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Planning and Control in Smart Grids

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Outline

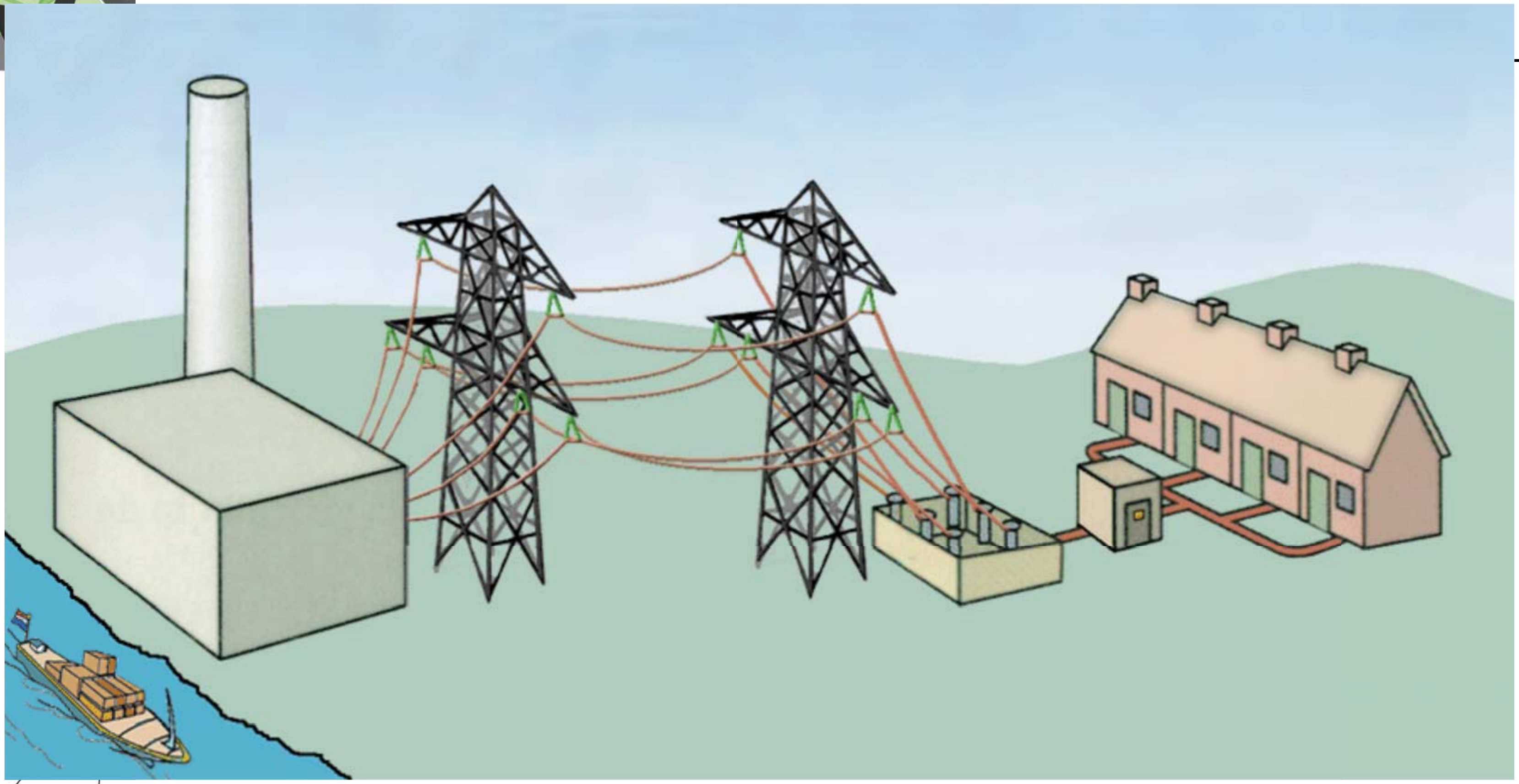
- Background and trends
- Energy management with TRIANA
- Ultimo energy-management / planning & control
  - Energy-autonomous systems
- Conclusion

Background

- EU statement 20-20-20 scenario: in 2020:
  - 20% CO_2 reduction (compared to 1990)
  - 20% of generated energy stems from renewable sources
  - 20% better energy-efficiency

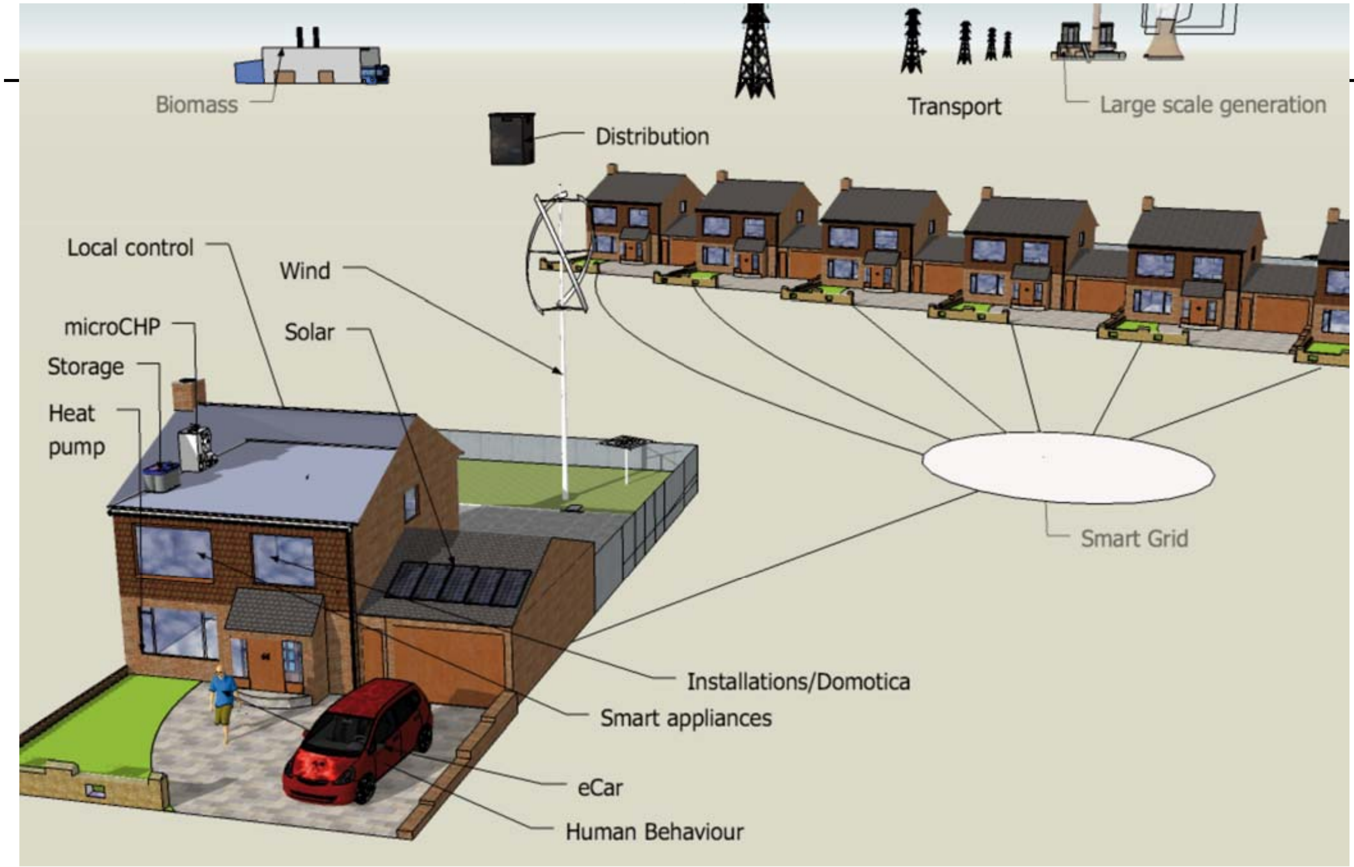
- Topteam Energy TKI Smart Grids and TKI EnerGO
- Topteam HTSM
- ICT Roadmap

