

Impact of Building Electrification on the Electric System of the Future

Erik Delarue, KU Leuven / EnergyVille, Belgium

Session: Building Sector Decarbonization in Energy Systems Modeling

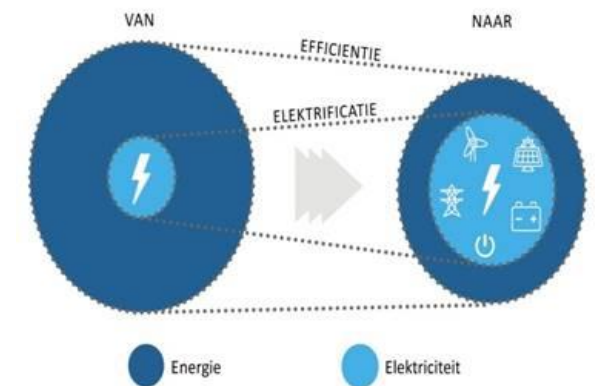


Overview

- Impact of Building Electrification on the Electric System of the Future
 - Building electrification
 - Distribution grid impact
 - System-level impact
 - Interactions and flexibility valorization
 - Modeling these interactions
 - Conclusions

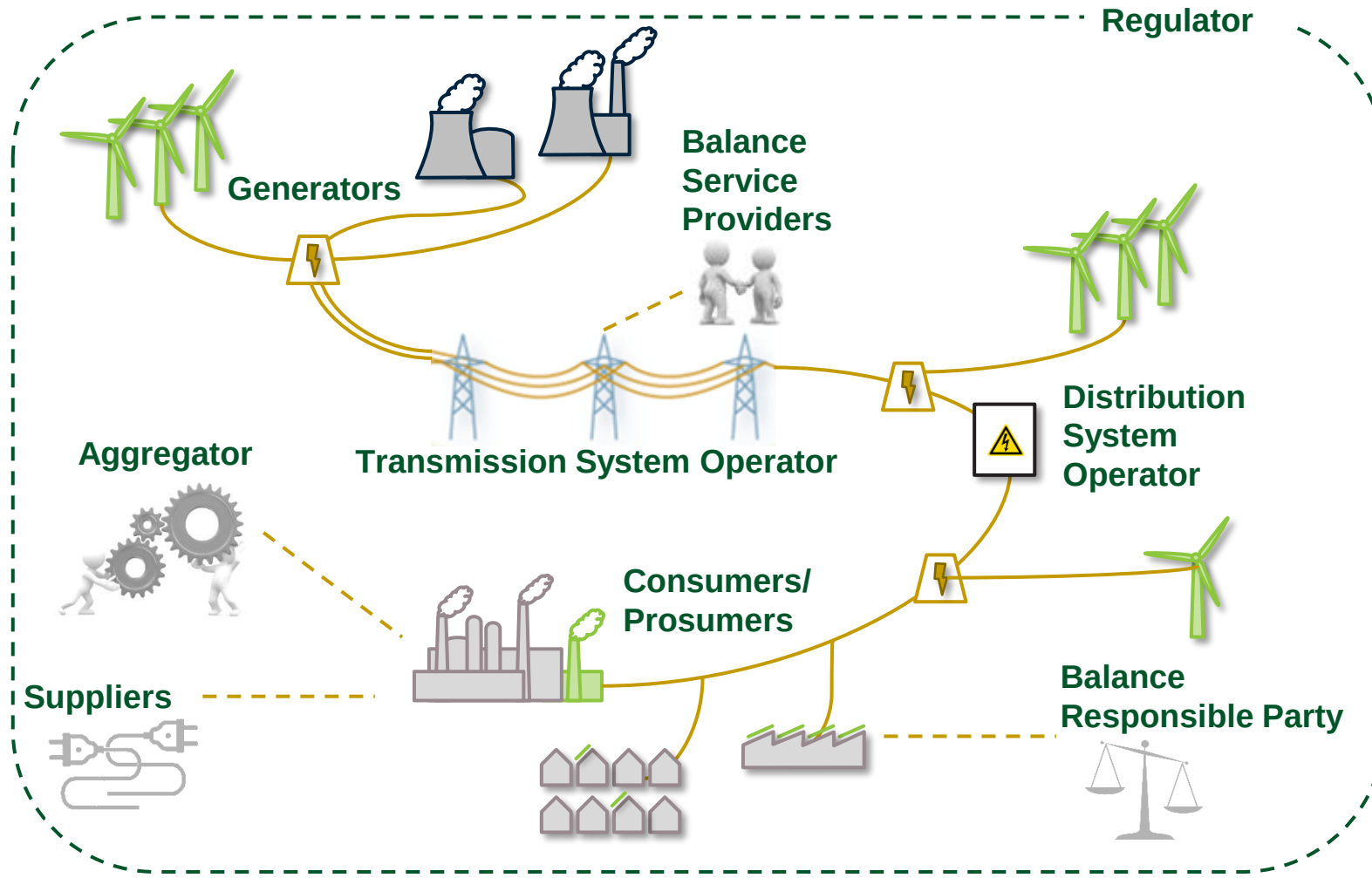
Building electrification

- Electrification to increase energy efficiency and decarbonize
- Consumers becoming prosumers or prosumagers
 - Becoming central actor in the transition
 - Possible assets
 - Local generation: solar PV
 - Local storage: home battery, electric vehicle (with V2G)
 - Local (flexible) demand: Heat pumps (with thermal inertia, water buffers), electric water heaters, electric vehicles, smart devices



