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A three-step methodology to improve domestic energy efficiency

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A three-step methodology to improve domestic energy efficiency – Albert Molderink

1. **Why** do we want to monitor and manage energy streams?
2. **What** do we need to do to achieve this?
3. **How** can we achieve this?
4. **Results** of our methodology
5. **Conclusions**

Outline

Why

What

How

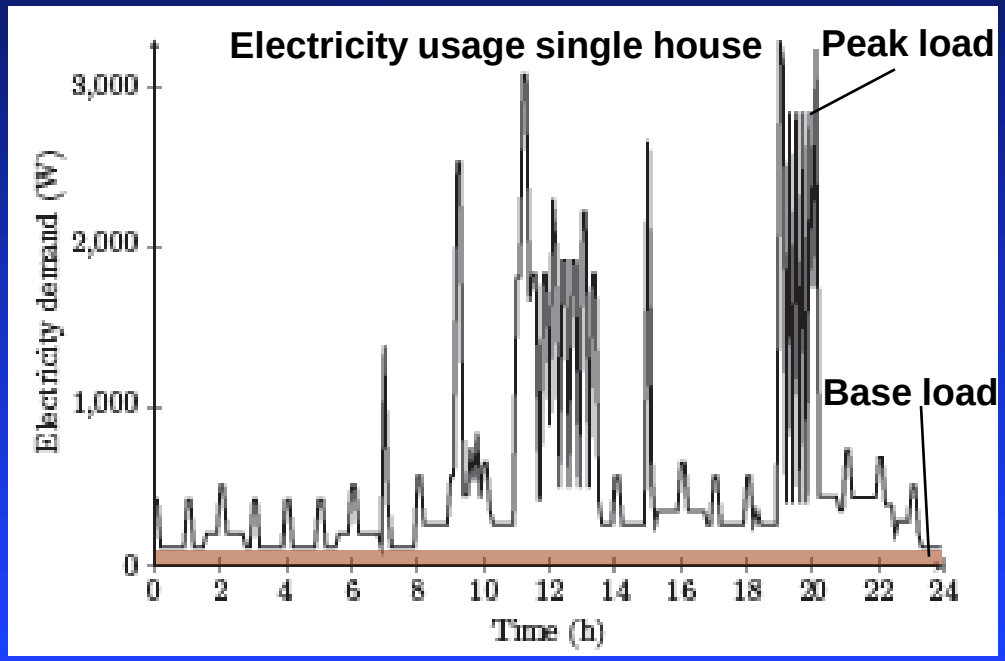
Results

Conclusions

1. **Why** do we want to monitor and manage energy streams?

Increase energy efficiency – focus on electricity

- Power plants: efficiency 30% – 50% (60% for a CHP plant)
- Balance: always as much production as consumption



Increase energy efficiency – challenges for Smart Grid

Why

What

How

Results

Conclusions

- Less predictable pattern
- More fluctuating pattern

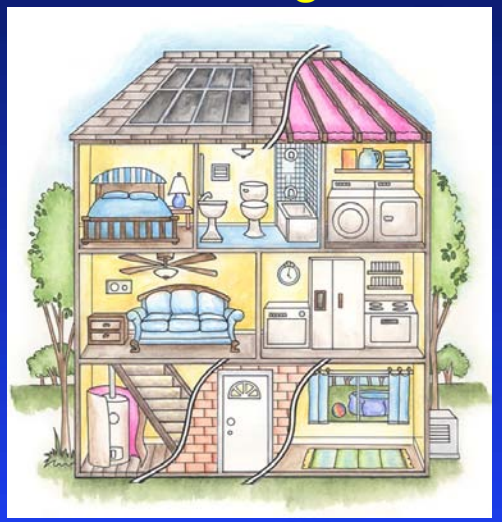
Increase energy efficiency – domestic opportunities

- **Why**
- What
- How
- Results
- Conclusions

Energy storage

Distributed generation

Demand-side Load Management



Outline

Why

What

How

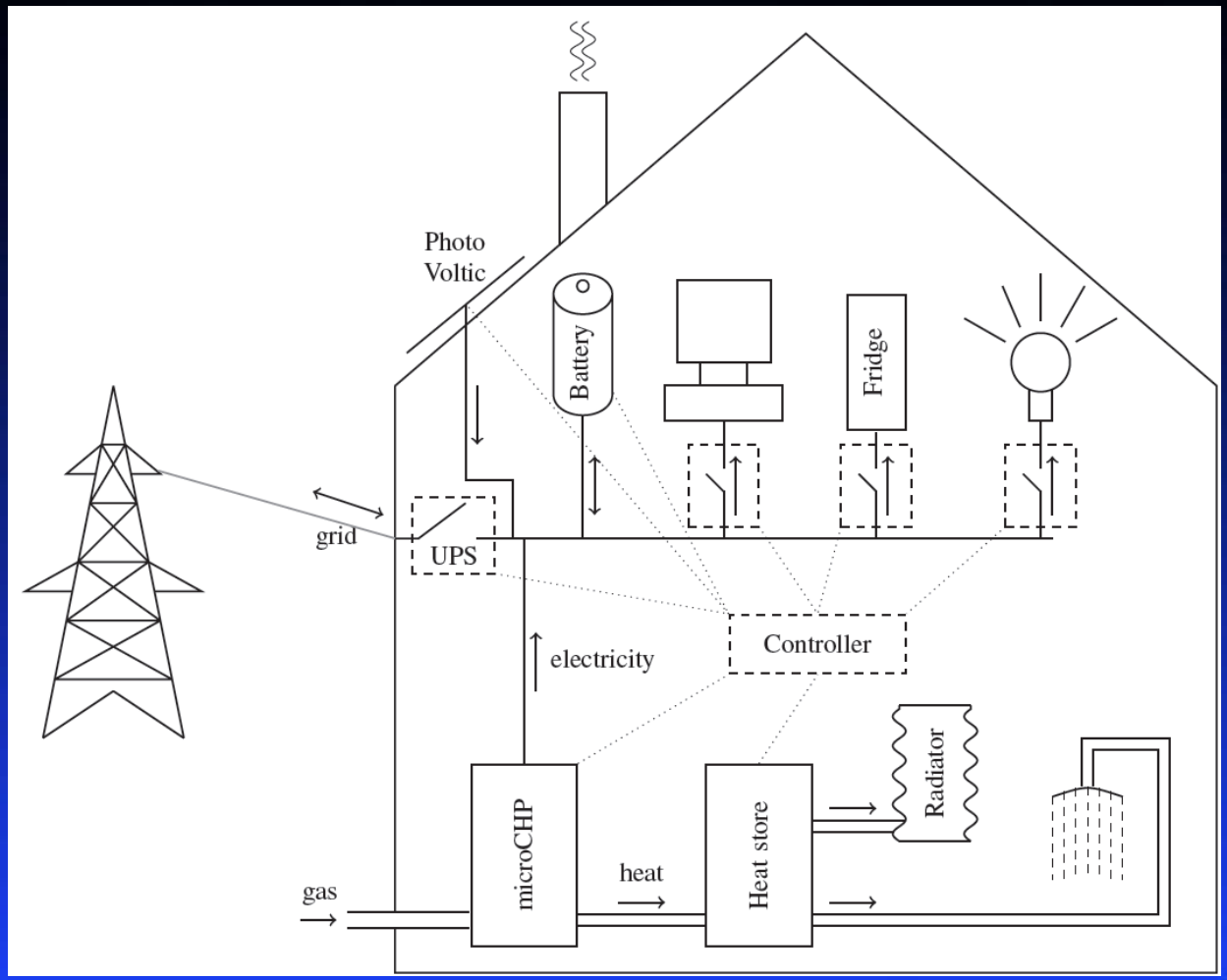
Results

Conclusions

2. **What** do we need to do to achieve this?

