



System-wide benefits of temporal alignment of wholesale–retail electricity prices

Yucun Lu

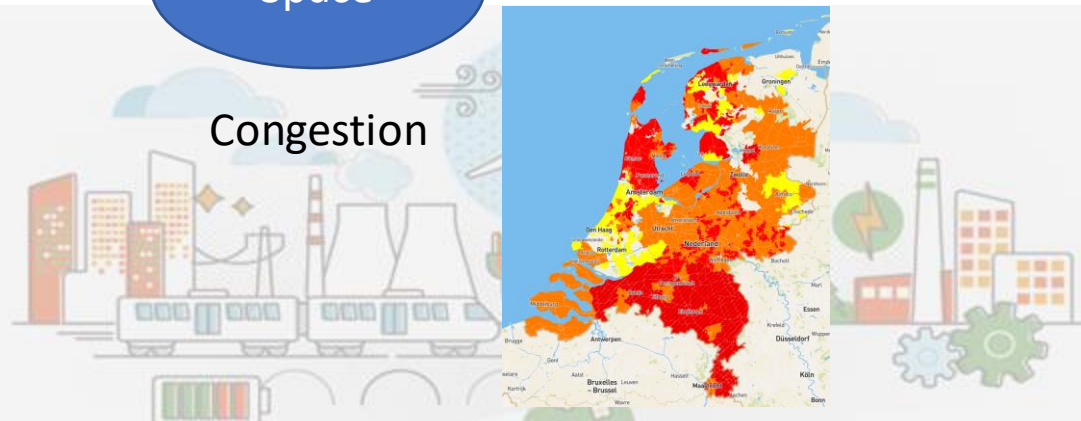
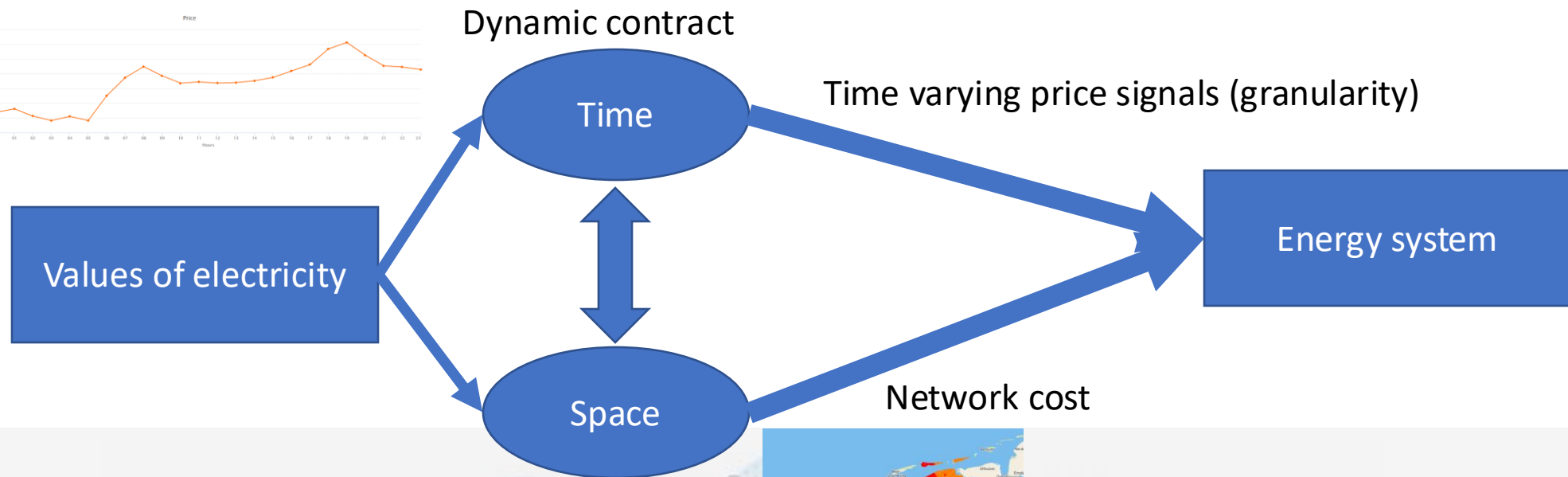
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Research Question

How does the temporal granularity of retail electricity prices interact with different distribution tariffs, considering the interplay between consumers' decisions and the rest of the electric power system?