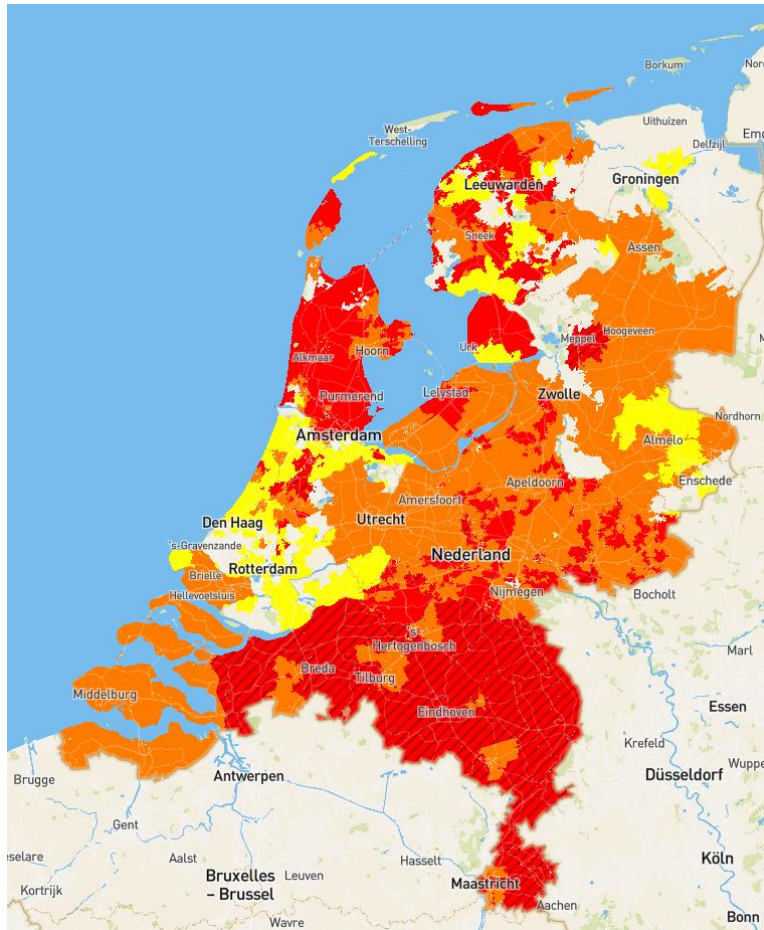
Source: VREG 2020

Building electrification

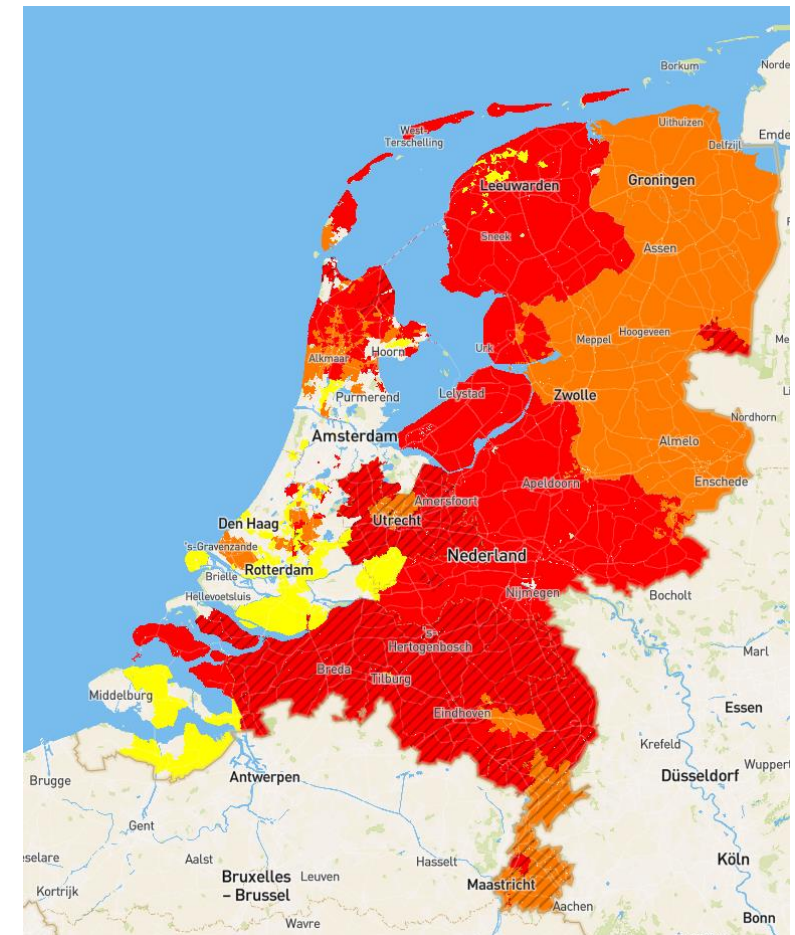


Distribution grid impact

Offtake



Injection



Distribution grid impact

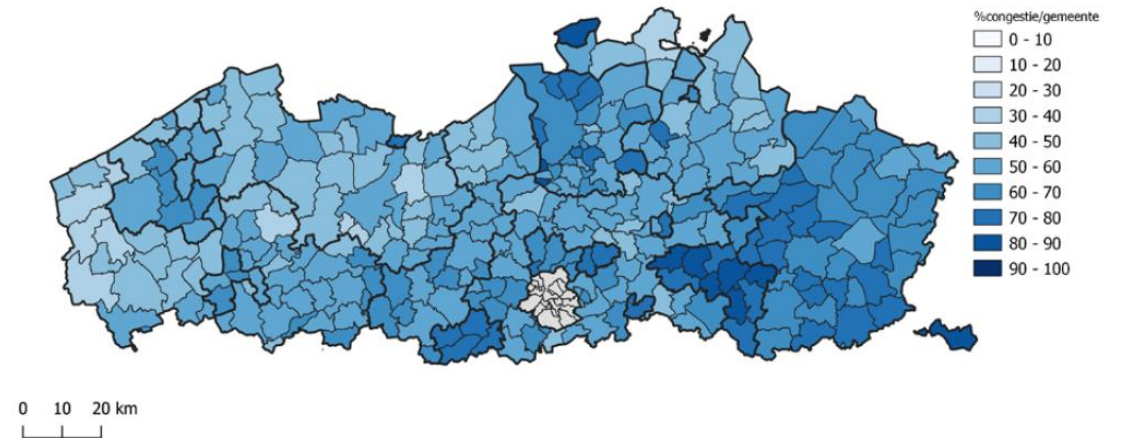
- Development of distribution network investment plans



