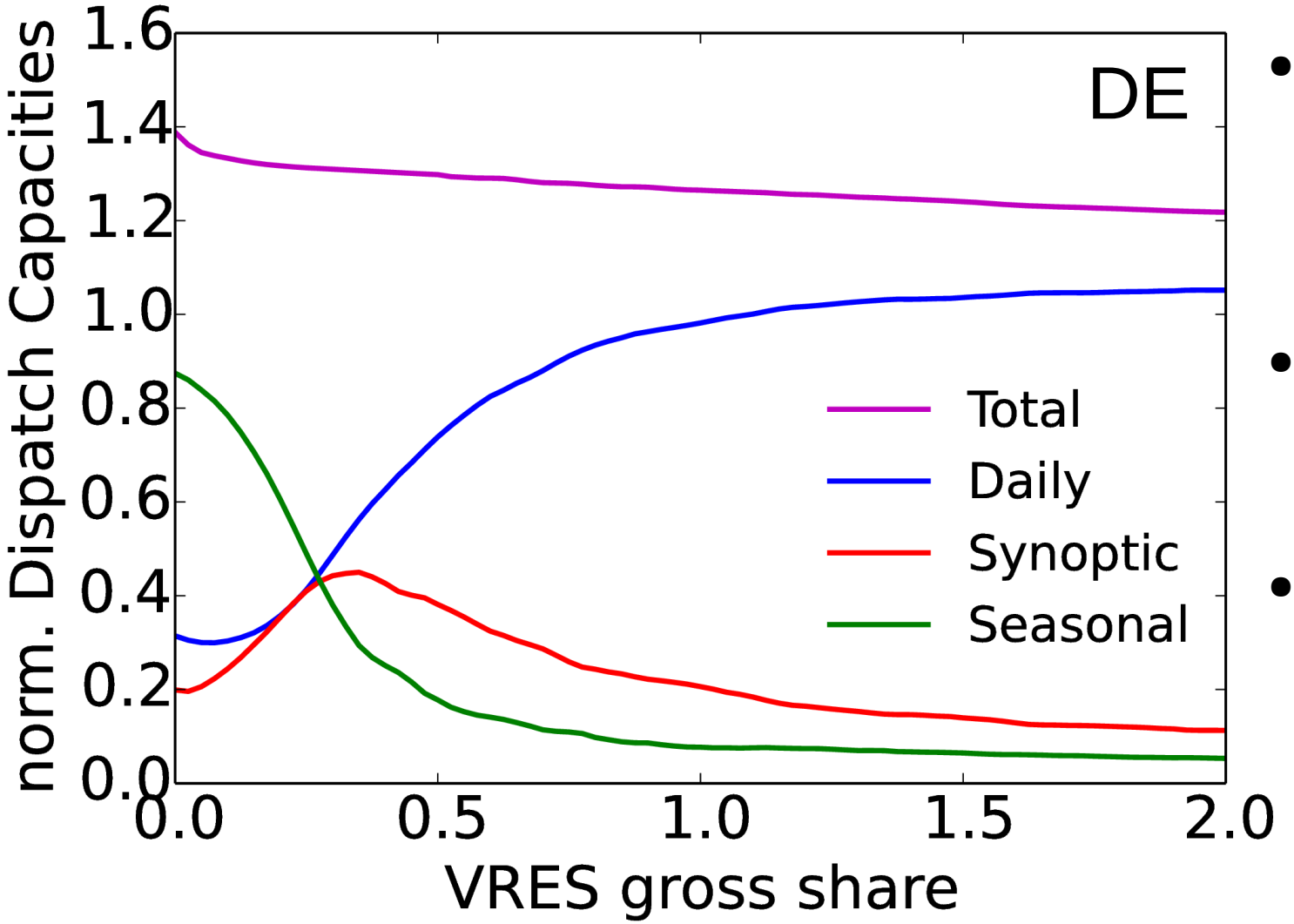
- Intra-day
- Intra-week more in use
- Seasonal rarely in use