Increase energy efficiency – realtime control

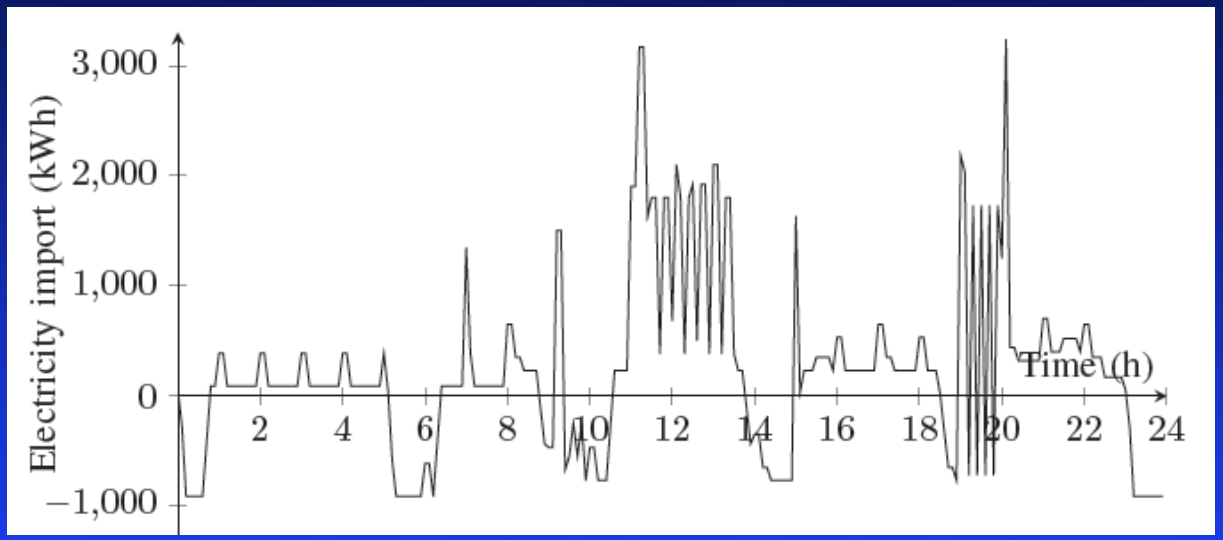
- Why
- **What**
- How
- Results
- Conclusions



Increase energy efficiency – prediction and planning

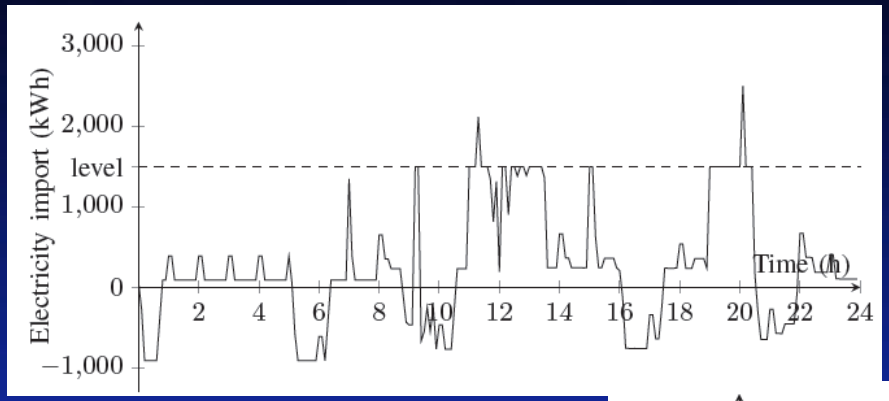
- Why
- **What**
- How
- Results
- Conclusions

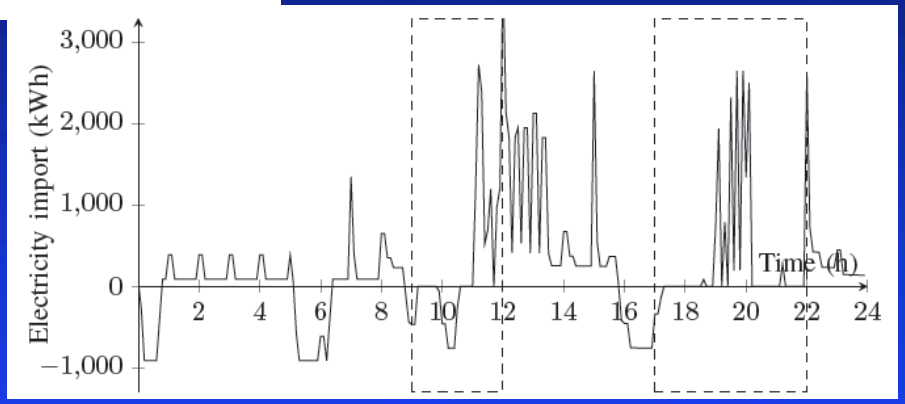
- Electricity import of a house using a microCHP



Increase energy efficiency – prediction and planning

- Using a 1kWh battery





Prediction and planning required!!

Increase energy efficiency – together!