Current situation



For all forms of energy: electricity, gas, heat, ….
Power quality control centralised → mechanical

Future: Distributed Generation



- End-user more prominent
  - Delivers energy
  - Flexible loads

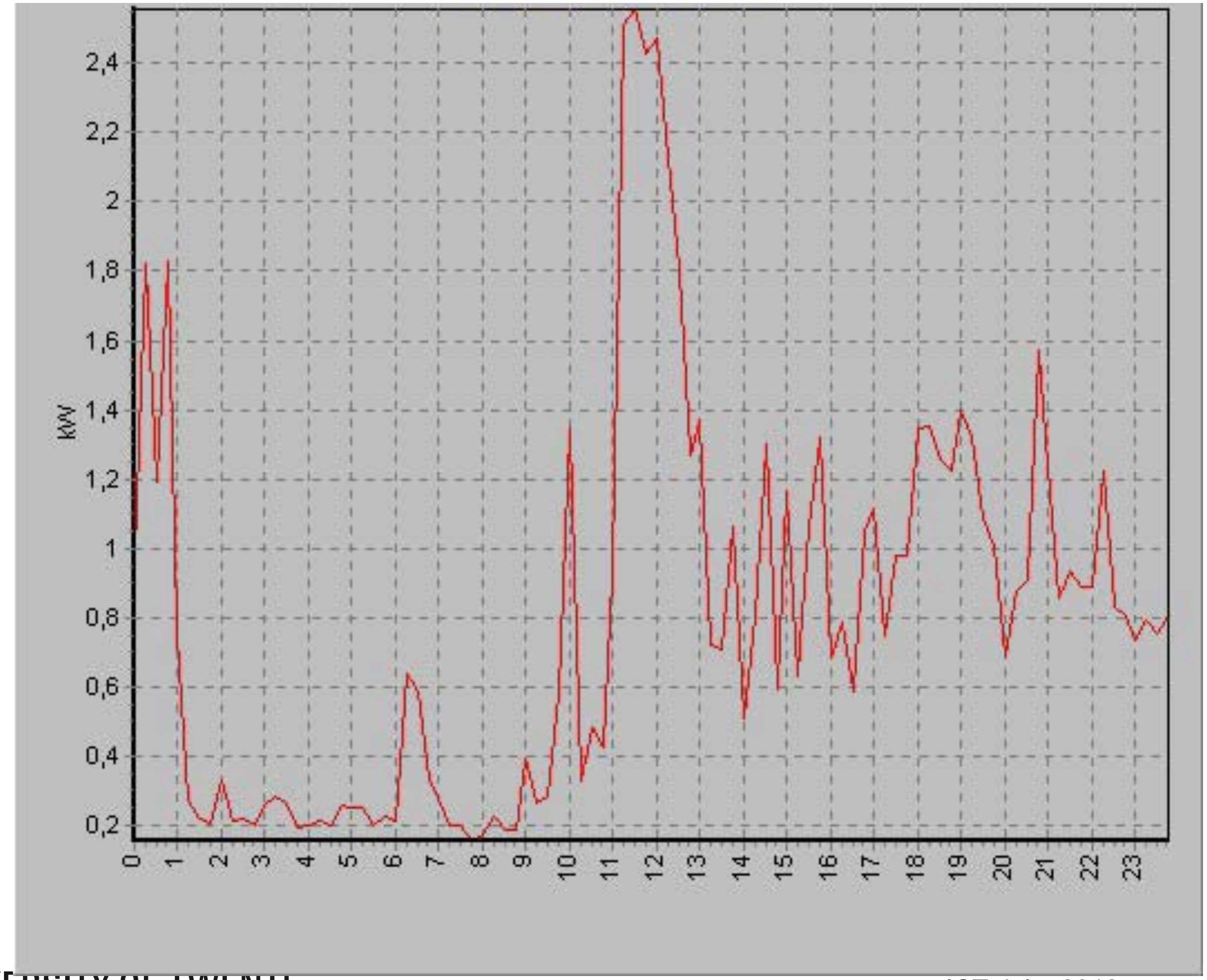
Challenges in smart grids / renewable energy sources

- Micro-generation not always available / predictable
  - Solar cell only works during daytime
  - micro-windmill works when there is wind
- Micro-generation not always controllable
  - sometimes delivers energy when it is not needed
- Expect higher peaks in consumption patterns
  - the heating elements of heat pumps
  - the simultaneous charging of electric vehicles
- Find and use the flexibility in buildings / micro-grid
- Storage of energy is needed
  - storage is expensive and bulky
  - heat storage, batteries

Challenges for the ICT for Smart Grids

- Large distributed Real-time control system
  - High reliability: should continue even when some parts fail
  - Hierarchical control system: scalable to large systems
- Highly dynamic / stochastic system
- Find a generic approach
  - Covering multiple scenario's, objectives and technologies
  - Local and global optimization
- Dependability
- Non-technical issues
  - Privacy
  - Guaranteed comfort level for resident
  - Who is benefitting economically from this?

