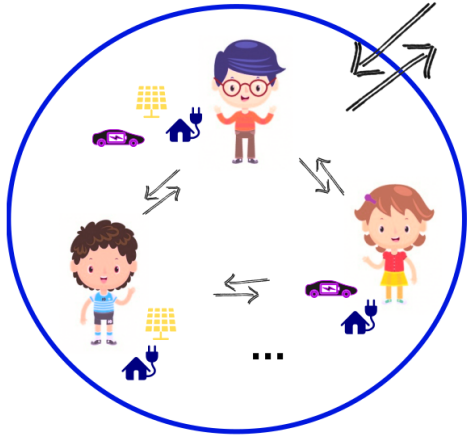
Future Electricity Markets

From coupling of energy markets to consumer-centric market design



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(Ackn. to **all contributors to CITIES WP4, as well as L. Mitridati, C. Ordoudis, J. Kazempour, L. Bobo, E. Sorin, F. Moret, T. Soares, A. Marin Radoszynski, H. Esch, T. Baroche, A. Schwele, etc.)**

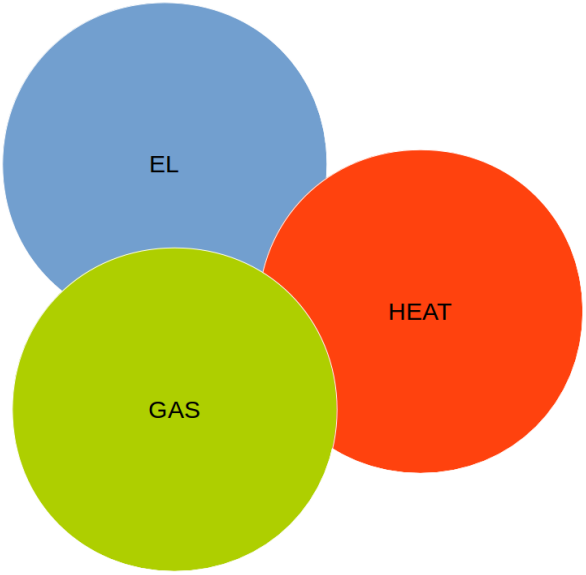
Outline

1. Higher level perspective: **markets for integrated energy systems**
   - from complete to loose coupling
   - heat and gas
   - heat and electricity

2. **Consumer-centric and community-driven electricity markets**
   - from concepts to application
   - key relevant features
   - challenges ahead

1. **Markets for integrated energy systems**

Complete coupling



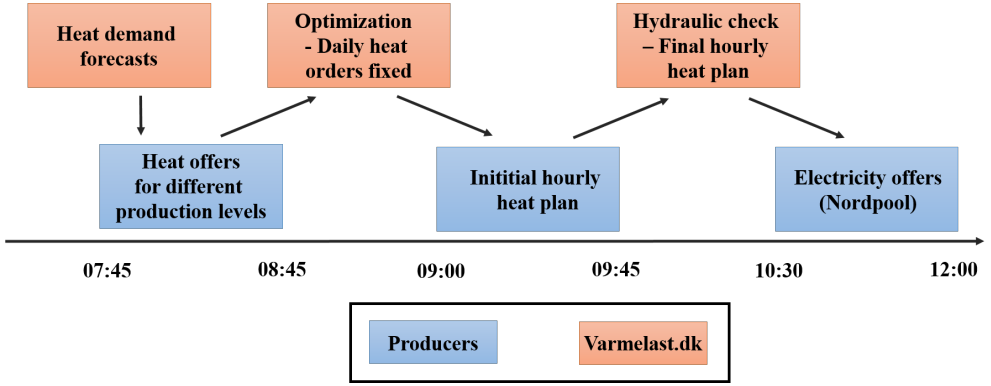
For a mathematical point of view, we can write and solve fully integrated markets for el-gas, el-heat, el-gas-heat... **but...**

Loose coupling

What do we mean by loose coupling?