Why

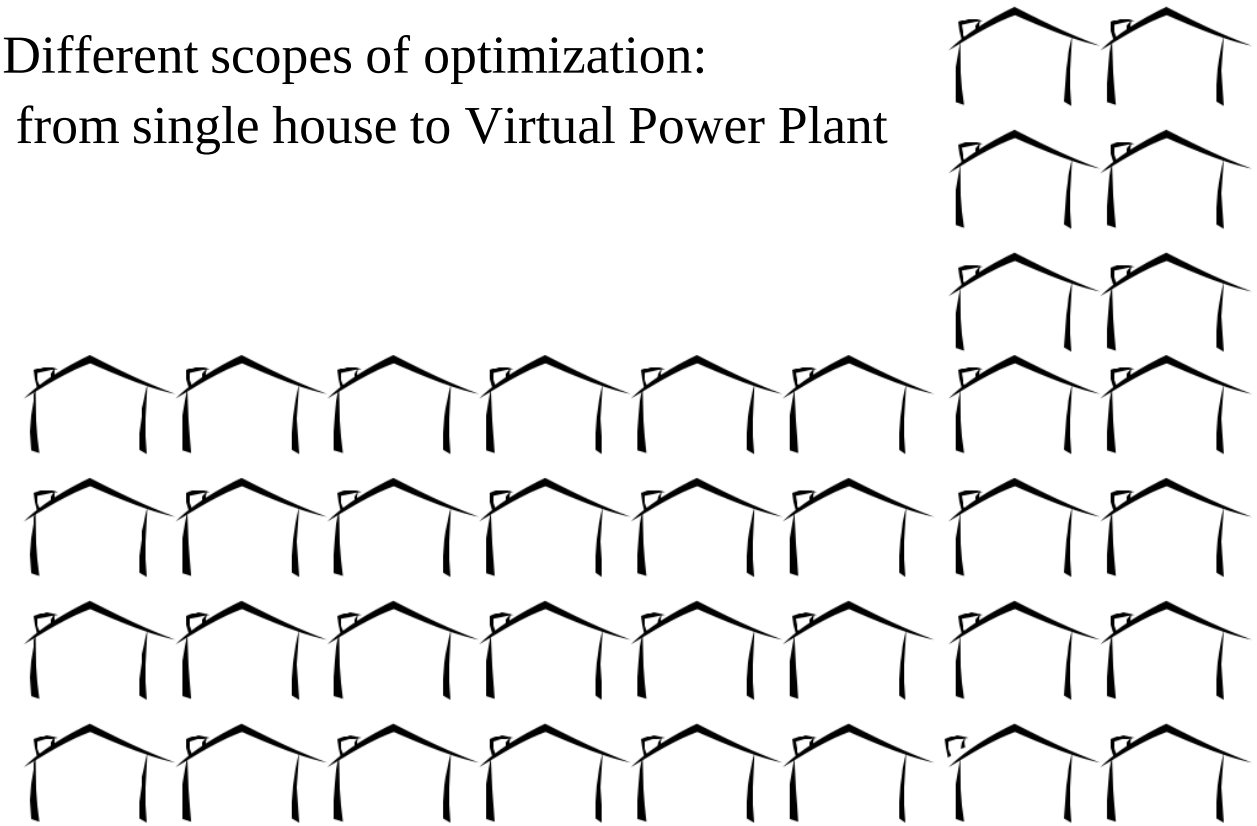
What

How

Results

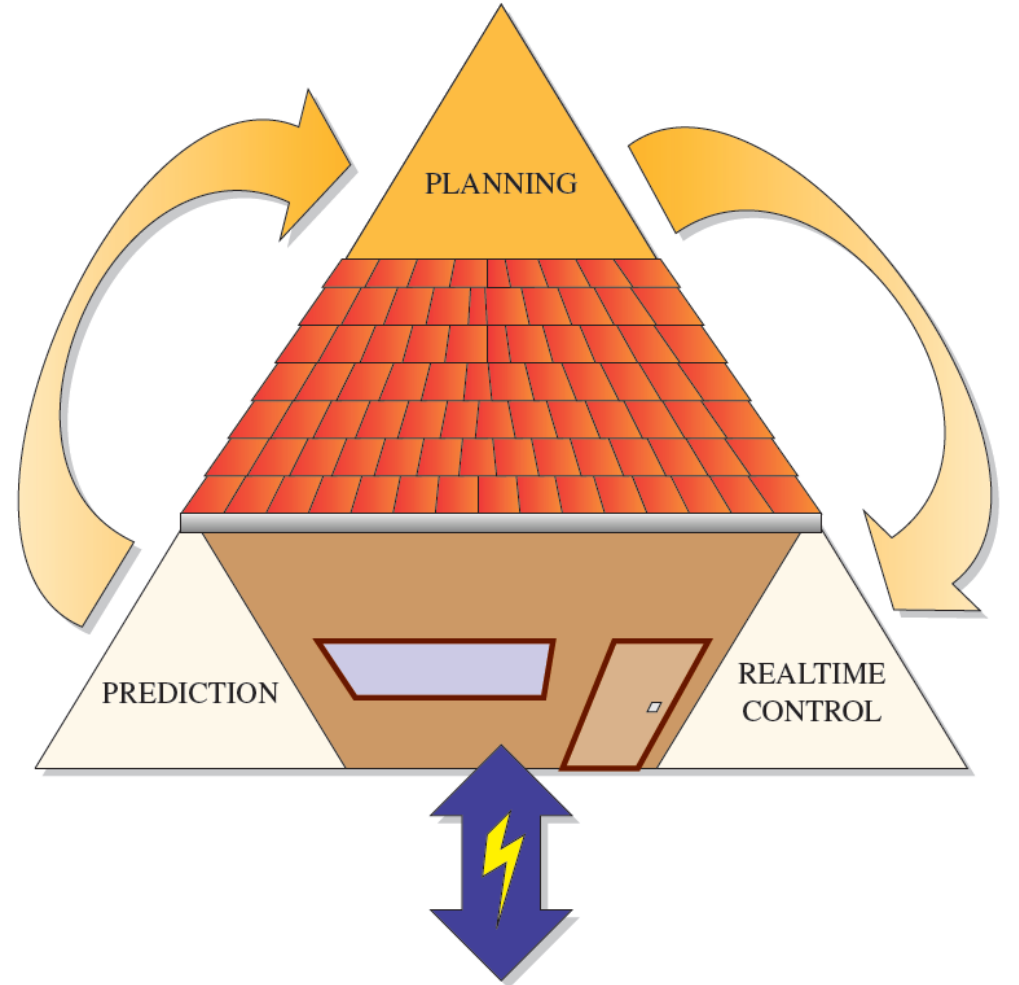
Conclusions

Different scopes of optimization:
from single house to Virtual Power Plant



Global optimizations – 3 step methodology

- Why
- **What**
- How
- Results
- Conclusions



Global optimizations – challenges

- Flatten production pattern power plants by optimizing domestic electricity import/export

Why

What

How

Results

Conclusions

- Up to one day ahead (electricity markets and predictions) – planning combined with realtime control
- Generic
  - Covering multiple scenario's, objectives and technologies
- Scalability
- Guaranteed comfort level for residents
- Local and global optimization
- Both heat and electricity
- …

Outline

Why

What

How

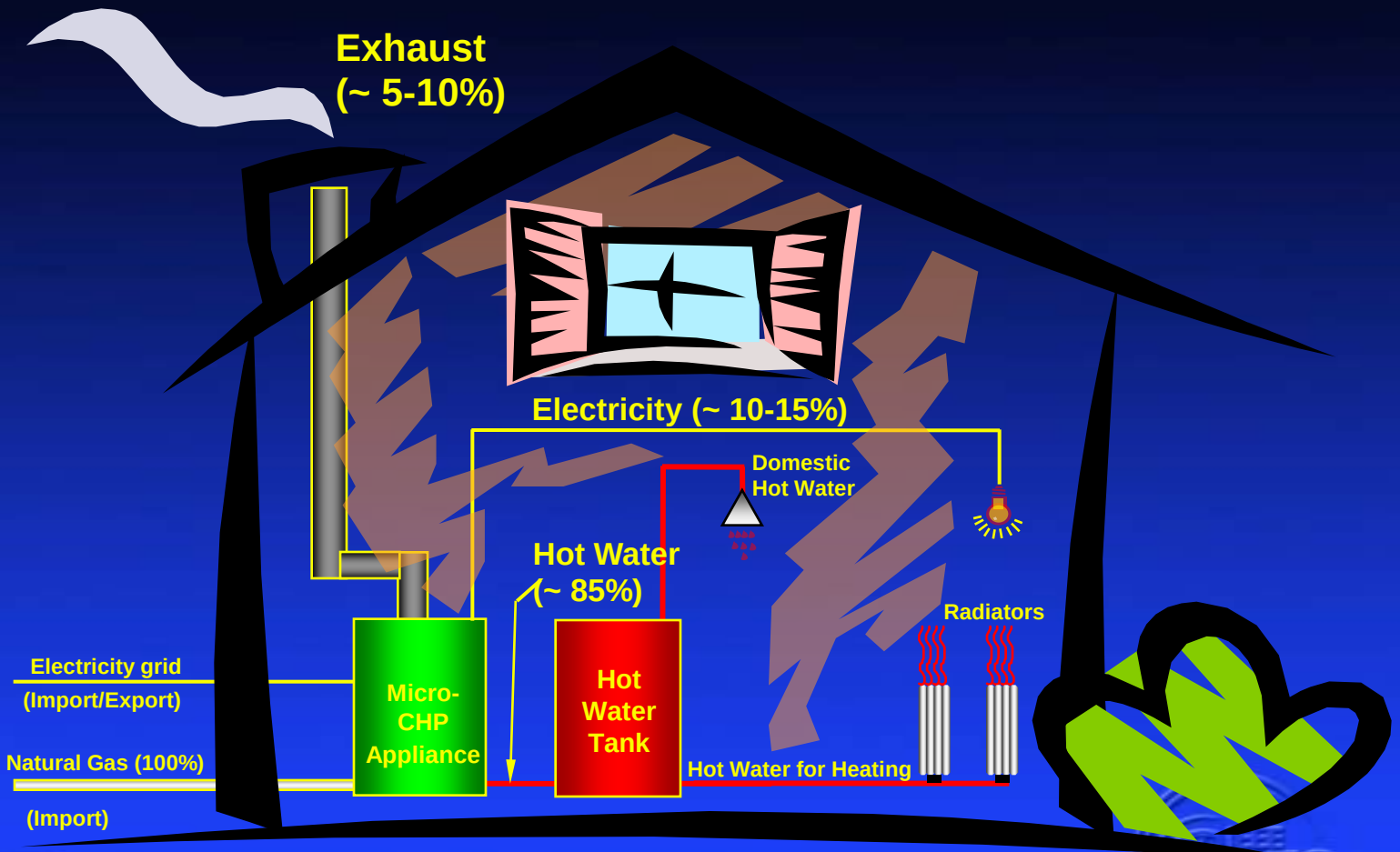
Results

Conclusions

3. **How** can we achieve this?

