Demand Response for increased DER hosting

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PSMIX Group
KTH – Royal Institute of Technology
Stockholm, Sweden

KTH – Royal Institute of Technology,

- **Established 1827 in Stockholm**
- **KTH in numbers:**

  800 Faculty

  2200 Research, tech & admin staff

  1800 PhD Students,

  13000 M.Sc &.B.Sc. students

- **Focus Areas:**

  Energy, Life Science, Materials, ICT & Transportation

#34 Technical University

Power Systems Management & Related Information Exchange

Group lead: Nordström
Affiliated: Ekstedt, Ericsson(SvK), Wang (ABB)
Post-Docs: Saleem, Chenine
7 PhD students + 2 Industrial PhD @ ABB
8 MSc Students

Research Areas:

- Reliable and High-performing ICT infrastructures
- Distributed Control of Power Systems
- Novel Market Models for Active Power Systems

Educational Activities:

- Communication & Control for Power Systems
- Computer Applications in Power Systems
- Circa 20 Masters & Bachelor projects annual

Funding:
1,2 MEUR Annual
58% External
Main sources:
FP7, Swedish Energy Agency ABB, SvK.

STRONgrid
iTesla
GRID4EU INNOVATION FOR ENERGY NETWORKS
High Voltage Valley
DISCERN
eit KIC InnoEnergy

www.ee.kth.se/psmix

Acknowledgements

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  - Claes Sandels, KTH
  - Pia Stoll, KTH/ABB
  - Daniel Brodén, KTH
  - Nils Brandt, KTH
  - Joakim Widén, Uppsala University
  - Ewa Wäckelgård, Uppsala University

Scope of the presentation

- **Focus**

  Modeling of end-users (residential & commercial) for the purpose of assessing amount of flexibility available in a grid segment.

- **Assumptions**

  Incentives and pricing of electricity is not included in the studies other than to illustrate potential. I&P is part of control stage still being defined.

Flexibility

- Flexibility is here defined as the amount of load deferrable to another time period respecting end-user comfort constraints.

- Available flexibility varies with
  - Load type and comfort constraints
  - Building parameters
  - Exogenous (temperature, sun irradiation, ..) variables

Outline

Finding Value in Demand Response

Modeling Residential Flexibility

Case Study – Congestion Management

Ongoing work:

- Modeling Commercial Flexibility

Next steps

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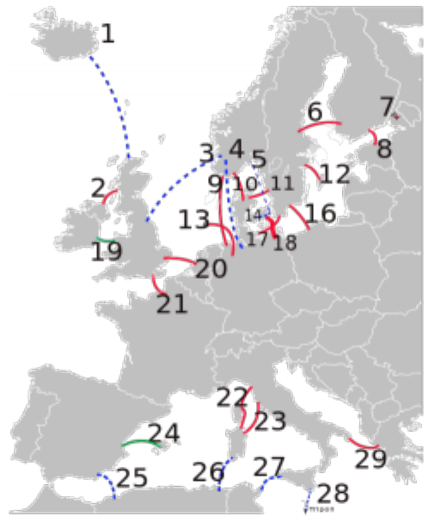
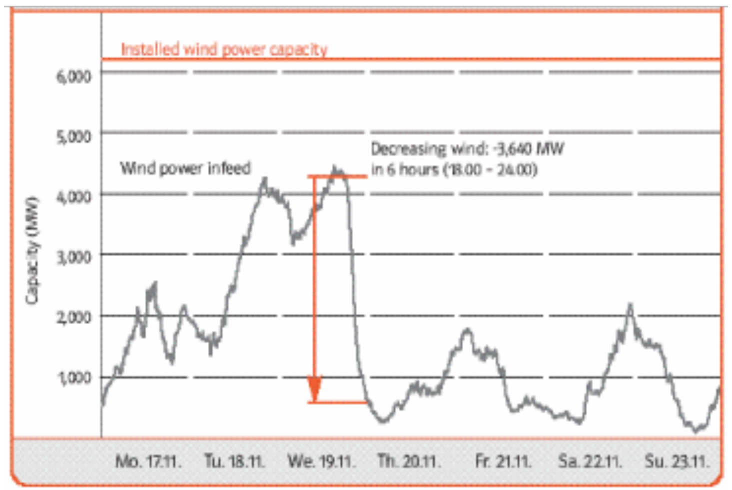
Transmission System Challenges

Increased market coupling leads to larger variations in power flow



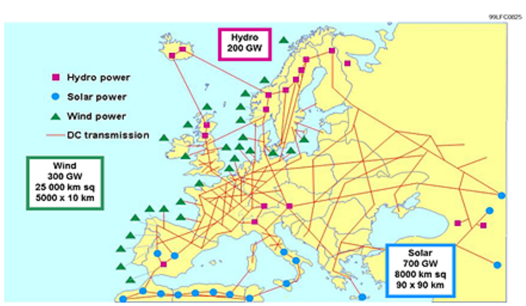
Source: Tintazul, Maix, J JMesserly;



E.On Netz (2004), *Wind Report 2004.*

Inherent variability of supply and power flow increases stress to the system

Large amounts of renewables not in close proximity to load centers.

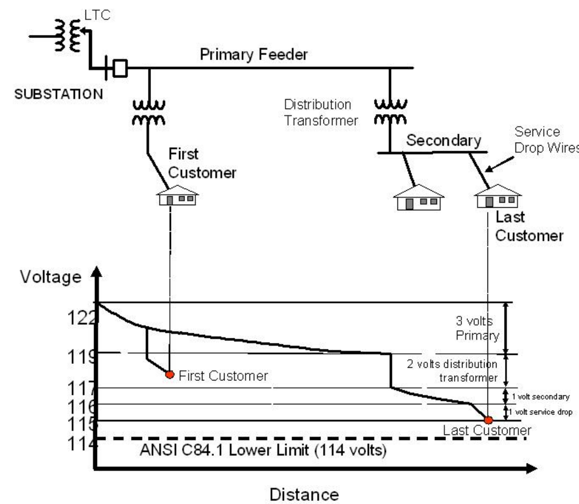


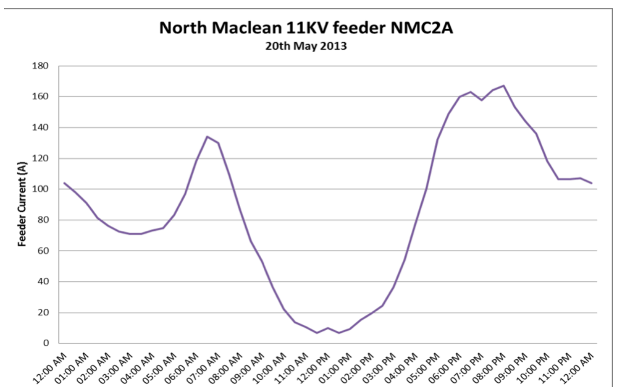
Source: Gunnar Asplund, Elways AB

Distribution System Challenges

Prosumers as market participants

Voltage control in active feeders



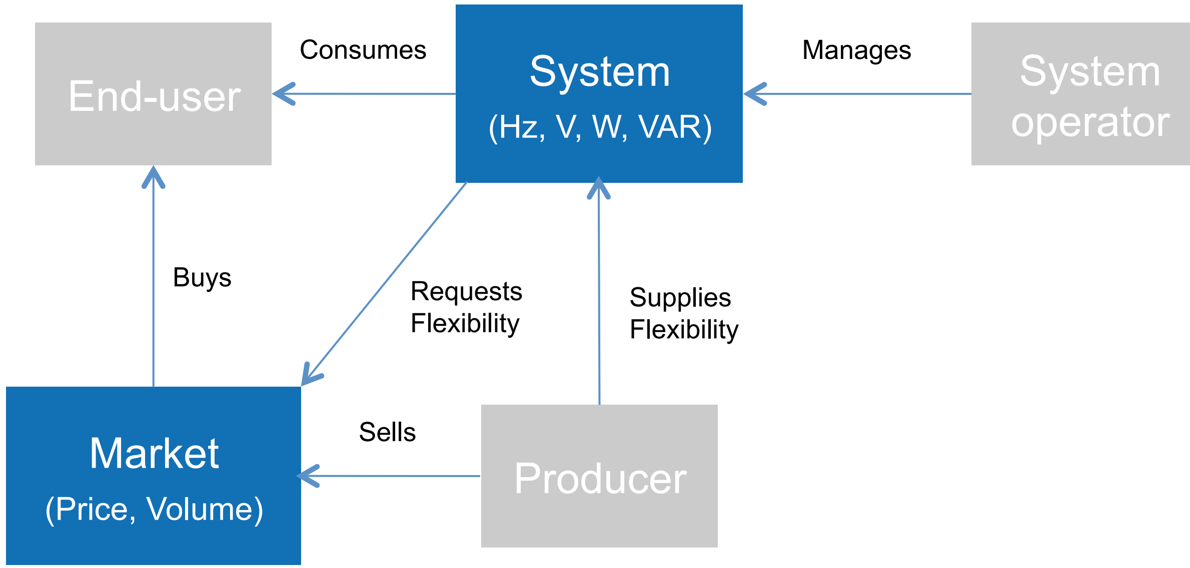


Source: Giles Parkinson RE Economy

Protection settings under varying load & production

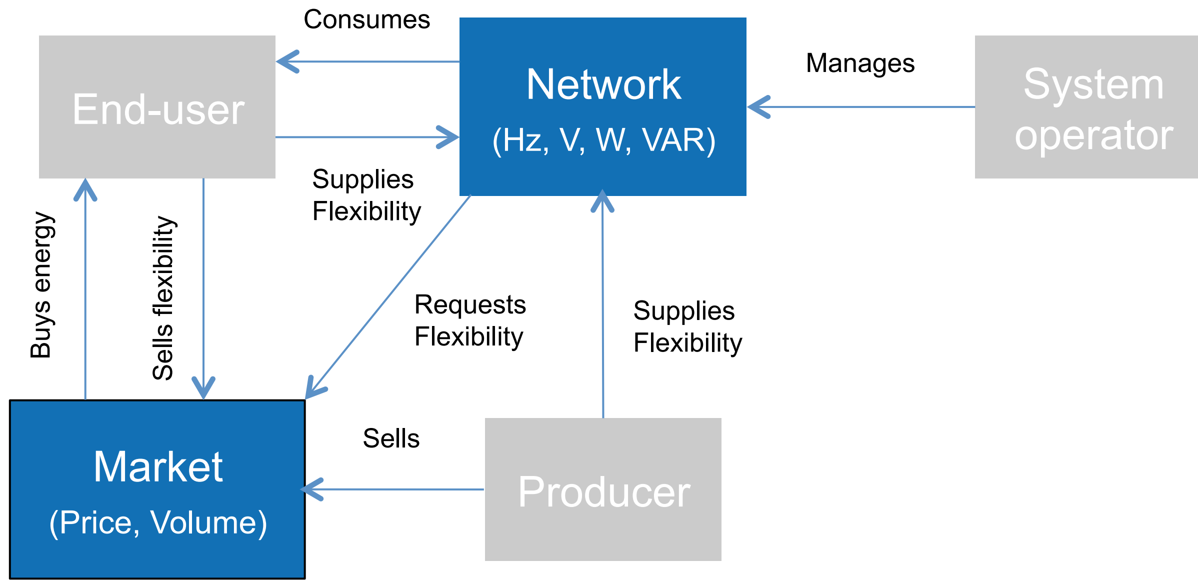
New types of load – ancillary services?

To handle imbalances, flexibility is required



Bulk producers provide flexibility today!

