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A three-step methodology to improve domestic energy efficiency

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

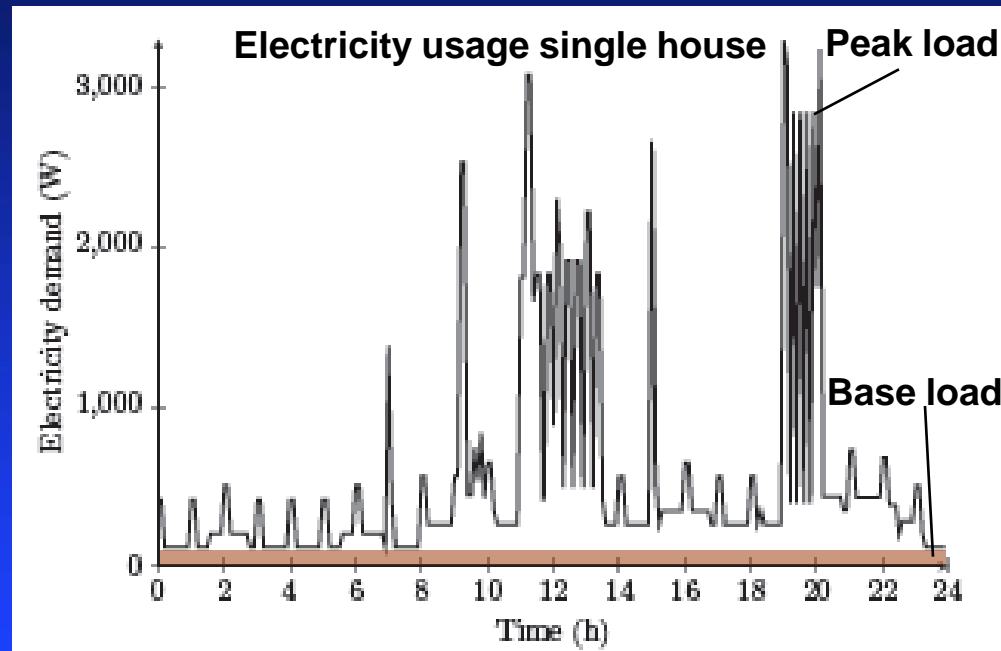
Why

What

How

Results

Conclusions



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

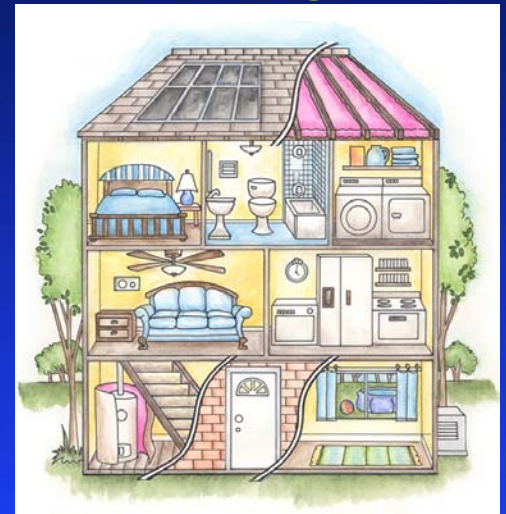


Energy storage

Demand-side
Load Management



Distributed generation



Outline

Why

What

How

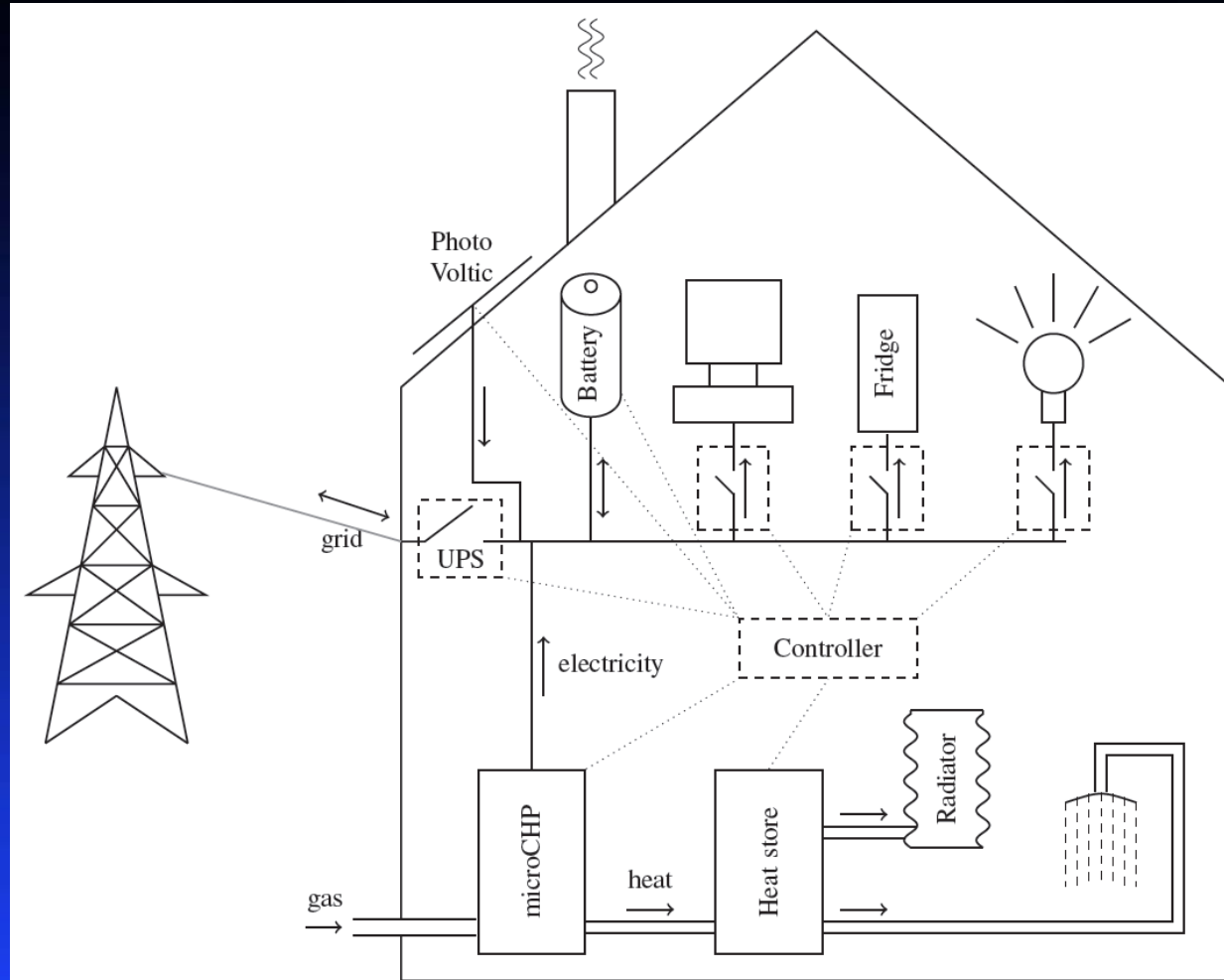
Results