Actueel aandeel netten dat potentieel in congestie kan komen (% per gemeente)



2035 - aandeel netten dat potentieel in congestie kan komen (% per gemeente)



Distribution grid impact

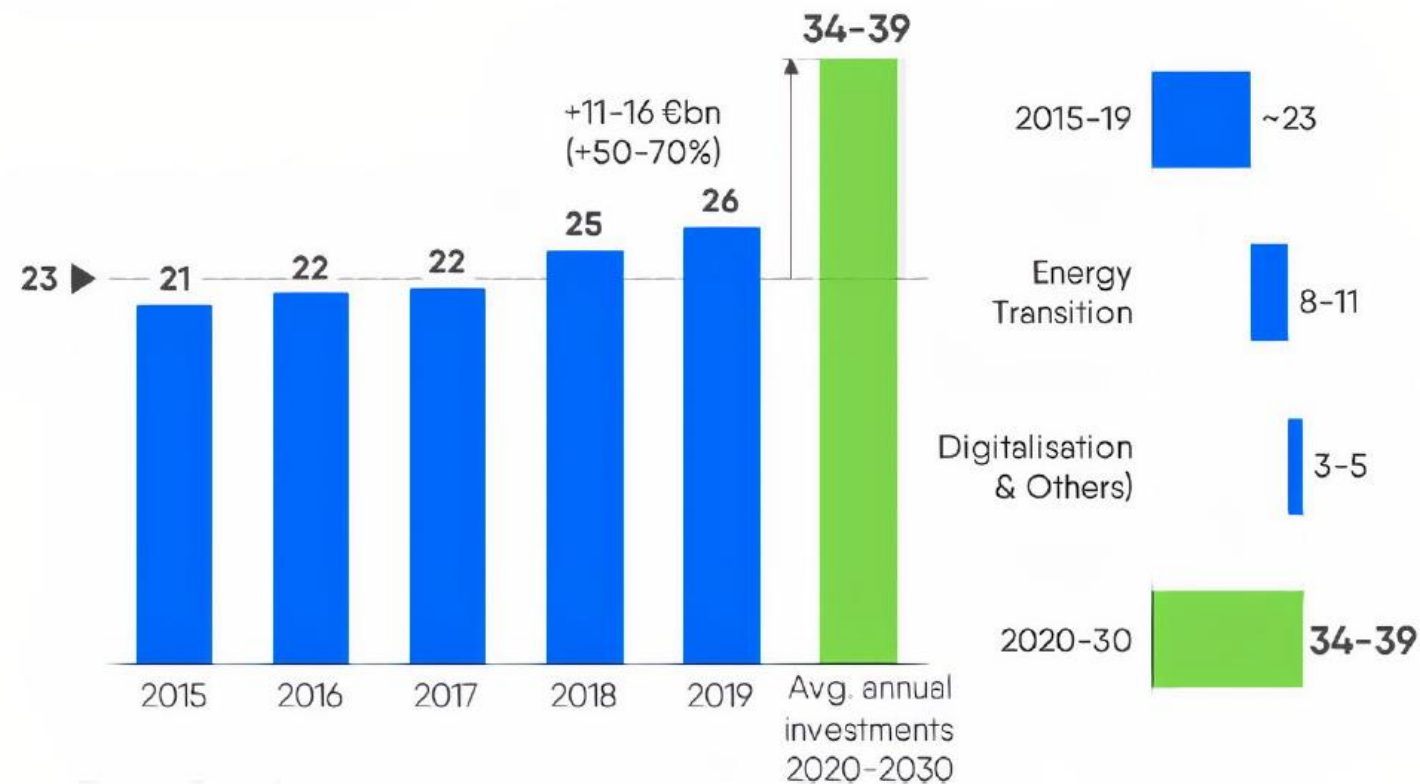
- To support development of distribution network plans, Clean Energy Package introduced provisions across five planning dimensions:
 - Planning frequency
 - Coordination with the TSO
 - Digitalization
 - Transparency
 - **Flexibility as an alternative/complement to grid investments**
- Description of these provisions remains relatively high-level, leaving detailed implementation up to Member States

Distribution grid impact

- DSOs can use regulatory tools to source flexibility at the distribution level:
 - Dynamic network tariffs
 - Flexible connection agreements
 - Flexibility markets
 - Bilateral contracts
 - Cost-based mechanisms
 - Obligations
- Currently most mature in Europe: dynamic distribution network tariffs and flexible connection agreements

Distribution grid impact

- Annual distribution network investment cost in Europe



System-level impact

- Impact of increased electrification
 - Affect residual demand (or injection) profiles as seen on transmission level
 - E.g., impact of massive EV penetration with certain charging behavior
 - Impact 'optimal' generation mix of system / profitability of transmission level assets
 - Offer flexibility services
 - On different time scales
 - Long-term – Adequacy
 - Short-term – Arbitrage
 - Real-time – Balancing