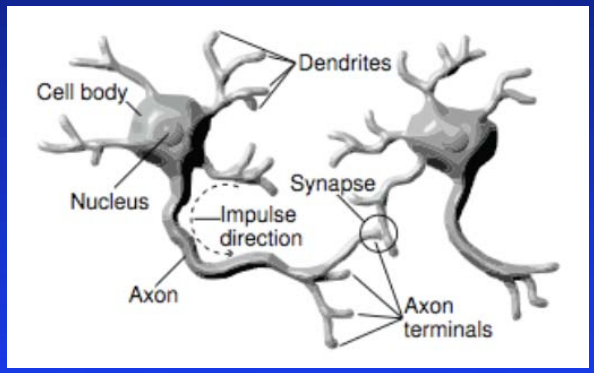
Global optimizations – use case

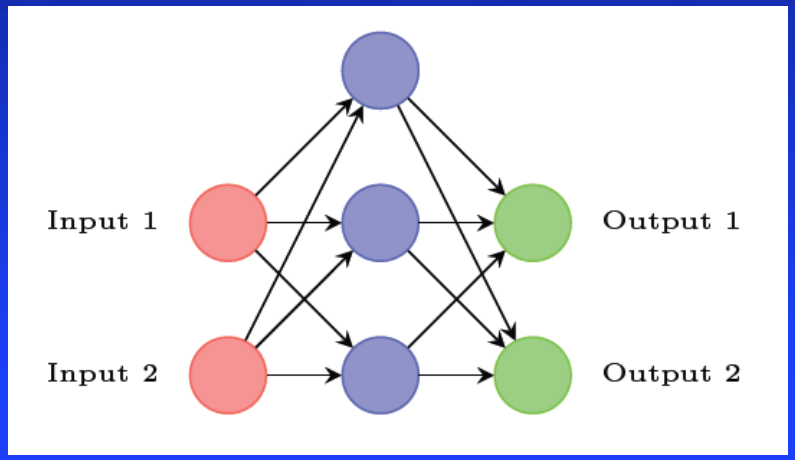
- Why
- What
- **How**
- Results
- Conclusions



Global optimizations – prediction

- Determine the scheduling freedom
  - Energy demand and production prediction
  - For every individual house
  - In every individual house





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Global optimizations – prediction

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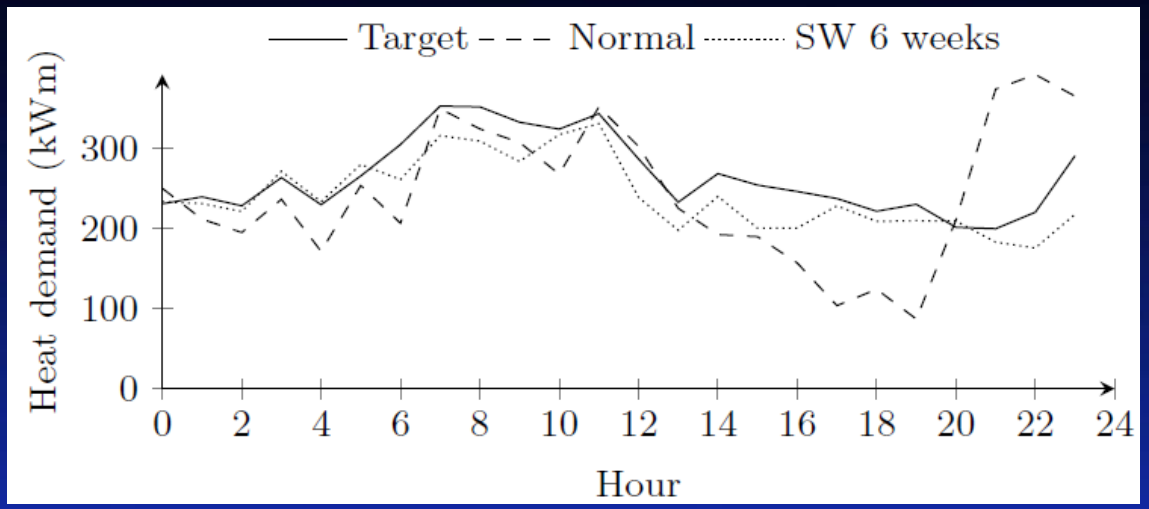
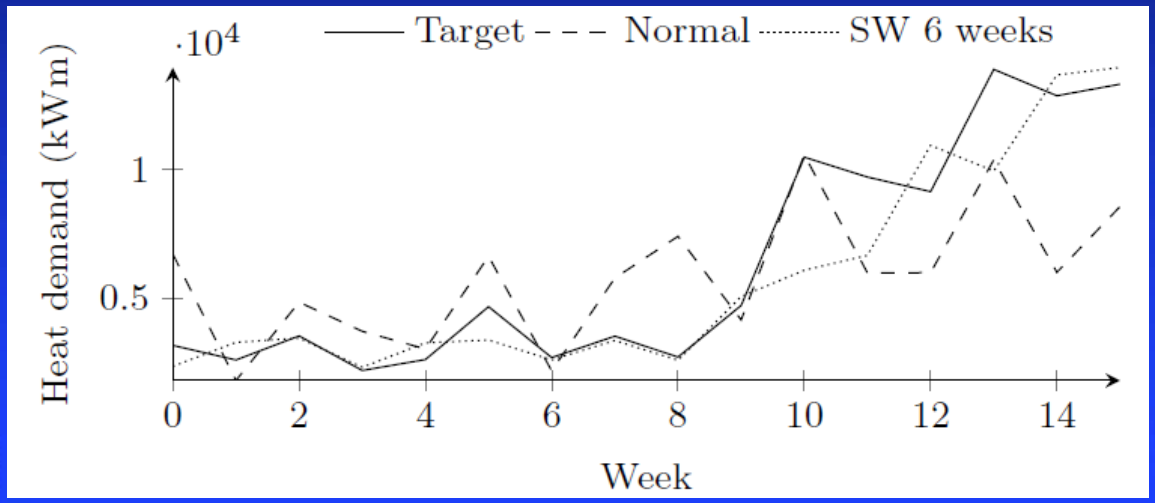
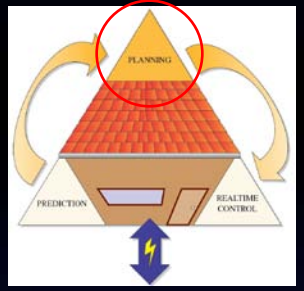




Global optimizations – planning



- Harvest and aggregate information hierarchically
  - First versions based on ILP
  - NP-complete for only microCHP installations – heuristics, iterative ILPs, etc.

