Where to place new power generation?

Cost-reflective locational investment signals for generators

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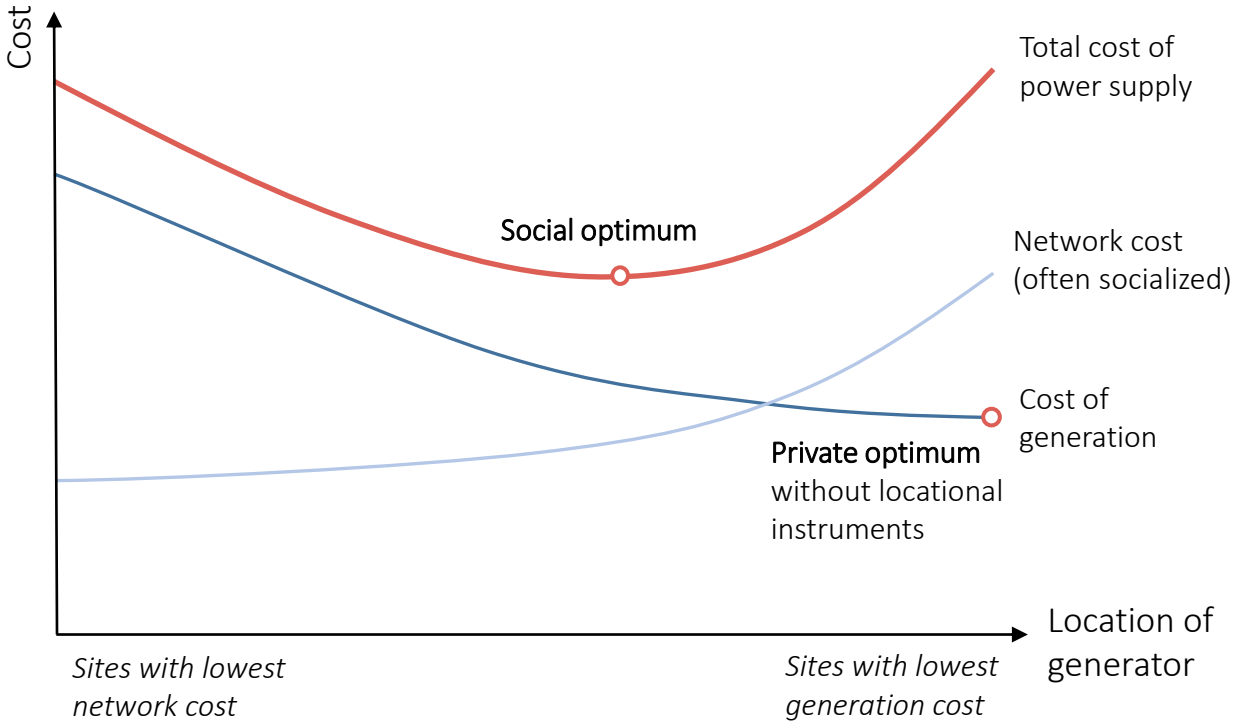
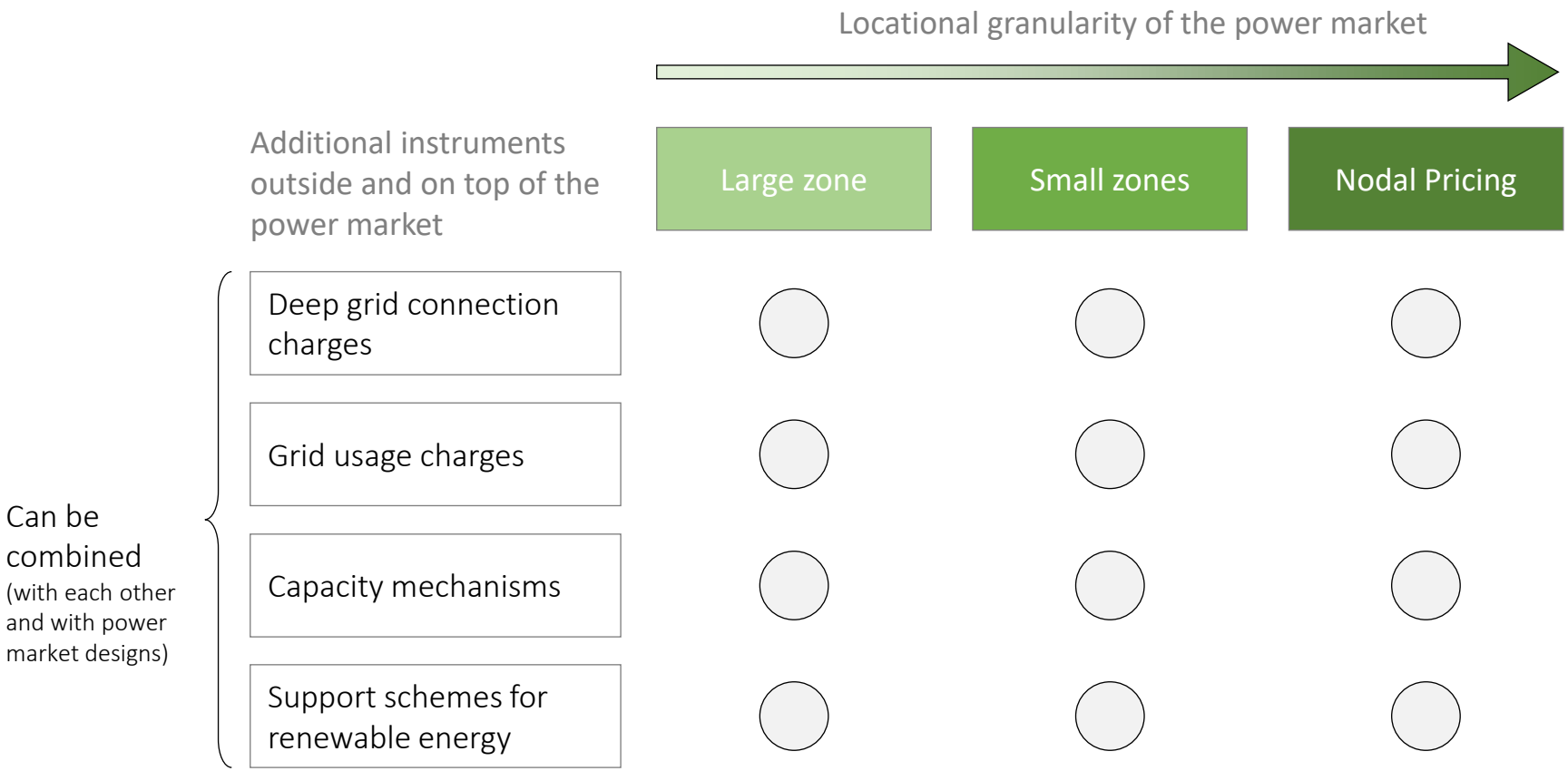
Trade-off between the cost of power generation and transmission