Interactions and flexibility valorization

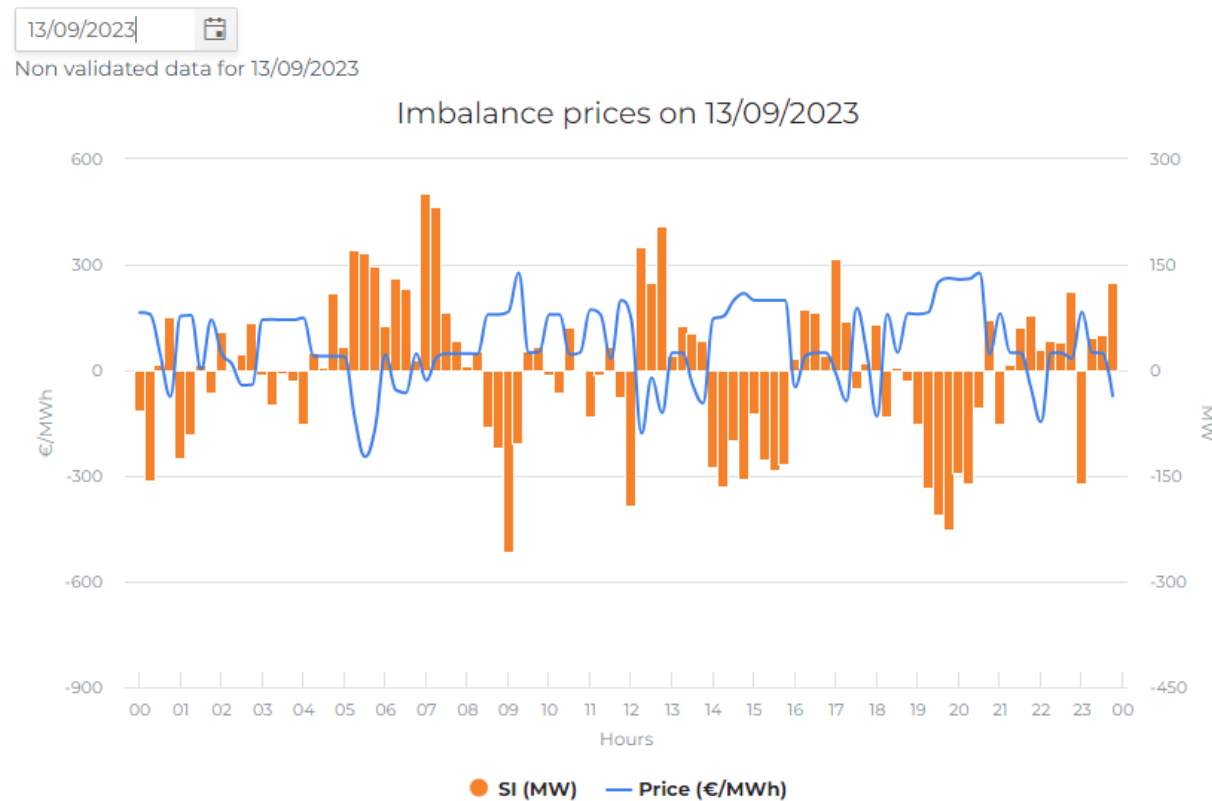
- As a consumer directly
 - Responding to
 - Dynamic electricity tariffs
 - Distribution tariff (design)
 - Being active in energy community / P2P trading
- Via intermediary / aggregator
 - Revenue stacking, offering services to/interacting with
 - DSO (e.g., flexibility market)
 - Manage congestion issues
 - TSO
 - Balancing capacity and energy (e.g., FCR/aFRR/mFRR)
 - Adequacy / CRM
 - BRP
 - Market arbitrage
 - Balancing position