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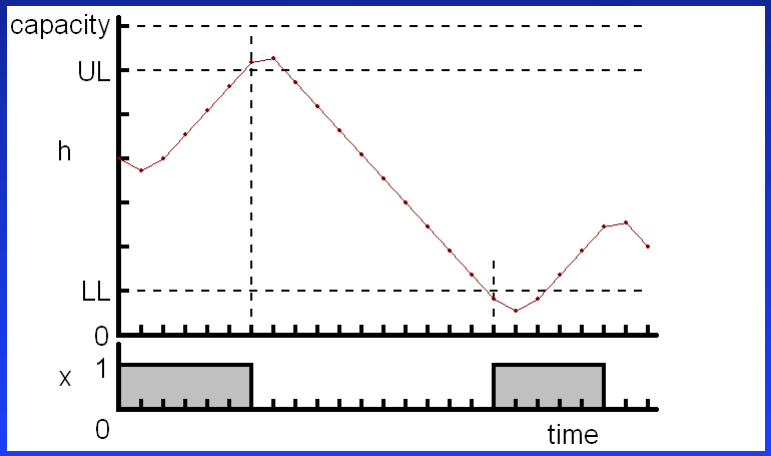
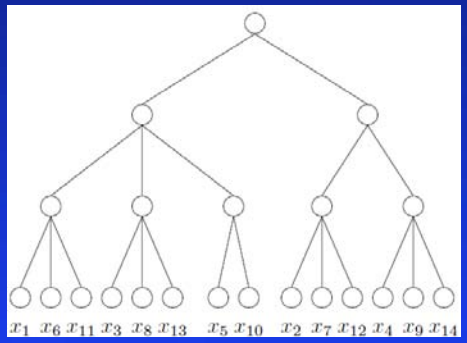
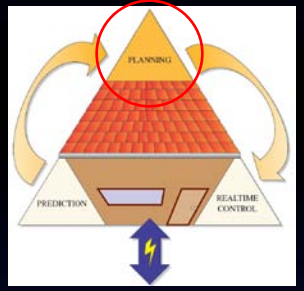




Global optimizations – planning



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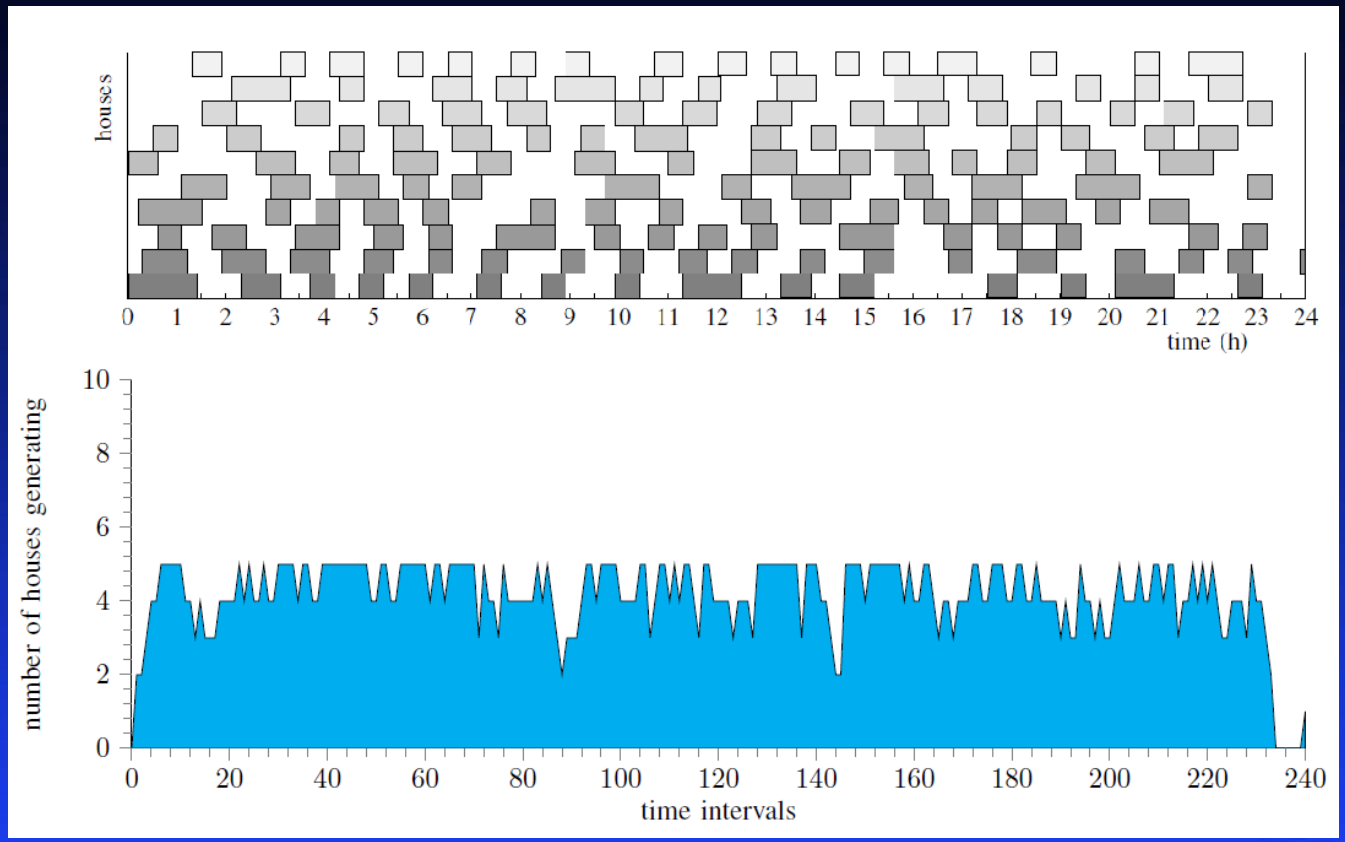

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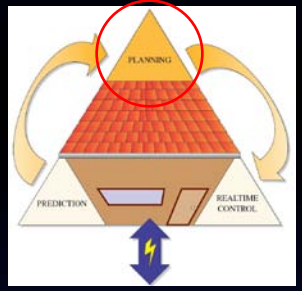

- Why
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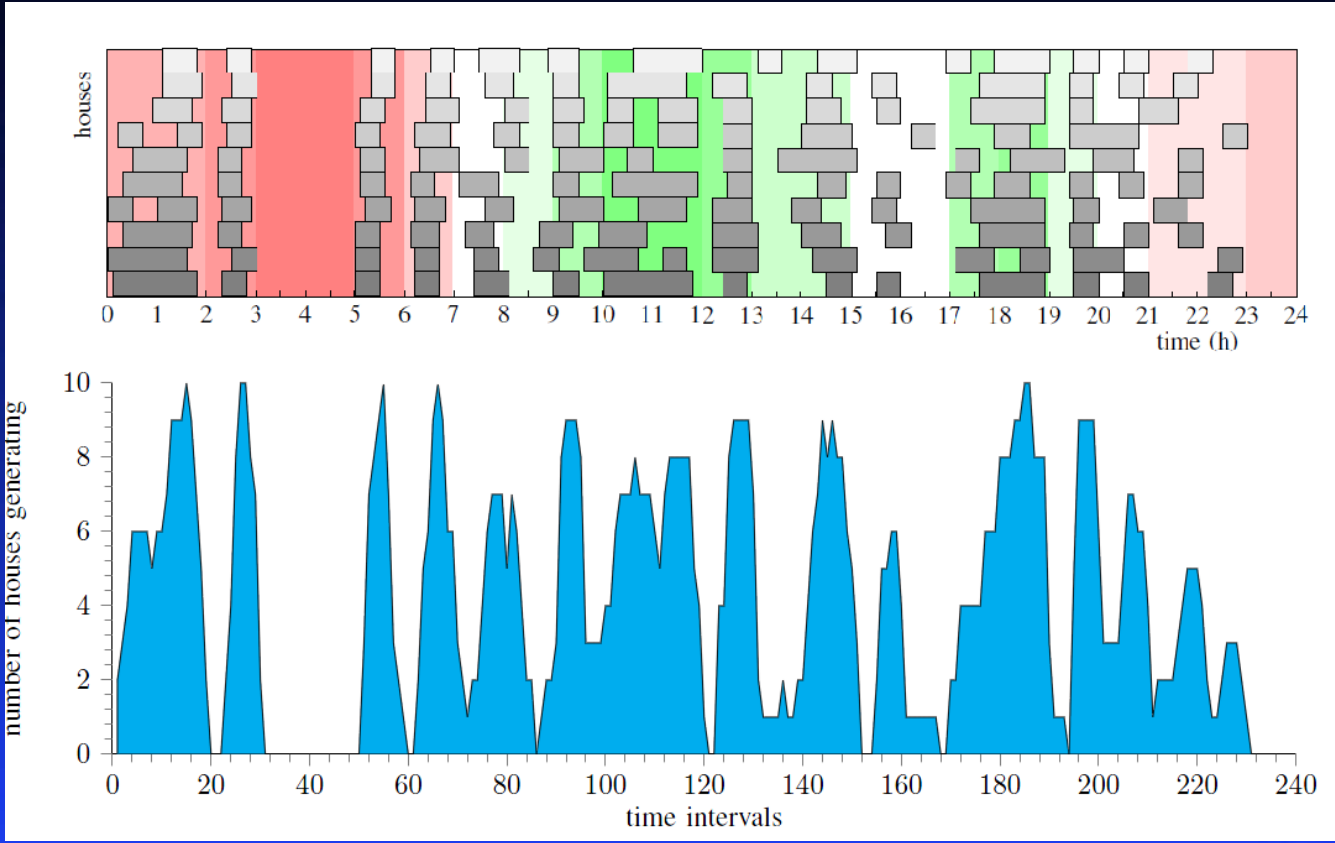
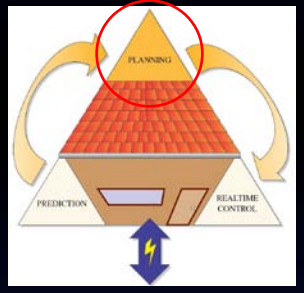