In many systems, the cost of power generation is lowest at remote sites that result in high network costs

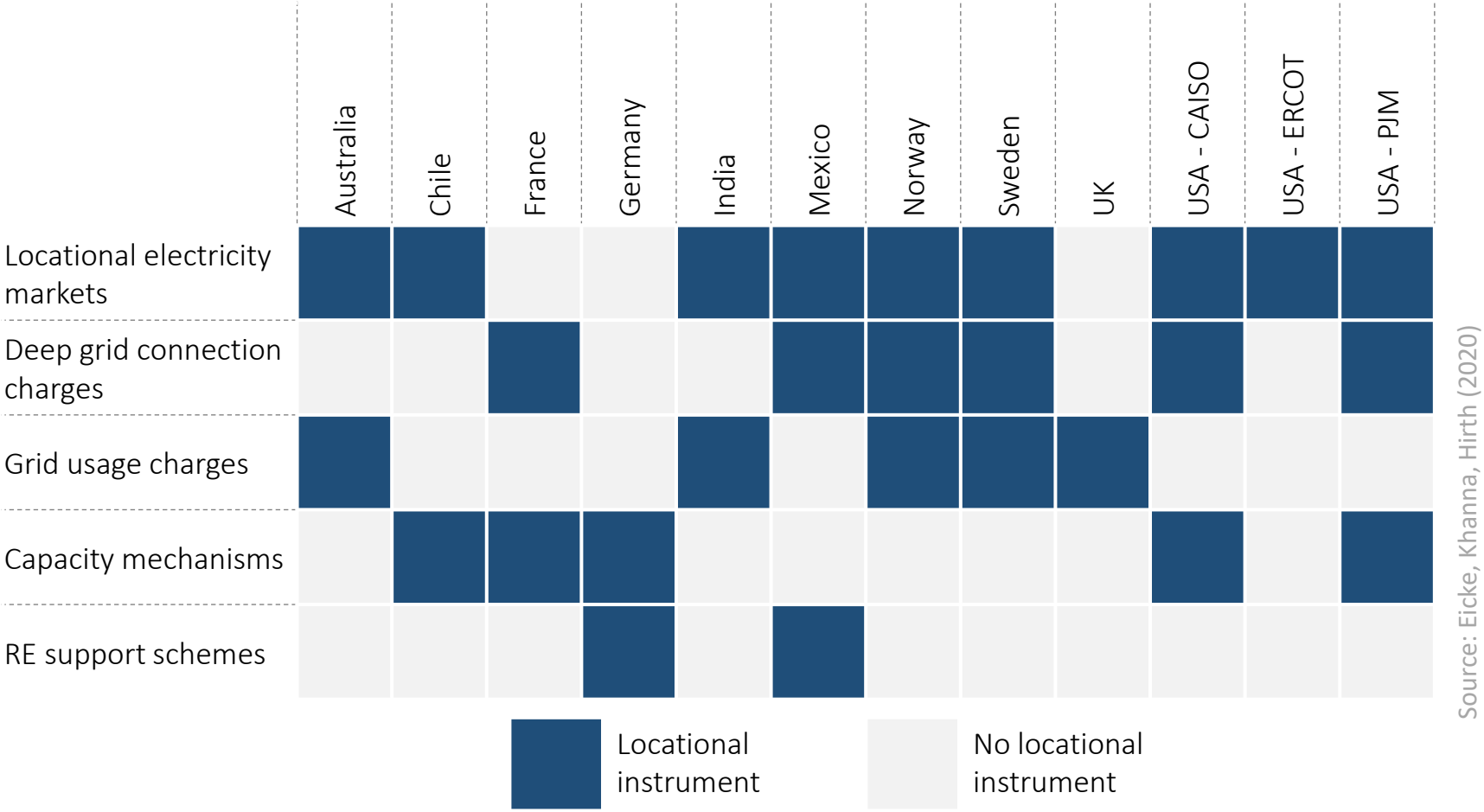


When grid costs are internalized to generators, the private optimum equals the social optimum

How can network cost-internalization be implemented?



Locational signals in practice



Source: Eicke, Khanna, Hirth (2020)

Note that some instruments might not be intended as a locational signal but they provide an incentive nevertheless

Why do many countries combine locational markets with other locational instruments?

Short-run vs. long-run network cost internalization

Which costs shall be internalized?

1. Short-run network cost (=cost of operating the existing network)
   - Costs of congestion and losses
   - In nodal pricing systems, the short-run network costs are reflected in the **differences of LMPs**.
   - In zonal systems, these costs result from **redispatch costs** and the costs of **transmission losses**

2. Long-run network cost (= building and operating the optimal network)
   - Cost of extension, congestion and losses
   - Calculation is much more complicated. Among others, it depends on the network topology, reliability standards, geographical constraints and citizen‘s opposure.
   - Two common approaches to calculate LRNC: investment cost related pricing and DC load flow pricing (Bakirtzis et al. (2001))

How do short-run and long-run cost interrelate?