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

- Electricity import of a house using a microCHP

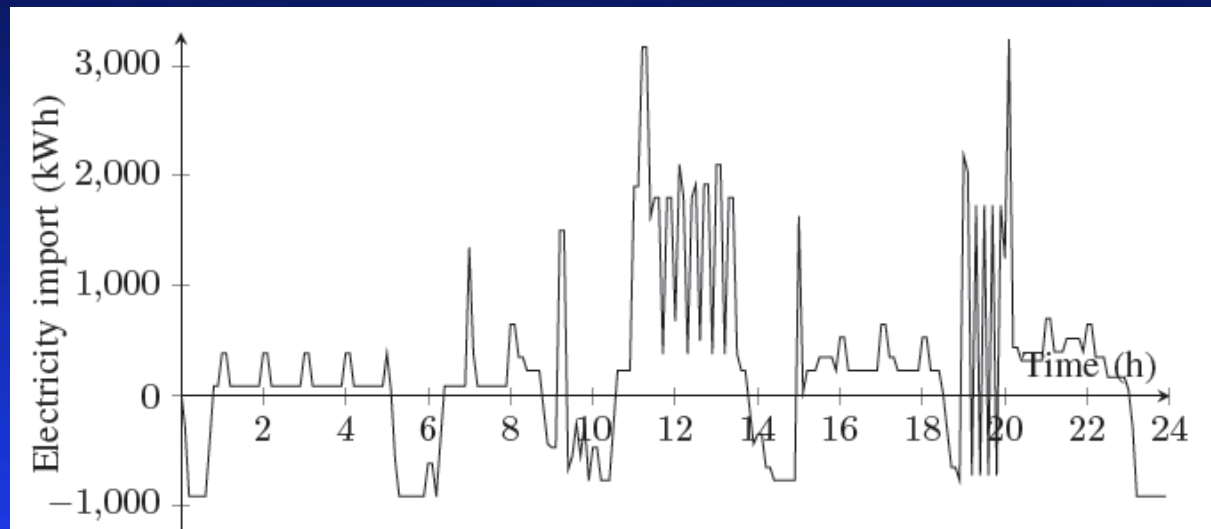
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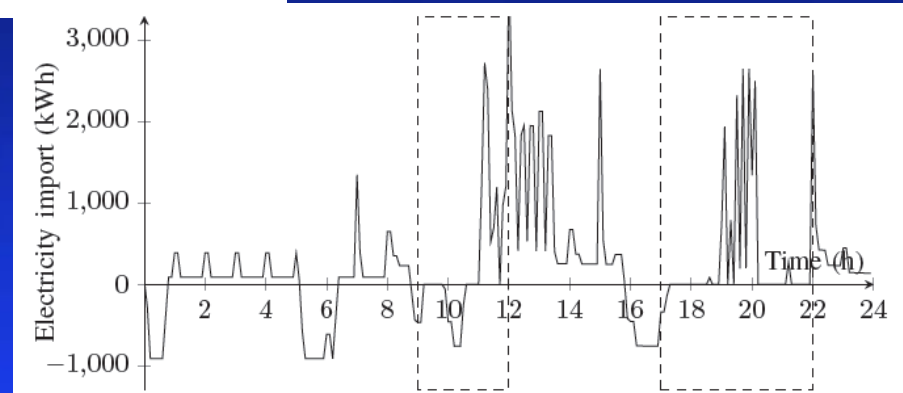
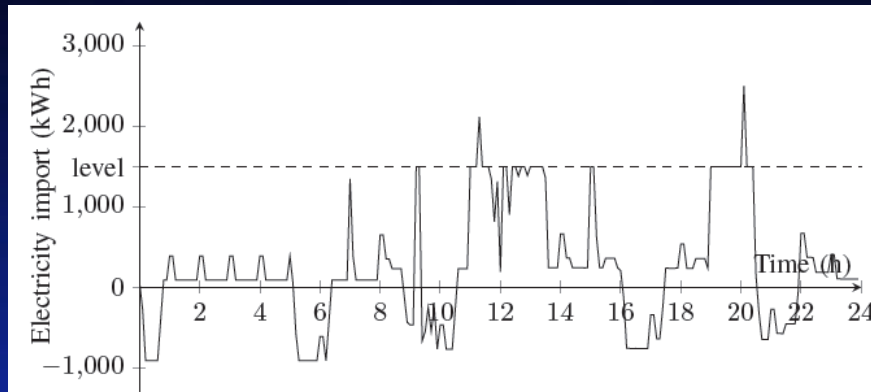
Results

Conclusions



Increase energy efficiency – prediction and planning

- Using a 1kWh battery



**Prediction and
planning required!!**

Why

What

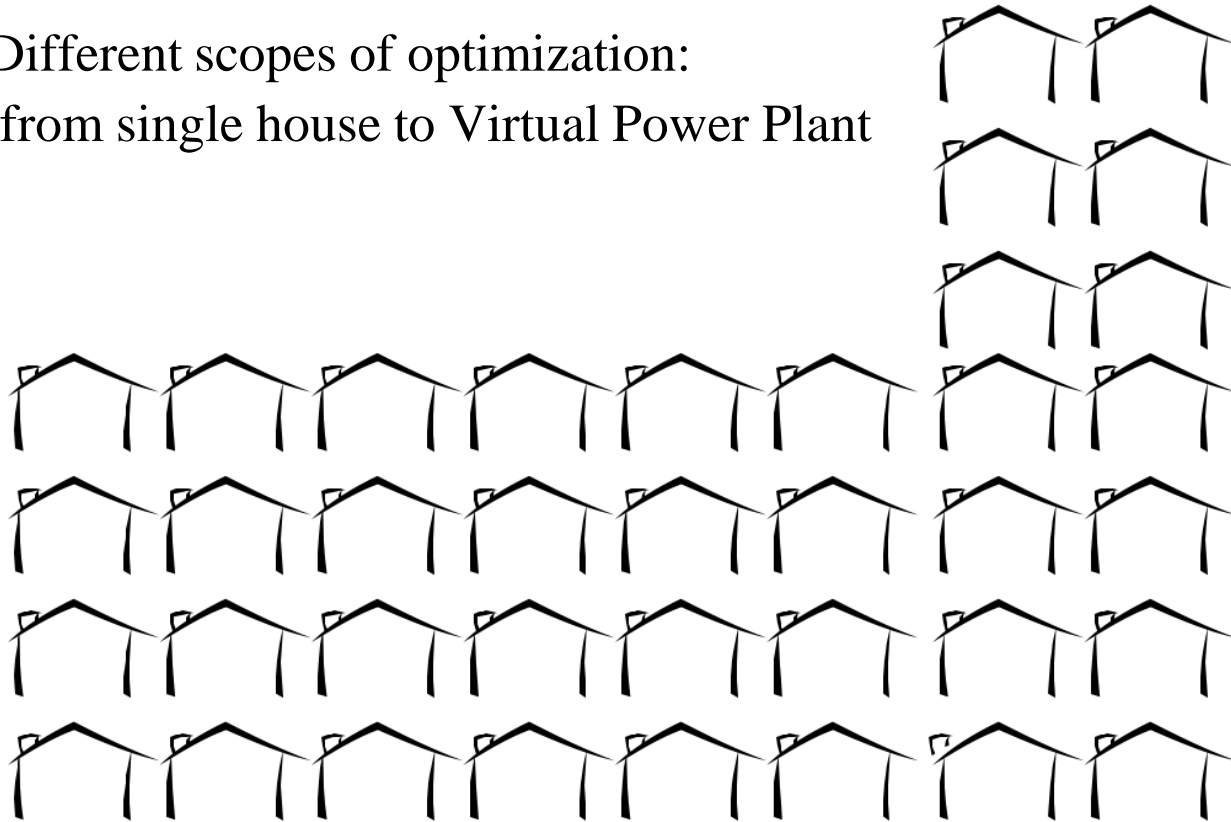
How

Results

Conclusions

Increase energy efficiency – together!