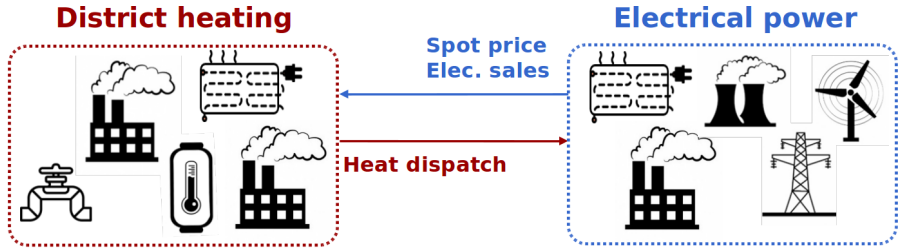
- *respecting organizational aspects of the energy system*, e.g., heat and el management are separated, the system operator is not taking care of day-ahead electricity market clearing, etc.
- *profit of existing levies* for impacting dispatch, costs, etc.

A practical example: heat and el interaction through Varmelast



Loose coupling of el and heat markets

One may respect the leader-follower structure of the market sequence, though optimally dispatching heat in view of future electricity dispatch!



Sequential:

1) Heat dispatch

- **Anticipate** electricity market clearing
- Explicitly formulated as a **constraint** of the heat dispatch
- **Stochastic:** scenarios of wind production, rival participants bids, elec. and heat demand

2) Electricity dispatch

From the PhD thesis work of Christos Ordoudis, available through DTU Orbit/Findit:

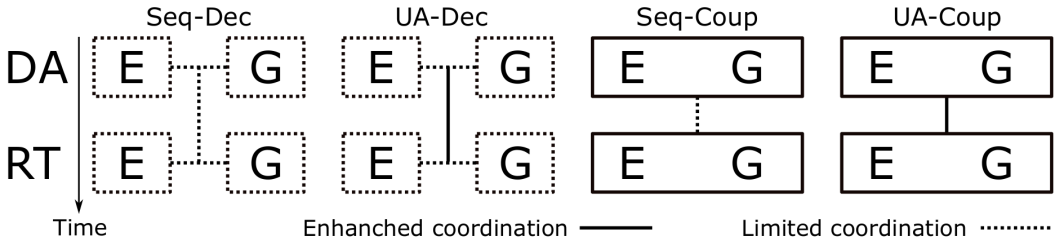


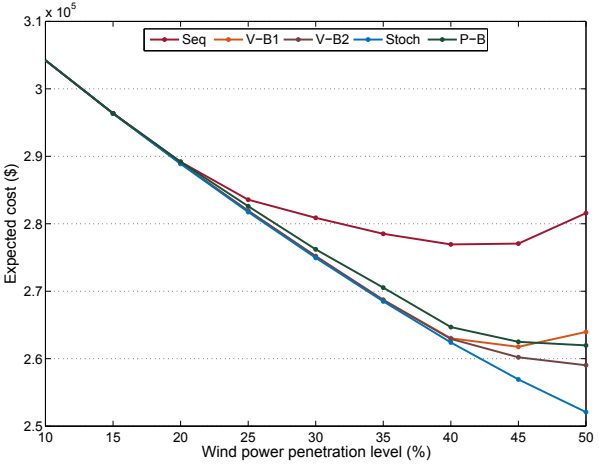
Figure 3.7: Coordination of electricity and natural gas markets in short-term operations (DA: day-ahead stage, RT: real-time stage, E: electricity, G: natural gas, Seq: sequential, UA: uncertainty aware, Dec: decoupled, Coup: coupled).

Besides, we also looked at the possibility that certain agents (virtual bidders and self-schedulers) contribute to that coupling...

Loose coupling of el and gas markets

Important starting statement: *Beware of the gas network modelling* since the potential buffer (offered flexibility) is to be well represented