End-user Flexibility enters the stage

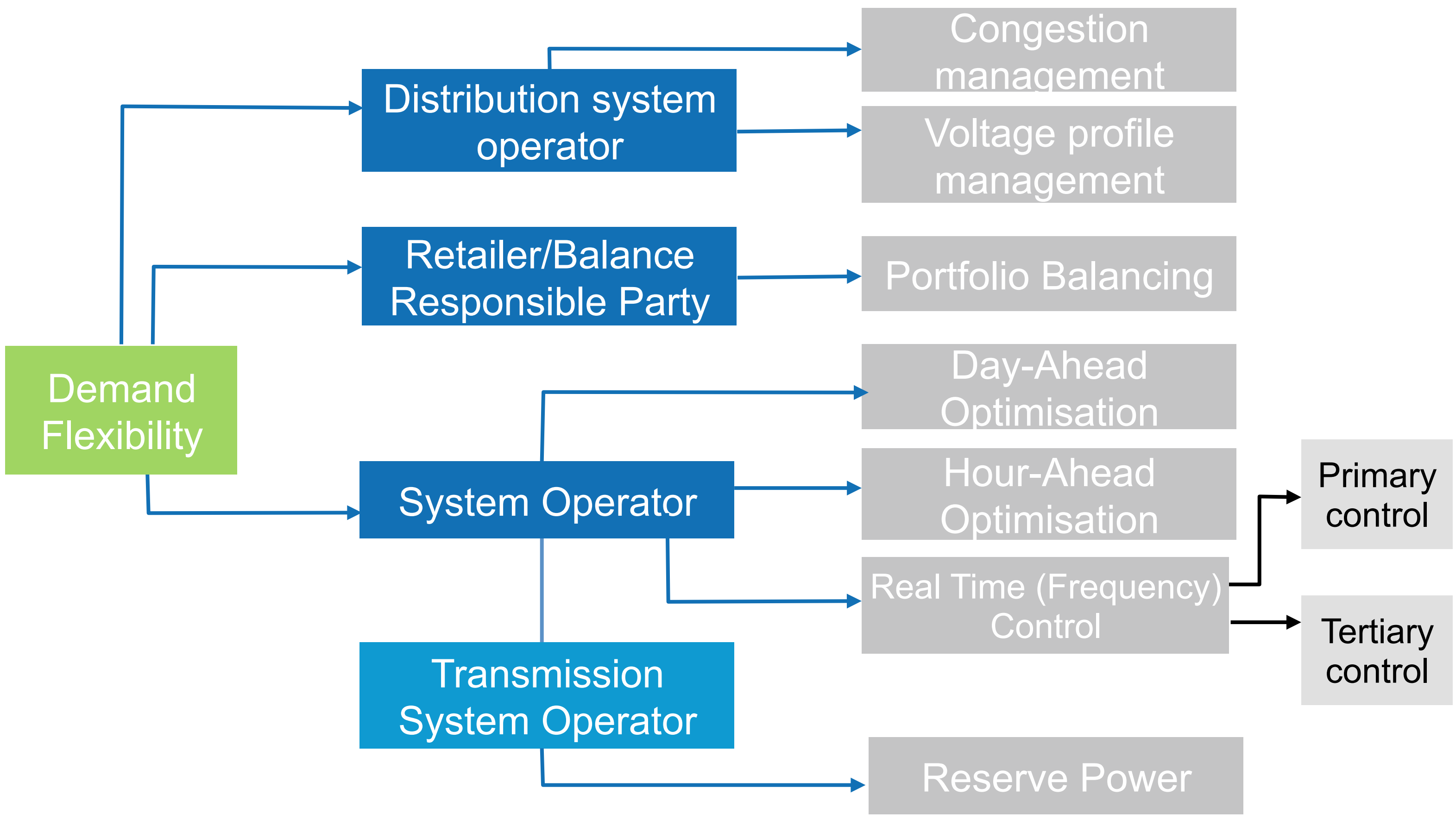


End-users may have to provide a ratio of the flexibility tomorrow

Hard-earned experiences

BEA Systems, Inc. (Nasdaq: BEAS), the E-Commerce Transactions Company(TM), announced that [redacted] one of the largest energy companies in Europe, is using BEA's WebLogic product family of industry --leading e-commerce transaction servers, along with BEA components, to build an integrated network A network that supports both data and voice and/or different networking protocols for providing 'smart building' subscription services throughout Sweden. The services let customers remotely monitor their refrigerators, ovens, electricity consumption and power mains status, and control their burglar alarms and heating and air conditioning air conditioning, mechanical process for controlling the humidity, temperature, cleanliness, and circulation of air in buildings and rooms.. [redacted] estimates that, before the end of next year, 150,000 Swedish households will be using the new services, and hopes to add 200,000 new customers a year en route to a customer base of one million households within five years.

Value can be sought on several different markets



C. Sandels, K. Zhu, and L. Nordström, "Analyzing fundamental aggregation functions in power systems," in 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies Europe 2011, Manchester, UK.

Q. Lambert, C. Sandels, and L. Nordström, "Stochastic Evaluation of Aggregator Business Models - Optimizing Wind Power Integration in Distribution Networks," in 18th Power System Computation Conference, 2014,

The inherent value in flexibility

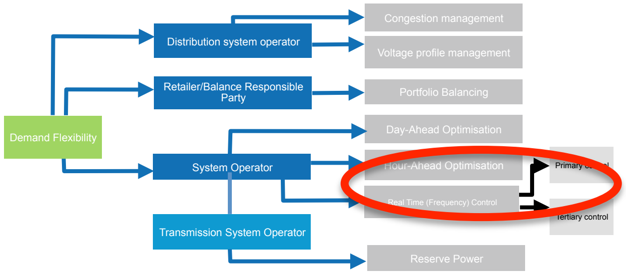
- Focus on correlation between CO_2 content and electricity price to investigate alternative forms of incentives
- Study of potential end-user savings on three markets (UK, Ontario & Sweden)
- Assuming 1kW shifted from peak-hour every day, main point being correlation with CO_2 reduction potential

TOU Shift to nearest min price hour	Peak Hour	Cost difference	CO2 footprint difference
Great Britain	5pm	-29%	-10%
Ontario*	5pm	-46%	-4%
TOU shift to min price hour with min CO2 footprint	**Peak Hour**	**Cost difference**	**CO2 footprint difference**
Great Britain	5pm	-29%	-14%
Ontario*	5pm	-46%	-31%
RTP Shift	**Peak Hour**	**Cost difference**	**CO2 footprint difference**
Great Britain	5pm	-36%	-12%
Ontario*	5pm	-61%	-30%
Sweden	5pm	-23%	36%

* For Ontario, data from December 2012 to June 2013 was used. For Sweden and Great Britain, data from the full year of 2011 was used.

P. Stoll, N. Brandt, and L. Nordström, “Including dynamic CO2 intensity with demand response,” Energy Policy, vol. 65, pp. 490–500, Feb. 2014.

Control market – Freeze Storage

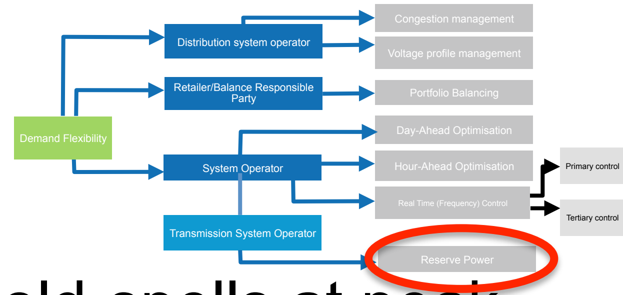


- Portfolio of Freeze Storage Bids on Swedish control market
  - Total load P_{tot}=15 MW
  - Returning to T_{nom} end of day
  - Up & down regulation, 5 MW bid minimum
  - Cost of control equipment negligble
  - Assuming 5 hours per day used for recovery.
- Formulated as Optimisation problem, bid size and cold debt repurchase challenging constraints
- Revenues of 130kEUR per annum

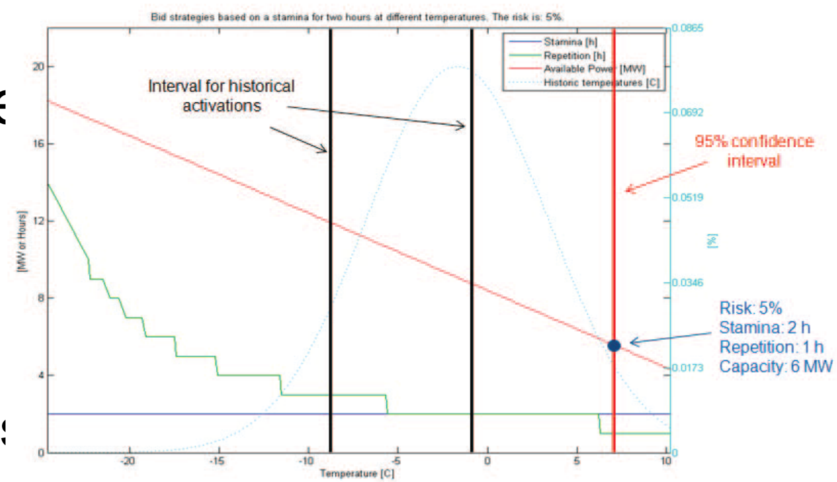
E. Candela and C. Petersson, "Analysis of a Mid-size Industry Load Management Aggregator on the Swedish Nordic Control Market," KTH - Royal Institute of Technology, 2013.

Peak Power Reserve Market

- Aggregating TCL for emerg-ency load reduction

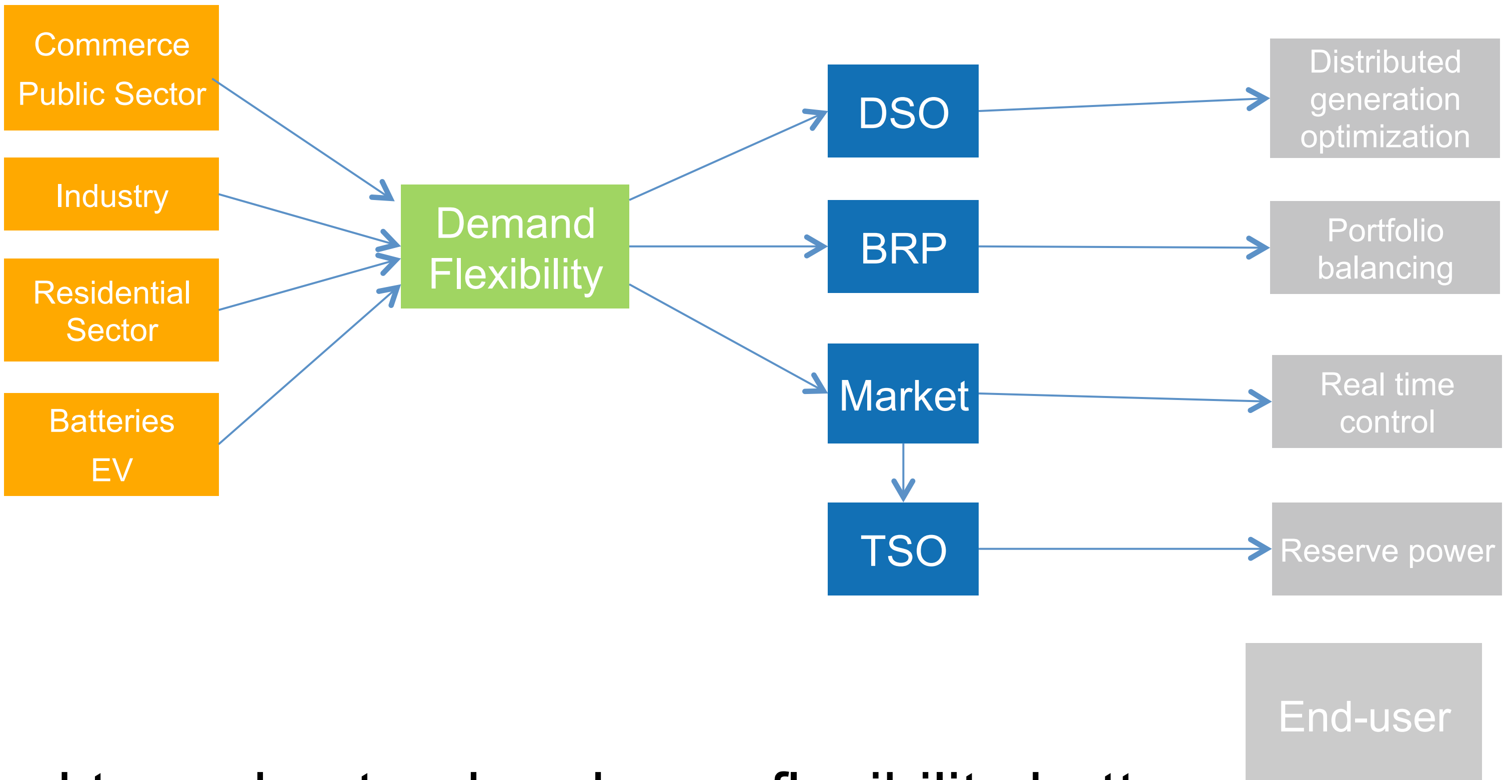


- Swedish setting – typical case are cold-spells at peak load week-days with production deficit – rare occasions.
- Market rules require:
- Bids placed 6 months in advance
  - Very careful bidding to hedge risks
- 24 hour readiness regardless of temperature
  - Large span of available resources mu be contracted



C. Sandels, M. Hagelberg, and L. Nordström, "Analysis on the profitability of demand flexibility on the swedish peak power reserve market," in IEEE PES Innovative Smart Grid Technologies (ISGT), 2013,

Common Denominator for all markets



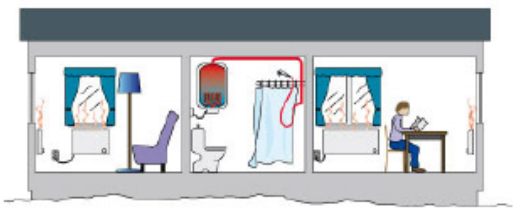
Need to understand end-user flexibility better

Outline

- Finding Value in Demand Response
- Modeling Residential Flexibility
- Case Study – Congestion Management
- Ongoing work:
  - Modeling Commercial Flexibility
- Next steps