Contribution

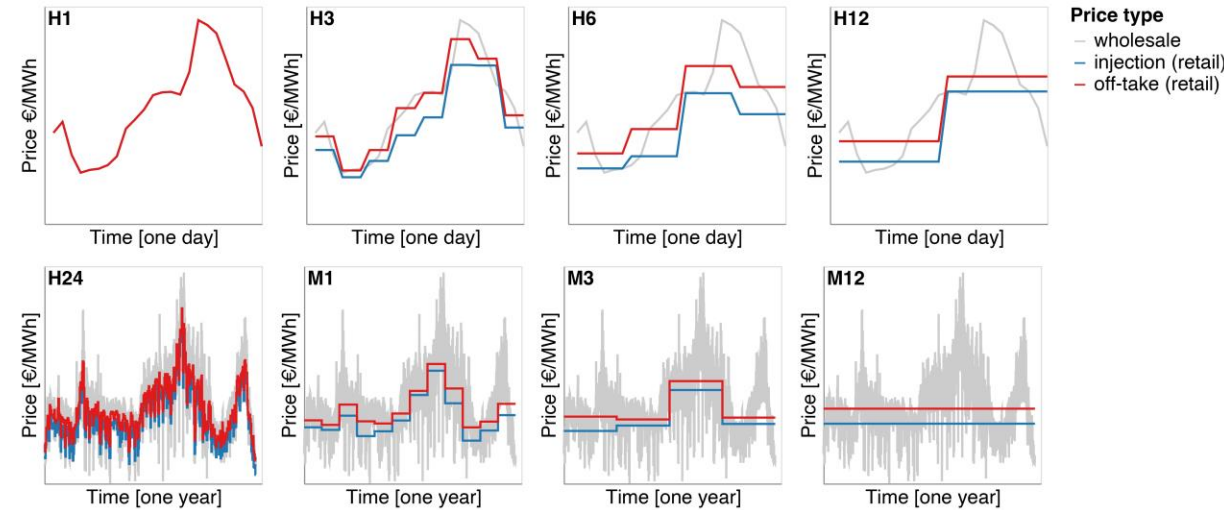
- Consider and evaluate a wide range of temporal granularities for retail electricity pricing in combination with different network cost.
- Account for the feedback loop in investments, operations and prices between wholesale and retail levels.
- Find alternatives for Real-Time Pricing (RTP) contract:
 - Mitigate practical challenges
 - Capture similar economic benefits



Research Scope

Note:

- All residential consumers take the same granularity of retail prices and same type of network cost in each case.
- Network fees are calibrated in the RTP (H1) cases and kept constant across all temporal granularities.
- Model an entire year with hourly temporal resolution by representative days.