Modelled Dispatch at 100% VRES



- Intra-day covers most
- Intra-week rarely in use
- Seasonal out of use

Backup Capacities vs VRES share



- Intra-day: grows, stays large
- Intra-week: intermittent
- Seasonal: used for VRES <50%

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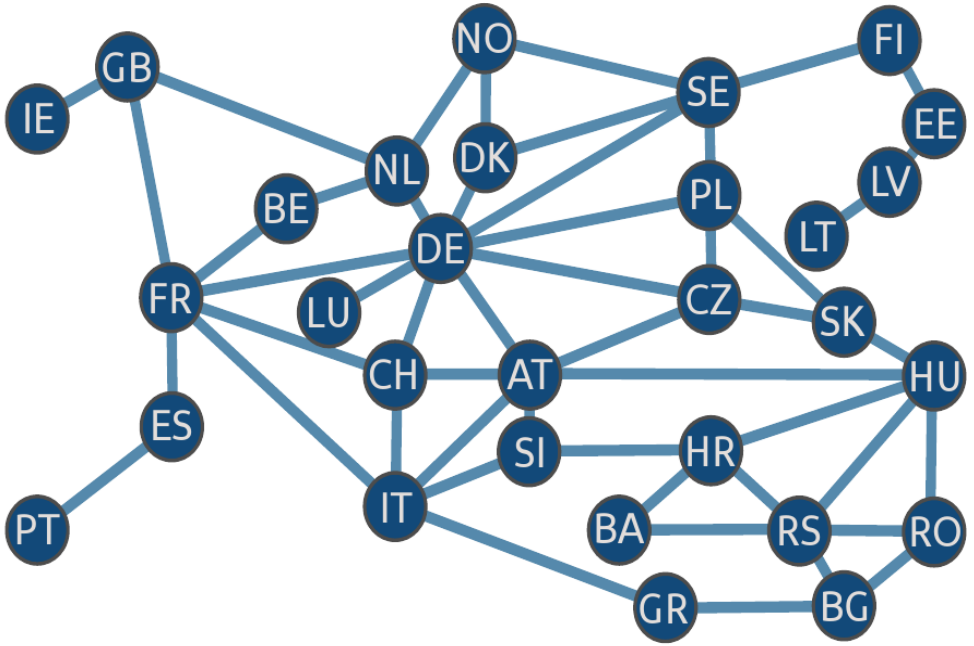