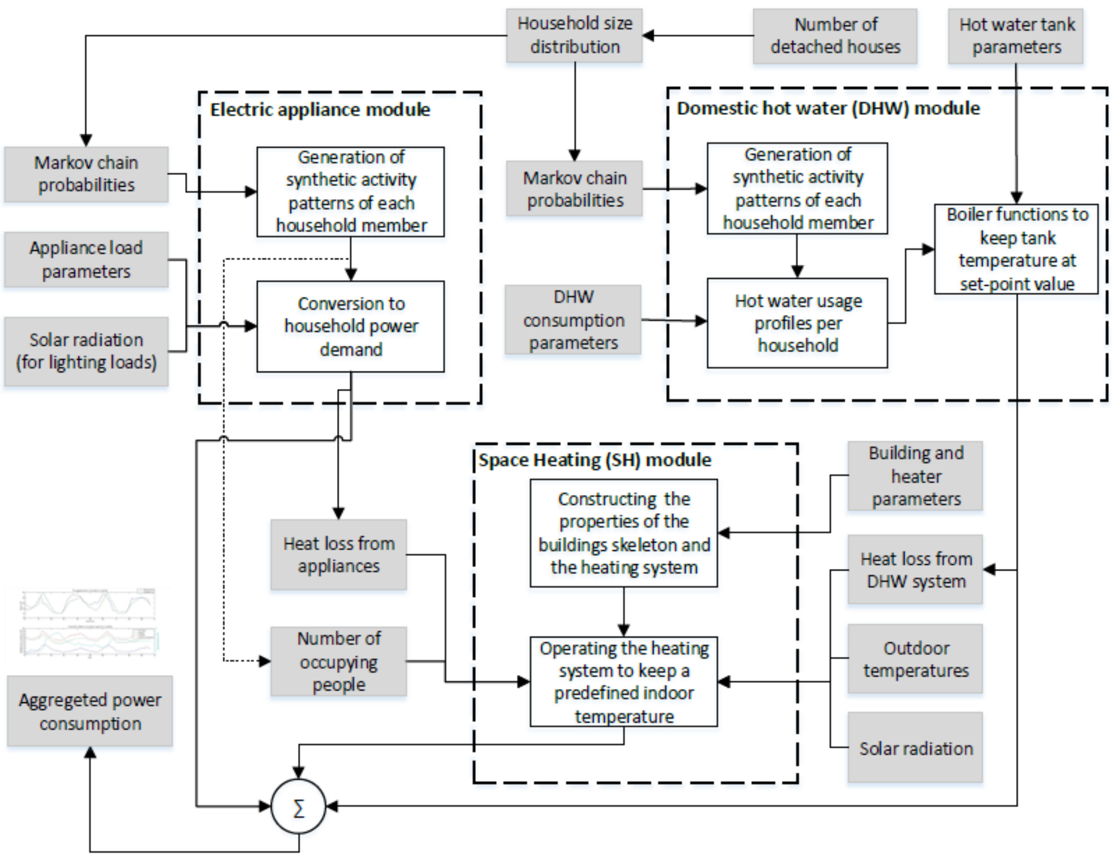
Modeling Residential Consumers

Residential Sector



- A simulation model which generates (forecasts) active power profiles for a population of “Swedish” detached houses.
- Built on non-homogeneous Markov chains that model consumer behavior combined with energy consumption for heating and hot water.
- Detached house architectures of the Swedish building stock are developed to reflect heating consumption patterns
- The model is intended to produce data that are of high detail when it comes to temporal and spatial attributes

Model components



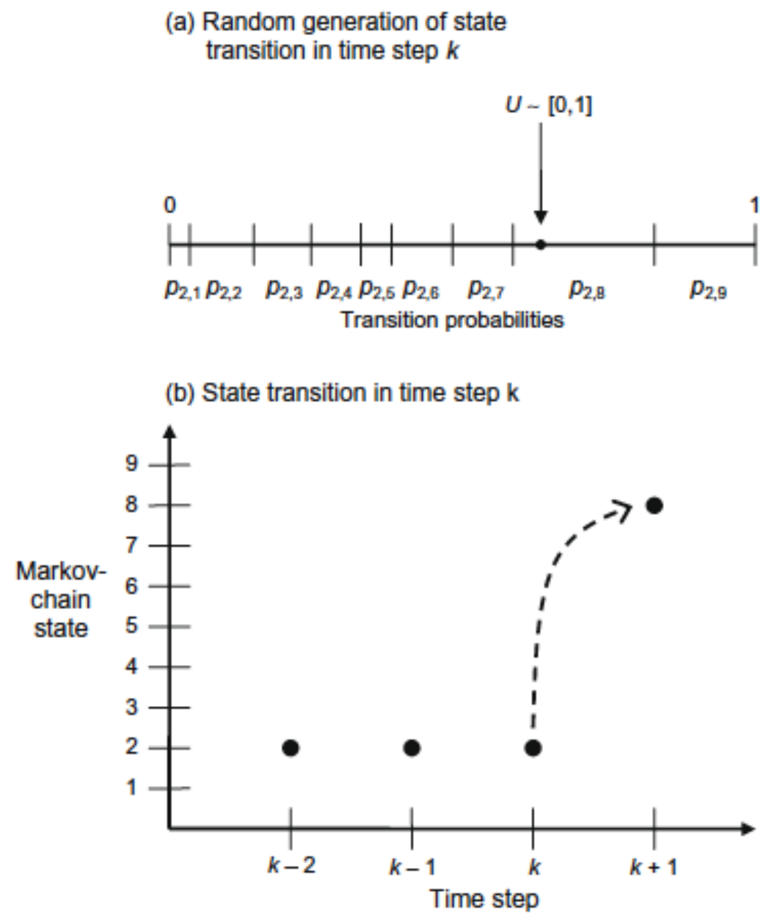
Appliances
Domestic Hot Water
Space Heating

C. Sandels, J. Widén, and L. Nordström, "Forecasting household consumer electricity load profiles with a combined physical and behavioral approach," *Applied Energy*, Vol: To appear, 2014

Appliances Model

- Markov chain models occupant state
- For each household member there is a transition matrix $T_i(k)$
- 9 activity types including away
- Markov-chain is non-homogenous
- Transition probabilities built on Time-Use st[illegible]96 households.

$$p_{ij}(k) = \frac{n_{ij}(k)}{n_i(k)}$$

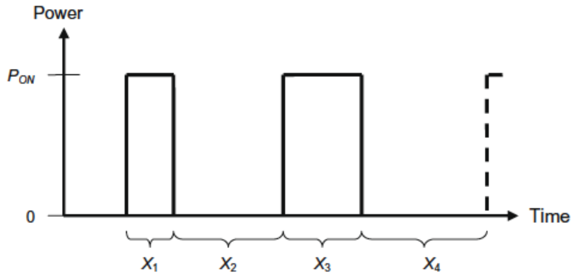


- Time-step k = 1 min

J. Widén and E. Wäckelgård, “A high-resolution stochastic model of domestic activity patterns and electricity demand,” Appl. Energy, no. 87, pp. 1880–1892, 2010.

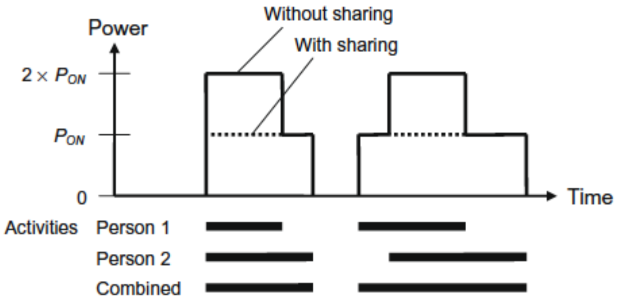
From activity to electricity use

End-use	j	Model routine	Parameters	Activities	Sharing
Cold appliances	1	Cyclic demand	P_{ON}, duration curves for $\Delta t_{ON}, \Delta t_{OFF}$	–	Yes
Lighting	2	Daylight-dependent	$P_{ABSENT}, P_{INACTIVE}, P_{MAX}, P_{MIN}, L_{LIM}, Q, \Delta P$	1–10	No
Cooking	3	Conversion scheme A	P_{ON}	3	Yes
Dishwashing	4	Conversion scheme B	$P_1, \ldots, P_N, k_1, \ldots, k_N$	4	Yes
Washing	5	Conversion scheme B	$P_1, \ldots, P_N, k_1, \ldots, k_N$	5	Yes
TV	6	Conversion scheme C	$P_{ON}, P_{STANDBY}$	7	Yes
Computer	7	Conversion scheme C	$P_{ON}, P_{STANDBY}$	8	No
Stereo	8	Conversion scheme C	$P_{ON}, P_{STANDBY}$	9	No
Additional	9	Constant demand	P_{ADD}	–	No

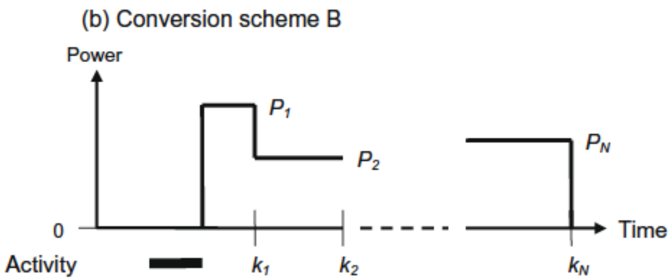


Randomised Cyclic loads

Direct activity loads



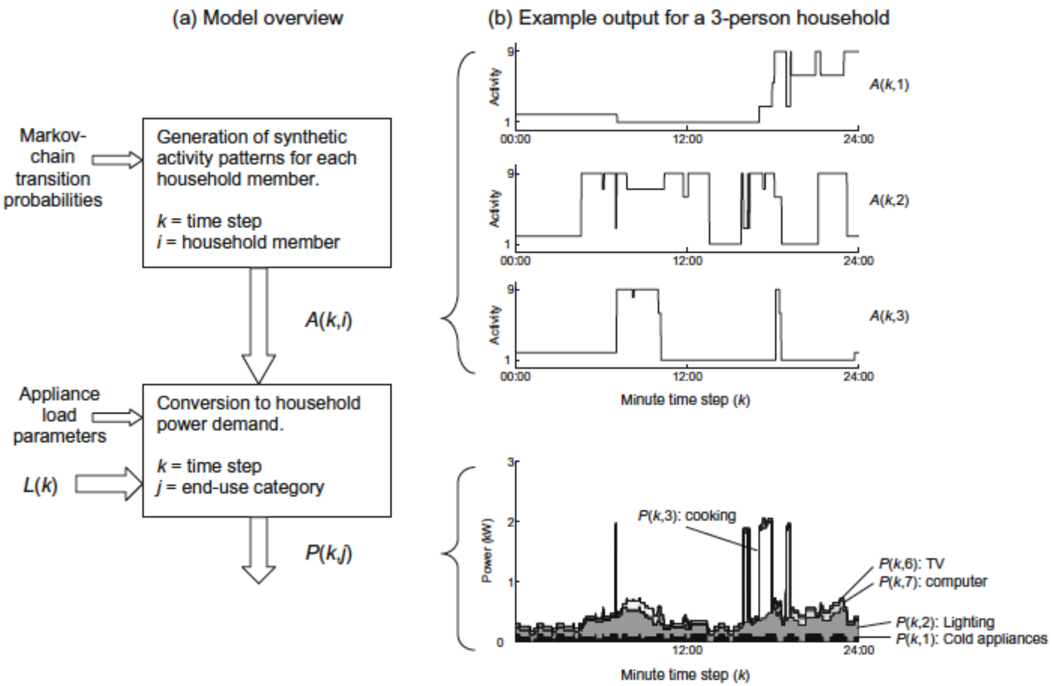
Shared loads



Indirect activity loads

From activity to electricity use

Parameter	Value
$P_{FRIDGE,ON}$	50 (W)
$P_{FREEZER,ON}$	80 (W)
$P_{COOKING,ON}$	1500 (W)
$P_{DISHWASHING,1}$	1944 (W)
$P_{DISHWASHING,2}$	120 (W)
$P_{DISHWASHING,3}$	1920 (W)
$k_{DISHWASHING,1}$	17 (min)
$k_{DISHWASHING,2}$	57 (min)
$k_{DISHWASHING,3}$	73 (min)
$P_{WASHING,1}$	1800 (W)
$P_{WASHING,2}$	150 (W)
$k_{WASHING,1}$	20 (min)
$k_{WASHING,2}$	110 (min)
$P_{TV,ON}$	100 (W)
$P_{TV,STANDBY}$	20 (W)
$P_{COMPUTER,ON}$	100 (W)
$P_{COMPUTER,STANDBY}$	40 (W)
$P_{STEREO,ON}$	30 (W)
$P_{STEREO,STANDBY}$	6 (W)
$P_{ADD,DETACHED}$	53 (W/person)
$P_{ADD,APARTMENT}$	11 (W/person)