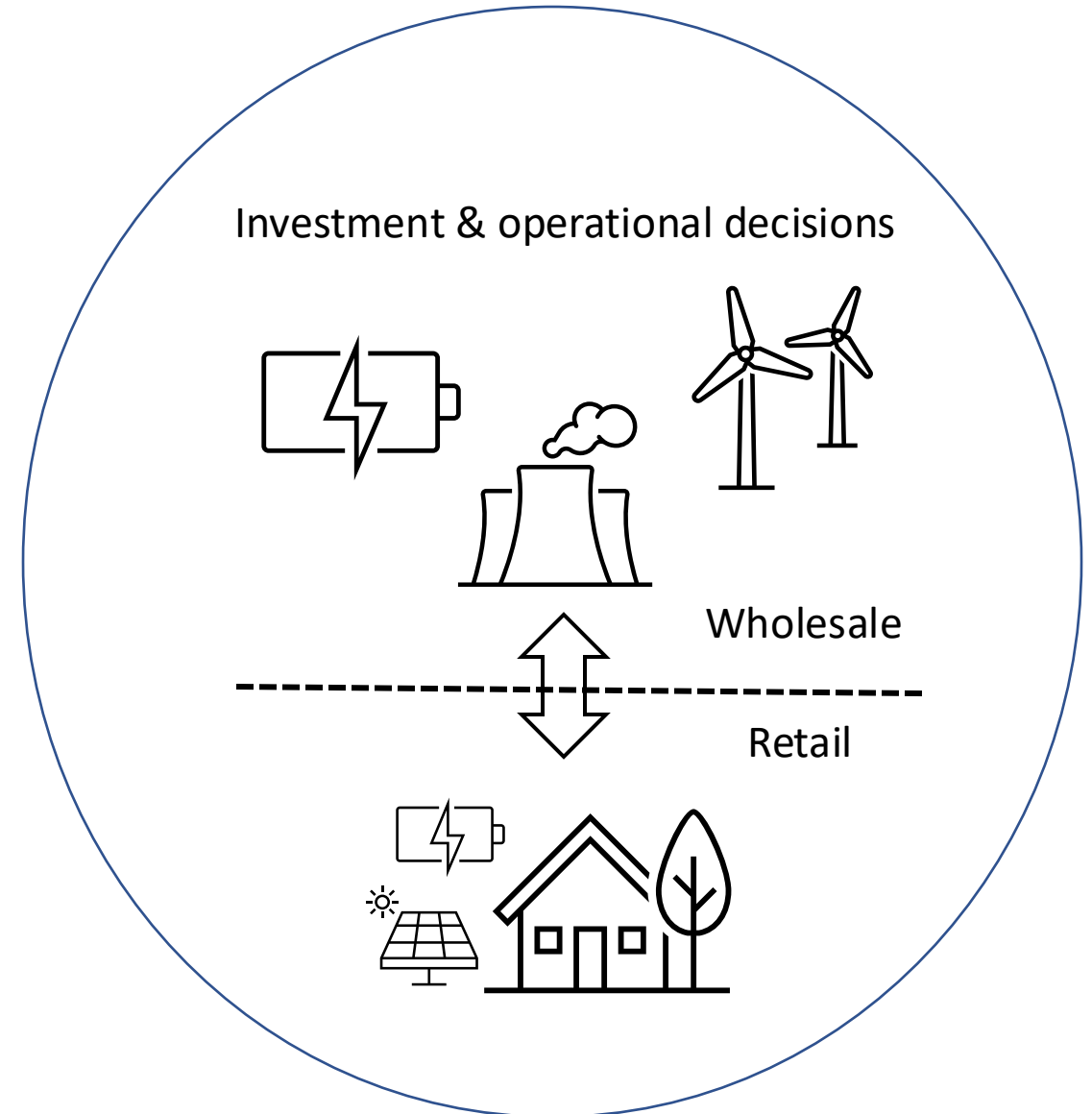


Network cost

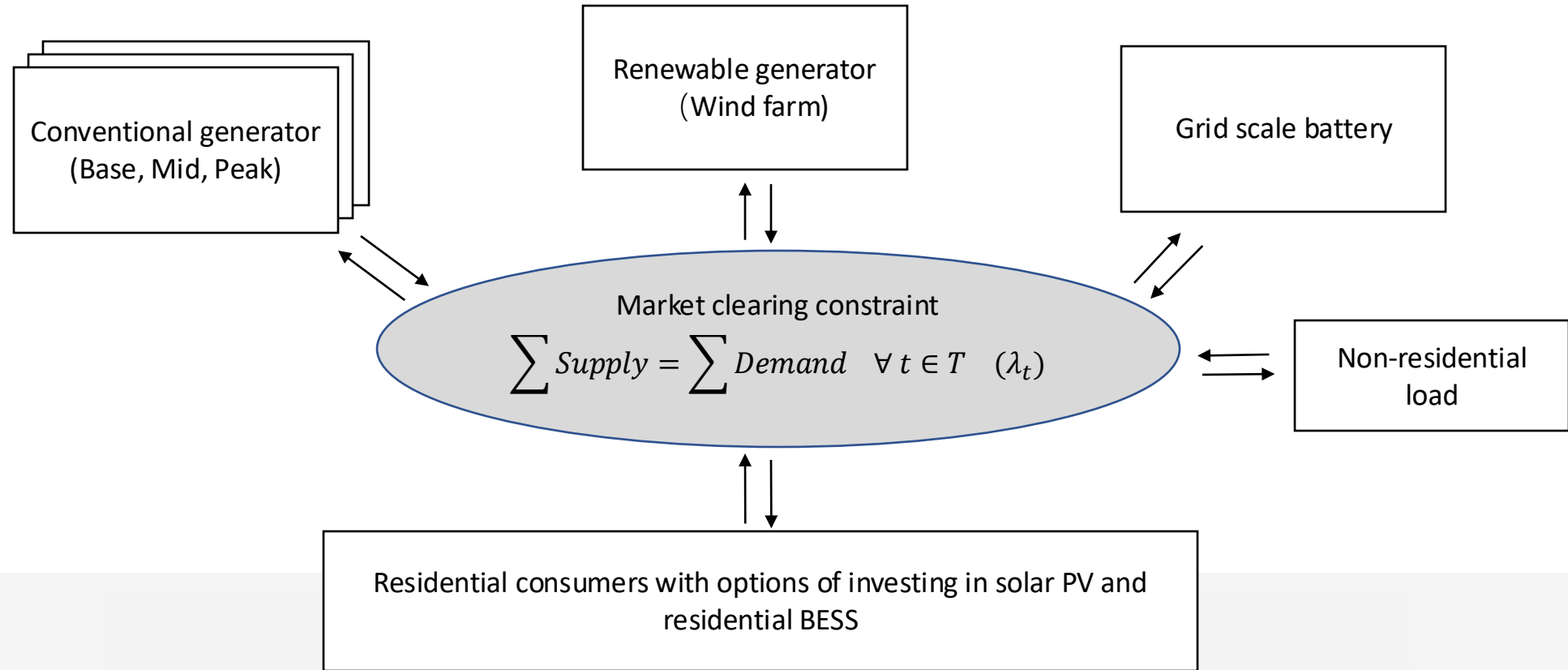
- Fixed (€/Year)
- Volumetric (€/kWh)
- Capacity-based (€/kW)