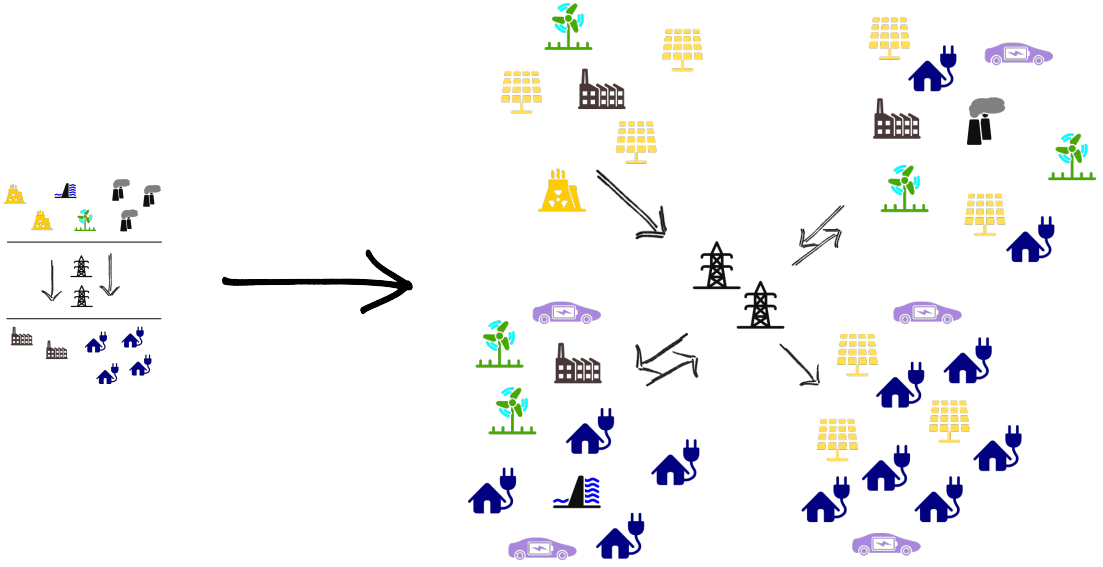
- Market coupling setups *accommodate renewable uncertainty*
- We have proposed and compared:
  - sequential coupling as of today (**Seq.**)
  - complete coupling of gas and el markets (ideal- **Stoch.**)
  - loose coupling through price premiums (with 'fairness' constraints - **P-B**)
  - loose coupling through gas volume availability (**V-B**)



P-B and **V-B** are in practice approaches that "upset" the merit-order at the day ahead stage to optimally place gas units...

2. **Energy communities and peer-to-peer markets**

From a supplier-centric model to a more decentralized setup



Eventually, electricity markets need to adapt to this new decentralized setup(!)

Organization of consumer-centric electricity markets

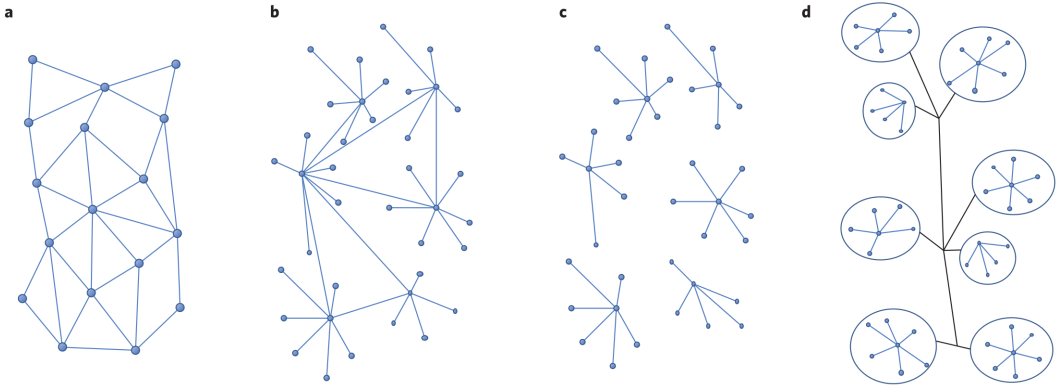


Figure 1 | Structural attributes of three prosumer markets. a, Peer-to-peer model, in which prosumers interconnect directly with each other, buying and selling energy services. **b**,**c**, More structured models involving prosumers connected to microgrids. These entail prosumer-to-interconnected microgrids, in which prosumers provide services to a microgrid that is connected to a larger grid (**b**), or prosumer-to-islanded microgrids, in which prosumers provide services to an independent, standalone microgrid (**c**). **d**, Organized prosumer group model, in which a group of prosumers pools resources or forms a virtual power plant. Dots represent prosuming agents; lines represent a transaction of prosuming service; circles represent an organized group of prosumers.