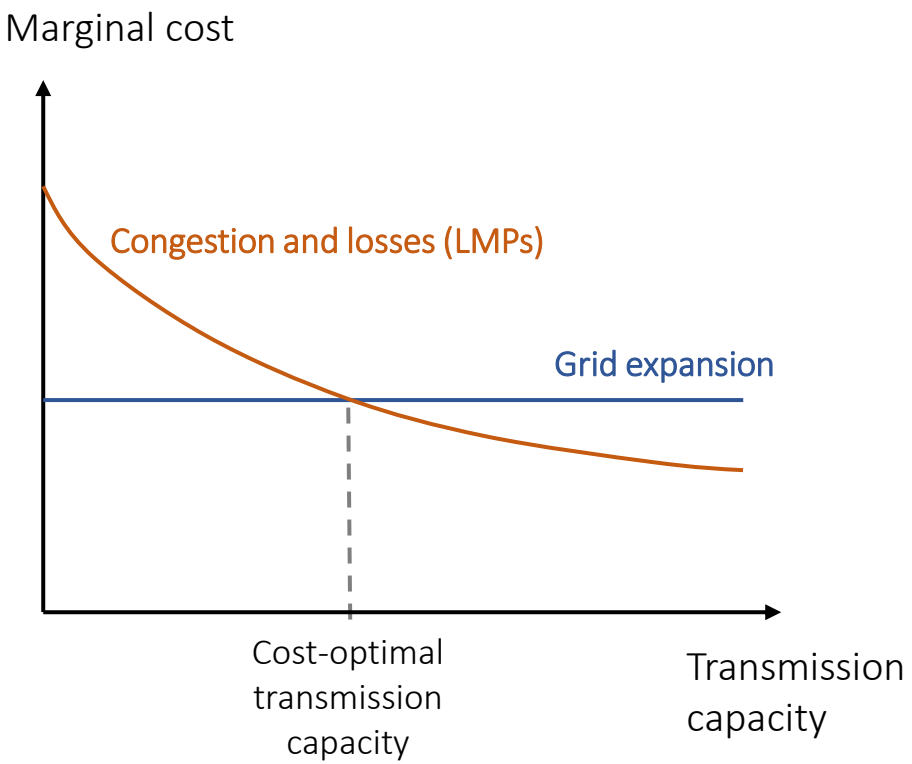
At the cost-optimal transmission level:

marginal cost of network expansion

=

marginal cost of congestion and losses

- LMPs reflect short-run marginal network costs
- Only in cost-optimal dimensioned transmission systems, these correspond to the long-run marginal cost.



In practice, transmission capacity is never cost-optimal

- Transmission investment is lumpy in voltage levels and in number of circuits

Reasons for over-sized capacity

- Transmission investment not market driven but subject to regulation
- Regulators tend to be risk averse

Reasons for under-sized capacity

- Transmission extension is very slow, requires decades
- Low acceptance of transmission extension

- In practice, transmission infrastructure tends to be over-dimensioned → Long-run marginal cost exceed short-run marginal cost
- LMPs structurally underestimate the value difference between locations and the resulting economic incentives for siting decisions of generation are too low

Locational signals can internalize short-run or long-run costs

Arguments for short-run cost (internalizing cost of existing transmission capacity)