Typical consumption profile of a house



Source: Essent

Profile of an area with PV panels

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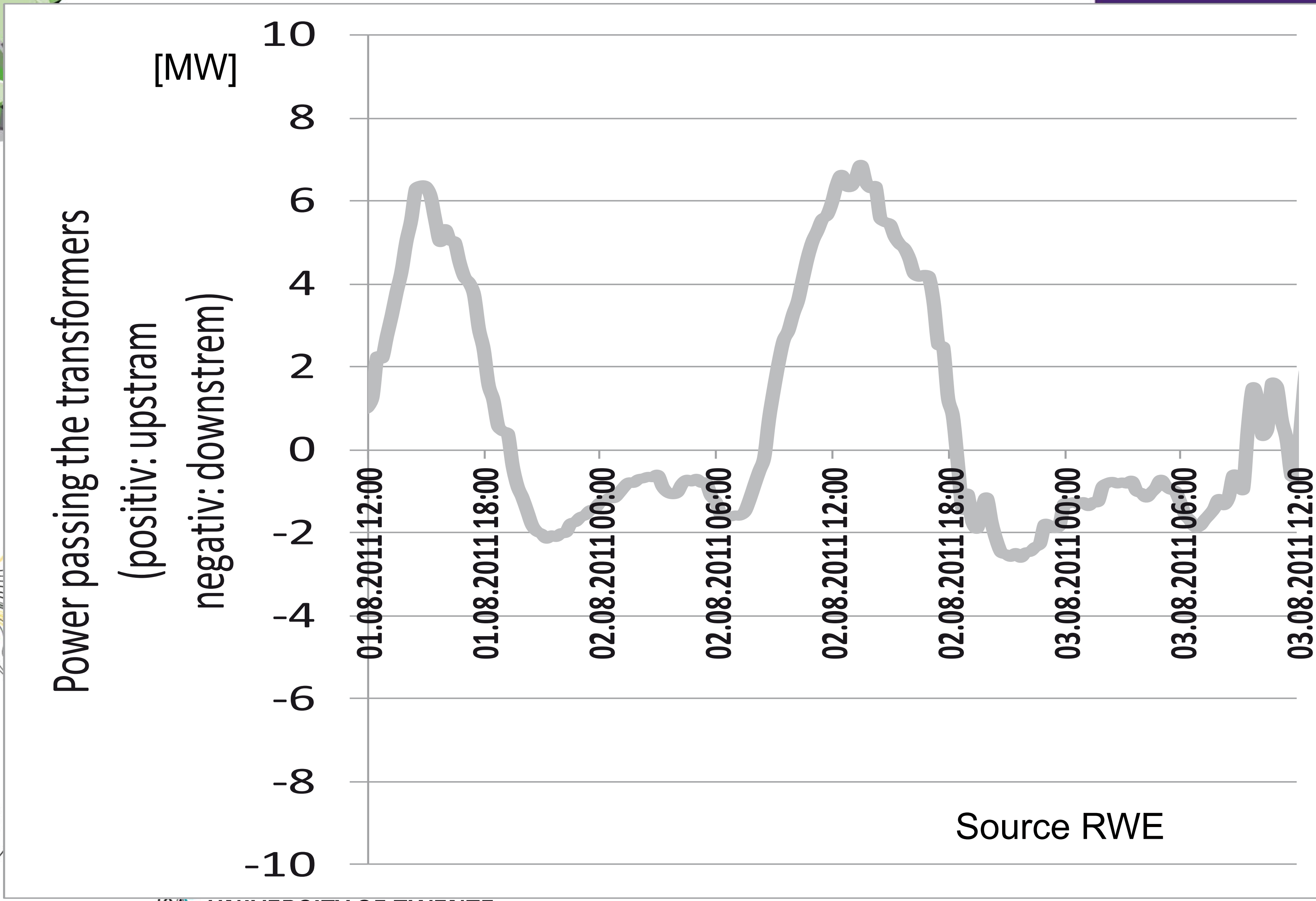
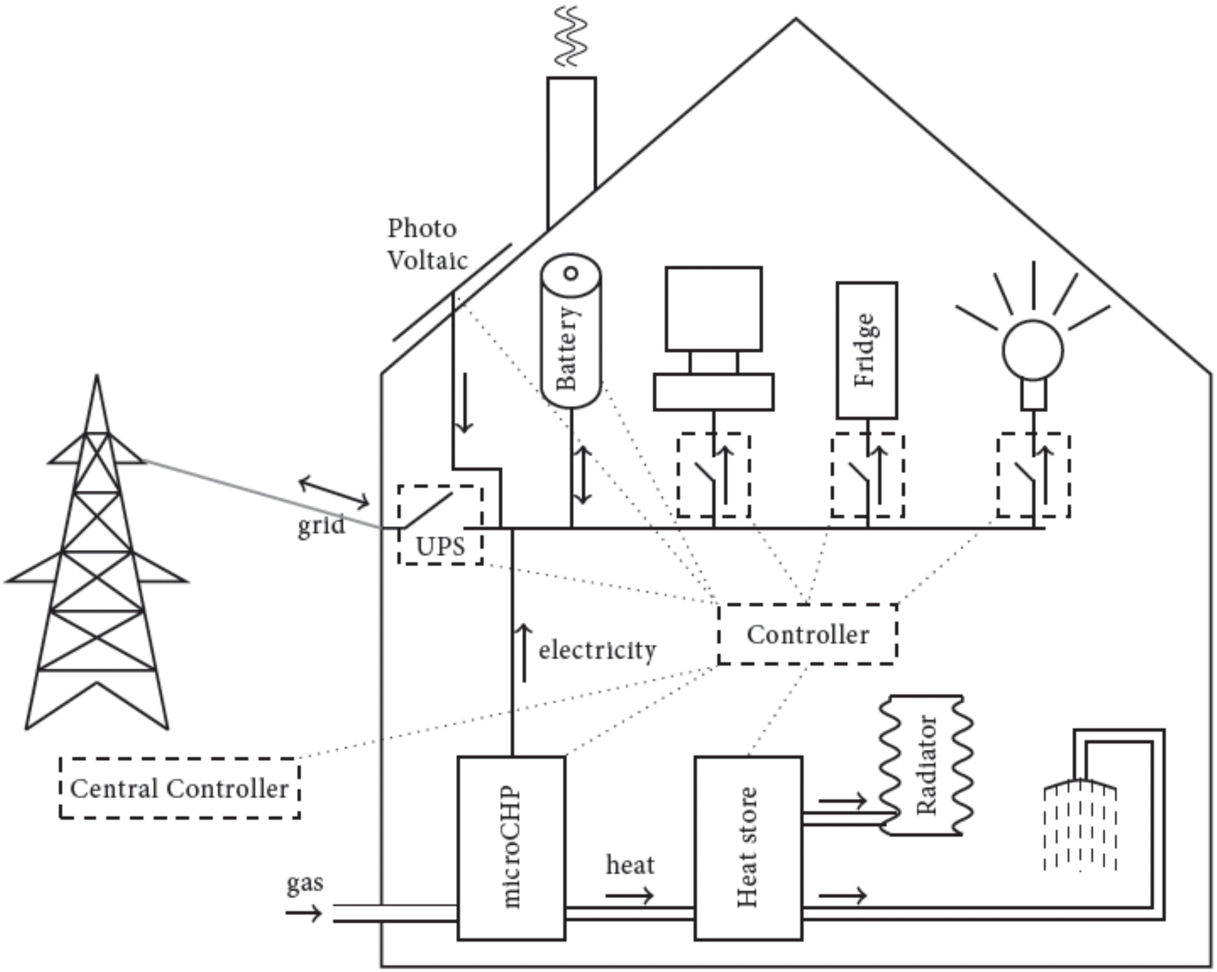
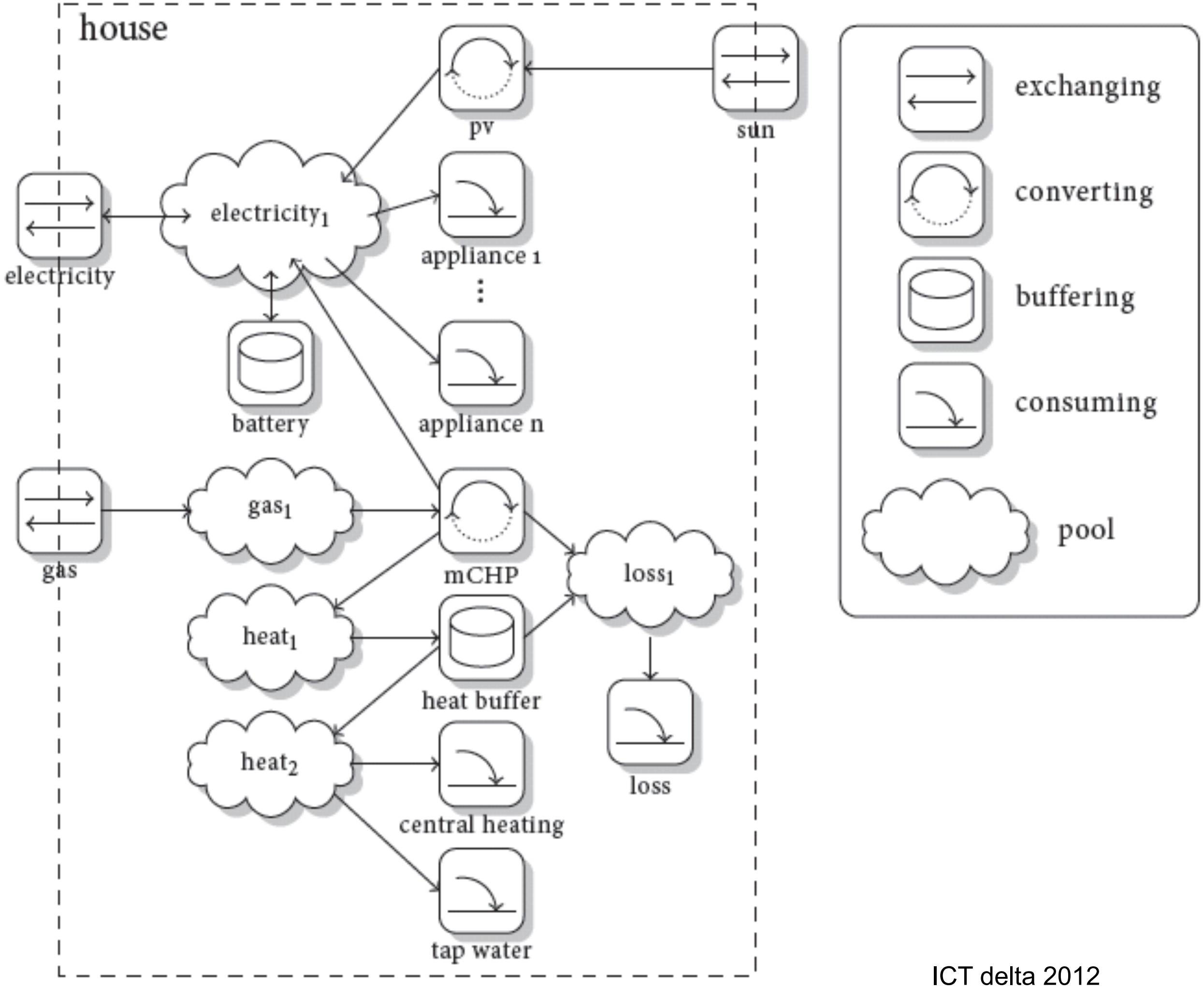