Global optimizations – planning



- Why
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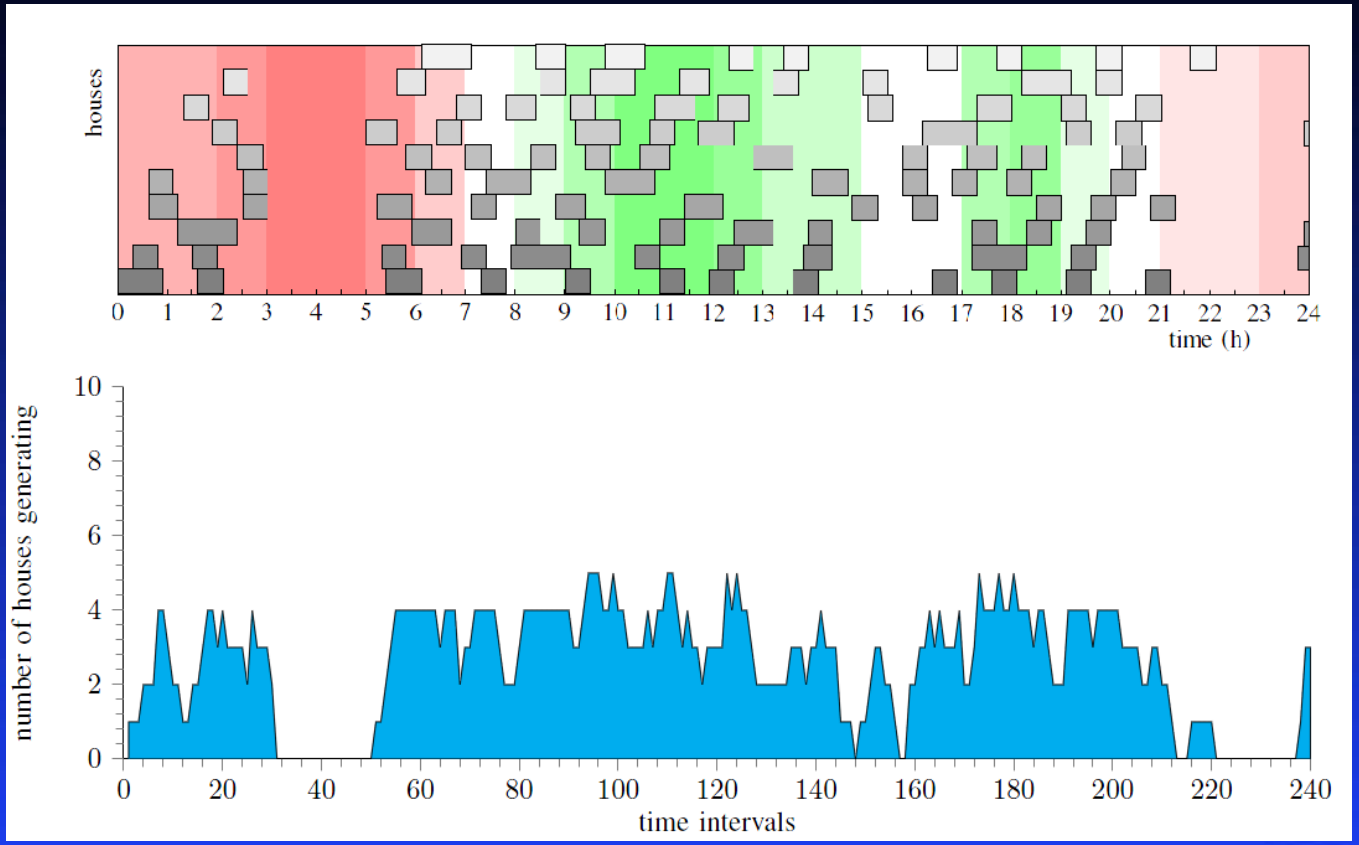
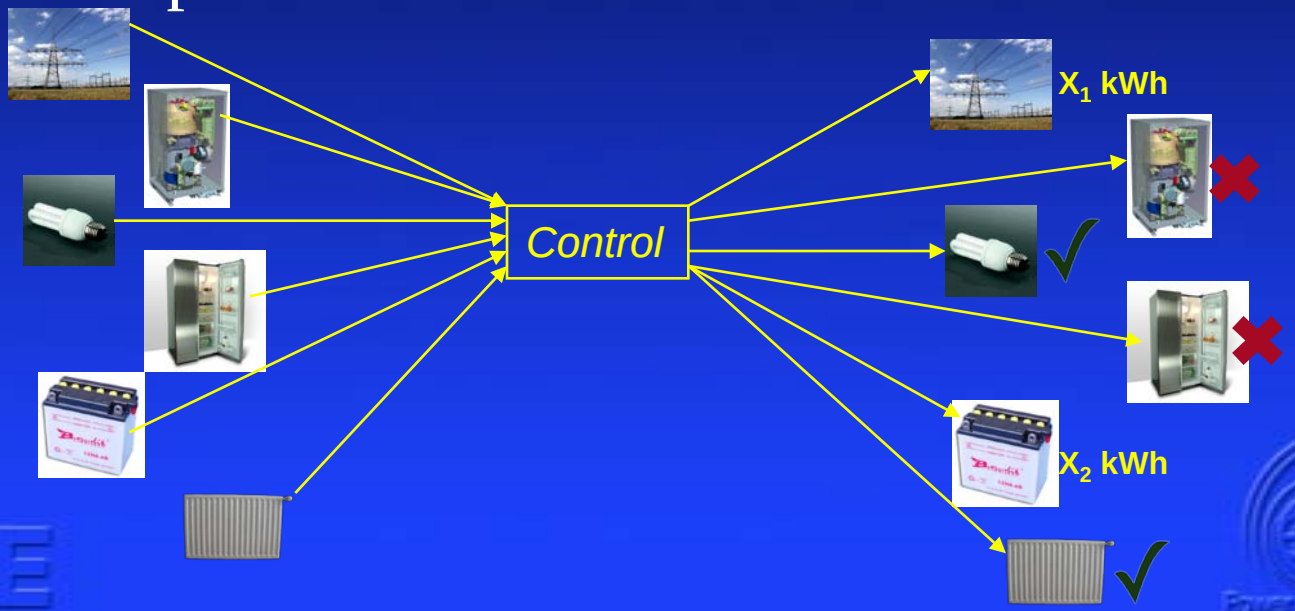