Model Setup

- Potential Belgian system in 2030
- Isolated electricity market
- Greenfield model with no grid constraint
- Ten types of representative residential consumer
- Scale up to 4.8 million households



Methodology



A common price (RTP) – Optimization problem with one objective:
Minimize total system cost

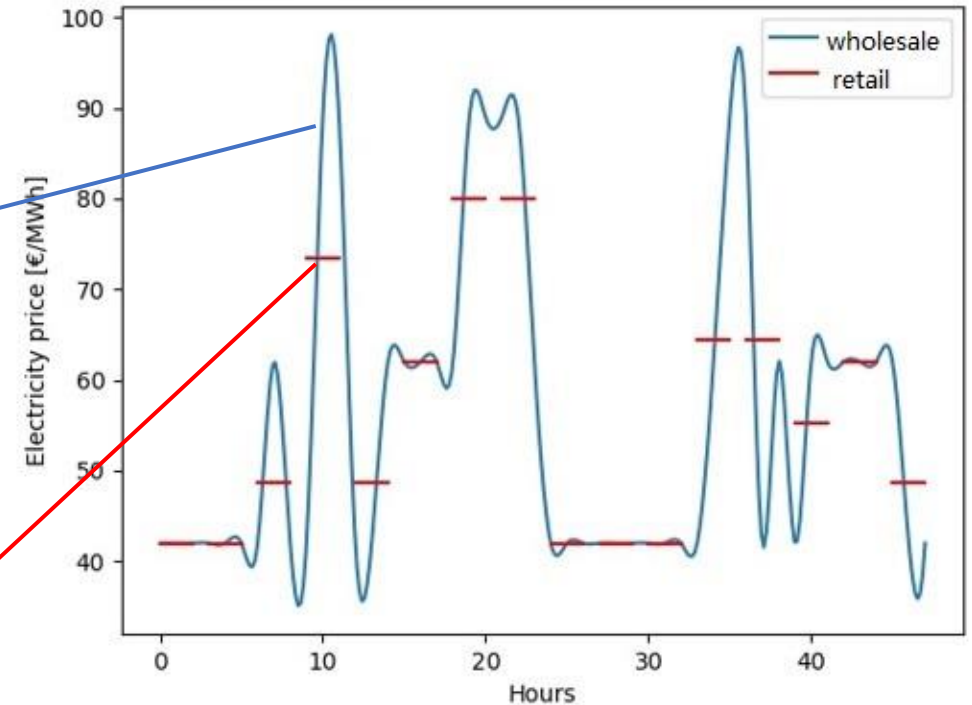
Methodology

Generators and residential consumers receive different price signals in the market!