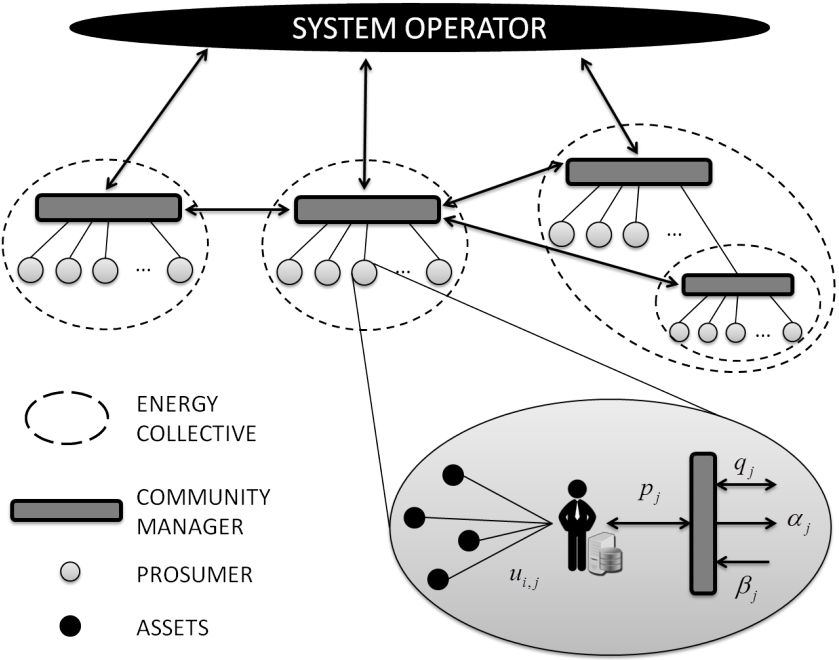
[Reproduced, with authorization, from:
Parag Y, Sovacool BJ. Electricity market design in the prosumer era. *Nature Energy* **1**, art. no. 16032, 2016]

For real in Denmark

[*Svalin* - a boffællesskab in Roskilde - The Energy Collective]

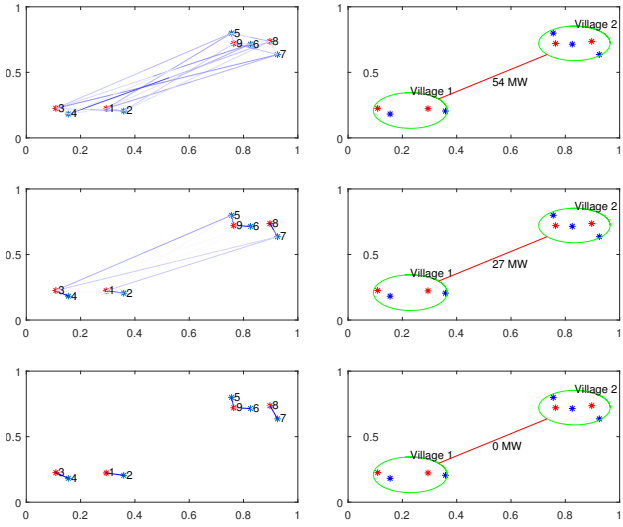
[*Nordhavn in Copenhagen* - generalizing to multi-carrier energy markets (heat and electricity, mainly) - EnergyLab Nordhavn/EMB3Rs]

[Many other experiments, led by academia and industry e.g. Norlys]


SYSTEM OPERATOR
ENERGY COLLECTIVE
COMMUNITY MANAGER
PROSUMER
ASSETS
q_j
p_j
α_j
$u_{i,j}$
β_j

Peer-to-peer markets allow agents to express preferences!