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



Why

What

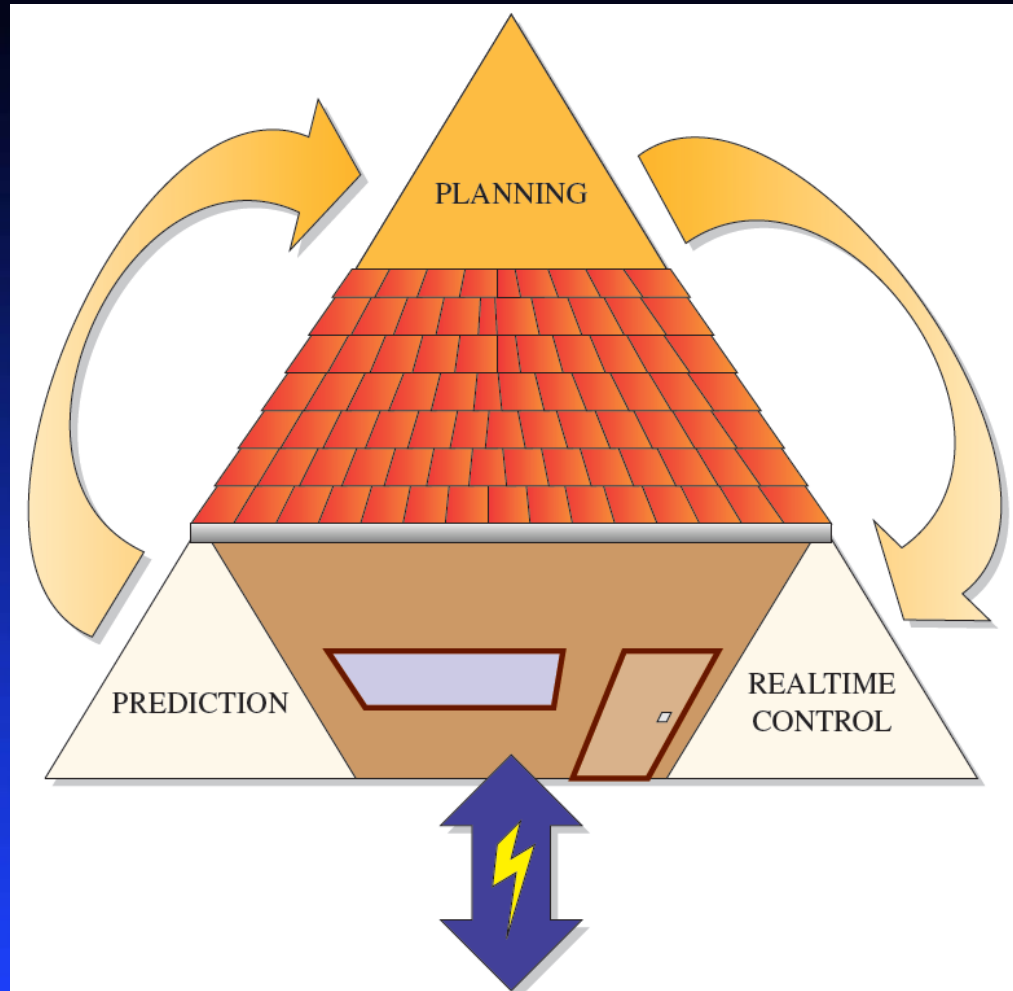
How

Results

Conclusions

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

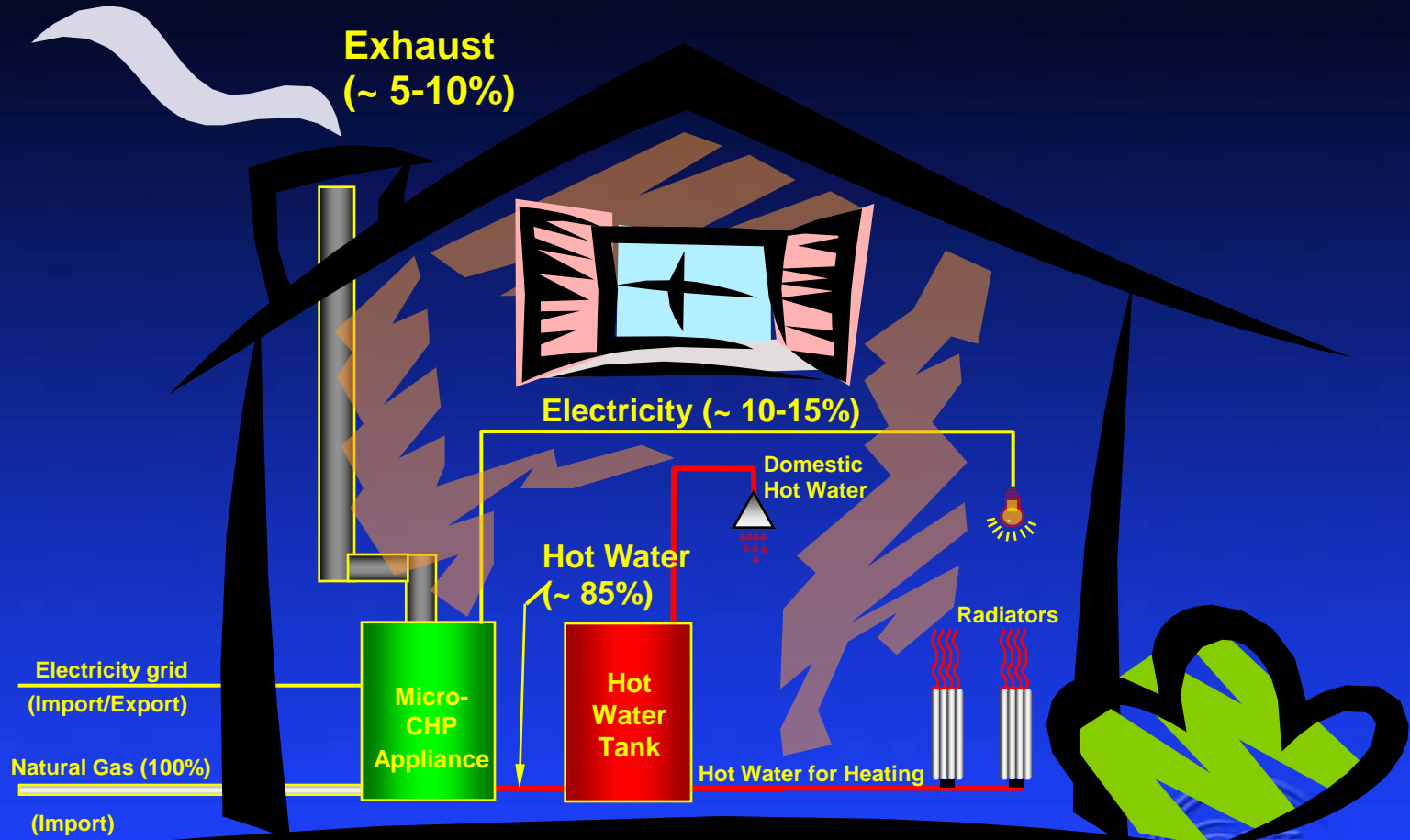
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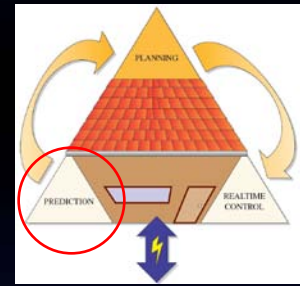
3. **How** can we achieve this?