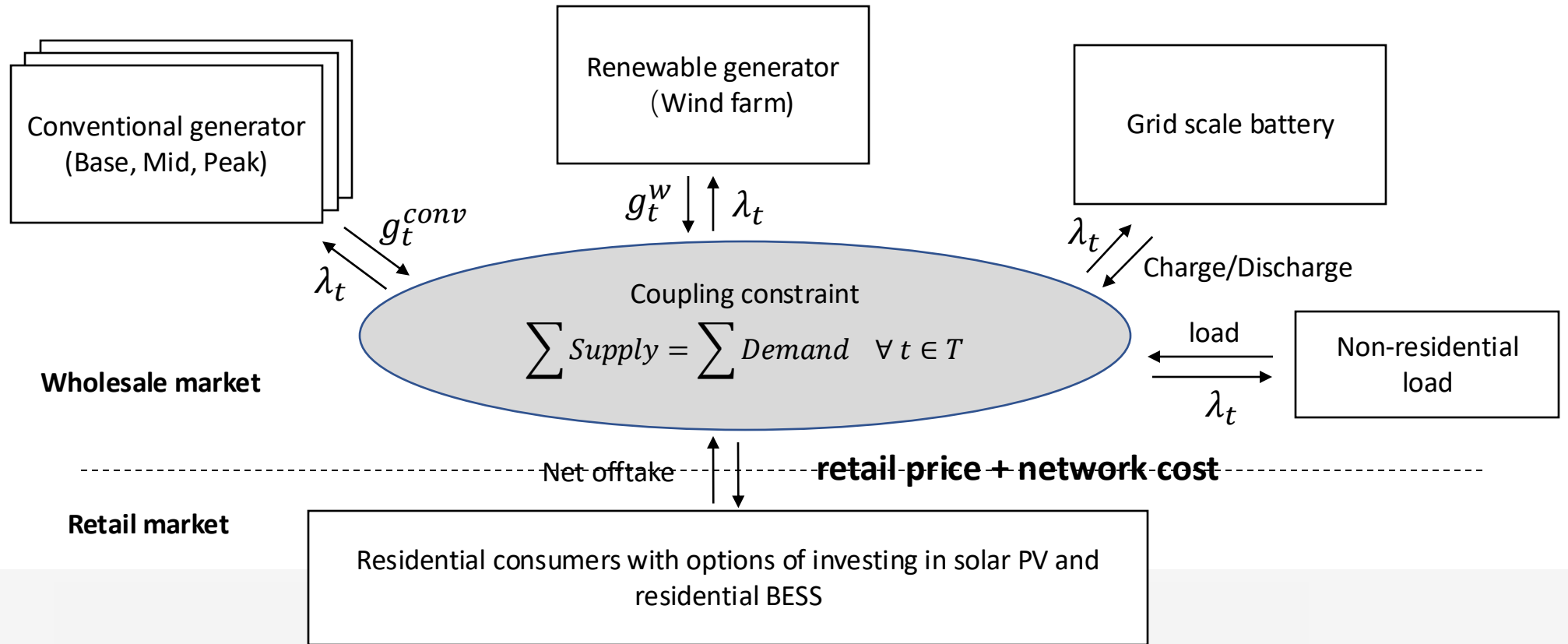
Price signals on wholesale market: wholesale market price

Price signals received by residential consumers: retail offtake/injection price

- Weighted average price for a certain period (3 hours as an example)
- Different for offtake and injection
- Additional incentives: three types of network charges are not included here



Methodology



Retail price – weighted average of wholesale price
No common price signal for all agents!