Global optimizations - control

- Realtime control of individual house
  - Global planning as input – pricing signals
  - Working around prediction errors
  - Guarantee the comfort given the electricity price



Global optimizations - control

- Matching of demand
  - 1) Import from the grid, 2) Supply by generator, 3) Supply by energy buffer, 4) Switch off appliance
- Find the best solution with a simple ILP that is solved every time a decision is needed

$$
\begin{aligned}
min \quad & \sum_{i,j} A_{ij} \times x_{ij} + c_{ij} \times B_{ij} \\
s.t. \quad & x_i = \sum_j x_{ij} \; \forall i \in Dev \\
& demand_{th} = \sum_i H_i \times x_i \\
& demand_e = \sum_i E_i \times x_i \\
& \sum_j c_{ij} = 1 \; \forall i \in Dev \\
& c_{ij} \times F_{ij} \leq x_{ij} \leq c_{ij} \times T_{ij} \; \forall i \in Dev, j \in S_i
\end{aligned}
$$

Global optimizations - control

- Every matching has a certain cost
- Cost function per device/grid import: discontinuous piecewise linear function (Ax + B)
- ILP finds the solution with the lowest costs

Why

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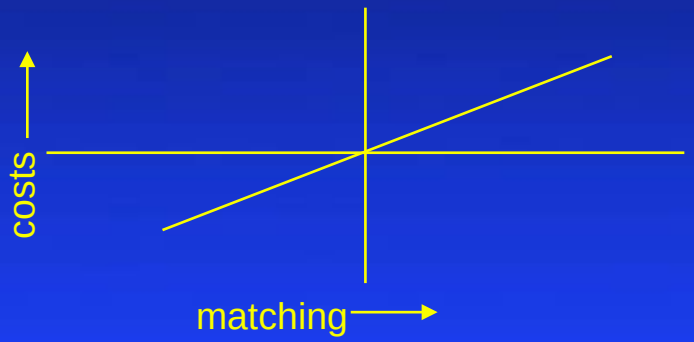
Example cost function buffer



Grid import costs: Peak shaving

Outline

Why

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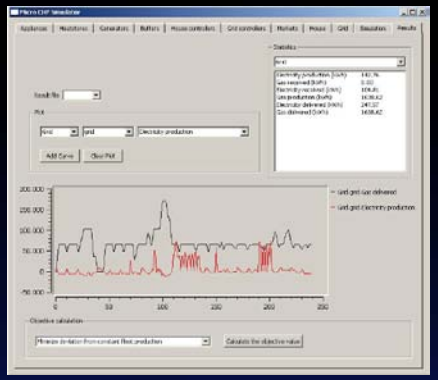
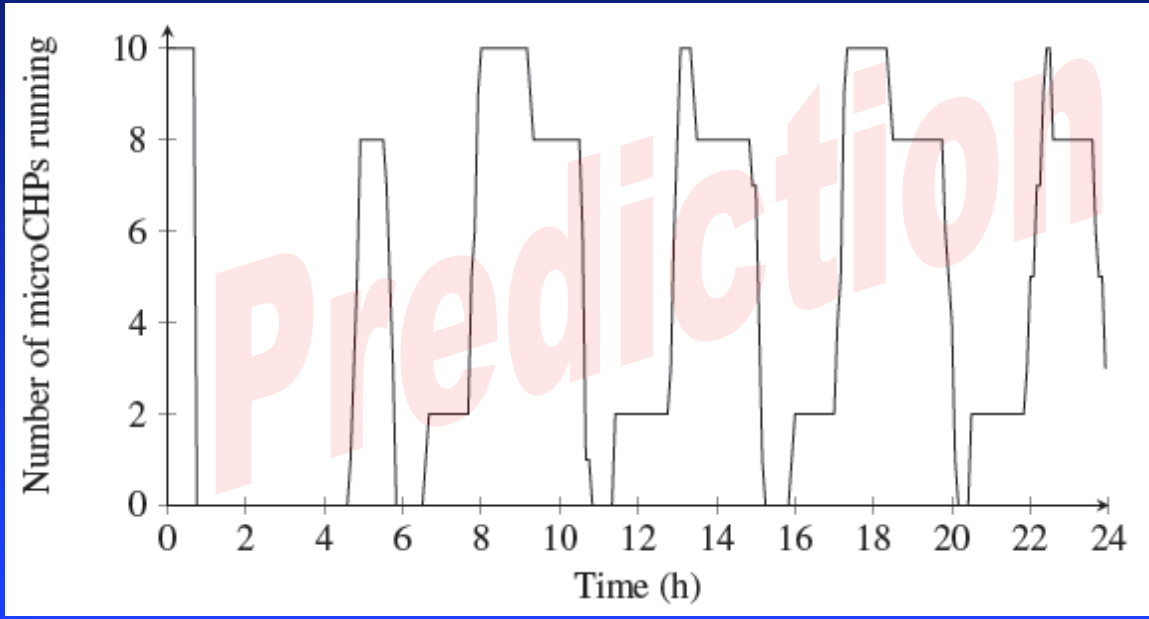
4. **Results** of our methodology

Results



- Simulation of 10 identical houses (microgrid scope), same heat demand
- Very difficult to schedule



Results

- Why
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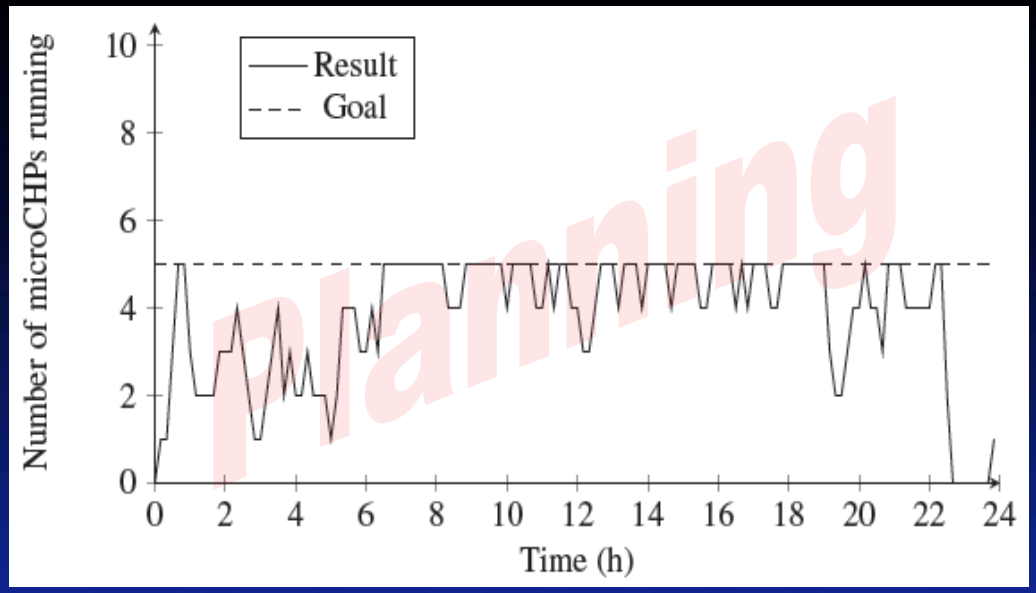
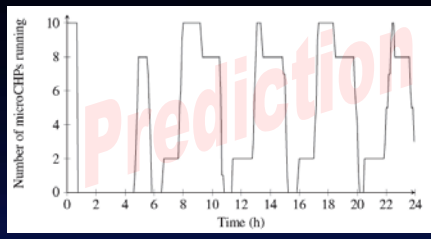
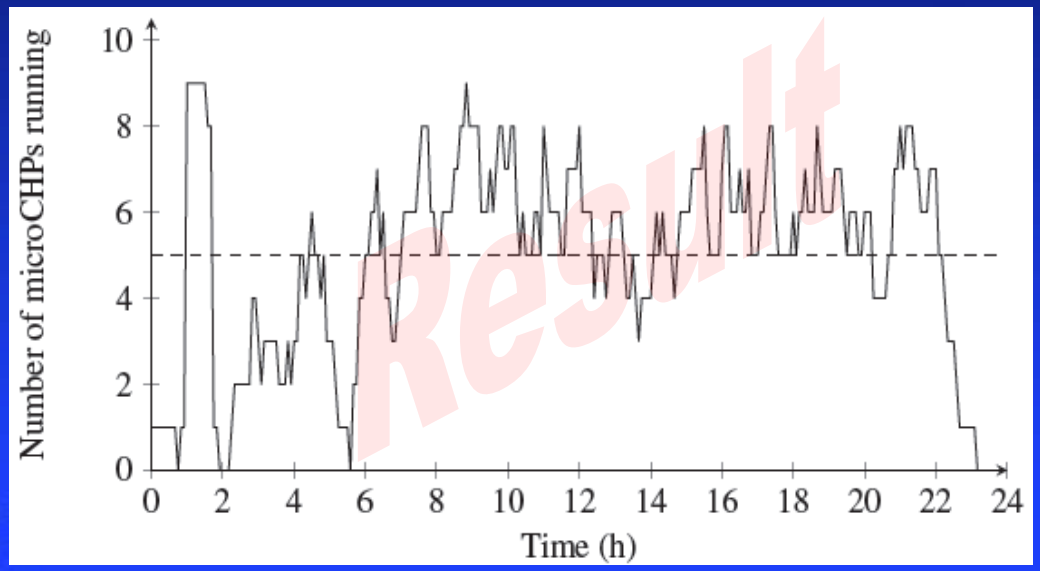