Global optimizations – use case

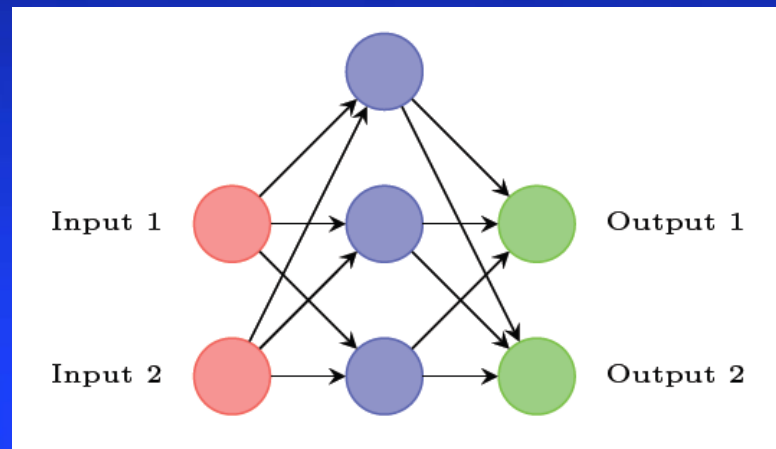
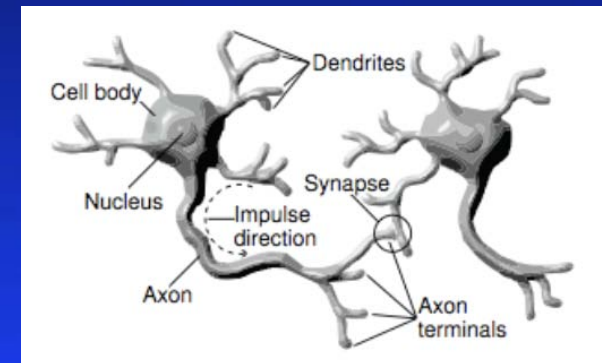
- Why
- What
- How
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Global optimizations – prediction



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



Why

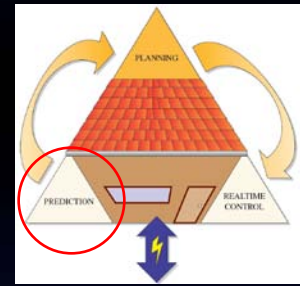
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Global optimizations – prediction



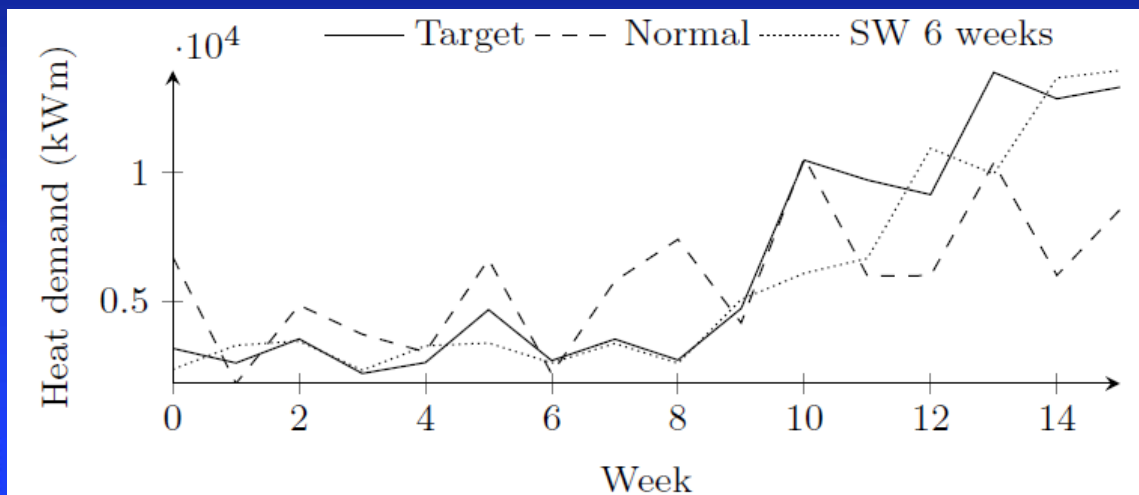
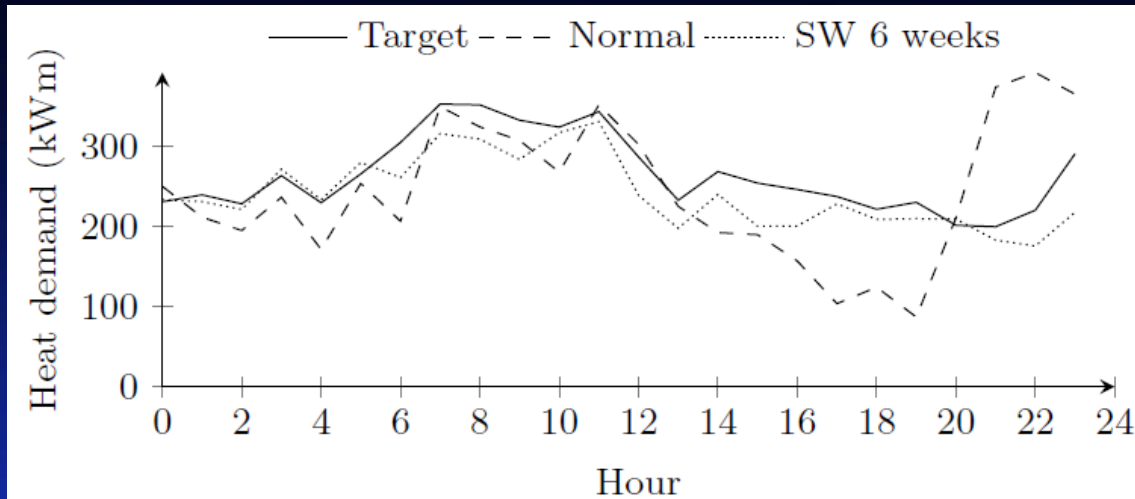
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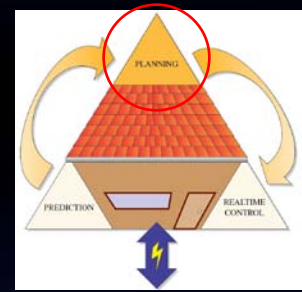
How