Source: energypost.eu

Interactions and flexibility valorization

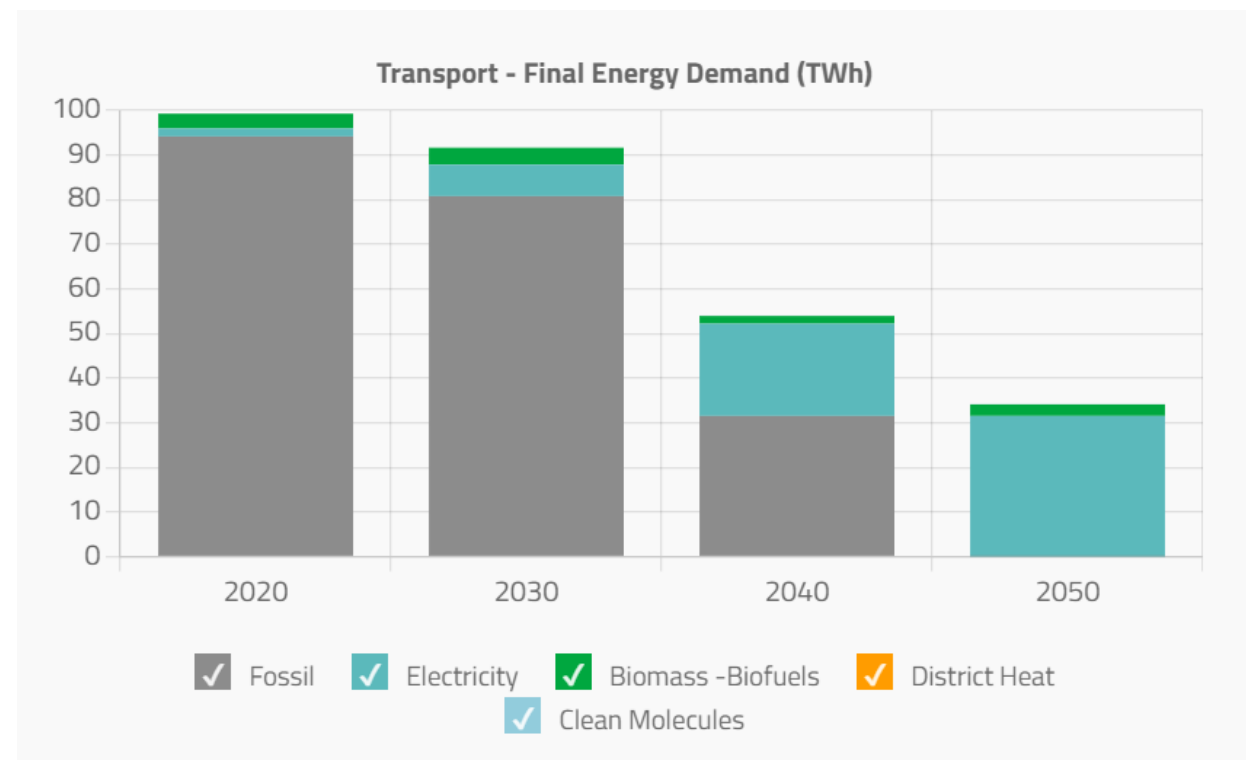
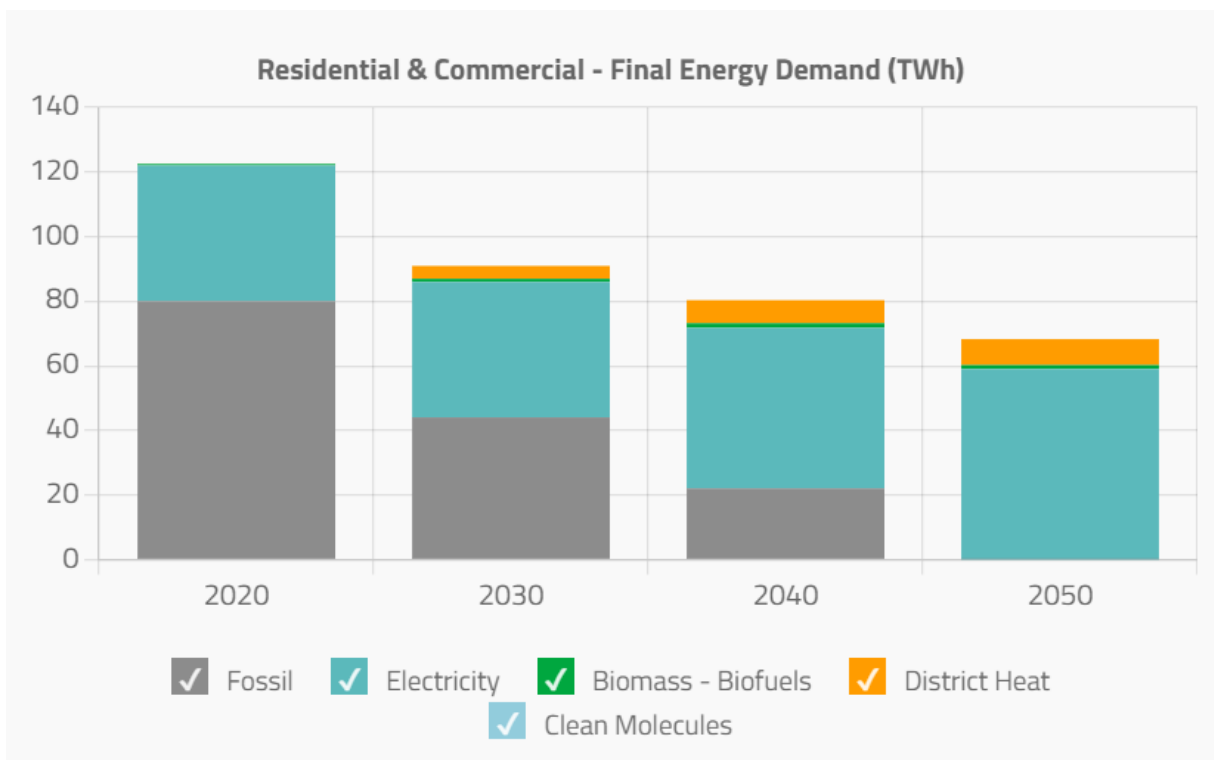
- Example of system imbalance and imbalance price in Belgium