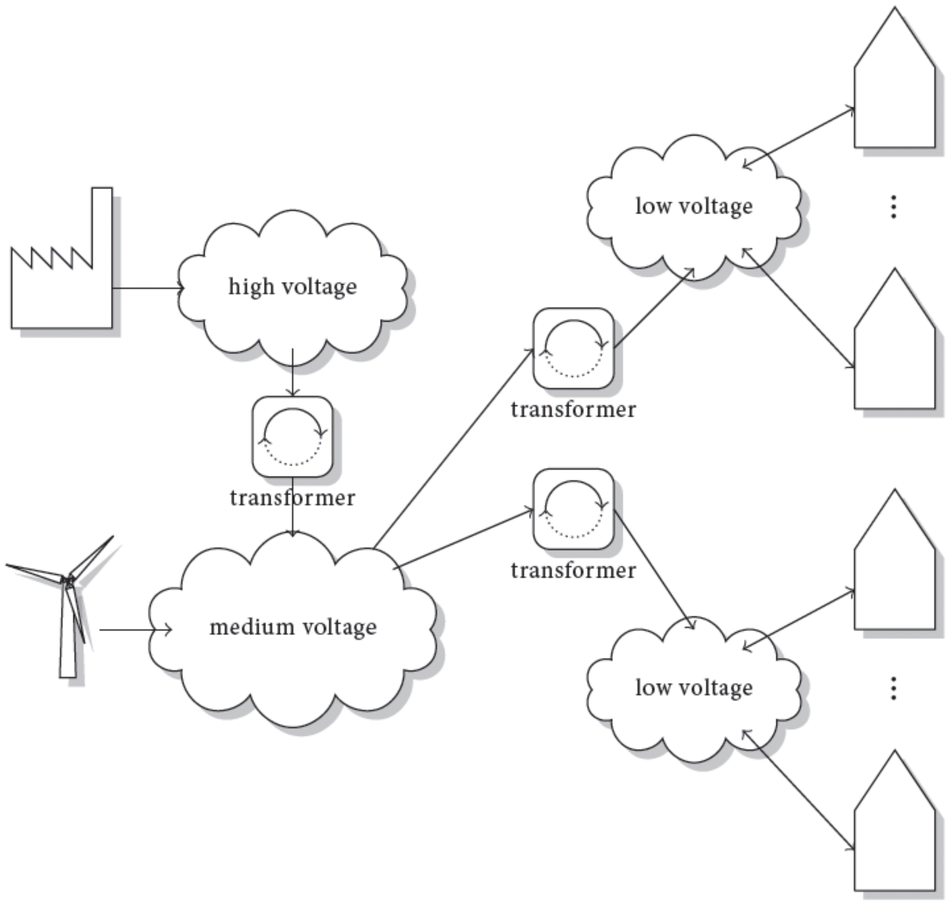
Energy model of a building



Modeling of energy streams in buildings



Modeling of smart micro-grids



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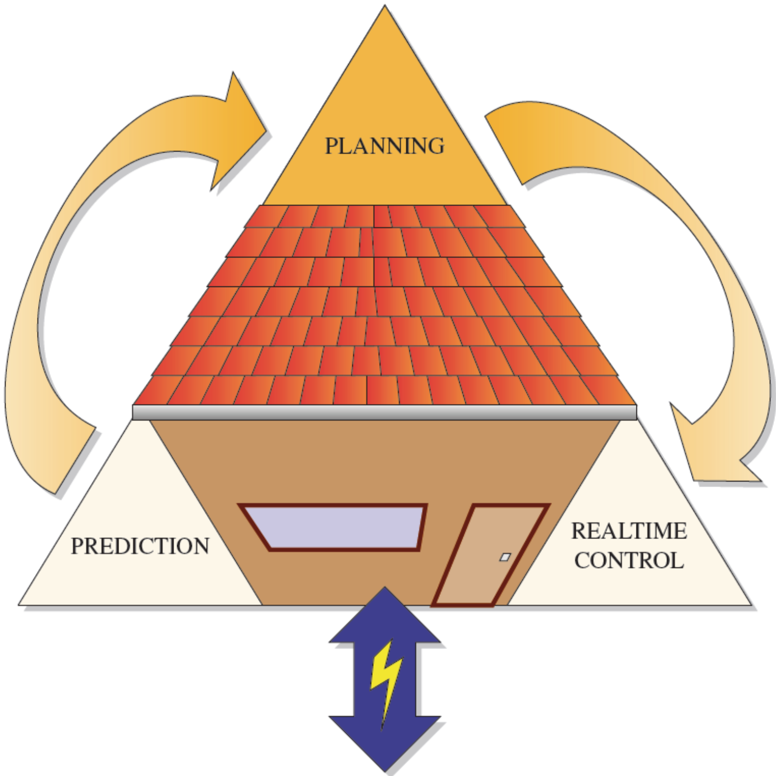
TRIANA: 3 STEP CONTROL METHODOLOGY

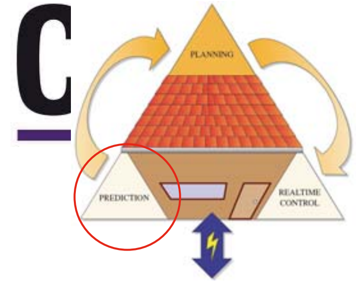


1: prediction on building level

2: planning in a grid

3. real-time control in buildings

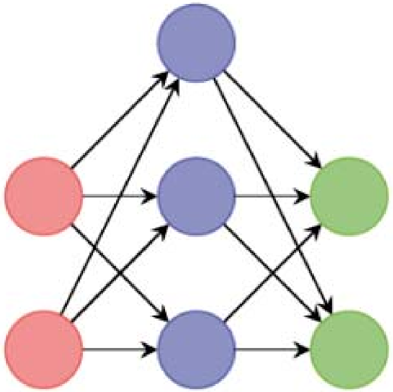
PhD theses Albert Molderink, Vincent Bakker and Maurice Bosman

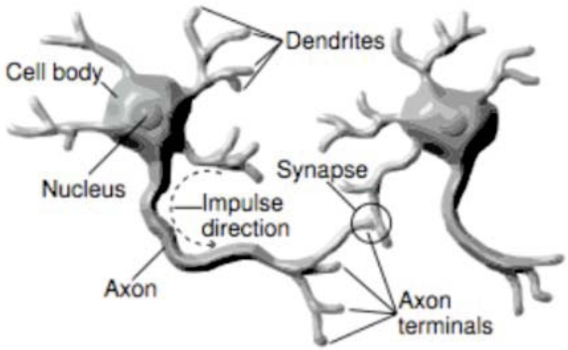


CONTROL METHODOLOGY

STEP 1: PREDICTION for each individual building

- Determine the scheduling freedom
  - Energy demand and production prediction
  - For every individual house
  - In every individual house
- Reasons: scalability, privacy, network BW, …

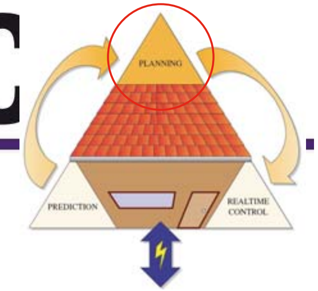




PhD thesis Vincent Bakker

CONTROL METHODOLOGY

STEP 2: PLANNING within a micro-grid (neighborhood)