Results

Conclusions



Global optimizations – planning



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

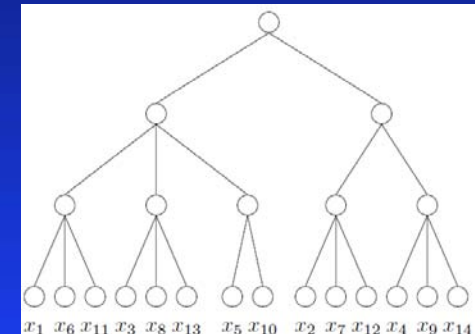
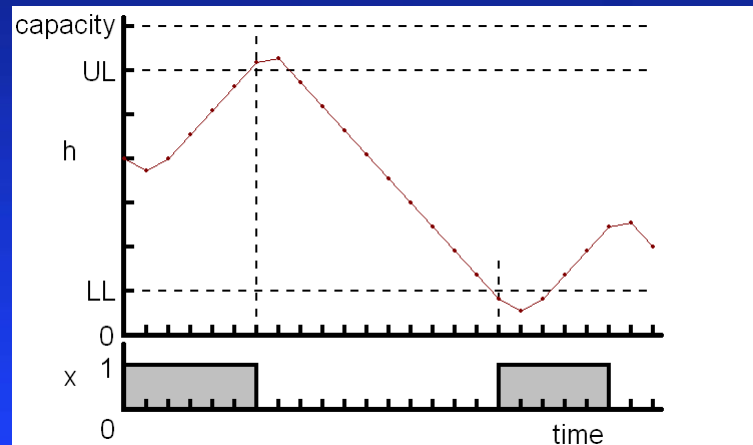
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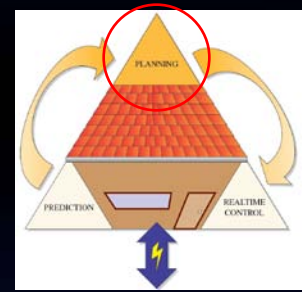
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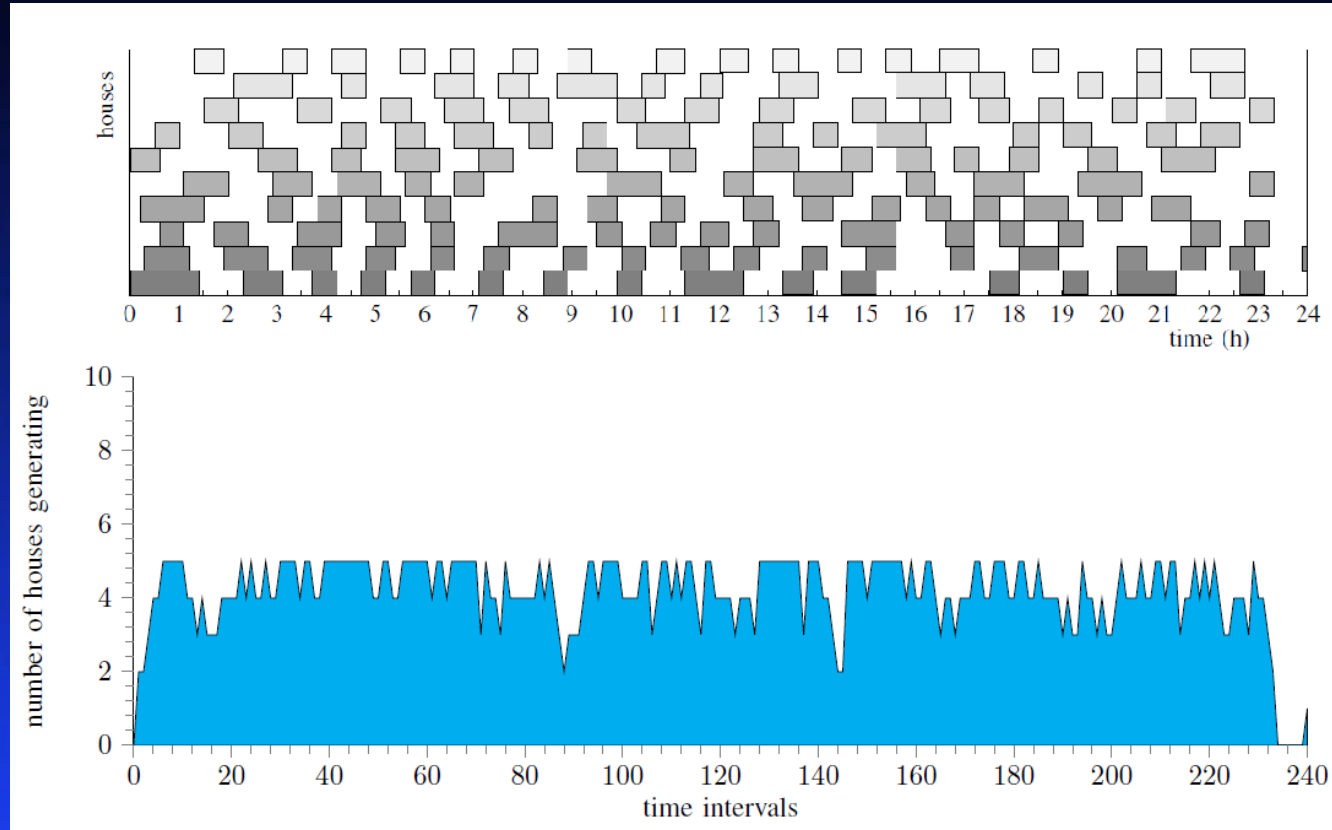
Conclusions



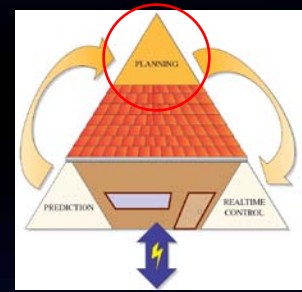
Global optimizations – planning



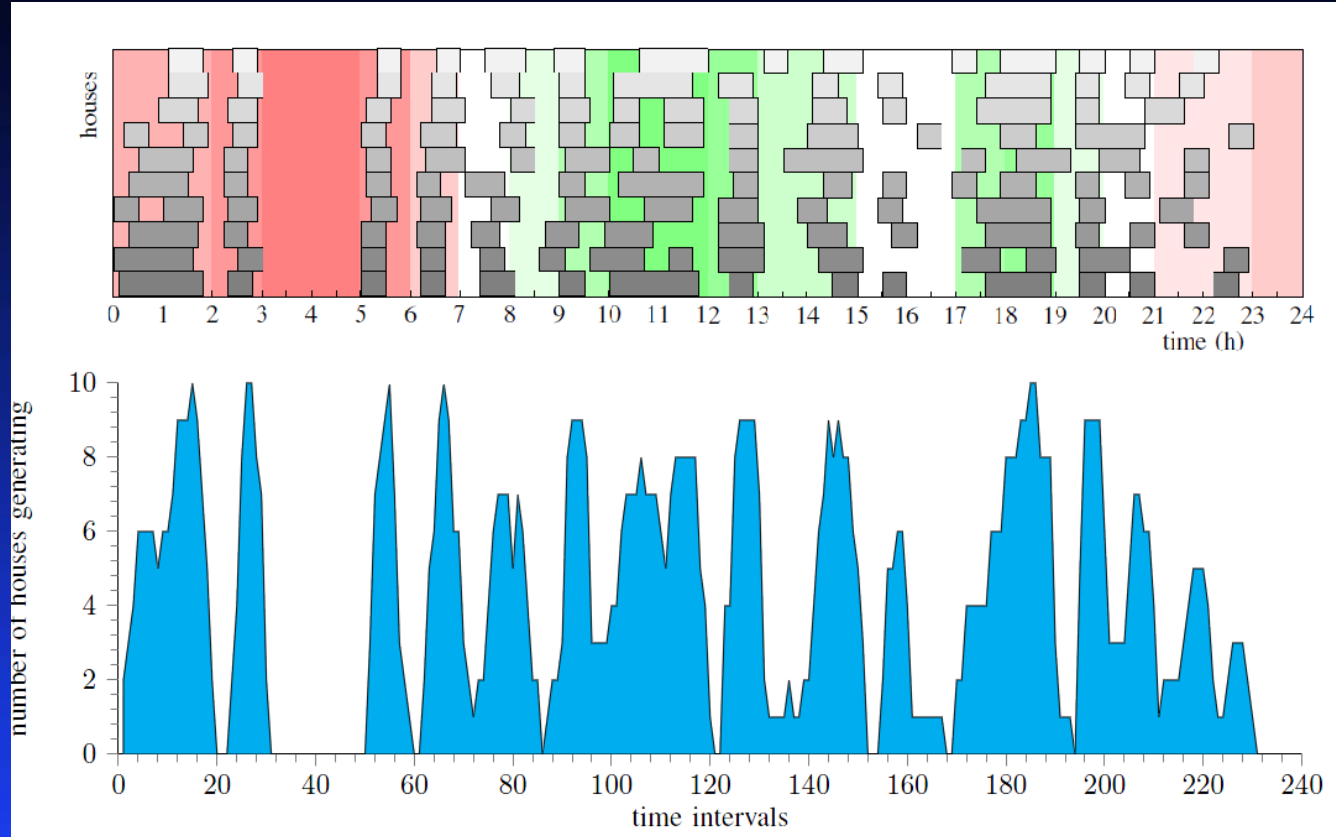
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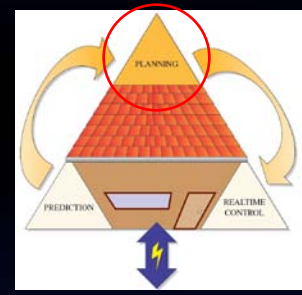
Global optimizations – planning