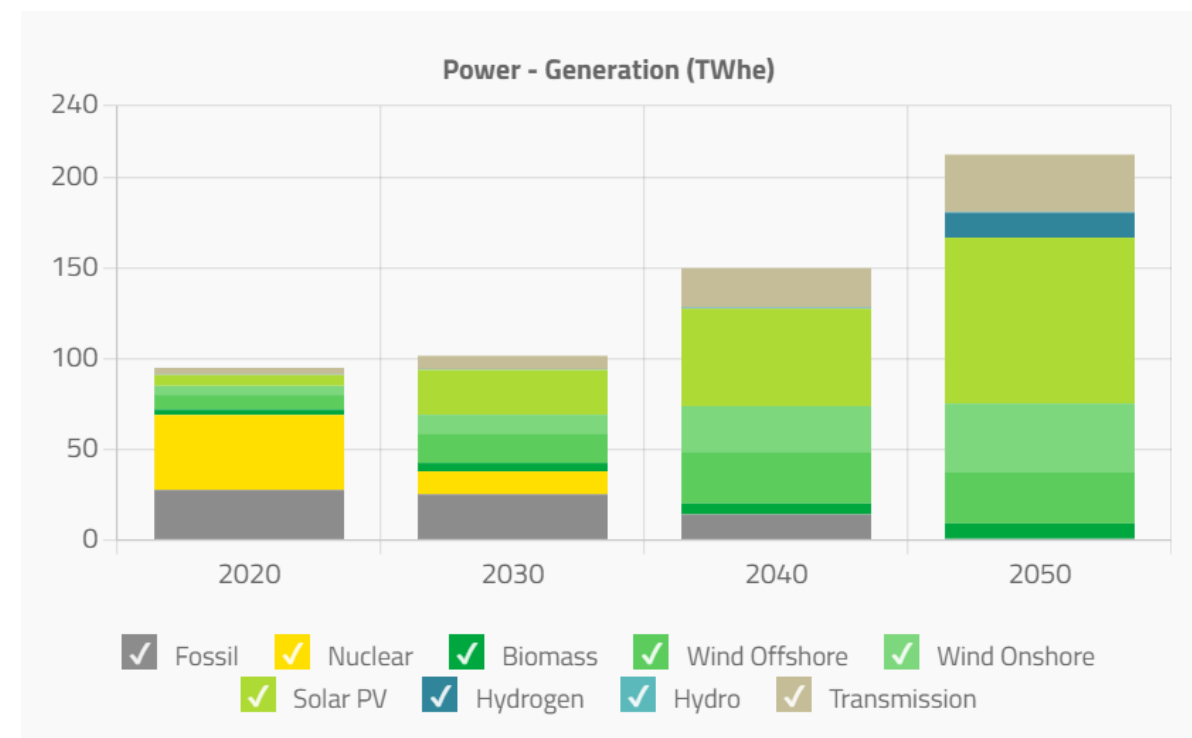
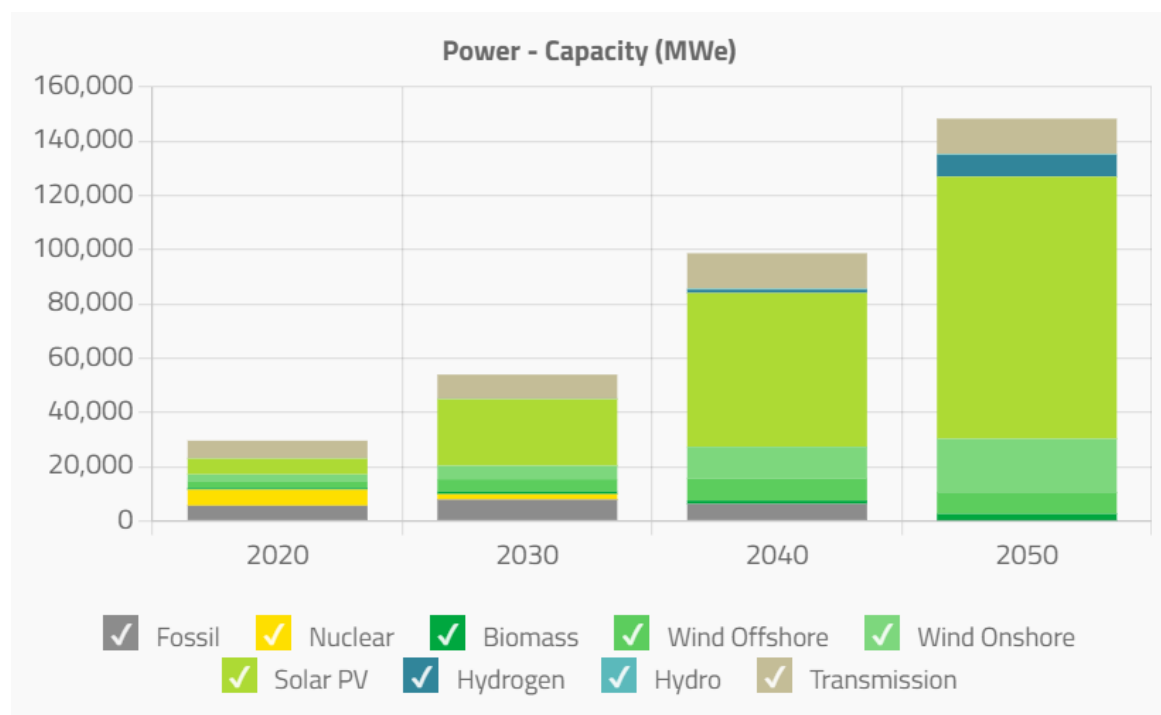
Energy Systems Modeling

- Our modeling framework
 - System optimization models
 - Operational model
 - Expansion planning models
 - Equilibrium modeling
 - Including e.g., risk-averse or strategic behavior
 - Agent-based modeling
 - More flexibility to account for incentives, boundedly rational decision process, and social interactions
 - Statistical methods and data-driven approaches
 - Open toolboxes and models
 - SpineOpt

Modeling example 1: Long-term planning model for BE

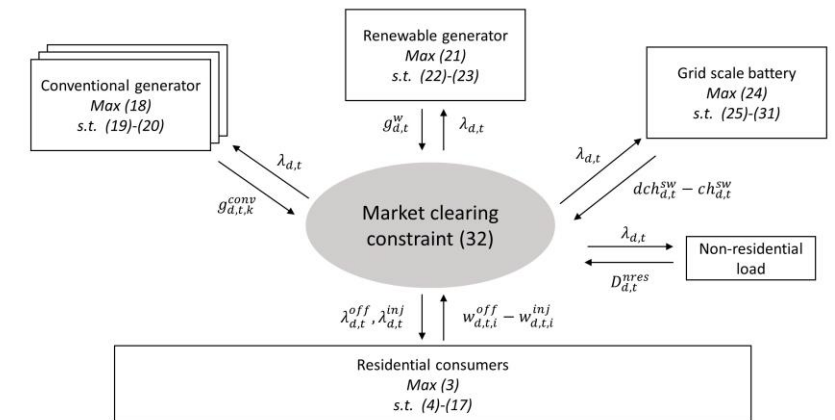
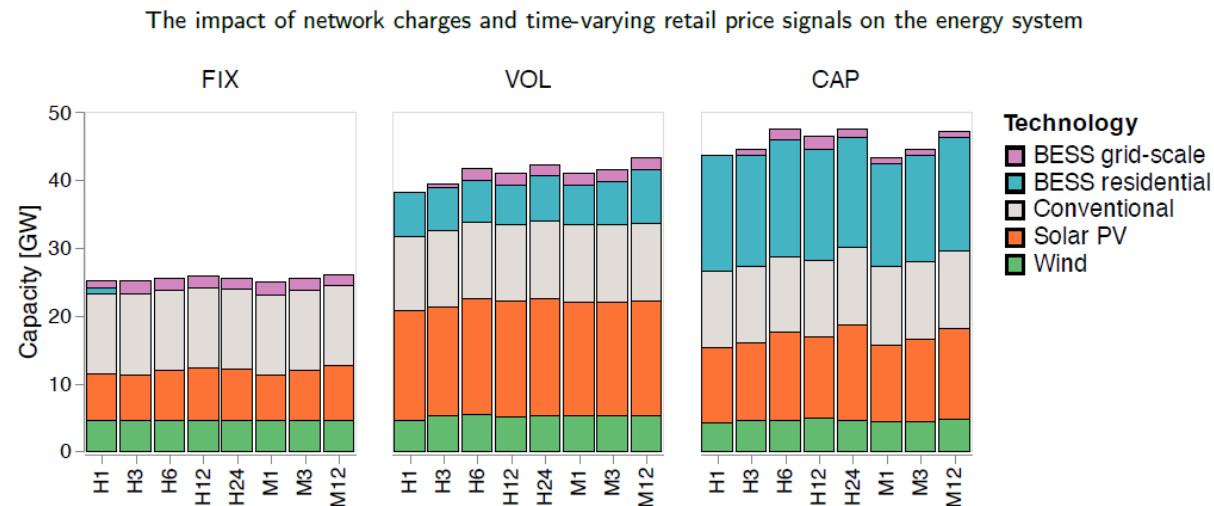