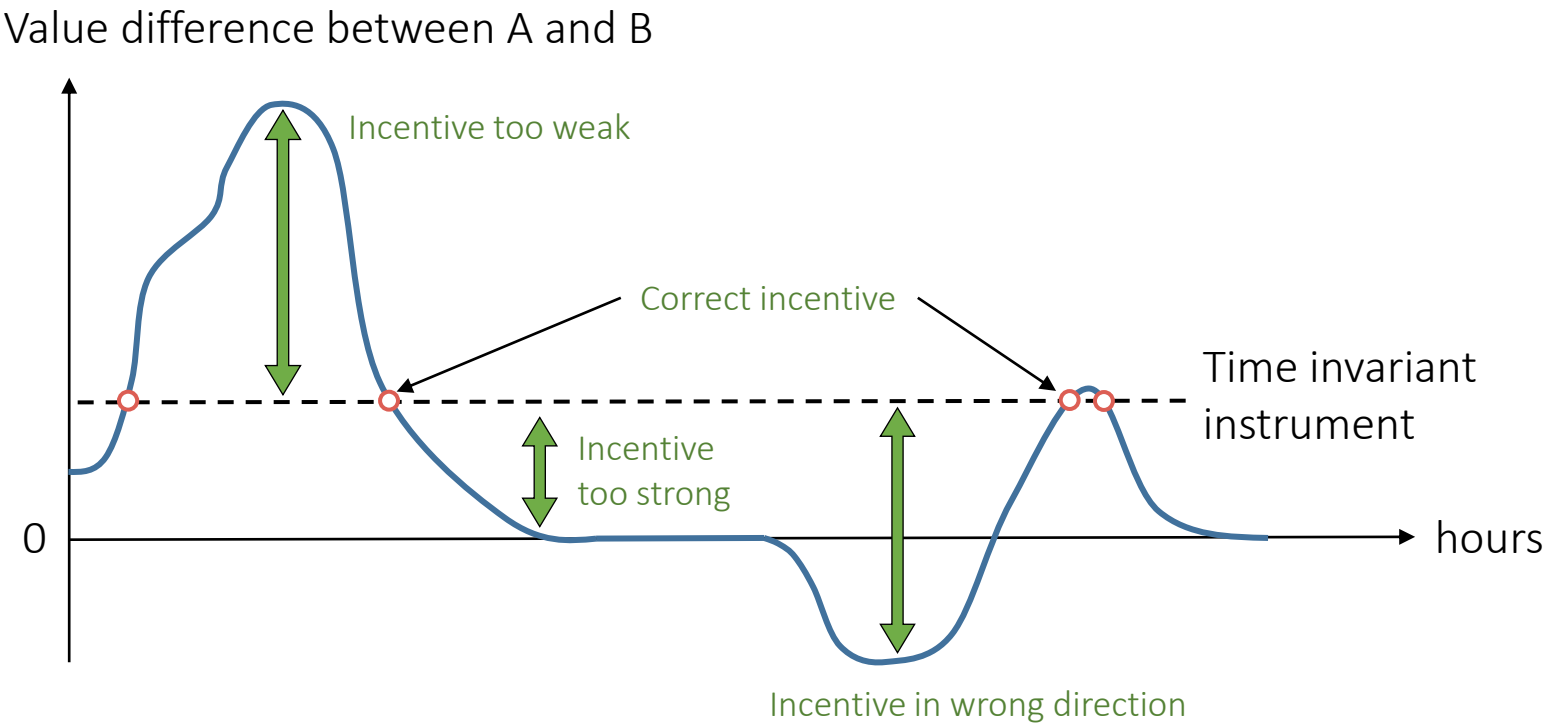
- Reflect cost of congestion in the existing transmission infrastructure
- Provides incentives to construct new generation when and where transmission capacity is available
- Discourages investment when transmission capacity is currently limited
- Easier to calculate

Arguments for long-run cost (internalizing cost for optimal transmission capacity)

- Signals less volatile and less affected by changes in grid, generation and consumption
- Lower volatility makes long-term signals easier to predict
- Recovers full costs
- Only viable option when transmission capacity is not yet available