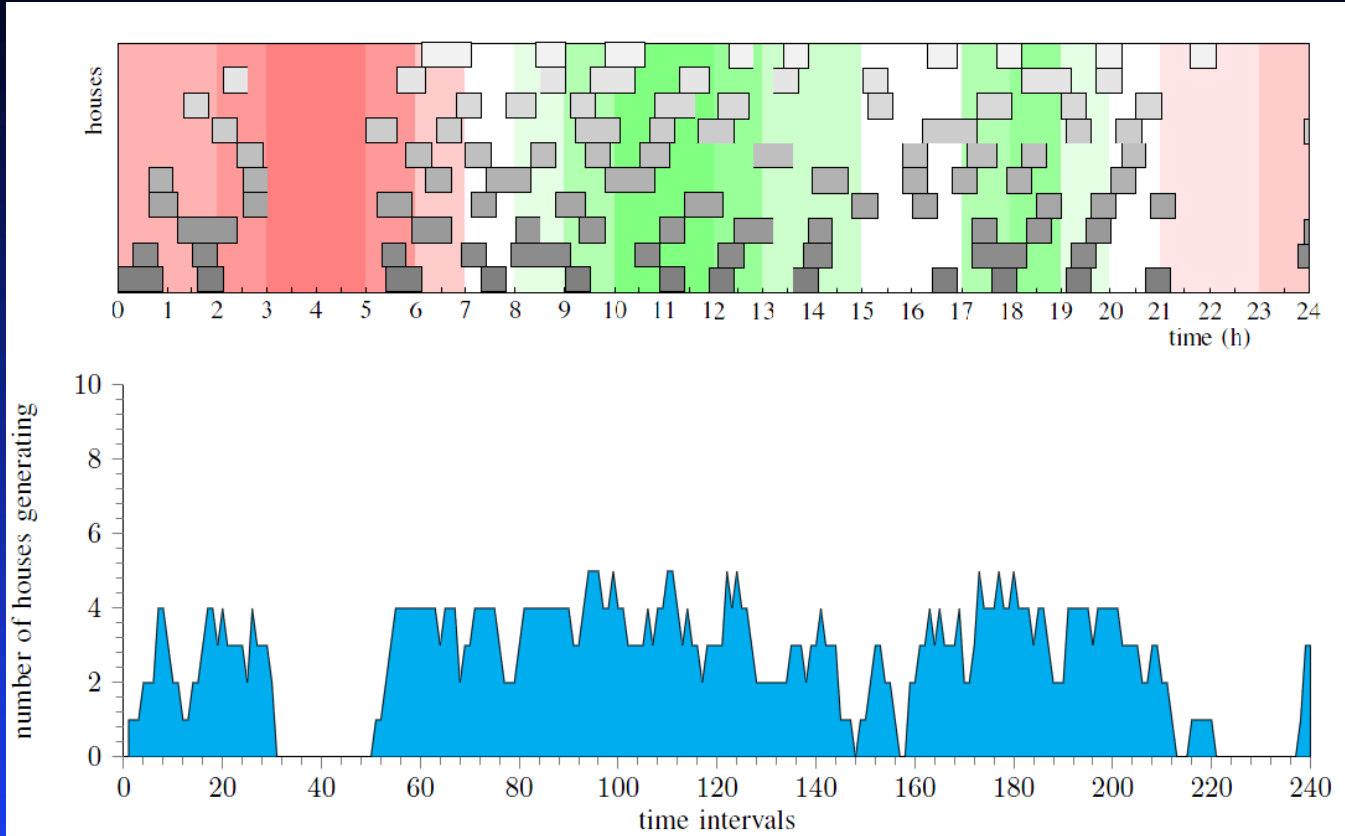
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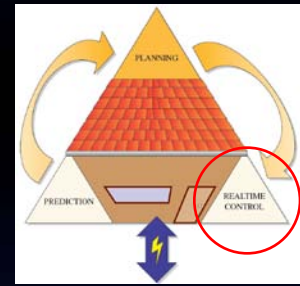
Global optimizations – planning



- Why
- What
- How
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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