Methodology

Initialize price signals (wholesale prices, retail prices)

While not convergence:

1. Send wholesale price signals to agents in transmission level and solve problems of each transmission level technology.
2. Send retail prices and network charges (parameter) to residential consumers and solve problems of ten representative residential consumers.
3. Calculate **primal** and **dual** residuals using obtained solutions and check convergence criteria with the calculated residuals.
4. Update wholesale prices: $\lambda = \lambda - \rho \cdot r_{mc}$, where $r_{mc} = \sum Supply - \sum Demand$.
5. Update retail offtake and injection prices.

end

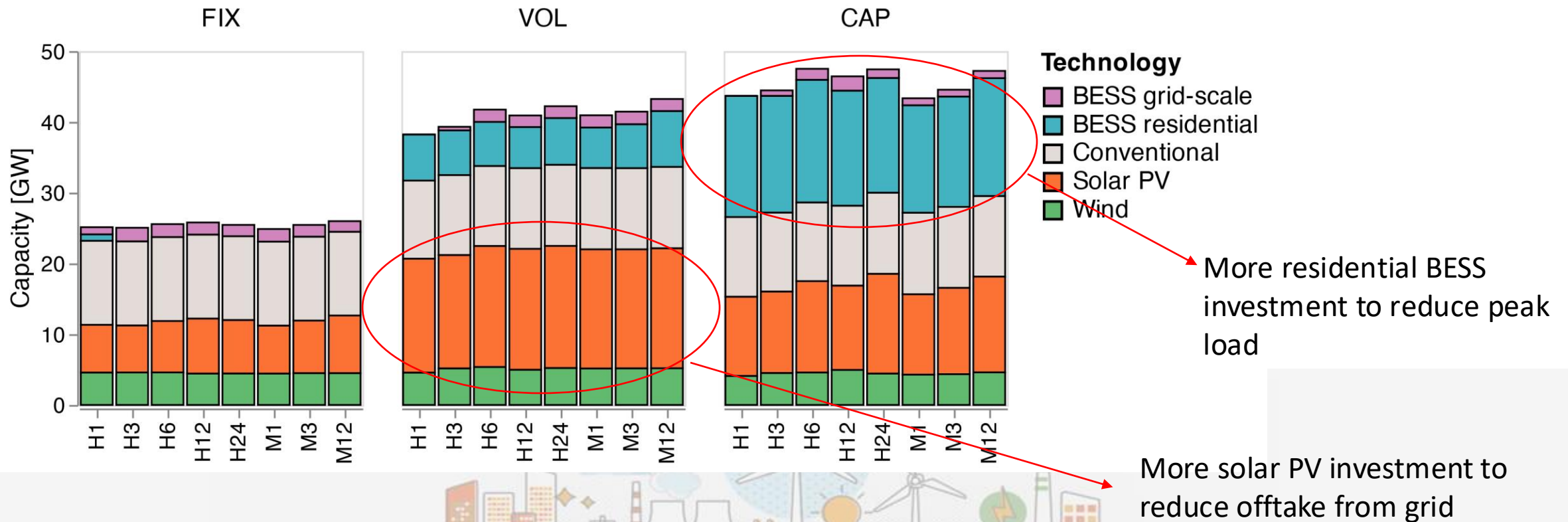
Until **Nash equilibrium**: No agents can be better off by changing its decisions.

Coupling constraints are satisfied while optimizing each agent's problem.