Domestic Hot Water

- Thermostat works to keep $T_{tank}=T_{ref}$ using P_{boil}, without deadband.
- Modeled as water-tank with outlet as a function of sub-set of activities (shower & bath for simplicity)
- Energy drained per household i time t, activity a

$$Q_{i,drain}(t)=V_{i,a}(t)Cp_{water}(T_{outlet}-T_{inlet})$$

- Energy drained as loss to surrounding environment

$$Q_{i,loss}(t)=\lambda_{tank}(T_{tank}(t)-T_{amb}(t))$$

T^{ref}_{tank}	80 °C	To avoid bacterial growth, it is recommended to maintain a high temperature [25]. Numerical value taken from a manufacture [26]
T_{inlet}	10 °C	Is equal to the soil temperature [13], which varies between seasons. The value is assumed to be constant for simplicity, and taken from [17]
T_{outlet}	40 °C	Assumed to be a preferred water temperature for baths and showers
T_{max}	100 °C	[26]
P_{boil}	3.0 kW	Common boiler capacity for larger DHW tanks [26]
Cp_{water}	1.17 Wh/kg°C	For a water temperature of 80 °C [9]
V_{tank}	300 litres	Ordinary size for a household with four members [26]
$V^{flow}_{i,a=shower}$	10 liters/min	Hot water flow for shower activities [17]
$V^{flow}_{i,a=bath}$	140 liters	Hot water requirement for a bath [17]
λ_{tank}	1 W/°C	The tank is assumed to be medium insulated [25]

Space Heating

- Thermostat works to keep $T = T_{ref}$ using P_{heat}
- Disturbances introduced by:

Occupancy,

$$Q_{occ}(t) = N_i(t) * P_{met}(t)$$

Sun irradiation

$$Q_{sun}(t) = \alpha_{red} A_{window} P_{sun}(t)$$

Ventilation & Leakage

$$Q_{loss}(t) = (T(t) - T_{out}(t))(\lambda_{trans} + \lambda_{vent})$$

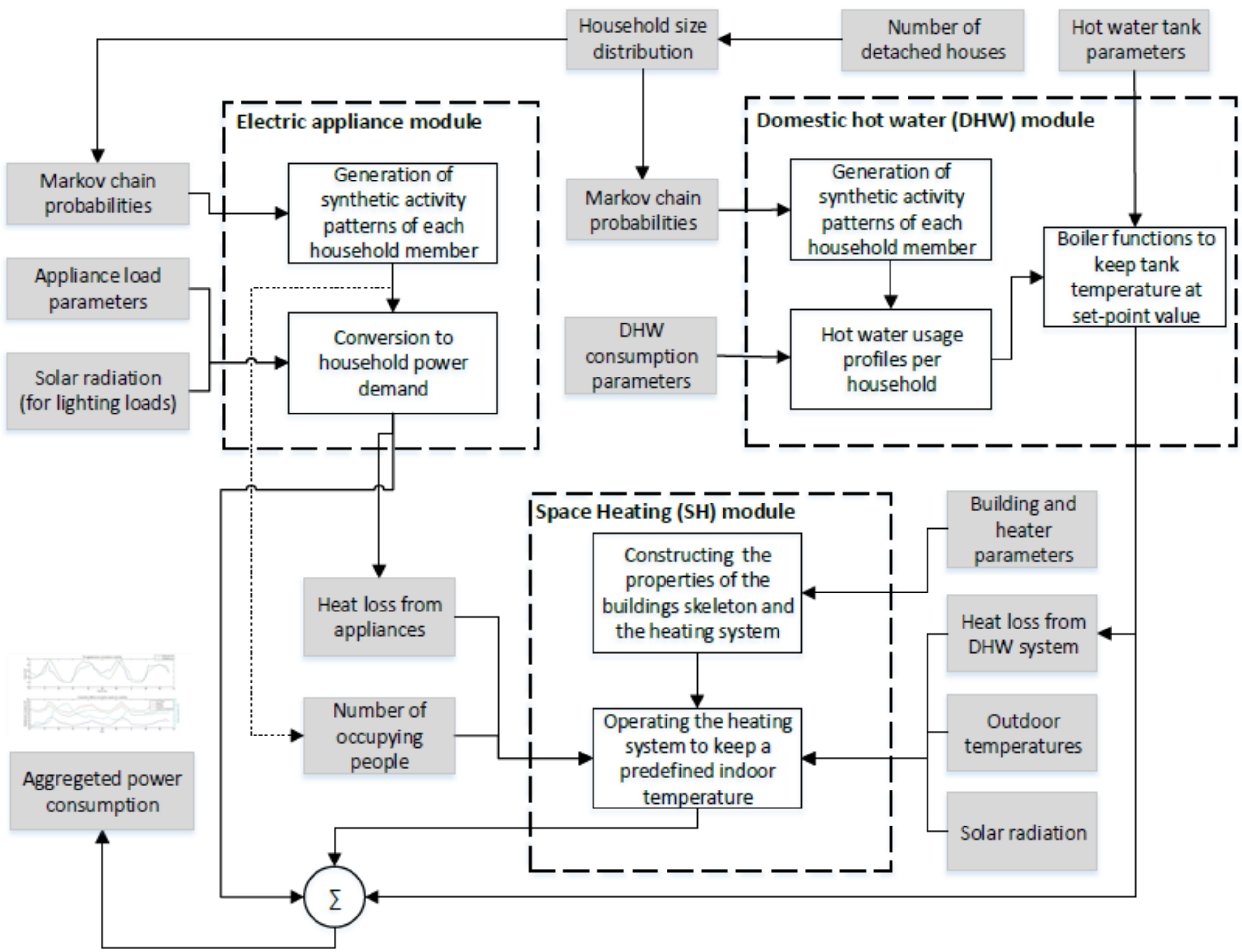
Appliance use

$$\boldsymbol{Q_{app}(t,n) = \gamma_{app} \beta_n(t) * P_{app}(n)}$$

Temperature

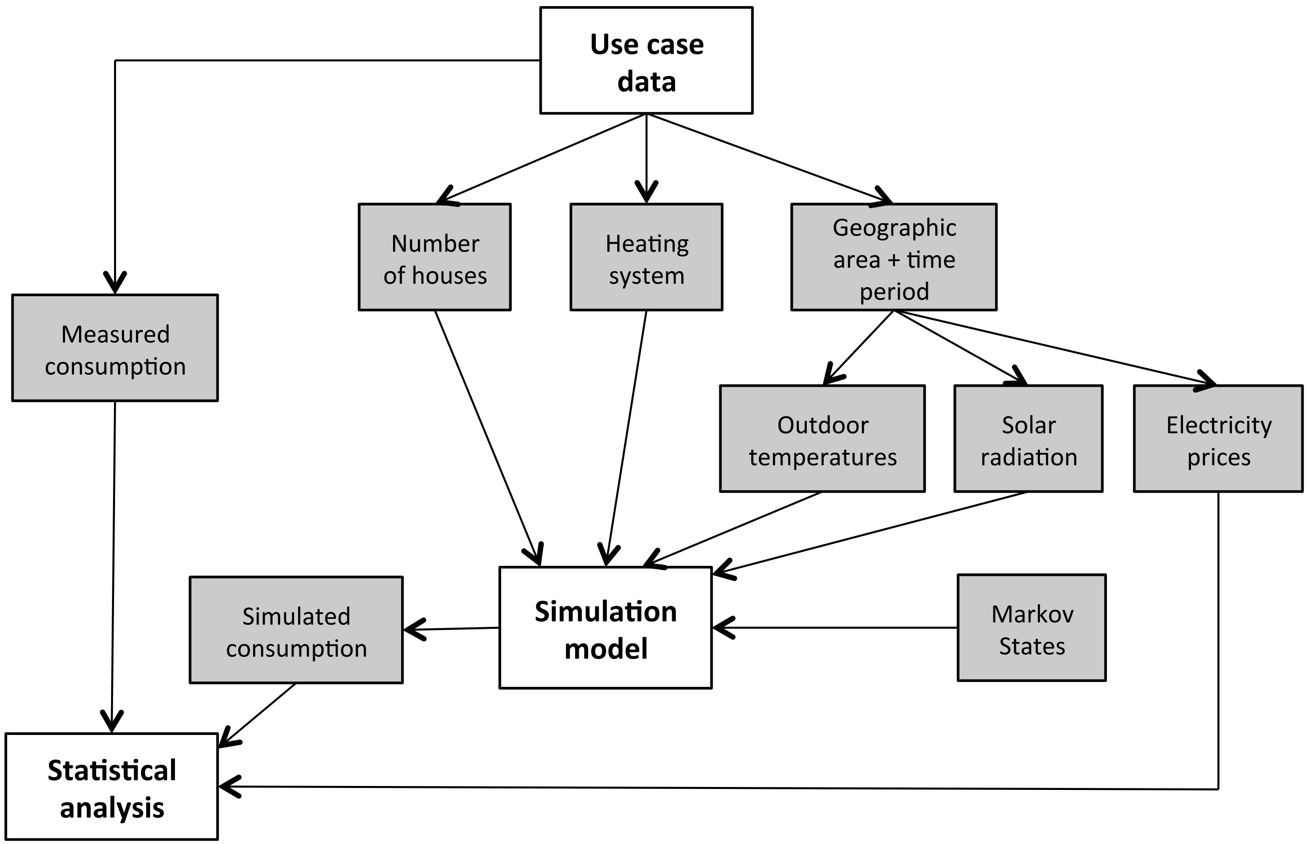
$$T(t+1) = T(t) + \frac{Q_{heat}(t) + Q_{sun}(t) + Q_{occ}(t) + Q_{app}(t) - Q_{loss}(t)}{\tau(\lambda_{trans} + \lambda_{vent})} \Delta t$$

Model components



C. Sandels, J. Widén, and L. Nordström, "Forecasting household consumer electricity load profiles with a combined physical and behavioral approach," *Applied Energy*, Vol: To appear, 2014

Model validation



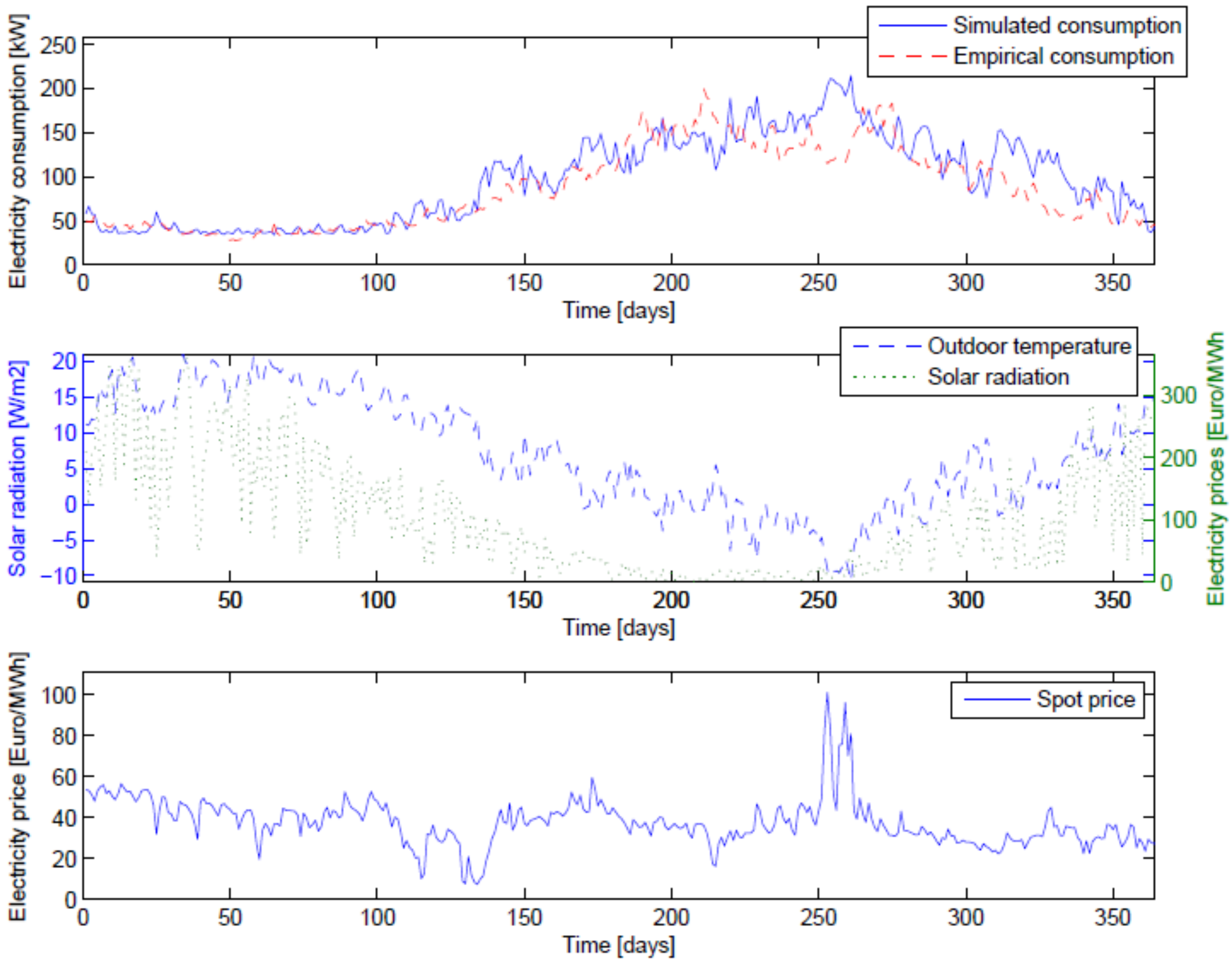
Validation data

- 41 detached houses, all electric heated
- 365 days 1-hour load profile.