- Let us consider distance between agents as a criterion (local production, local consumption!), for simplicity with a fixed unitary cost c_n^g

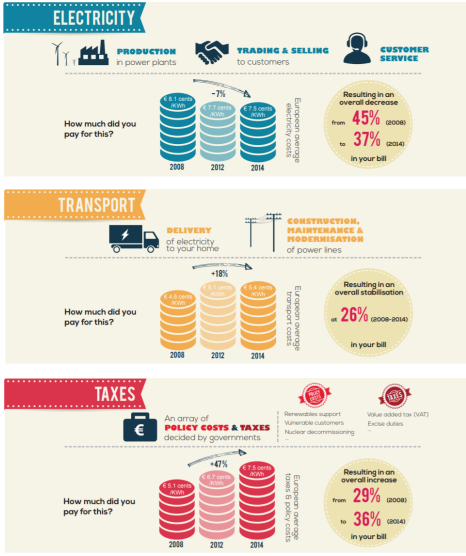


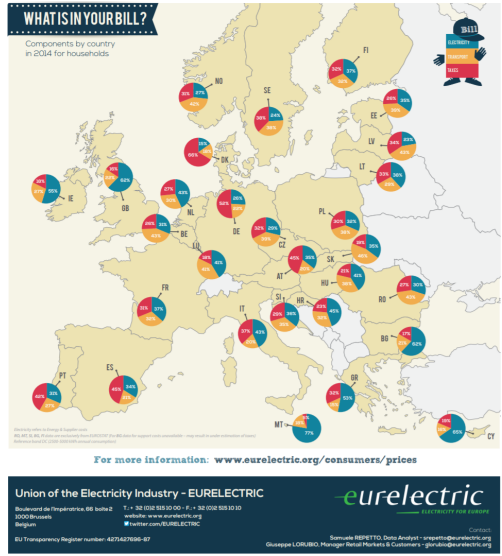
- $c_n^g = 0$
- $c_n^g = \frac{1}{2}$
- $c_n^g = \frac{3}{2}$

By tweeking this parameter for local energy perferences, eventually energy exchanges are impatced.

Play yourself at `https://p2psystems.shinyapps.io/ShinyApp_Project`

What about network charges?

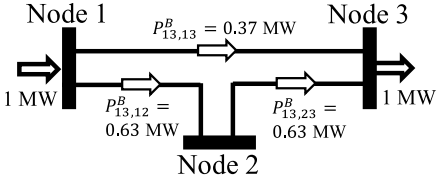


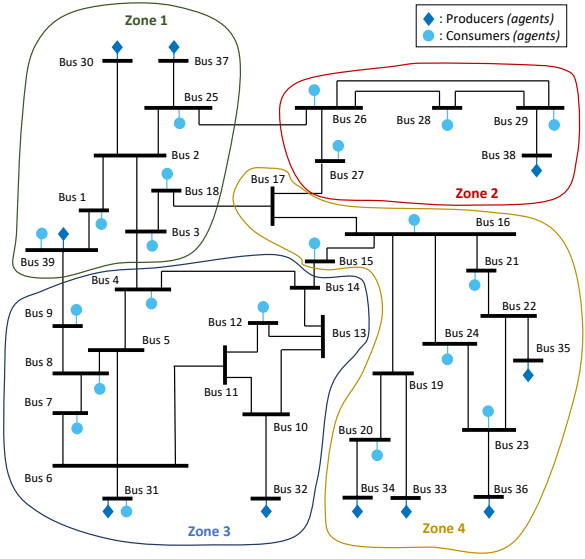


- In Denmark, 85% of the electricity costs relates to grid costs and taxes(!)
- Redesigning and modulating those will certainly be more efficient than price-based demand-response based on energy price only

- instead of preferences, let us rethink the *cost structure*
- network charges may be a function of the network needs of each and every trade
- some form of *electric distance* can be used as a proxy (others may also be relevant)

- Ex: fully socialized (as of today in most markets)
- Ex: zonal approach (right)
- Ex: Thevenin and PTDF-based electric distance (below)





(IEEE 39-bus New England system, also used as a case-study insome of our work)

Take-away messages

- There are many relevant ways to think of the coupling of markets for electricity, gas and heat
- Flexibility and uncertainty components need to be better modelled and accommodated in those markets
- Increased decentralization of our energy system may require rethinking electricity markets based on energy communities and peer-to-peer concepts
- Those bring interesting concepts and incentives, but also technical and regulatory challenges...

Thanks for your attention!