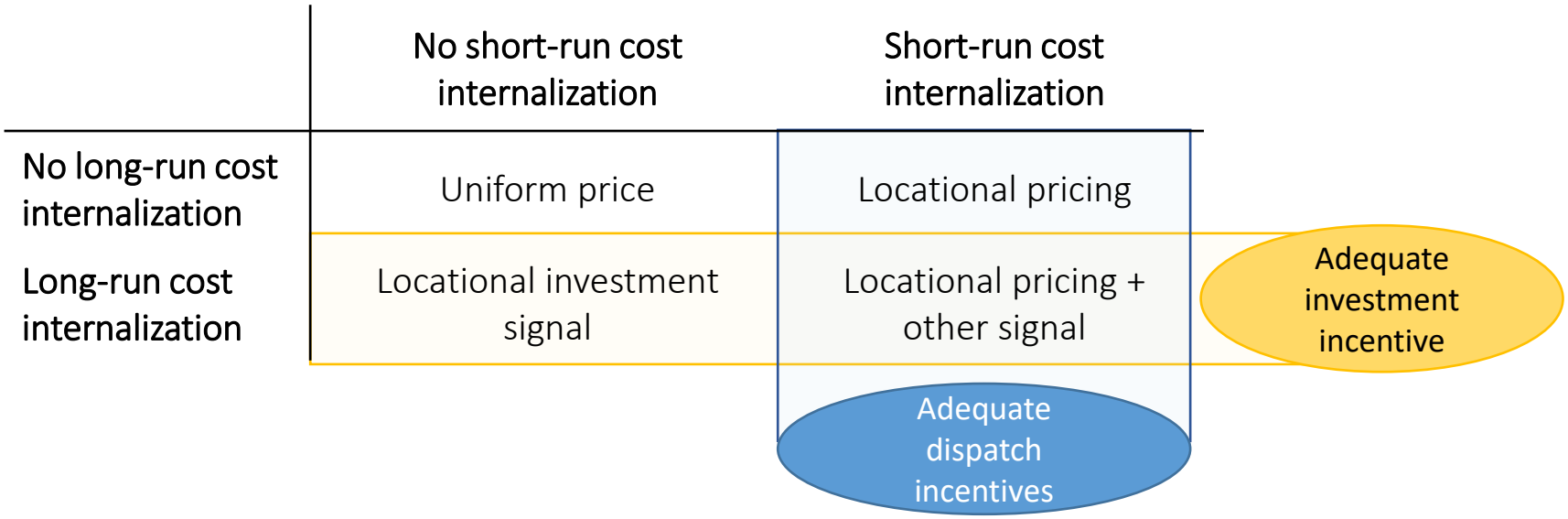
Locational instruments can internalize long-run network cost but are unable to incentivise an efficient locational dispatch

- Signals are usually time-invariant (from hour to hour)
- In most cases, the signal does not reflect the current value difference between locations correctly



Summary: Locational investment signals and locational prices

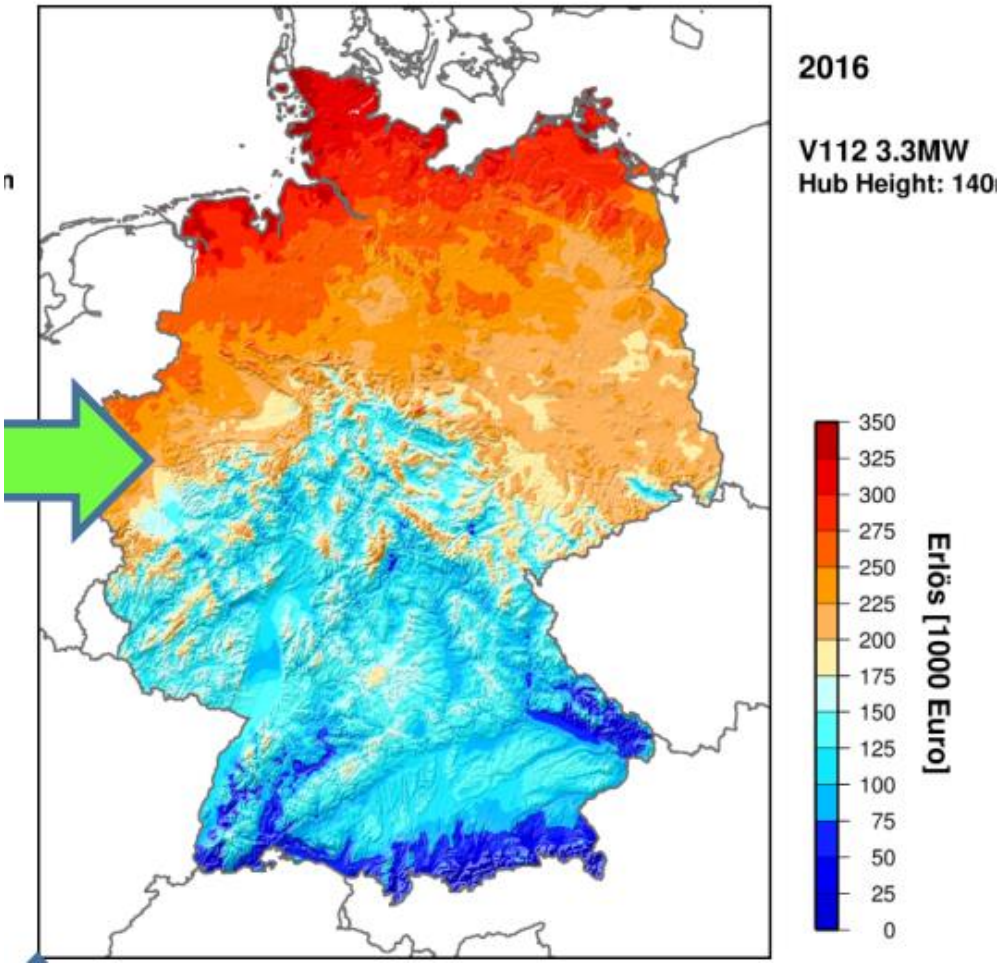
- Locational instruments (other than locational electricity market) are an alternative and a complement to locational pricing