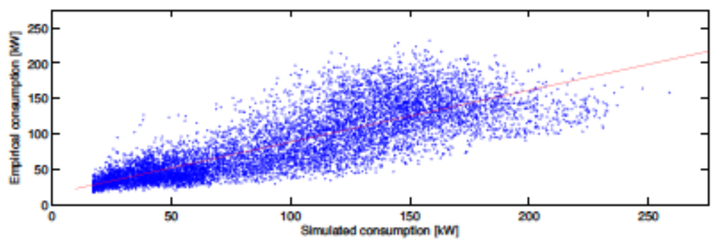
Table A1: Simulation parameters and initial data

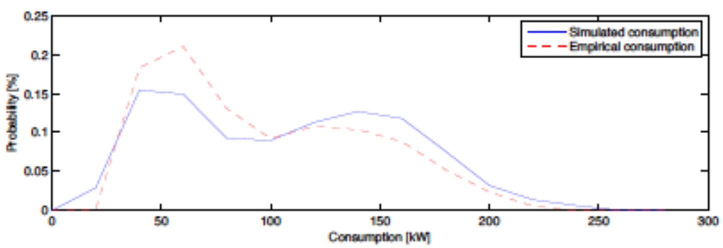
Parameter	Numerical Value	Description
Δt_{app}	1 min	The simulation time step for the electricity appliance module. This is believed to be sufficient to reflect the variation in appliance usage by the occupants [16]
Δt_{DHW}	1 min	The simulation time step for the DHW module. Set according to Δt_{app}
Δt_{SH}	1 h	The simulation time step for the SH module. The data for outdoor temperatures and solar radiation are only available for an hourly time resolution. In addition, it is appreciated that the static variation of the building's heating system is slow [24]
N_{det}	41 houses	Obtained from the use case data (see section 3)
β_{family}	1,...,7 members	The number of possible household members per detached house [18]
X_{family}	X_{family} ∊Uniform distribution	The following probabilities are given for the different household sizes β_{family} (starting from 1 member, and continuing to 7 members): 0.068, 0.379, 0.25, 0.22, 0.058, 0.01, 0.01 [18]

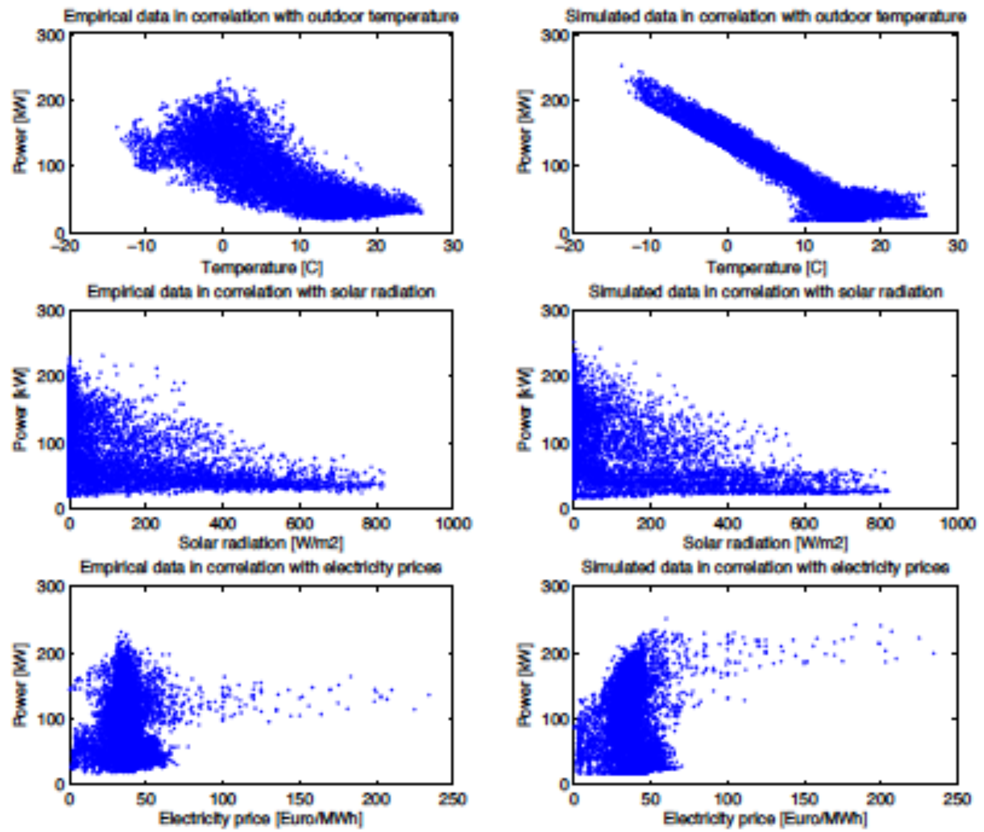
Validation results



Validation results







N.B. Model assumes use are are price insensitive

Outcome

- Load forecasting tool using minimal input data

  Number of households, means of heating.

- Considering exogenous variables

  Sun irradiation & outside temperature.

- Controllable parameters

  P_{heat} & P_{boil}

- Capturing the impact on comfort factors

  T_{in} & Q_{tank}

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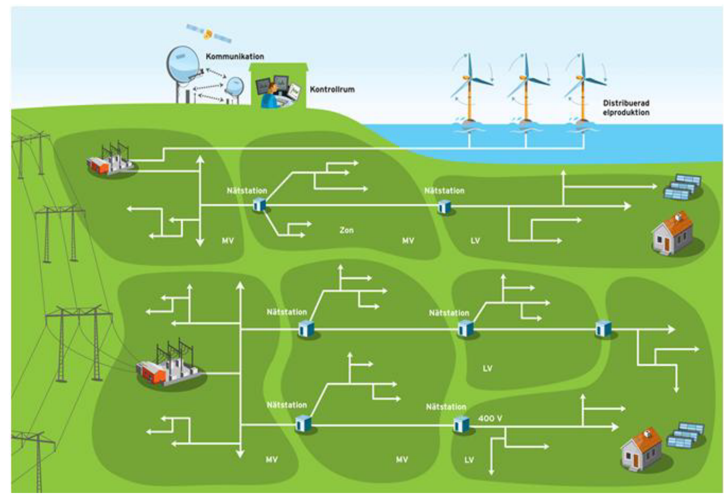
Ongoing work:

- Modeling Commercial Flexibility

Next steps

Smartgrids Gotland National Testbed

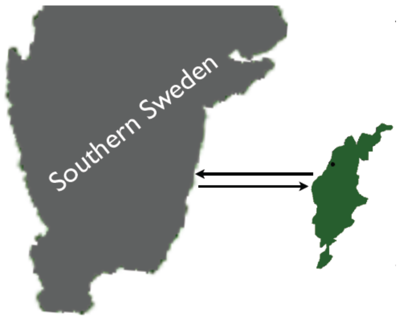
- Maximise Wind utilisation, minimise export to mainland
- Consumer engagement via price incentives directly to smart devices

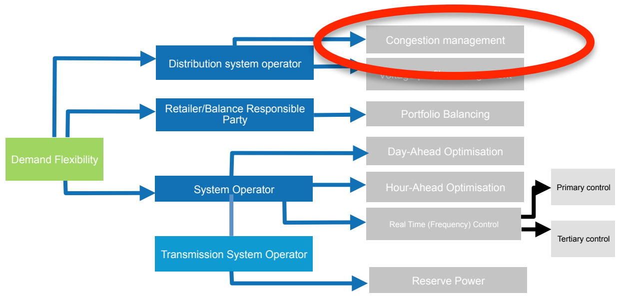


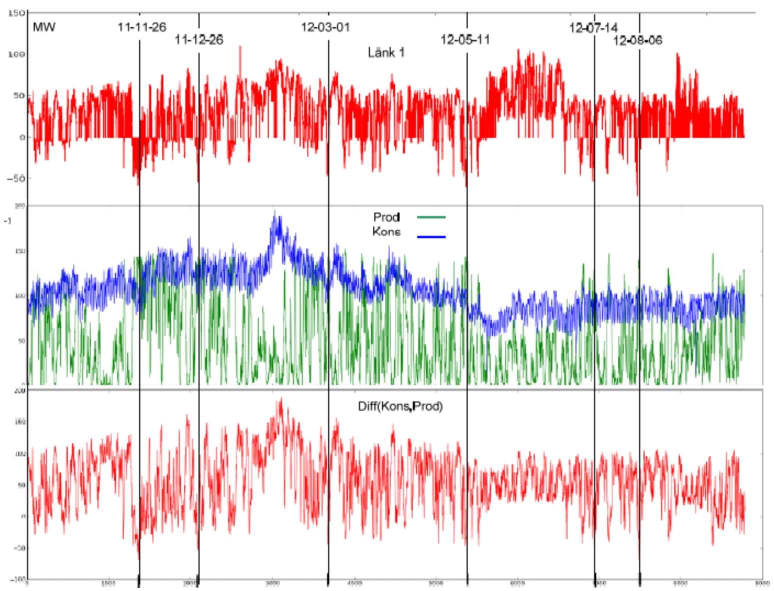
- Improve power quality (interruptions and voltage)
- Cost reductions at utility and minimised risk for QoS failure charges

GEAB · VATTENFALL · ABB · SVENSKA KRAFTNÄT · Schneider Electric · Energimyndigheten · KTH