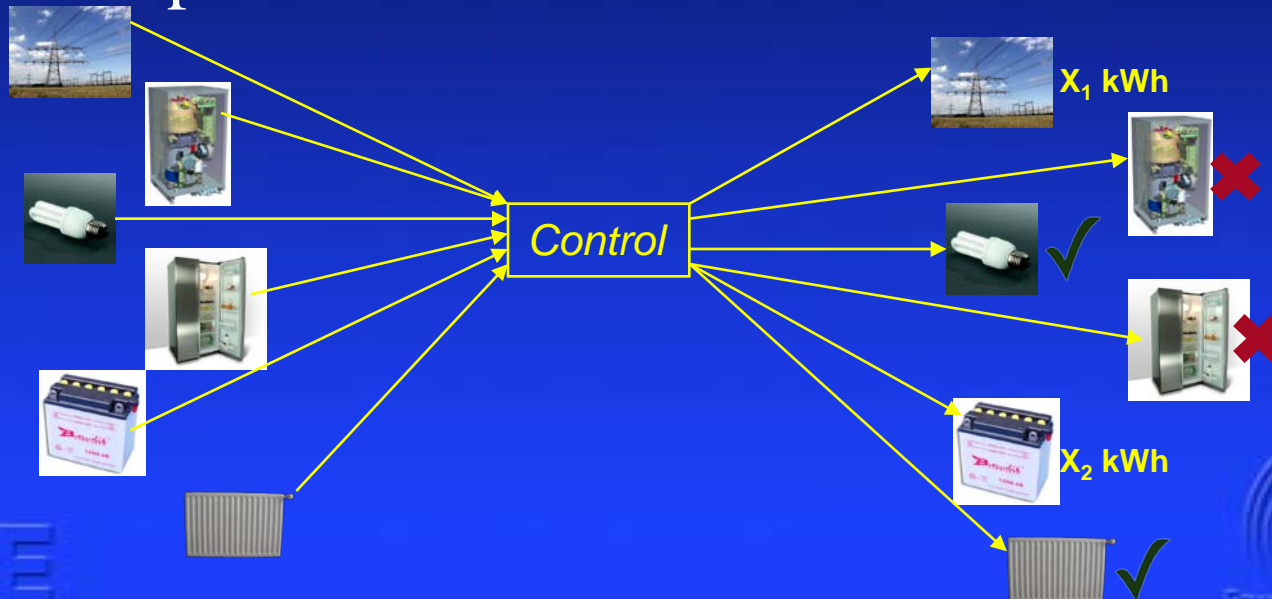
Why

What

How

Results

Conclusions



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

Why

What

How

Results

Conclusions

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

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

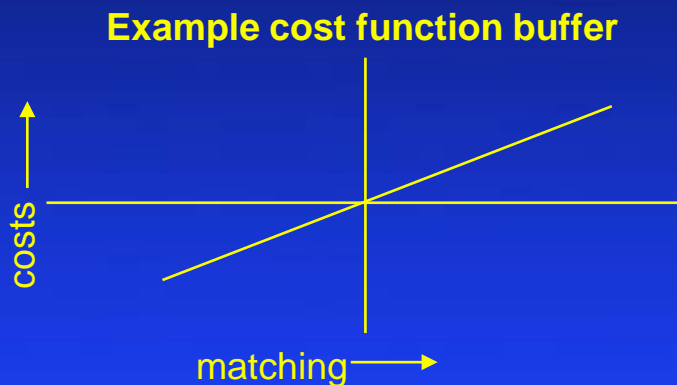
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Outline

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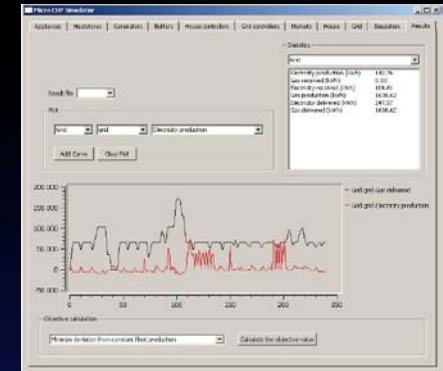
Results

Conclusions

4. **Results** of our methodology

Results

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



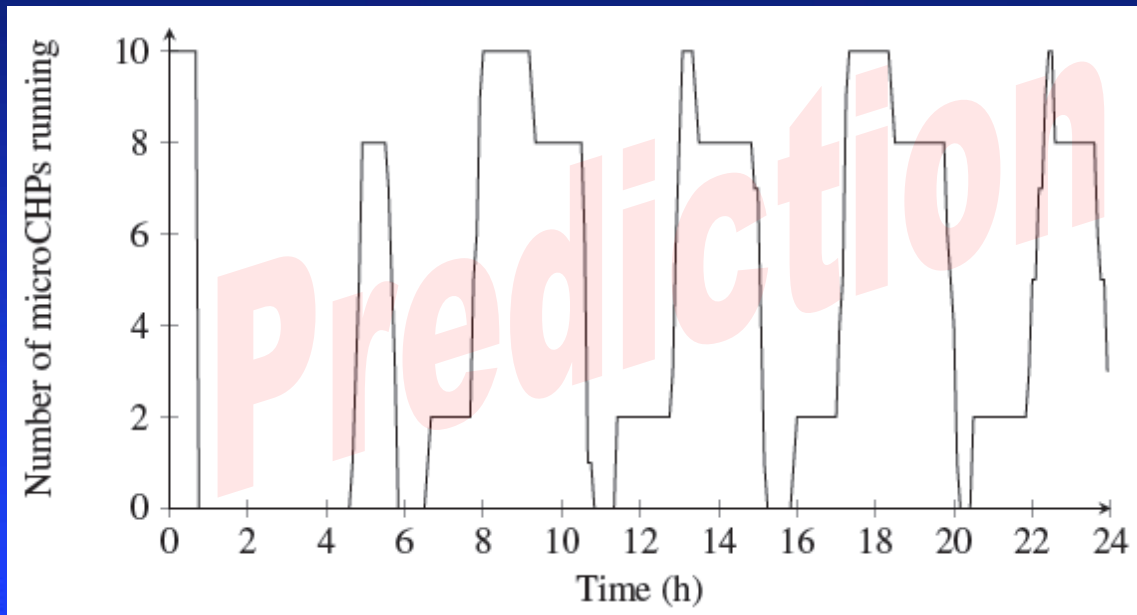
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Results

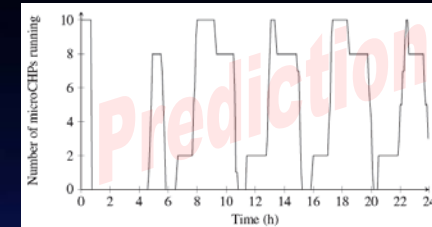
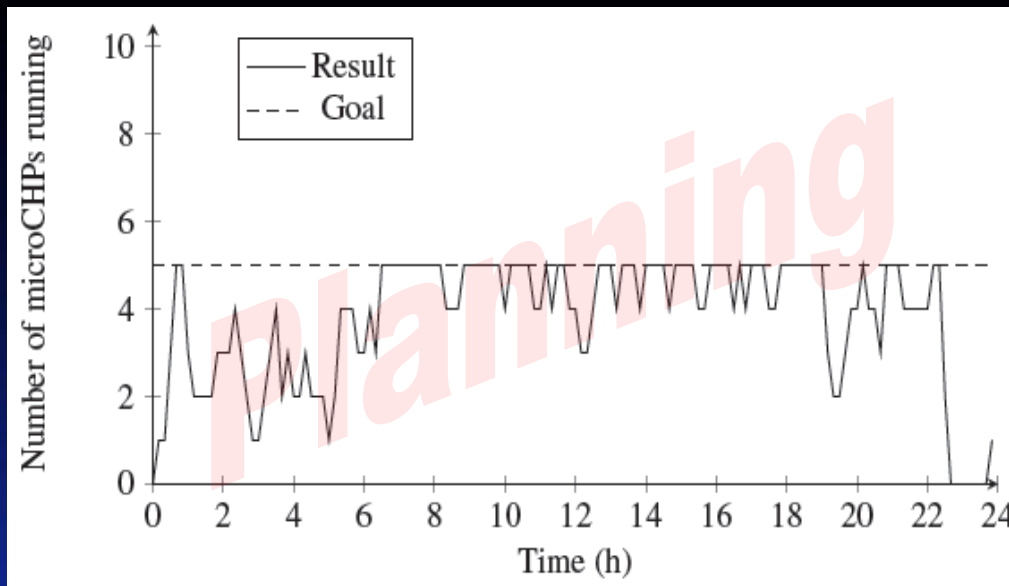
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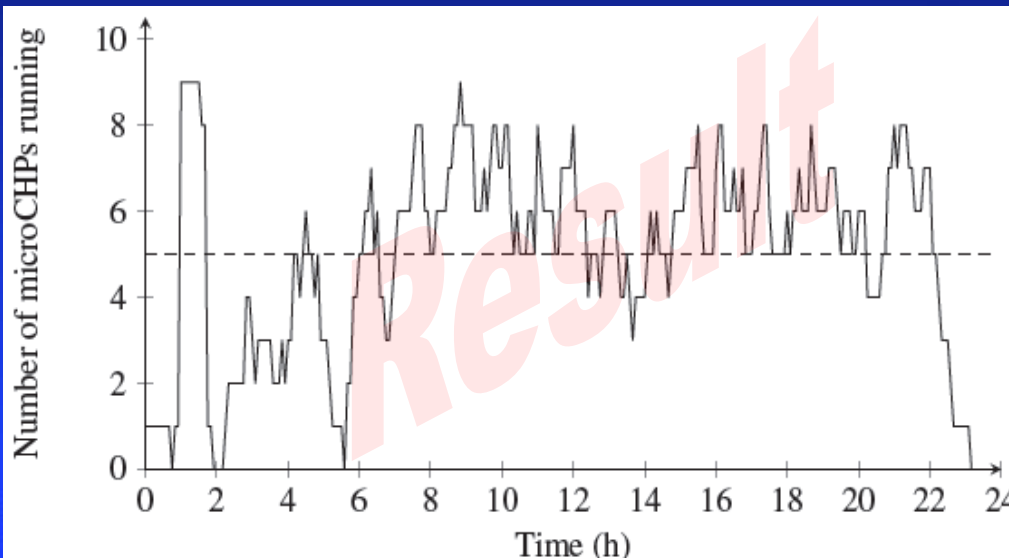
How