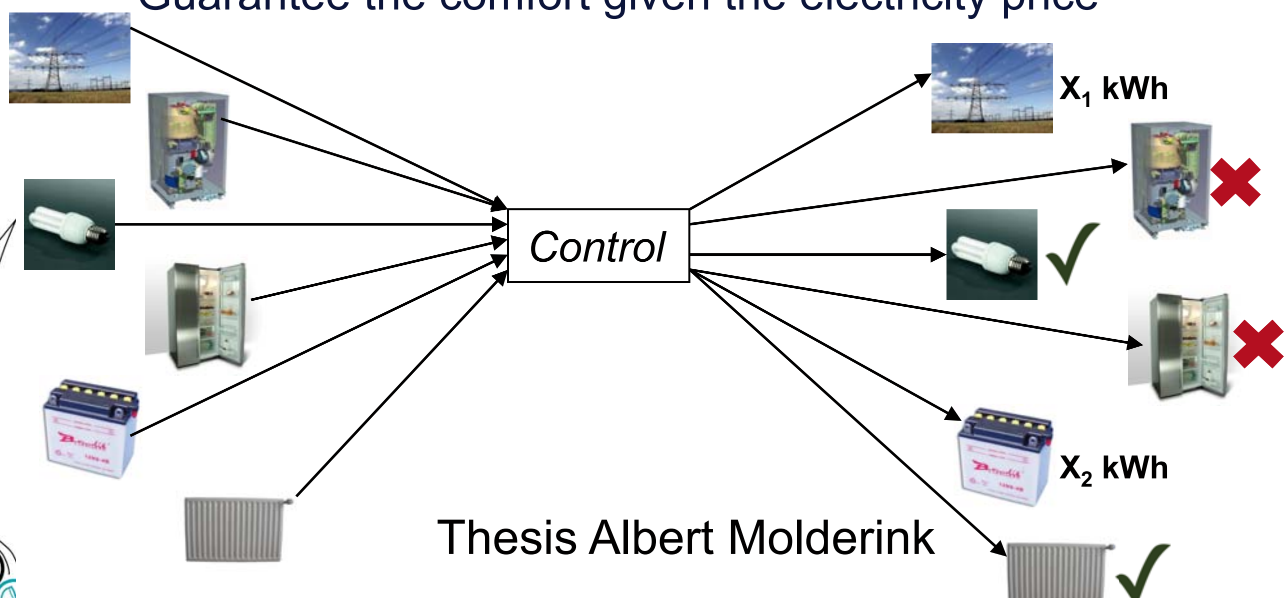
- Aggregate information hierarchically and use this for planning/control of the micro-grid
  - NP-complete problem → heuristics
  - Optimization objective depends on stakeholder
  - Used several approaches
    - ILP (computation time hours to days: takes too long)
    - Dynamic programming (hours: too long)
    - Local search (minutes: sub optimal)
    - Column generation (minutes: best)

  - PhD thesis Maurice Bosman

CONTROL METHODOLOGY

STEP 3: REAL-TIME CONTROL

- Real-time control of individual house
  - Global planning as input using artificial pricing signals
    - Houses can have different prices!
  - Working around prediction errors
  - Guarantee the comfort given the electricity price



Thesis Albert Molderink

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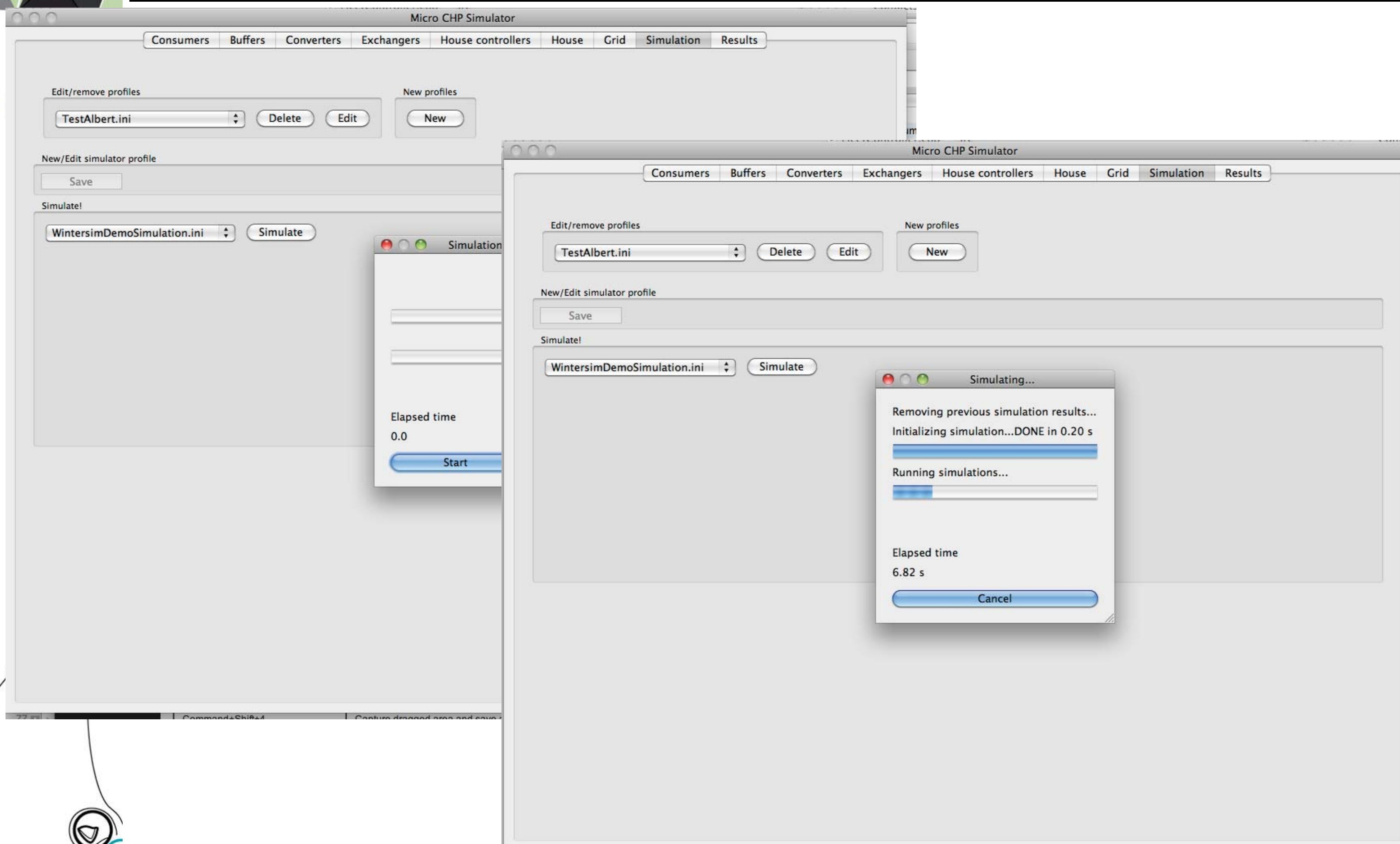
SIMULATOR