Modeling example 1: Long-term planning model for BE



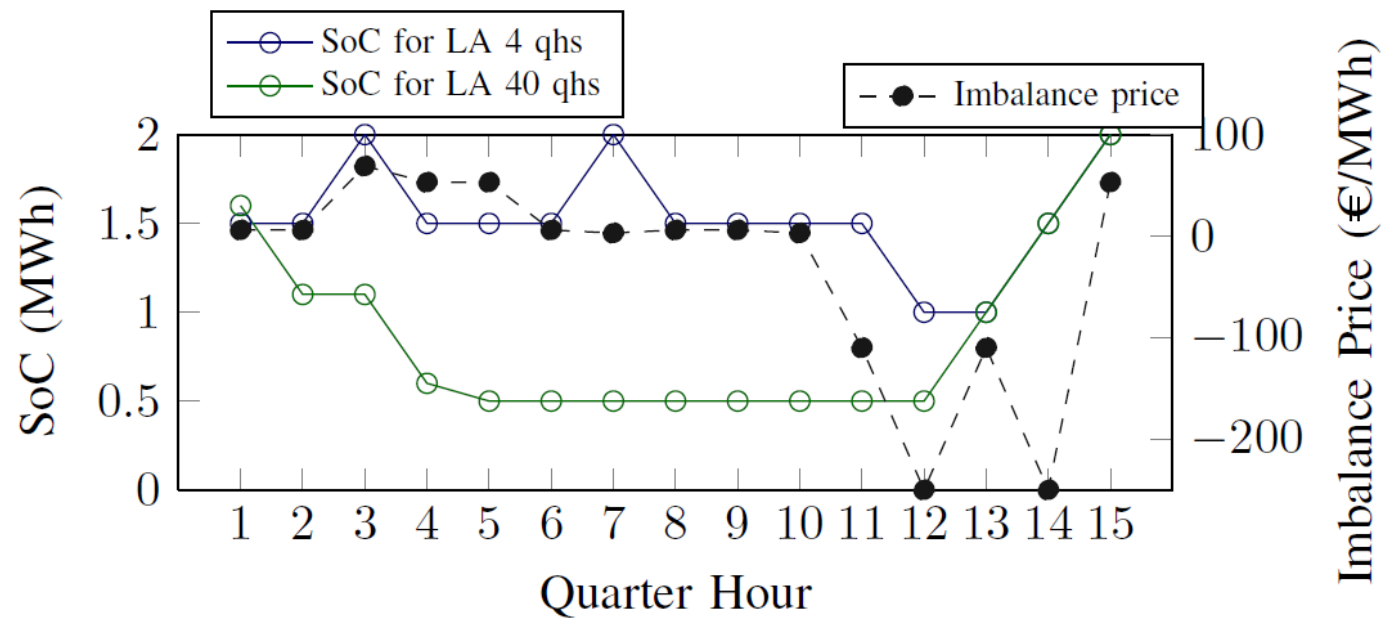
Modeling example 2: Impact of network charges and dynamic retail price signals on the energy system

- Decreasing price granularity leads to energy systems with less cost-effective generation mix
 - Distribution tariffs have stronger impact on generation mix