Three hypotheses on locational instruments and RE generation

Hypothesis I: Locational steering becomes more important at increasing VRE shares

- VRE feature larger differences in cost / revenues between locations than any other generation technology

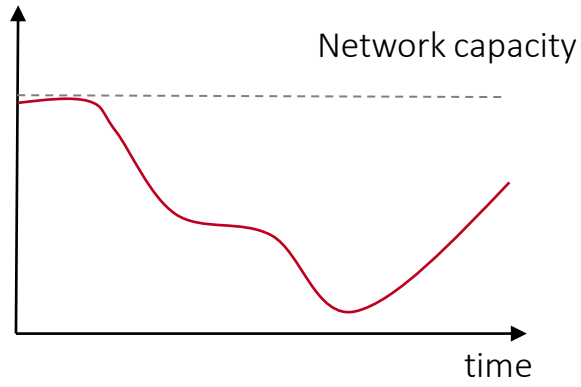


Source: Anemos

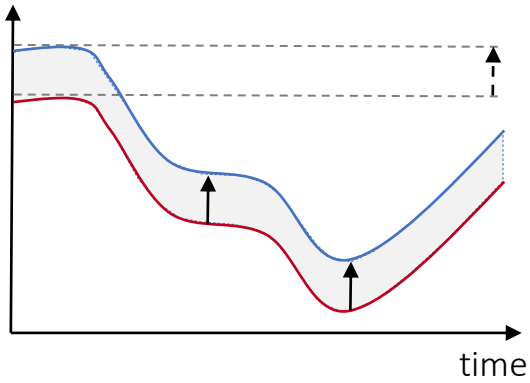
Hypothesis II: Locational instruments that internalize the long-run network cost vary by technology