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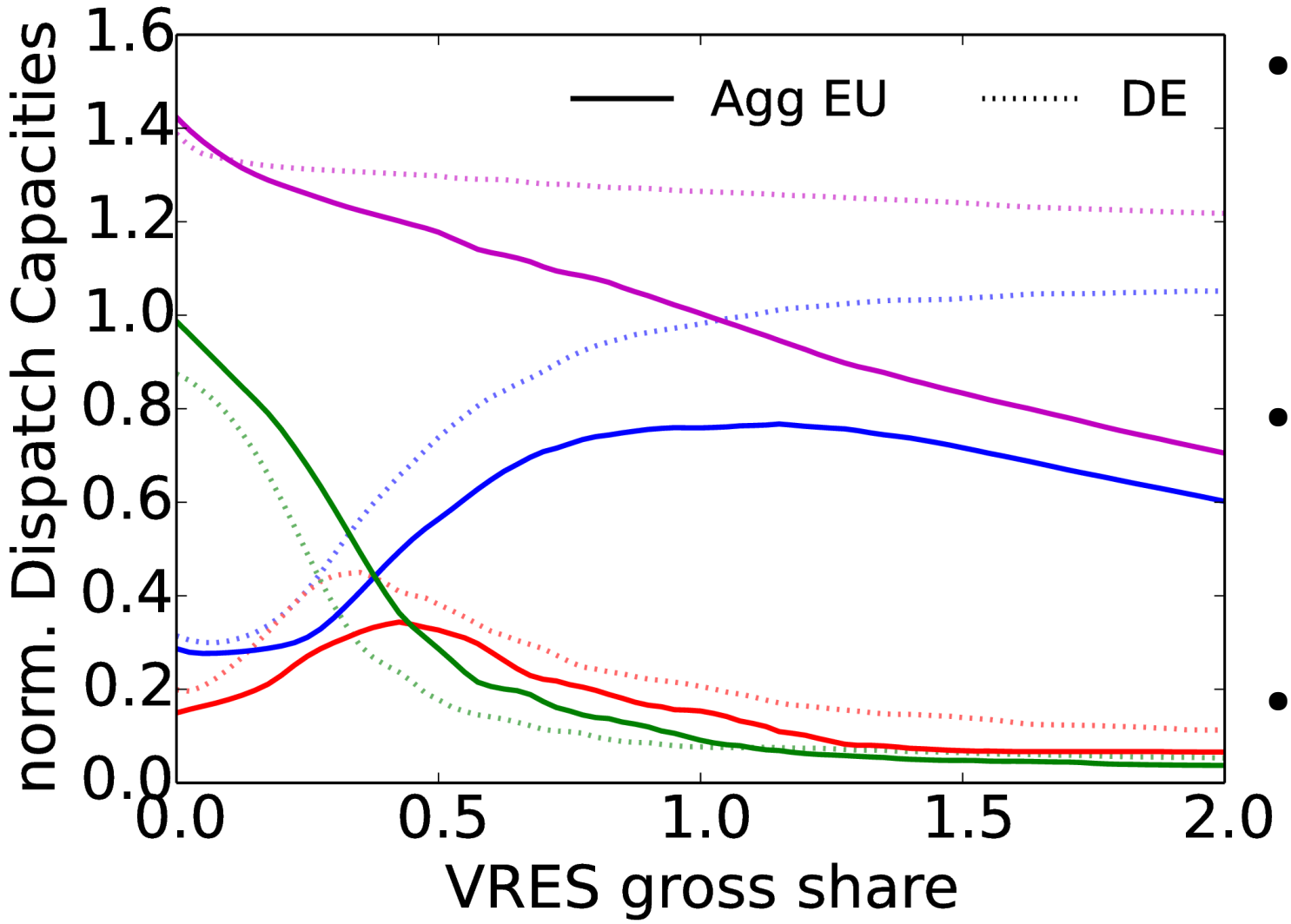
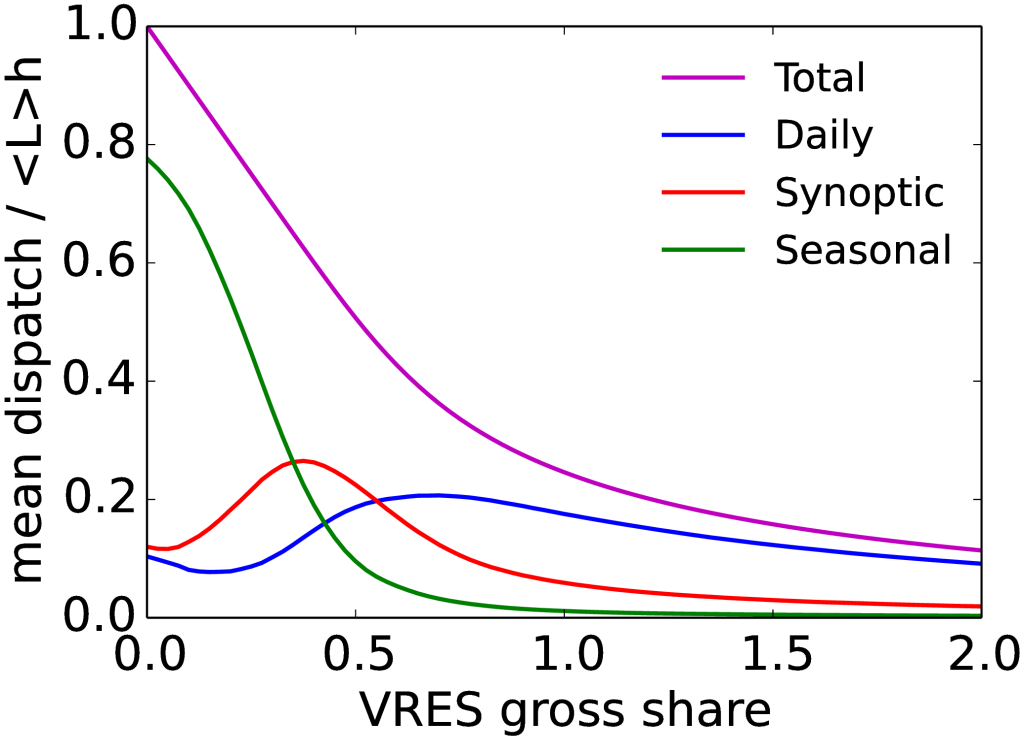
Transmission: Isolated vs Aggregated