Modeling example 3: Implicit balancing with storage

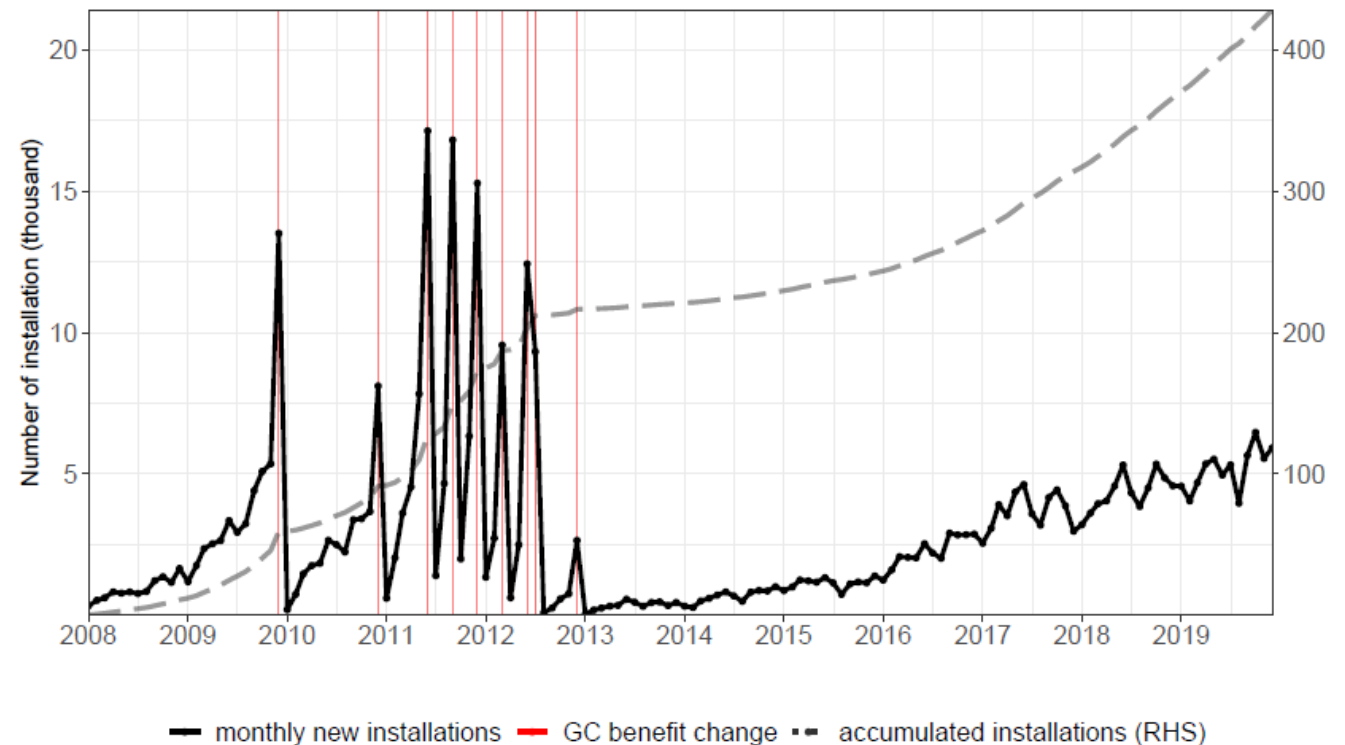
- Implicit balancing by taking out-of-balance positions in near-real time for storage
- Higher profit compared to optimizing profits solely from day-ahead electricity market with perfect price foresight



Modeling example 4: Drivers of PV adoption

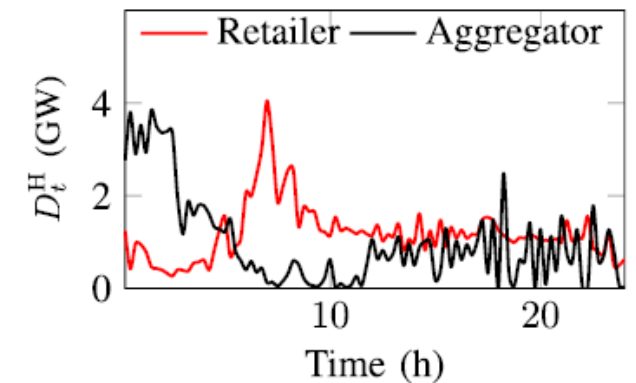
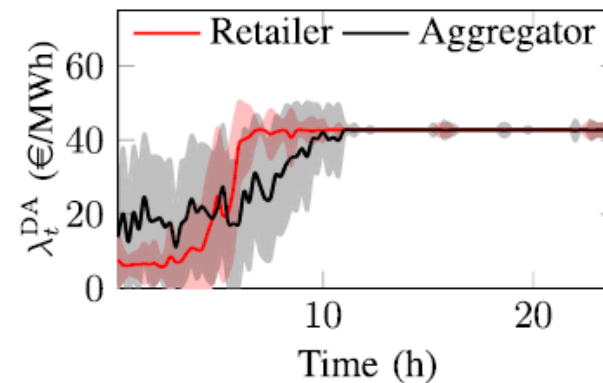
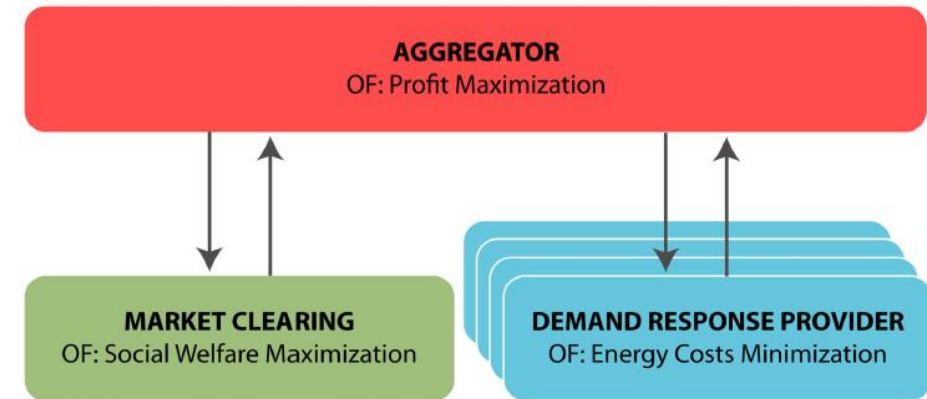
- Effect of different incentive schemes with future financial benefits on photovoltaic (PV) adoption patterns
- Direct compensation more effective than cost-saving

Monthly number of new and accumulated PV installations in Flanders



Modeling example 5: Aggregator and DR providers

- Strategic interactions between an aggregator, its consumers and the DAM
 - Using a bi-level optimization framework
 - Aggregator takes strategic positions in the DAM, considering uncertainty on market outcome



Wrap-up

- Building electrification, impacting
 - Distribution grid
 - Development plans, including use of flexibility
 - System-level
 - Modified demand and injection patterns + flexibility
- Interactions directly (via tariffs) or via intermediary
- Modeling examples
 - System-wide optimization models, equilibrium models, data-driven approaches
 - Capturing & modeling consumer behavior & decision making



Research group

Energy System Integration & Modeling

<https://www.mech.kuleuven.be/en/tme/research/energy-systems-integration-modeling>