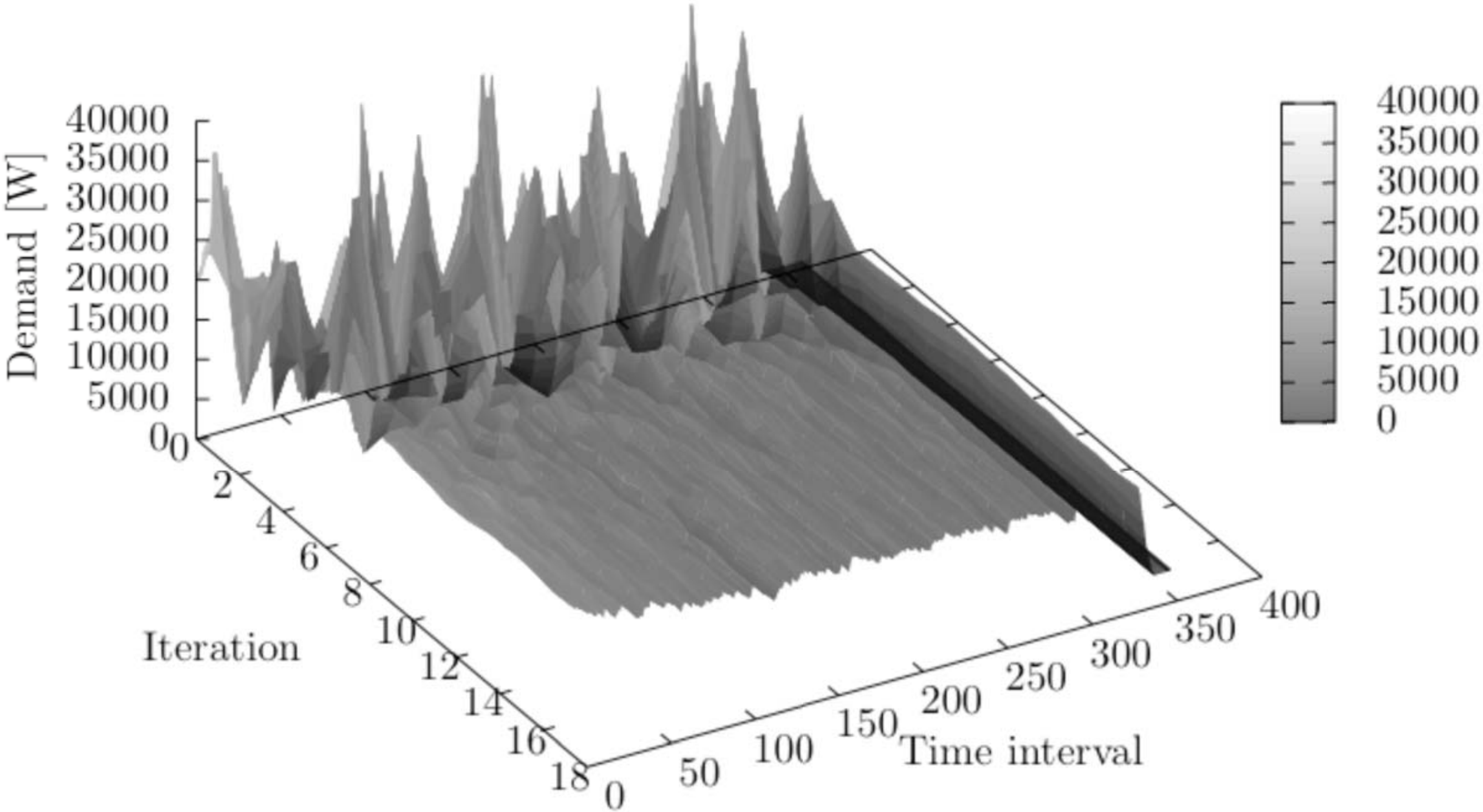


What is the role of monitoring and control?

- Control production / consumption and storage
  - Real-time optimization problem
  - Predict the production and consumption patterns
- Monitoring and control of power systems
  - In a micro-grid power quality needs to be controlled
- Financial transactions
  - who pays for what
- User awareness
  - show users status of the system

Some simulation results

Scheduling 500 freezers in a micro-grid (case Philips Research)