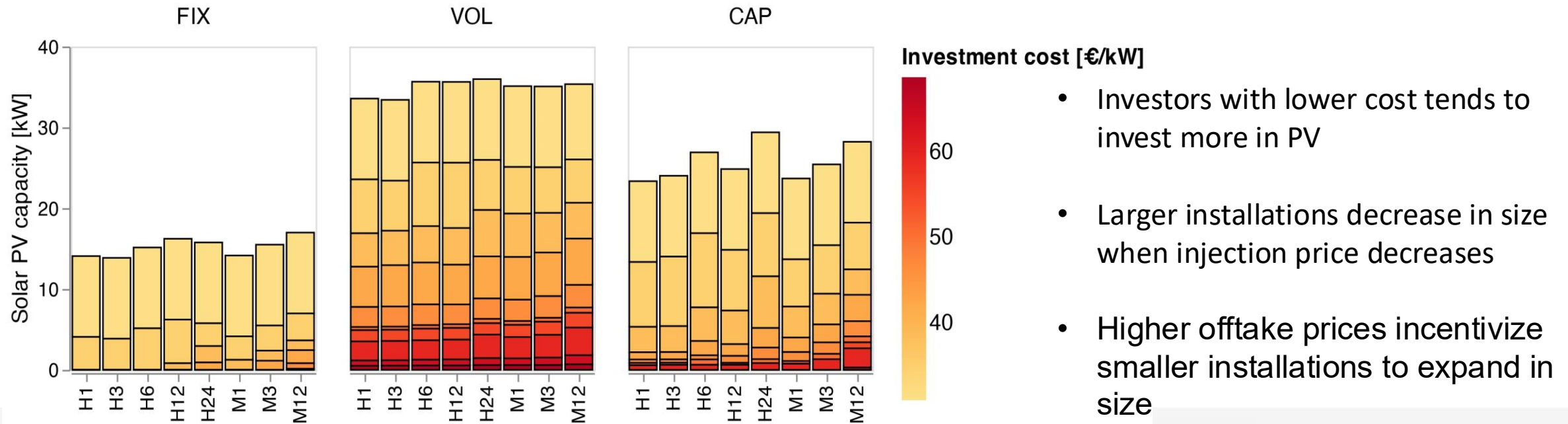


Generation capacity investment for all technologies

Under different granularity of retail prices and network cost schemes, residential consumers will act differently in investing DERs and then impact investment in wholesale level as well.



Lower temporal granularity incentivize PV installations to be widely distributed

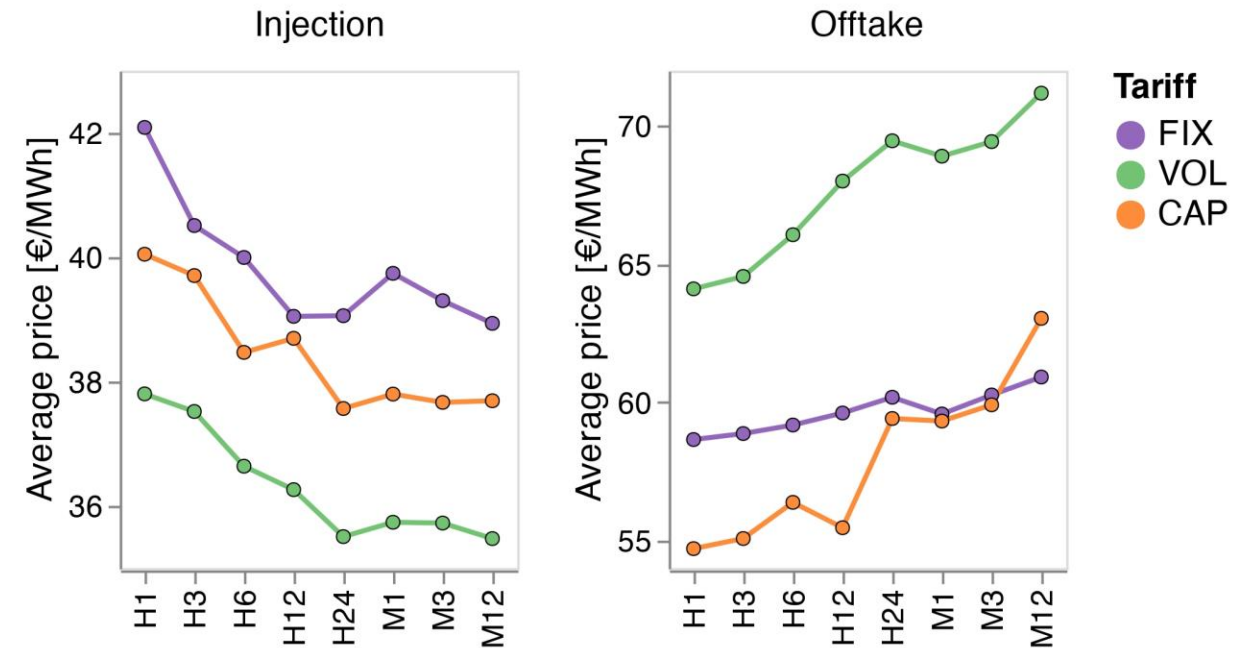


Note: With decreasing temporal granularity, injection price decreases and offtake price increases.