The long-run network cost may differ significantly between generators

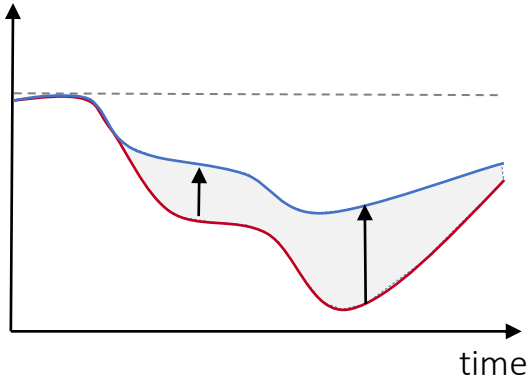
Current use of network infrastructure



Increase in network use through additional generator



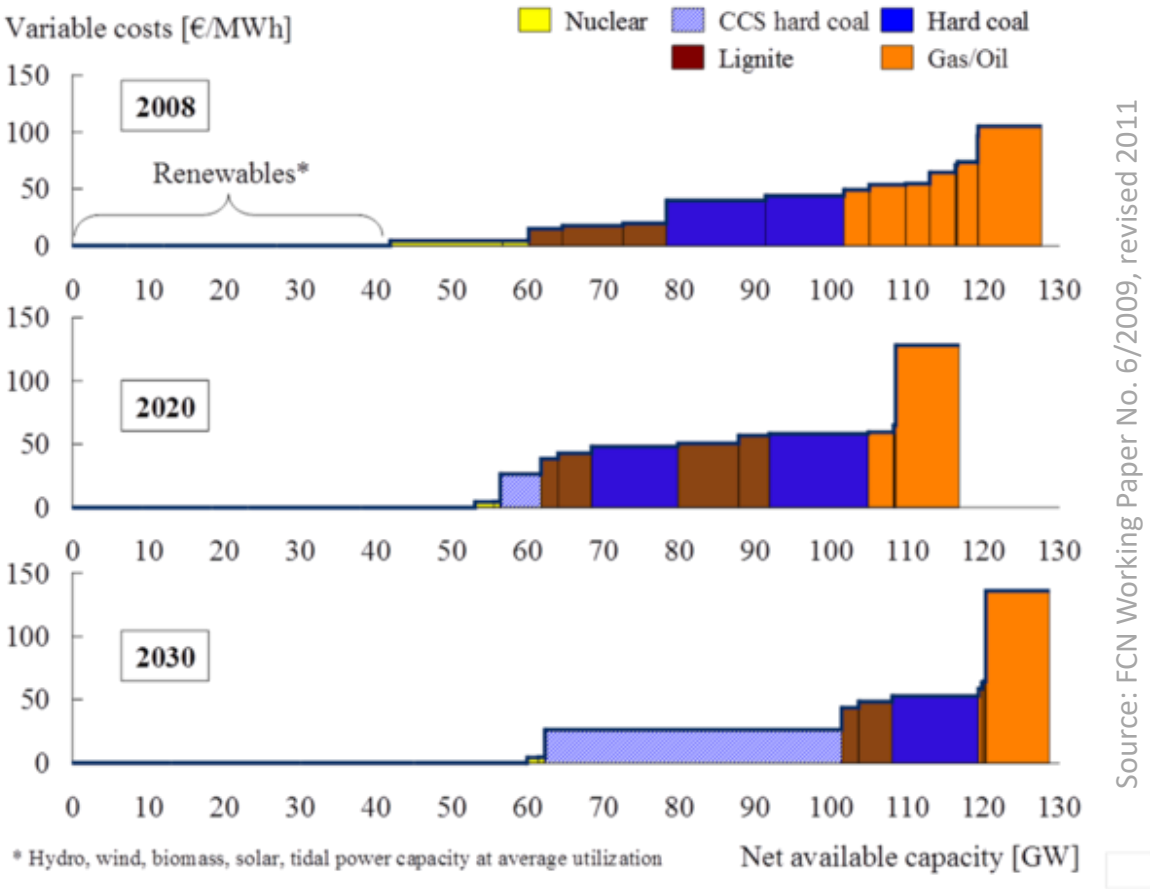
Increase in required network capacity



No increase in required network capacity

Hypothesis III: The missing locational dispatch incentive is less problematic for VRE compared to other technologies

Due to very low operation costs of VRE, dispatch is mostly driven by availability and less by electricity prices



Source: FCN Working Paper No. 6/2009, revised 2011

Next step: Modeling cost-optimal locational instruments

As a next step, I will test these hypotheses based on a numerical model of Germany

Bilevel optimization problem (Stakelberg game)

Leader: Regulator

- Chose level of locational investment signal for each technology and each location that minimizes the total cost of electricity supply (dispatch + investment + network cost)

Follower: Generator

- Chose investment and dispatch to minimizes electricity cost (dispatch + investment) for given locational investment signals

Thank you for your attention!

Questions? Feedback?