- Total installed capacity decreases for agg. Europe
- Intra-day: drops for VRES >1
- More use for seasonal systems

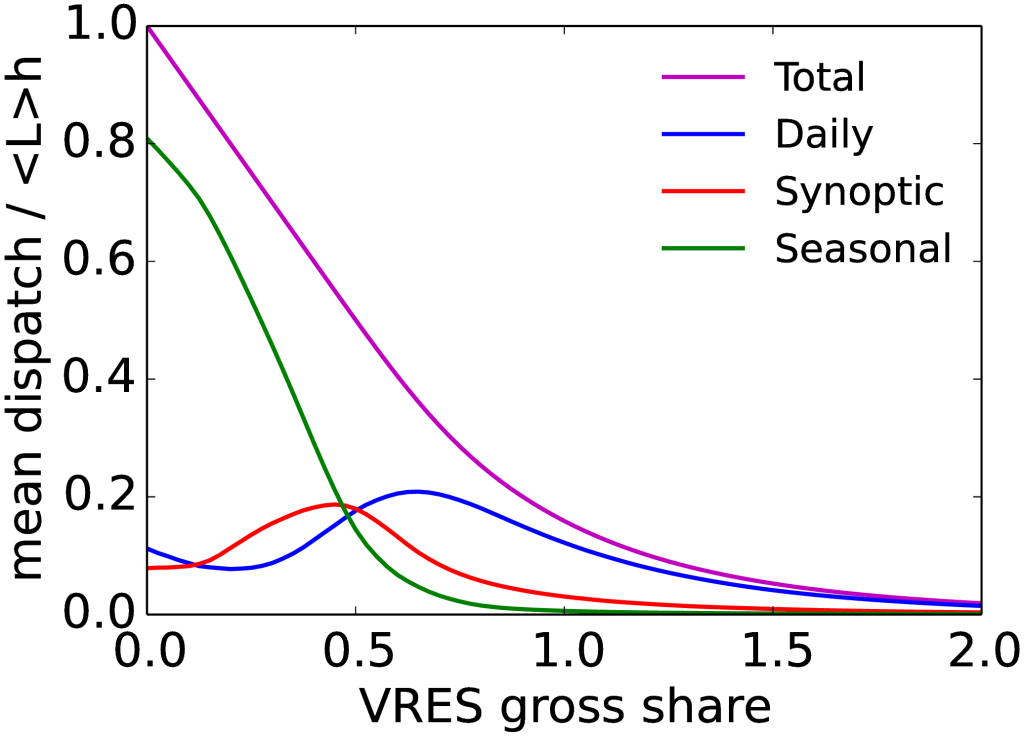
Mean dispatch energy

- DE



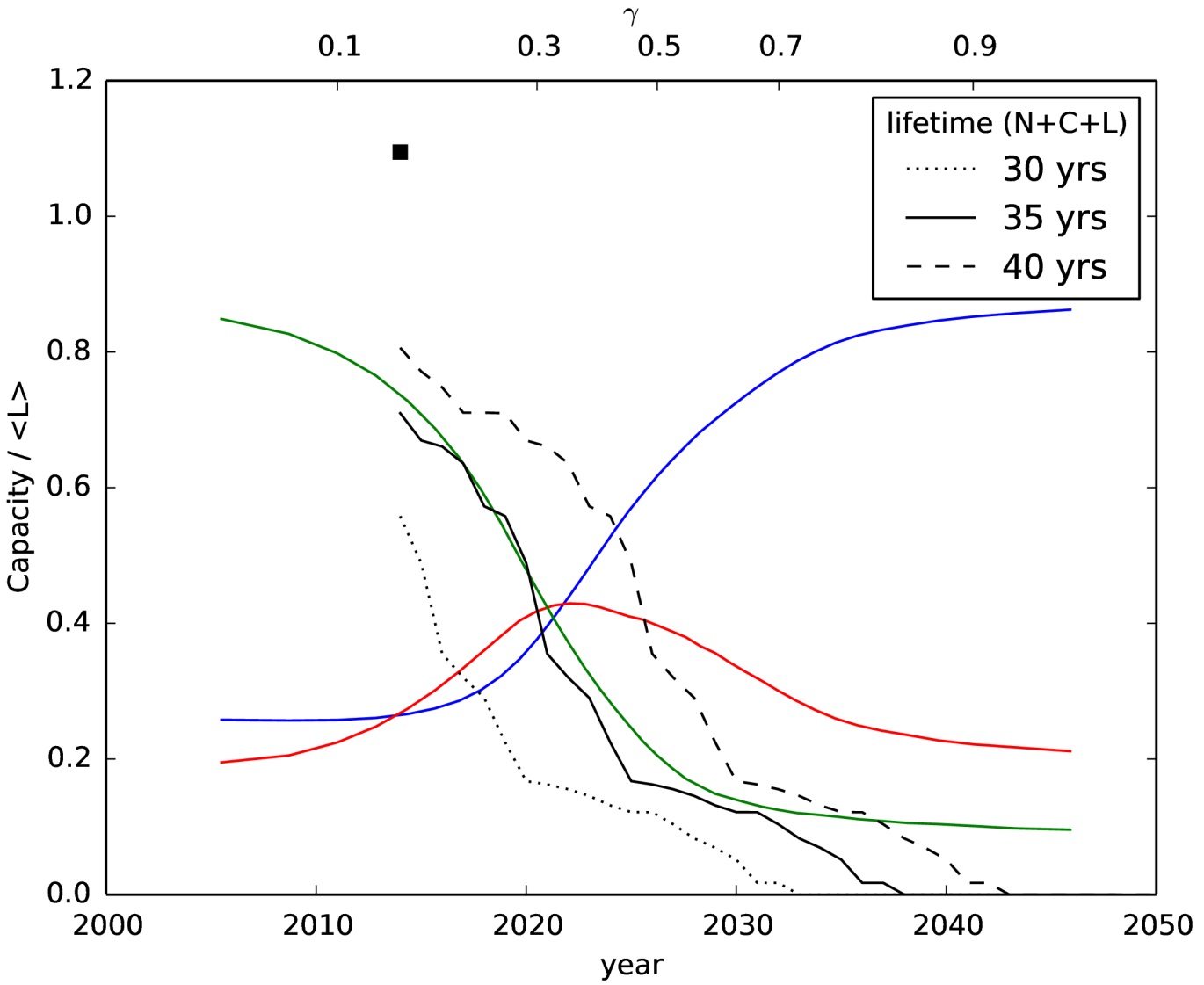
- Total backup energy remains large even for large shares of renewables

- Aggregated EU



- Total backup energy goes to zero for =2
- At =1: 15% of demand → can be covered by today's hydro

Power plant capacities Germany



Logistic fit: Becker et al., 2013, Energy, 64

DE power plant data: Bundesnetzagentur, 2014

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Conclusions:

- Seasonal systems only in use for VRES <50%
- Capacities decrease for aggregated Europe

Work In Progress:

- Introduce economic costs
- Introduce storage
- Transmission (constrained capacities)
- Limited forecast with uncertainties
- Coupling with other sectors (Heat, transport..)