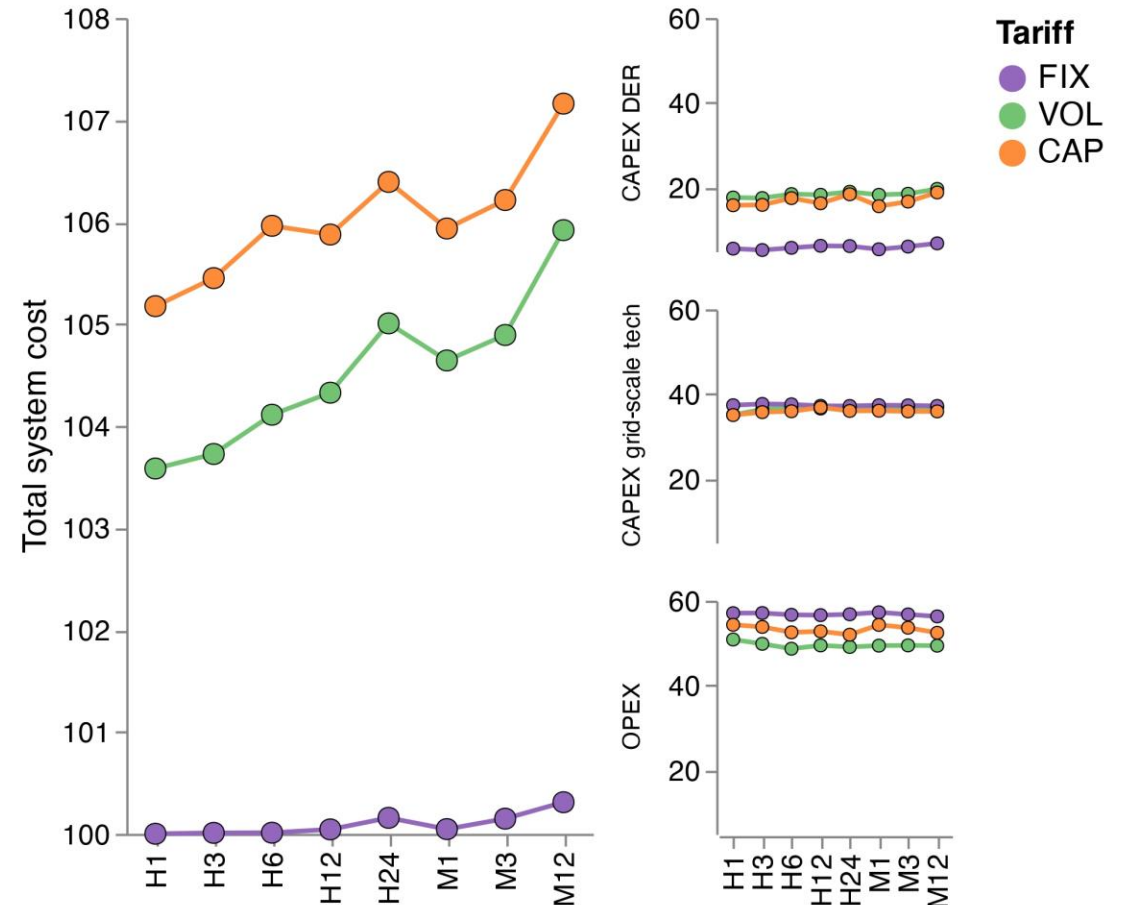
Average injection & offtake price

- Two major factors altering average retail price patterns:
- **Total PV Capacity**
- **Battery operations**
 - Smooth out price differentials
 - Altered by network cost and longer pricing resolutions



Total system cost

- Increased system cost
 - Inefficient generation mix
 - More DERs incentivized by tariffs and decreased temporal granularity.
 - VOL – Lower OPEX compared to CAP tariff
 - Inefficient residential battery operations, because residential consumers are
 - Not exposed to wholesale prices
 - Incentivized to avoid network cost



Conclusion

- Decreasing temporal granularity for retail electricity prices
 - Increase inefficient generation mix
 - Sub-optimal operations of residential storage
 - **Increase total system cost**
- Gains from dynamic pricing are **not so significant** considering interactions between wholesale and retail levels
 - **Granularity of H3 (or H6 in some cases) can be a valuable alternative to RTP (H1)**
- Decreasing temporal granularity will **increase offtake price** and **decrease injection price**
 - Magnitude is influenced by network charge types due to DERs investments they trigger
 - Volumetric and Capacity-based tariffs **erode electricity price signals** and **cause inefficiency**.



Thanks!



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<https://alexander-project.vito.be/en>

alexander@energyville.be