Congestion management using Demand response

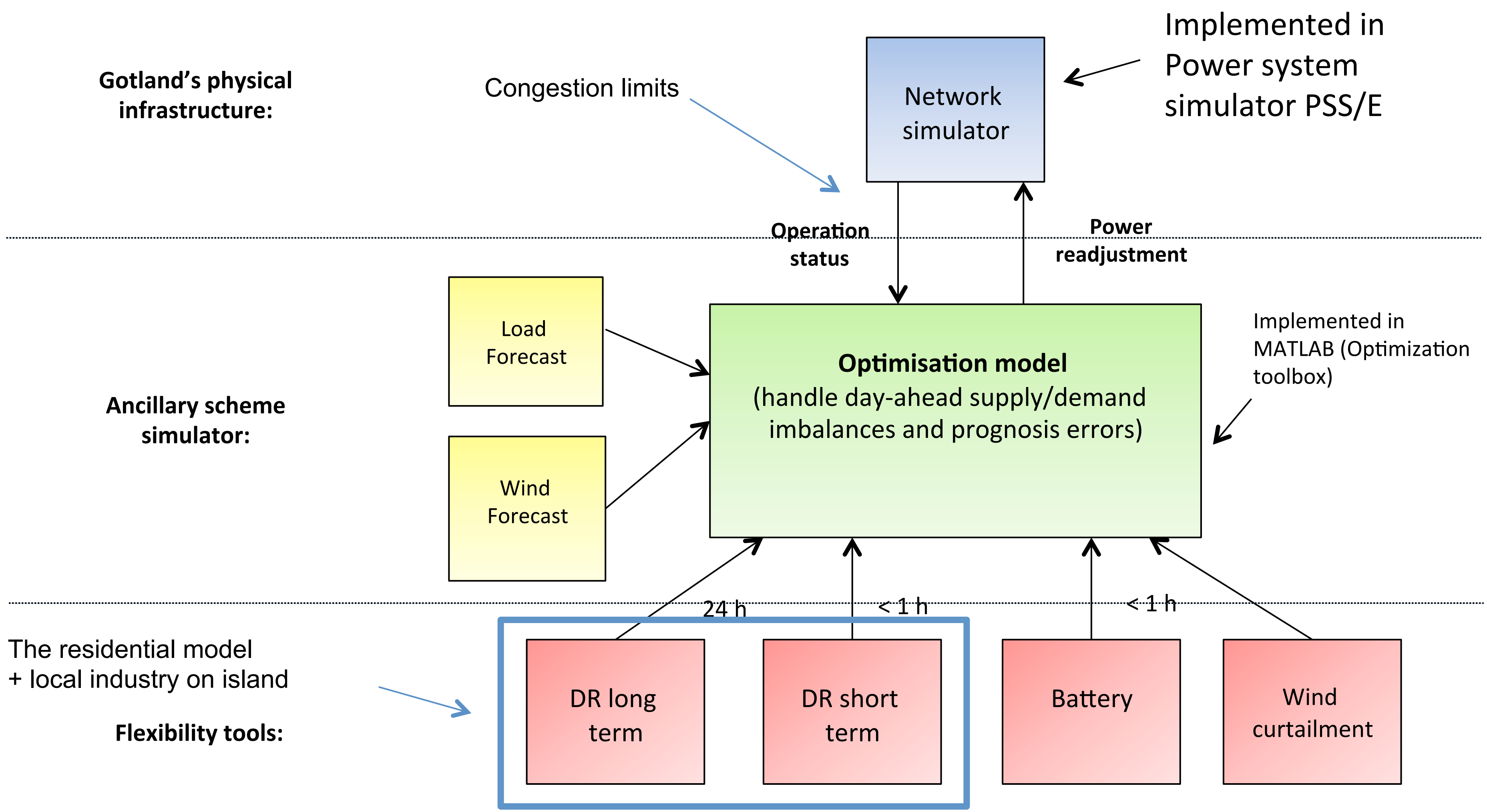




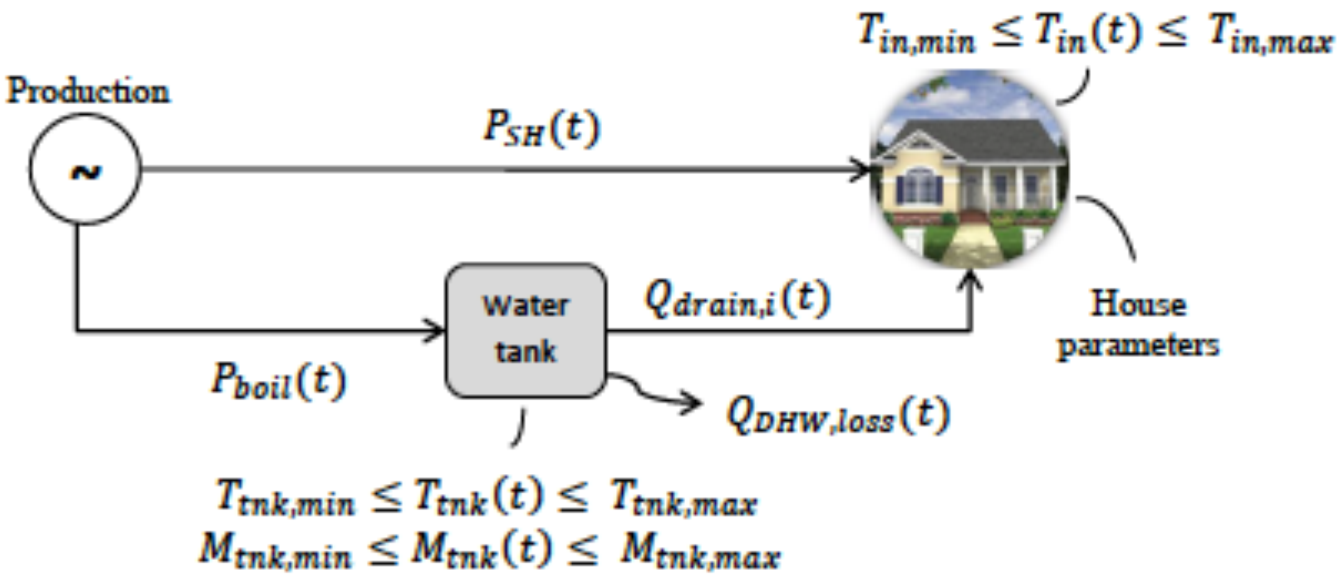


- The Gotland power system is project to within 5 years have 195 MW wind power installed => situations of export may occur
- Assessing the feasibility to balance 5 MW additional installed wind power capacity (i.e. 200 MW) in the existing distribution network of Gotland, thus deferring investment in mainland link
- Using residential clusters, industrial load and batttery energy storage could it be done? Which incentives would be needed?

Setup of the simulation platform



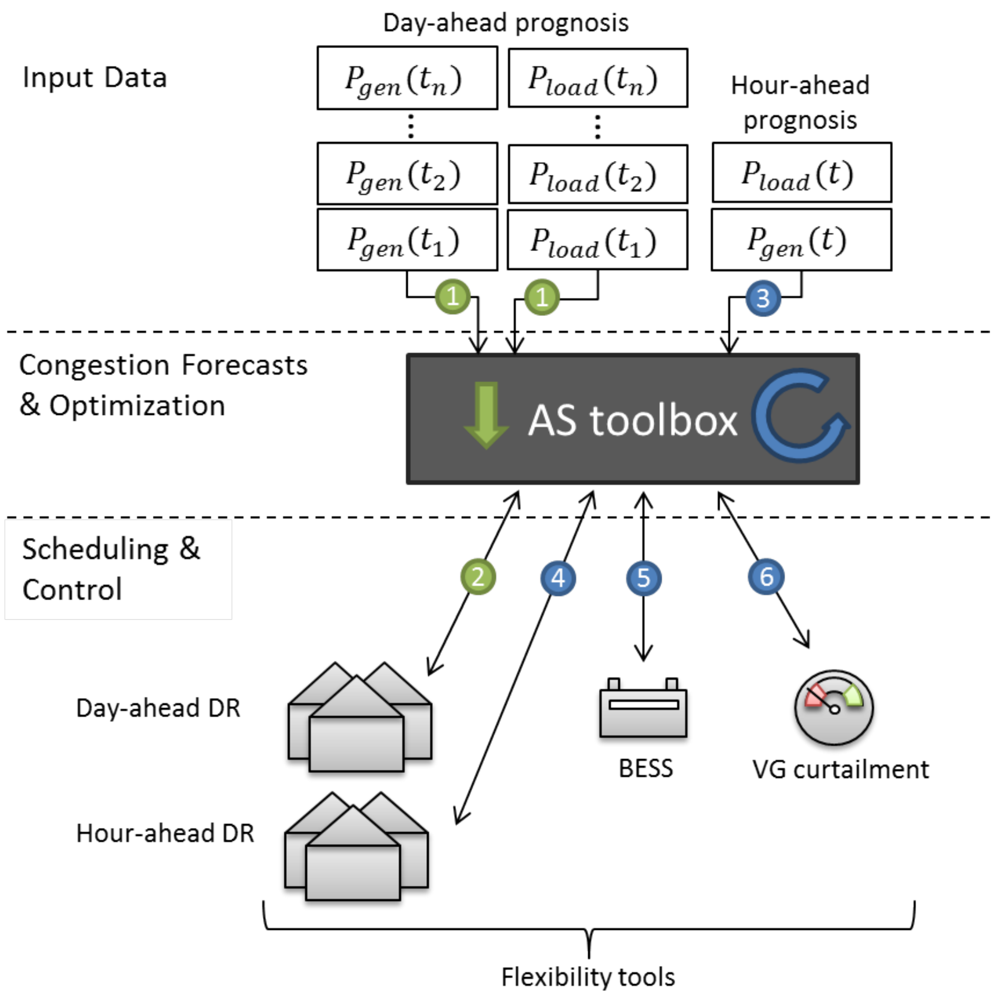
Residential Flexibility



- Indoor temperatures are allowed to vary 10% around Tref= 20°C
- Energy content of DHW tank is allowed to vary 24,6 ± 7kWh
- Temperature of DHW tank is allowed to vary between 60°C and 100°C

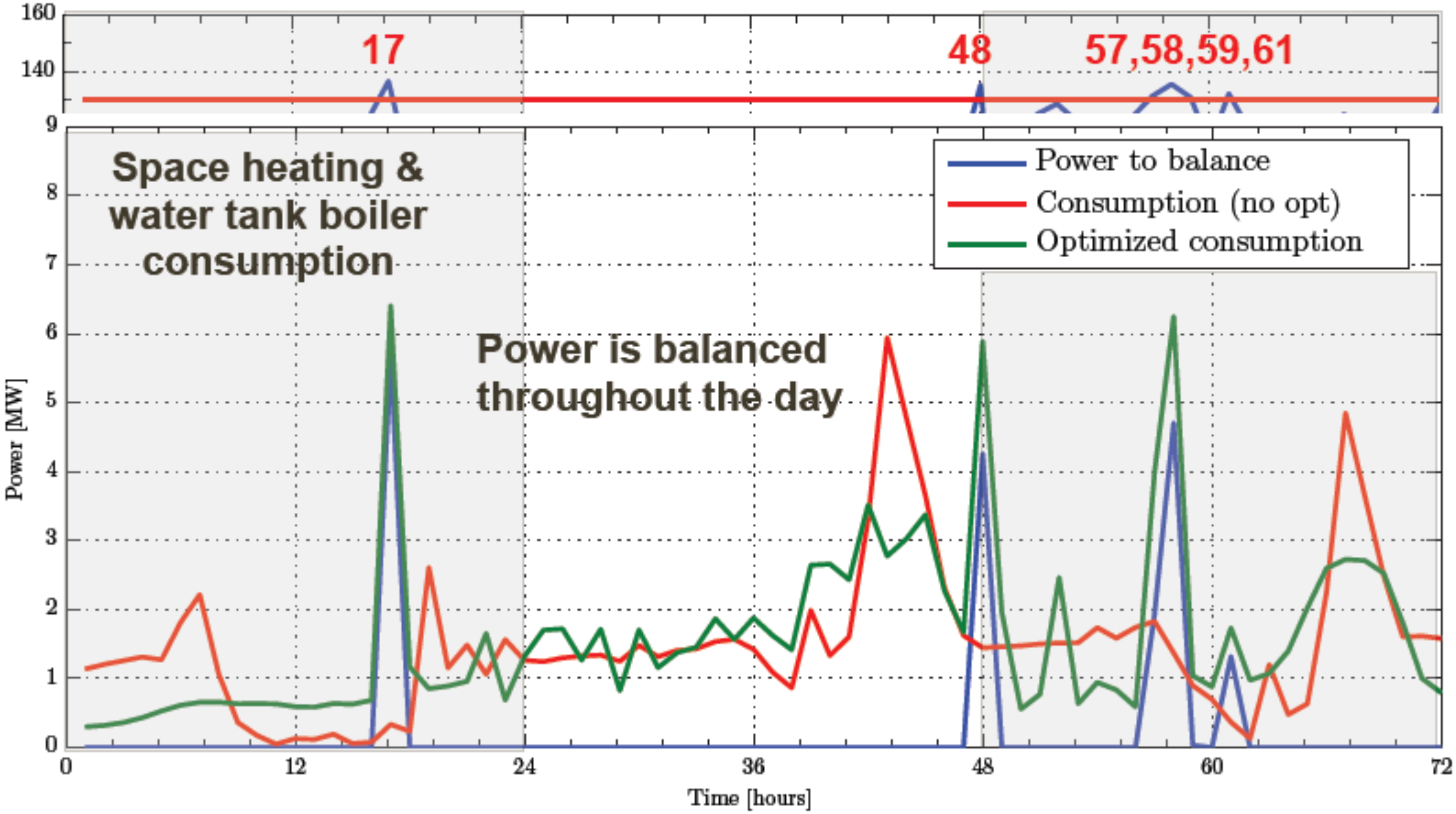
Stepwise optimisation

1. Load & production forecasts for H+25 to H+48 & Forecast for weather & sun irradiation.
2. Matched with forecasted available flexibility based on residential model - LT cluster.
3. LT cluster assumed activated. H+1 load and production forecast
4. Additional number of households - ST cluster.
5. H+1 forecast for battery storage/discharge
6. H+1 worst case Wind curtailment