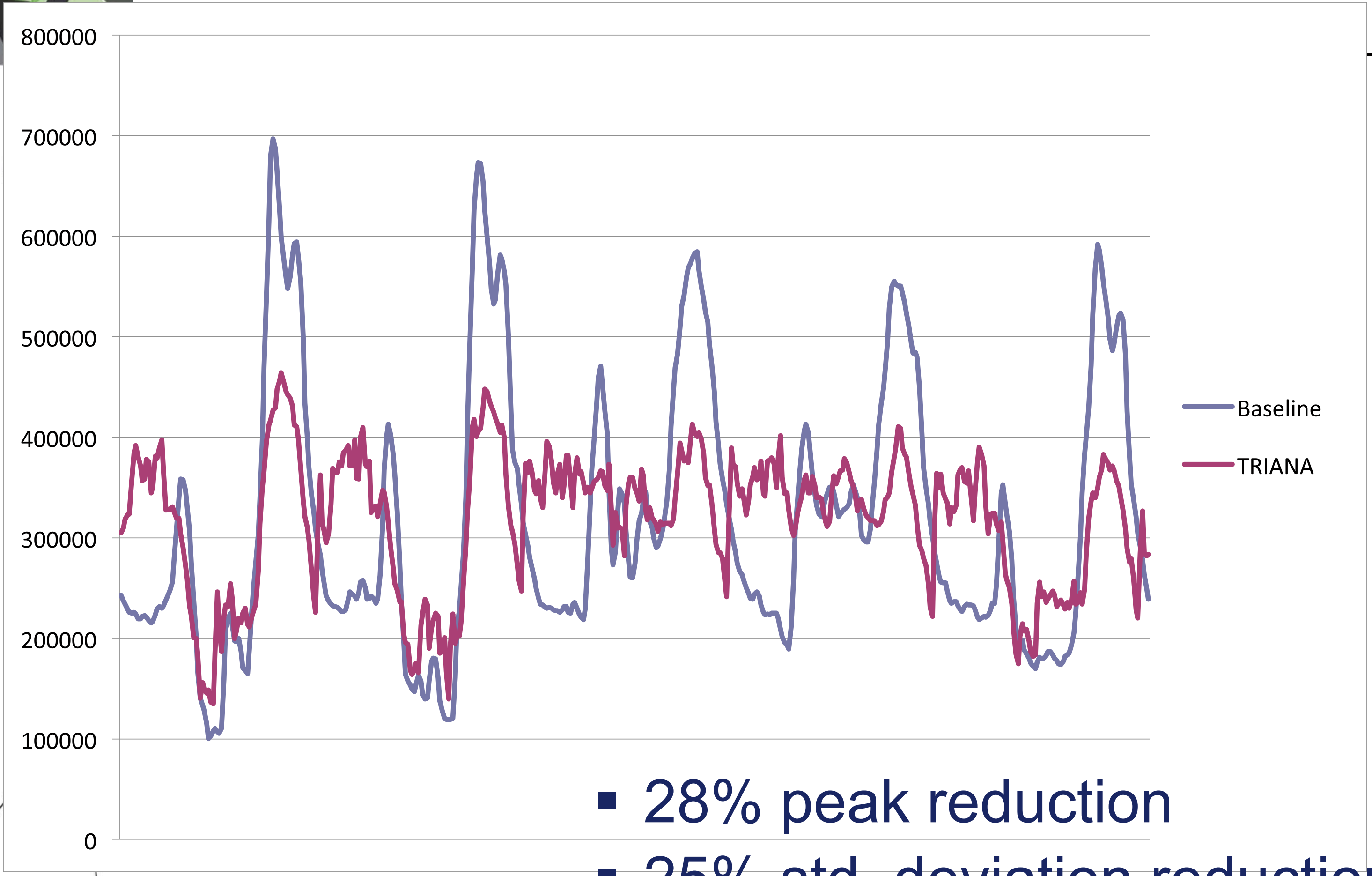


Year simulation case

- 400 houses, 365 days
- Heat pump + buffer
- Electric vehicles
- Washing machine
- Dishwasher
- Battery (5% of houses)
- Photovoltaics (15% of houses)
- Inflexible load

} Flexible

Results: objective peak-load reduction

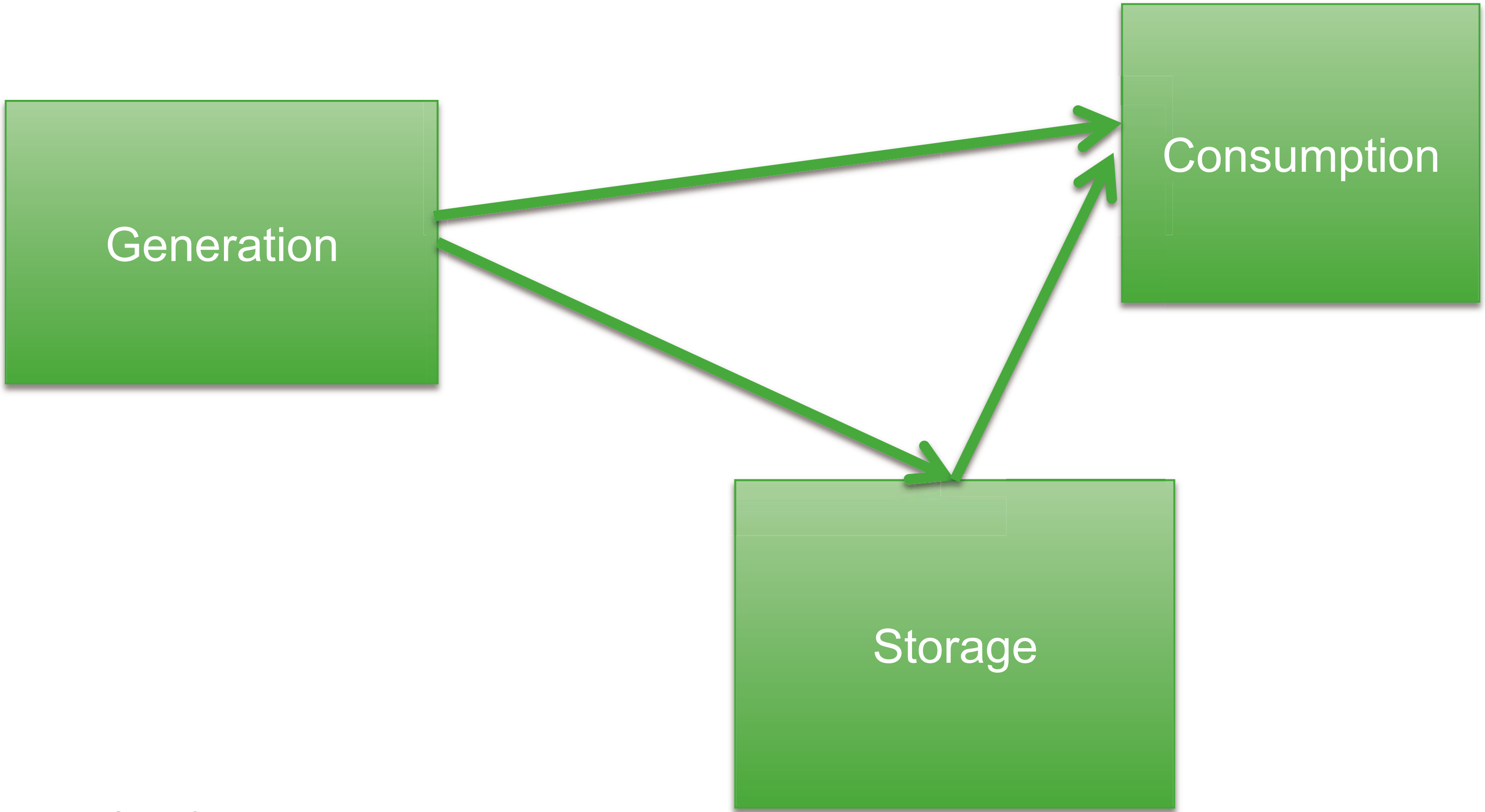


- 28% peak reduction
- 25% std. deviation reduction

Energy-autonomous systems

Energy-autonomous environments

It is all about energy balance



Why Energy Autonomous?

- Security of supply (individual user)
  - Independence of energy suppliers
  - Independence of foreign gas/oil supply
- Act on the energy market (group of users)
  - Buy electricity when it is cheap
  - See electricity when it is expensive
- Postpone investments in grid infrastucture (network company)
  - Avoid peaks in the distribution grid
  - Self-healing network
- 100% renewable generation based on local resources

Conclusions

- The energy field will change
  - From production follows the load
  - To load follows production
- 3 steps: Prediction, planning and control is quite promising
  - Not many systems work in that way
- Efficient embedded ICT needed
  - Control of appliances (micro-controllers)
  - In-building networks (wireless / wire-line / optical)
  - Energy management in buildings
  - Smart grid control

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Acknowledgements

- PhD / Post-Docs (together with DMMP: Johann Hurink)
  - Albert Molderink, Vincent Bakker, Maurice Bosman, Hermen Toersche, Stefan Nykamp
- Companies
  - E.ON UK, Essent (RWE), RWE GE, Gasterra, Philips Research, Alliander, Homa Software
- STW projects:
  - SFEER (finalized)
  - DREAM
  - i-CARE
  - STW perspectief program Robust design of CPS

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Questions ?