Results

Conclusions



50% reduction of peak-production!



Results

- Prototype implementation
- Single house scope
- Fixed heat demand



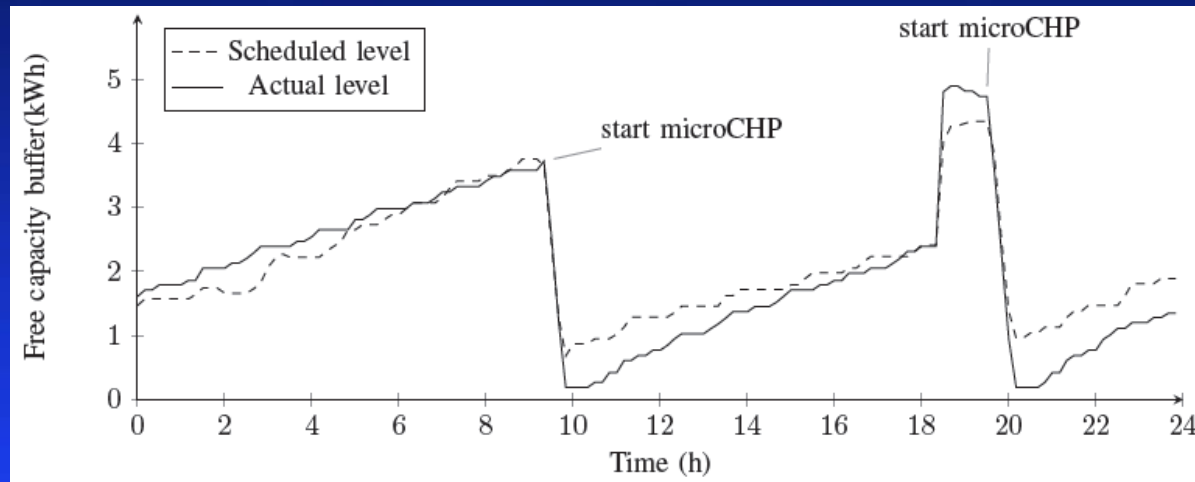
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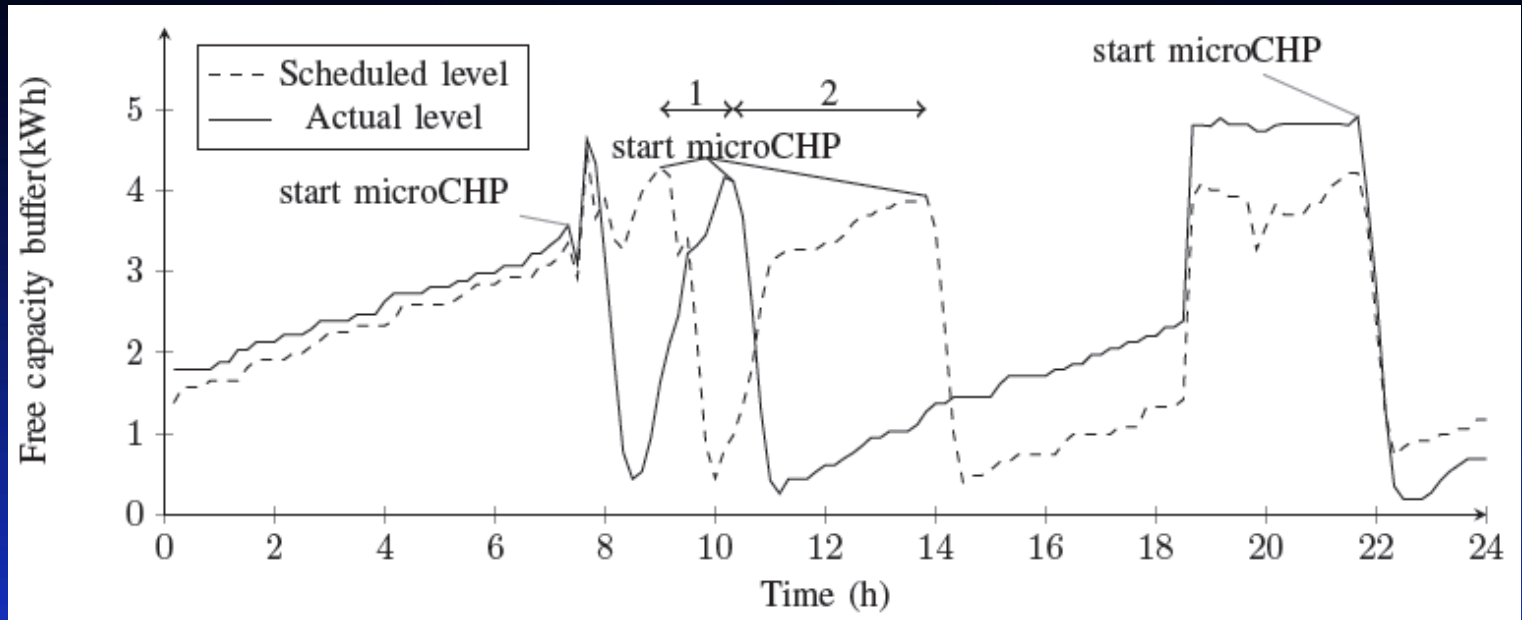
Results

Conclusions



Results

Why
What
How
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

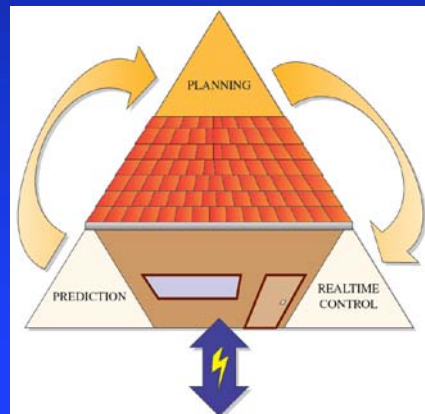
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Questions?

- Thank you for your attention
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