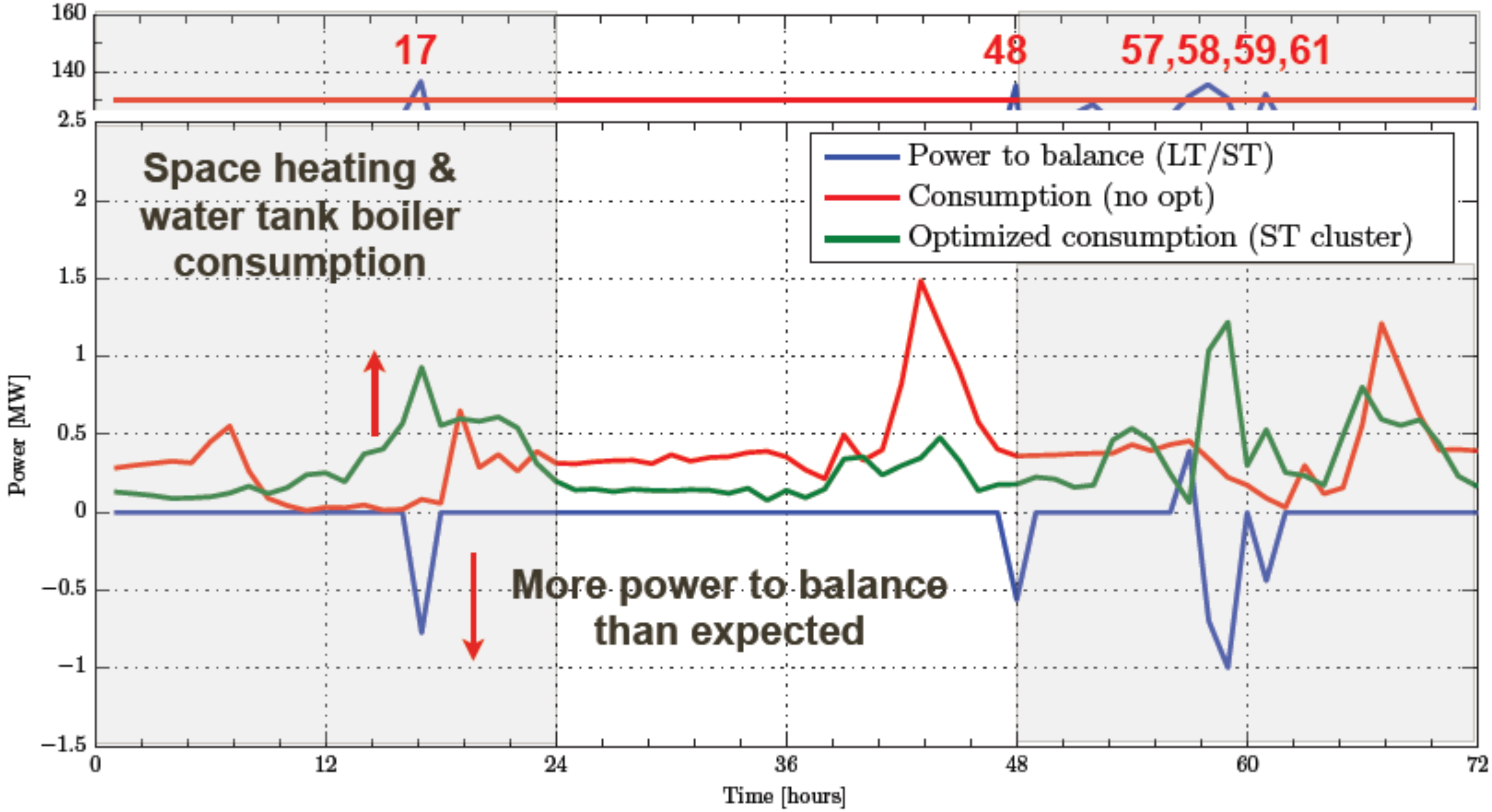
Simulation results for day-ahead demand flexibility clients

- LT Cluster consumption (900 small houses)



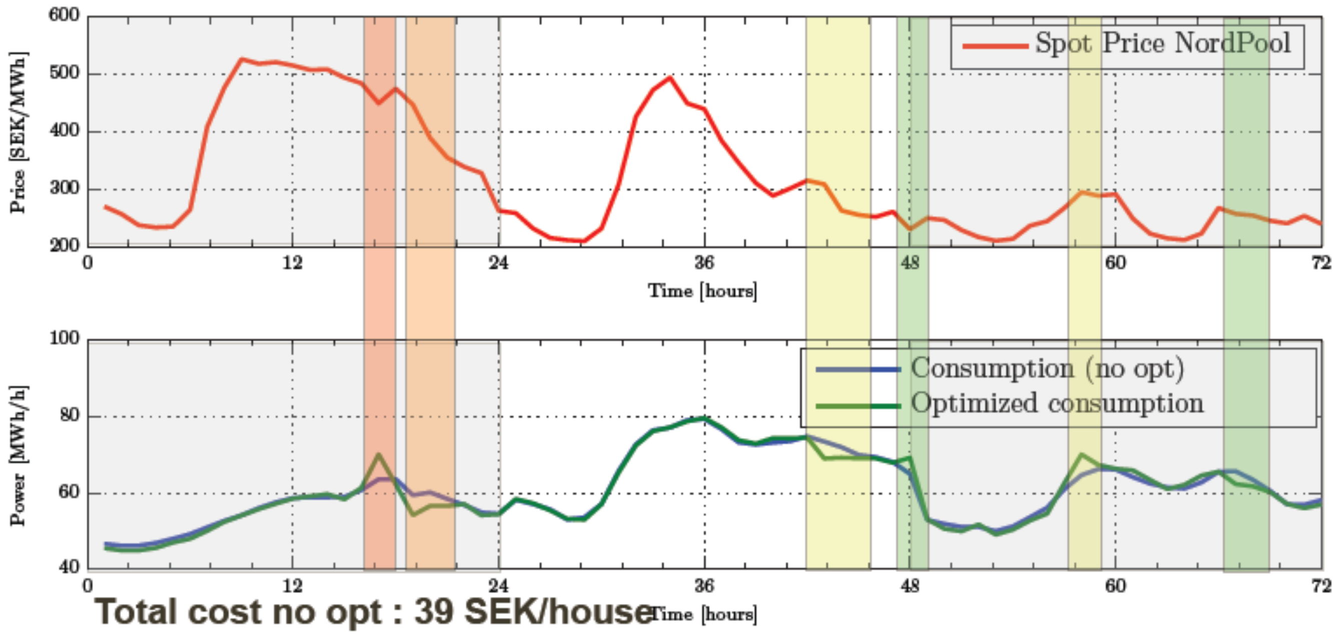
Simulation results for real-time demand flexibility clients

- ST Cluster consumption (200 small houses)



Technically feasible, But what about incentives?

- How much does optimized consumption cost the consumer?



Total cost no opt : 39 SEK/house
Total cost with opt: 83 SEK/house

- To be balanced against the cost of deferred investment in increased capacity on export link.
- Overall a positive results, since 900+200 households is a reachable amount

Outline

Finding Value in Demand Response

Modeling Residential Flexibility

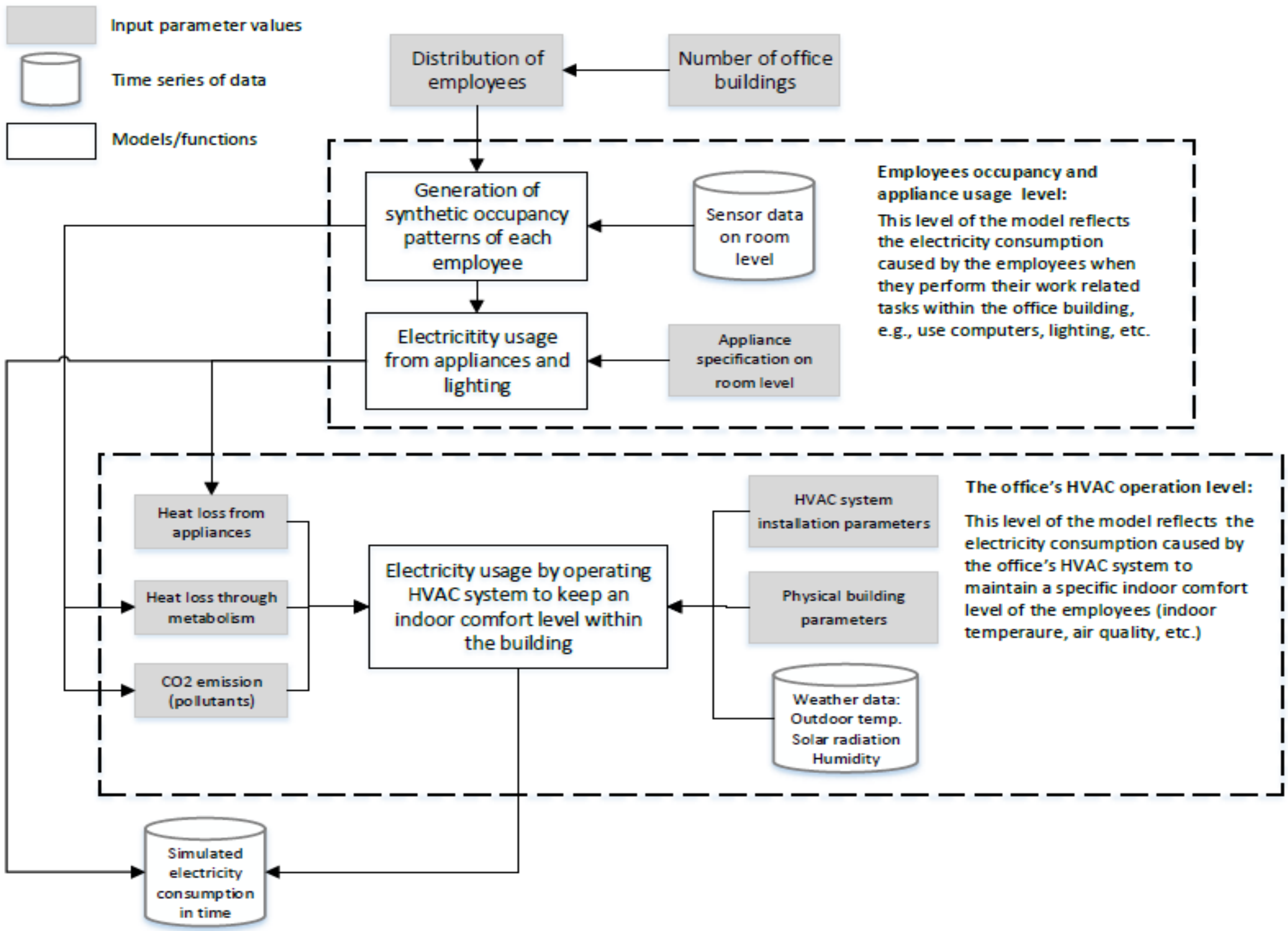
Case Study – Congestion Management

Ongoing work:

Modeling Commercial Flexibility

Next steps

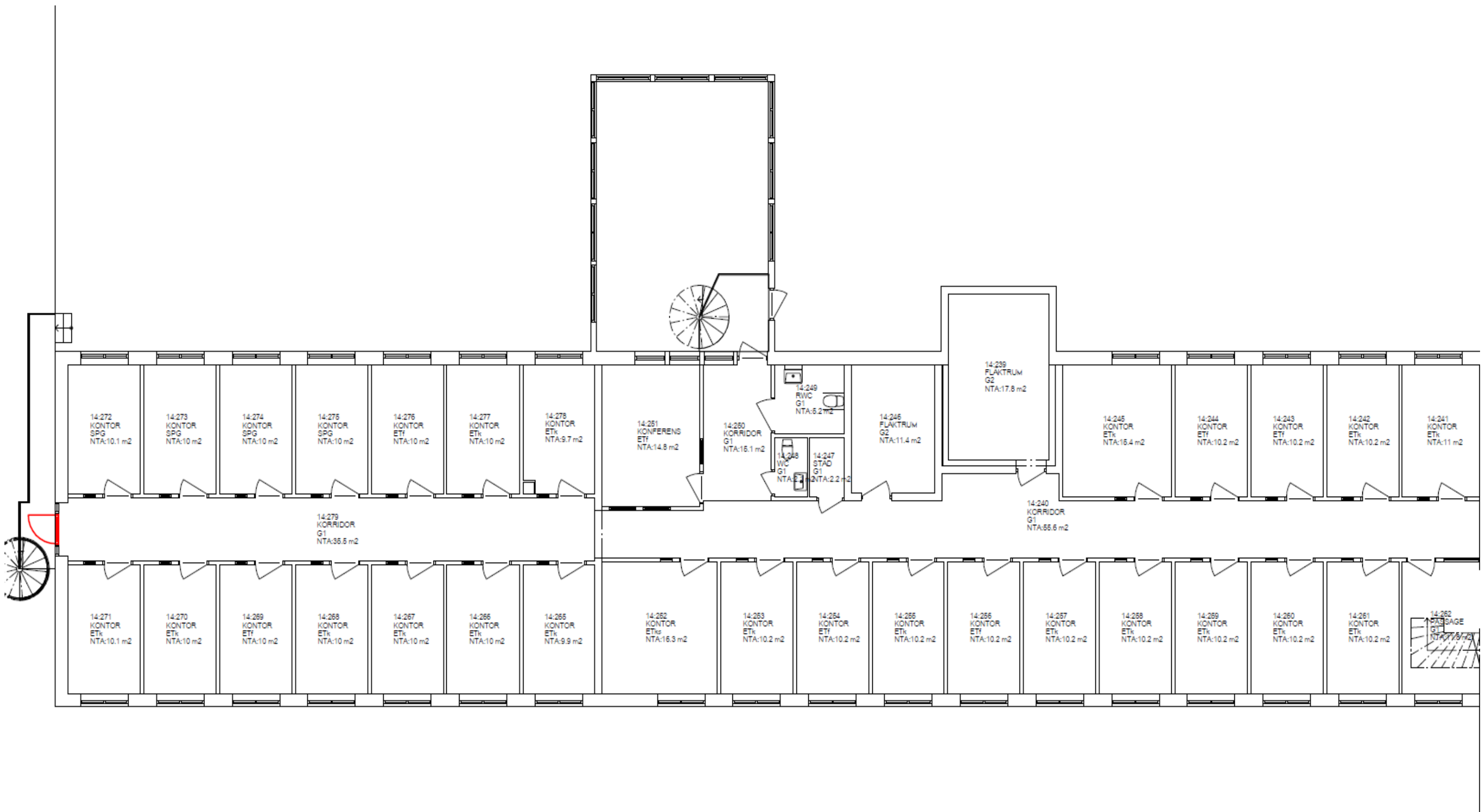
Office building meta model



Scope of the work

- Perform basic data analysis for office building data (exploratory analysis)
- Statistical test to prove significant correlation between consumption and weather and occupancy variables (ANOVA and regression)
- Developing a Markov chain occupancy model based on the sensor data
- Conduct prediction analysis with regression and the Markov chain models