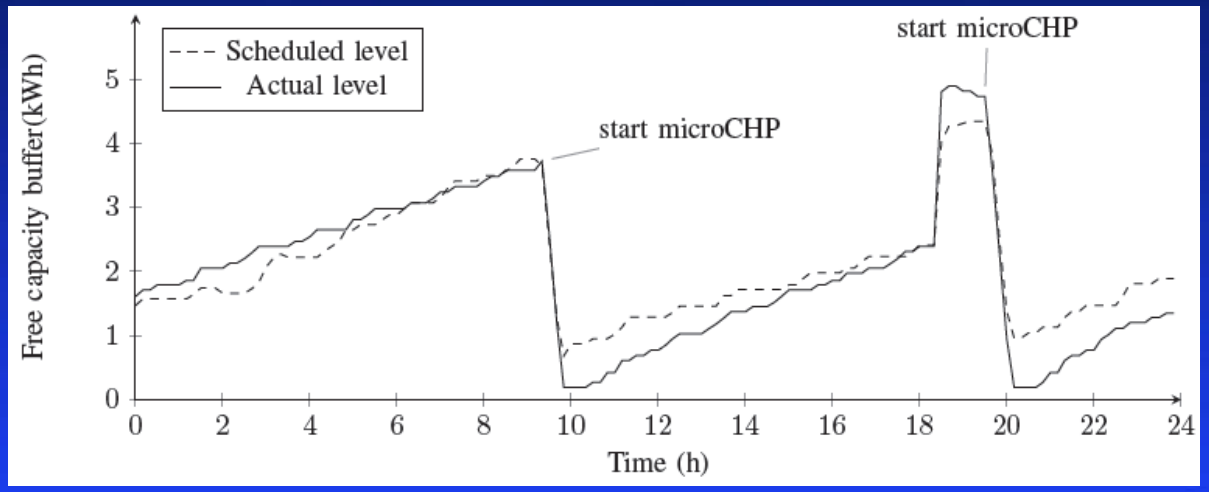




50% reduction of peak-production!

Results

- Prototype implementation
- Single house scope
- Fixed heat demand



Results

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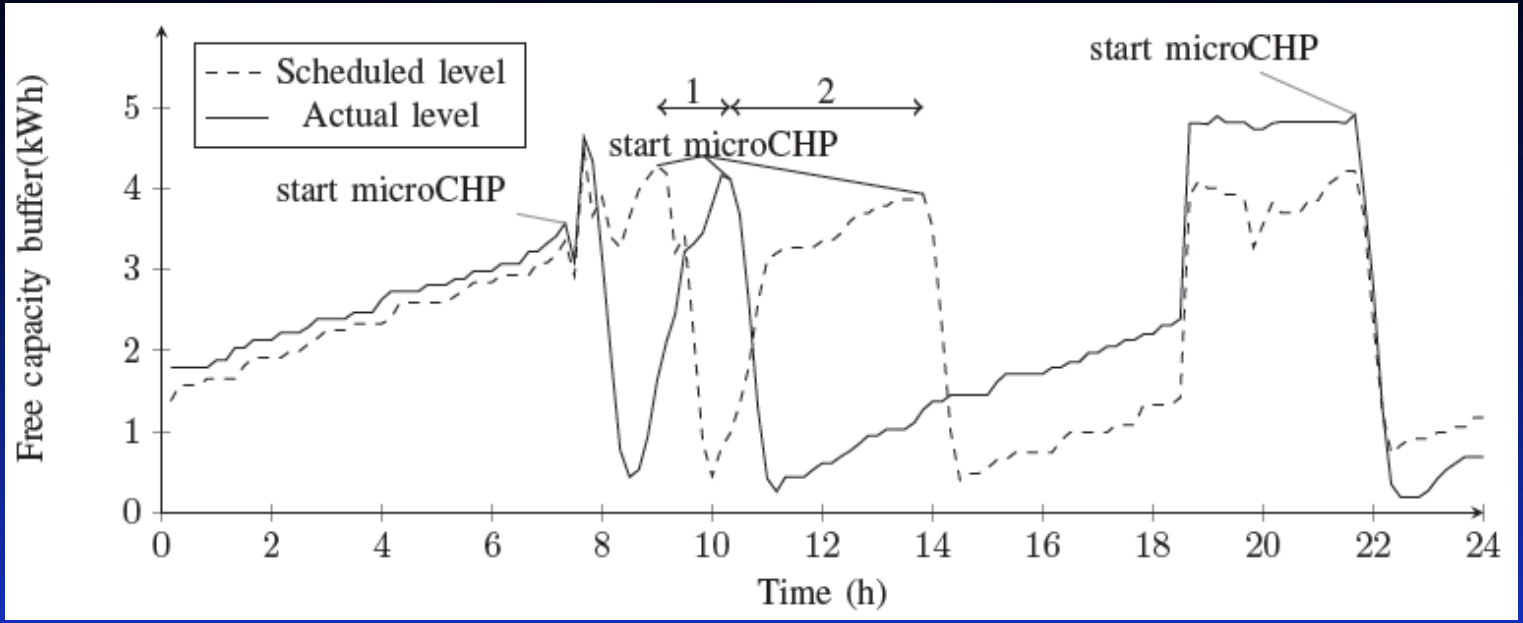

Good prediction important!
(Realtime) Rescheduling required!

Conclusion

- 3-step methodology can exploit optimization potential
  - Increase efficiency
- Possible commercial applications
  - Virtual Power Plant
  - Network stability
  - Lower required maximal capacity power plants and grid

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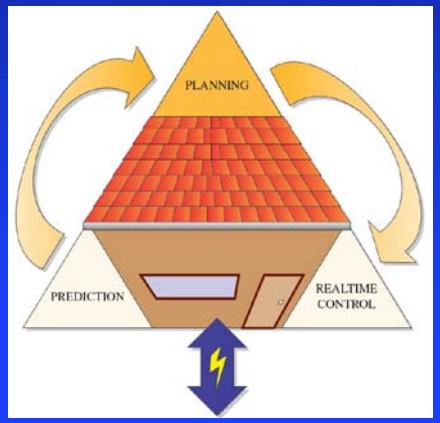

Questions?

- Thank you for your attention
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