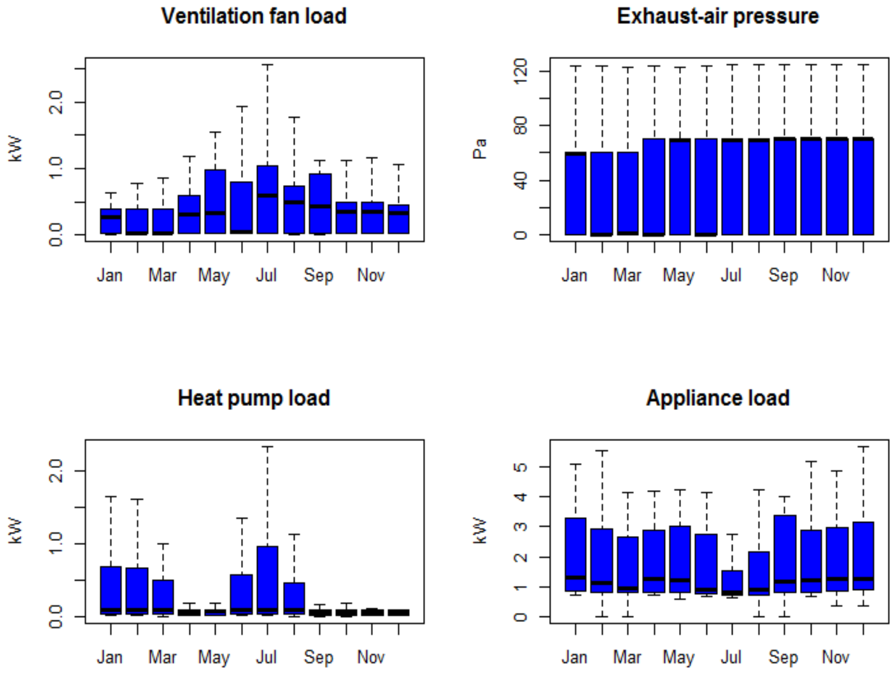
Data from built office floor extension in Borås, Sweden



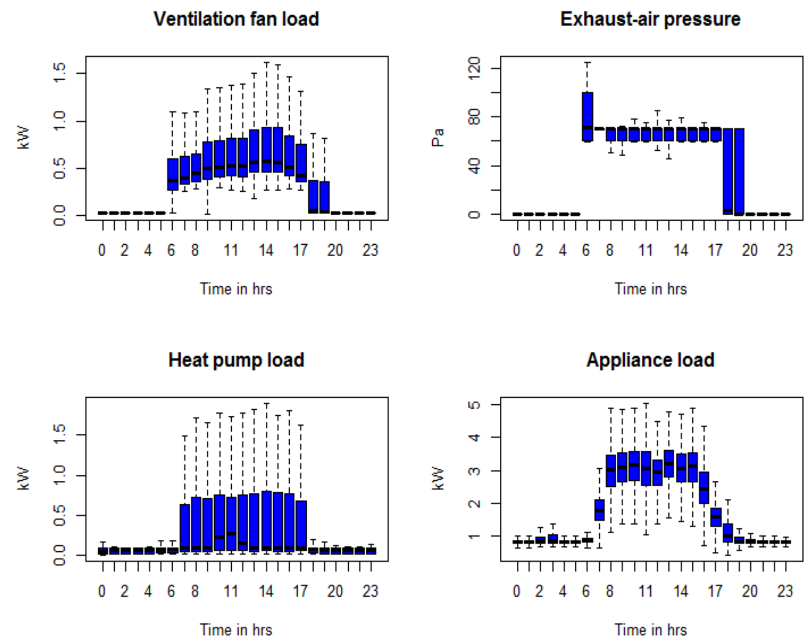
Raw time-series data used

Data	Description	Resolution
Outdoor temperature	Dry outdoor temperature time series at the premises of the office [C]	5 minutes
Daylight levels	Daylight level time series at the premises of the office [lux]	5 minutes
Solar radiation	Solar radiation data [W/m2]	Hourly
Wind speed	Wind speed data [m/s]	Hourly
Occupancy	Sensor data from 68 office rooms	Event based
Fan consumption	Power consumption data of the central ventilation system [W]	1 minute
Exhaust and supply air pressure	Exhaust and supply air pressure from the central ventilation unit [Pa]	5 minutes
Indoor temperature	Indoor temperature times series for three individual office rooms [C]	1 minute
Room electricity consumption	Electricity consumption times series for nine individual office rooms [kWh]	1 minute
Total consumption	Electricity consumption times series for the whole building [W]	1 minute
Heat pump consumption	Power consumption from heat pump (main application is cooling) [W]	1 minute
Appliance usage	Power consumption from appliances in office rooms [W]	1 minute

Seasonal and timing effects on electricity consumption

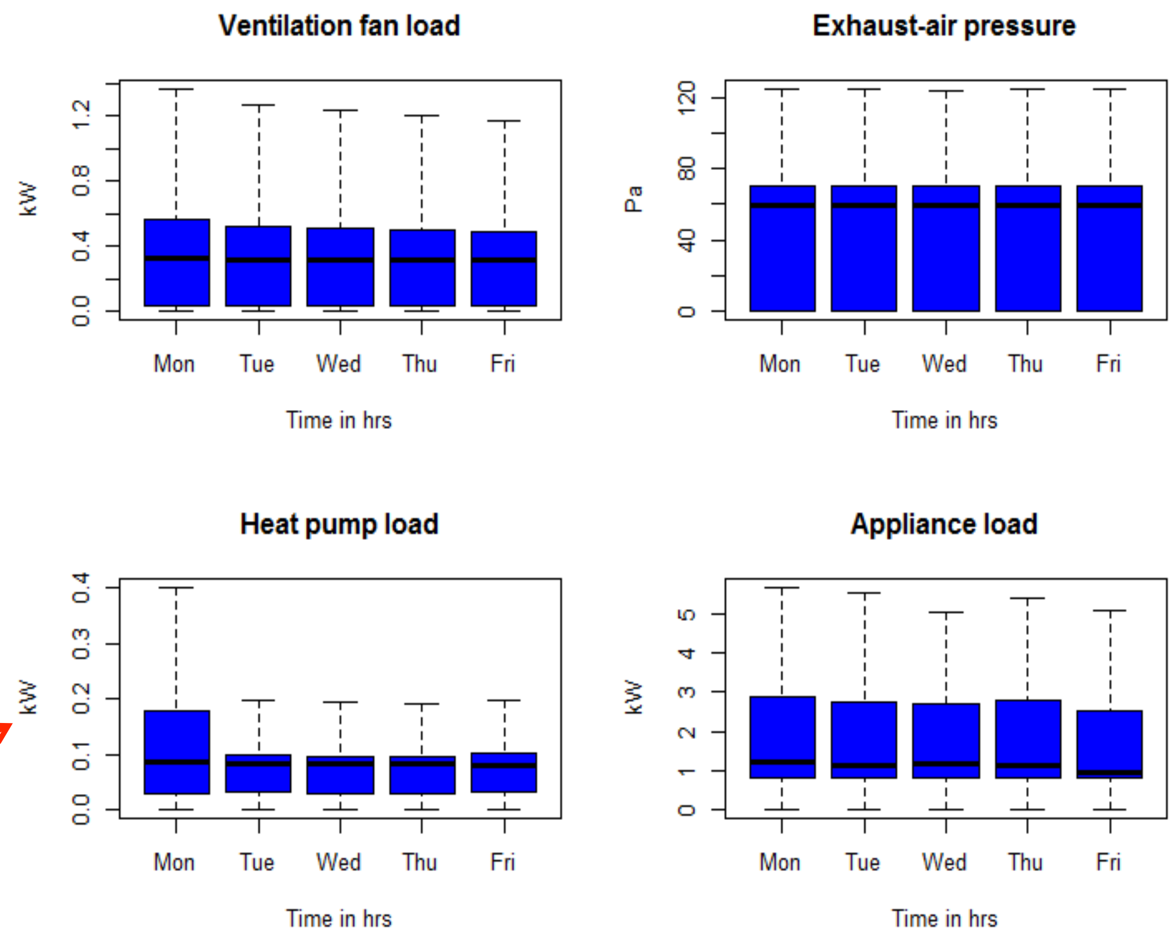


Per Month



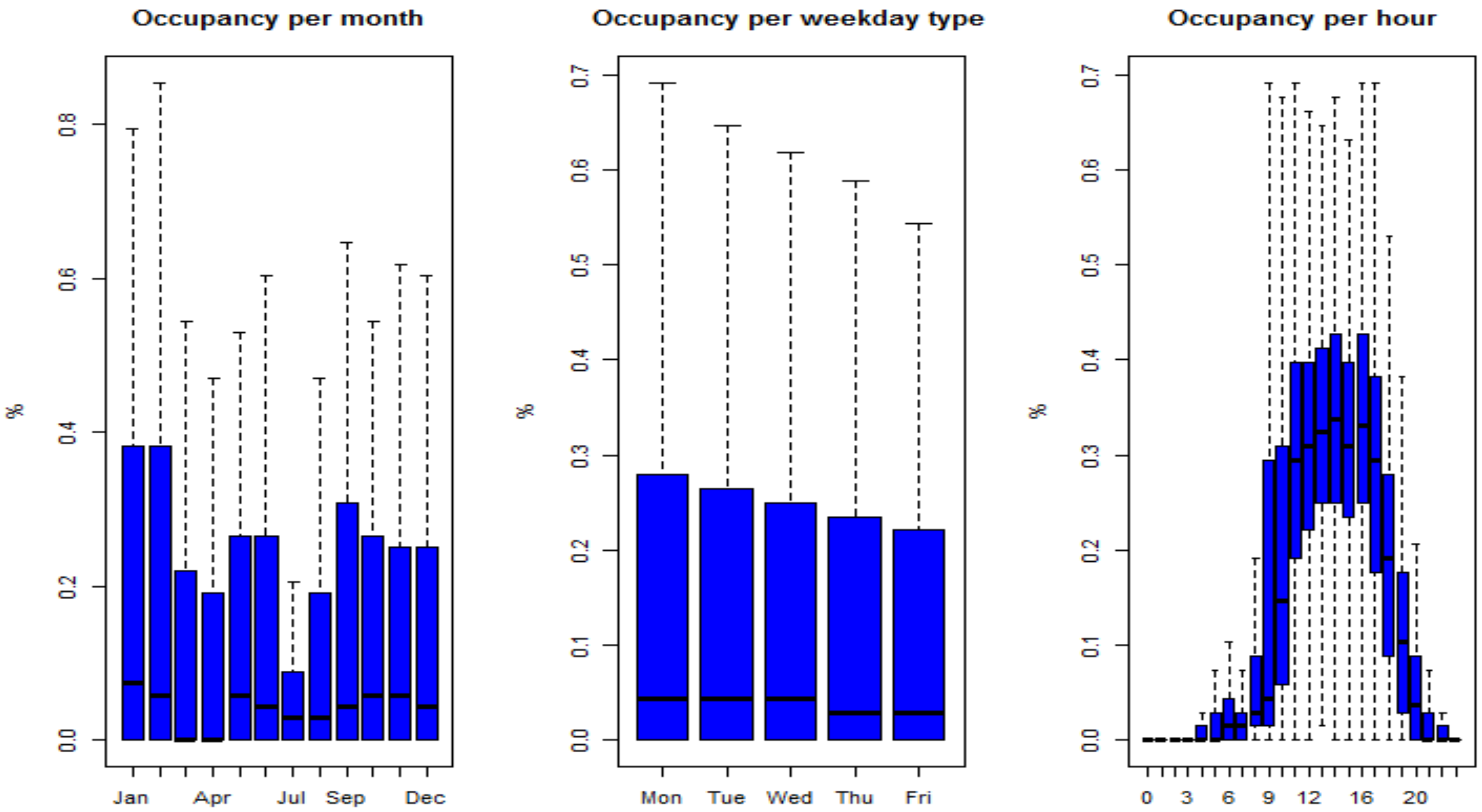
Per hour of day

Weekday effect on the consumption

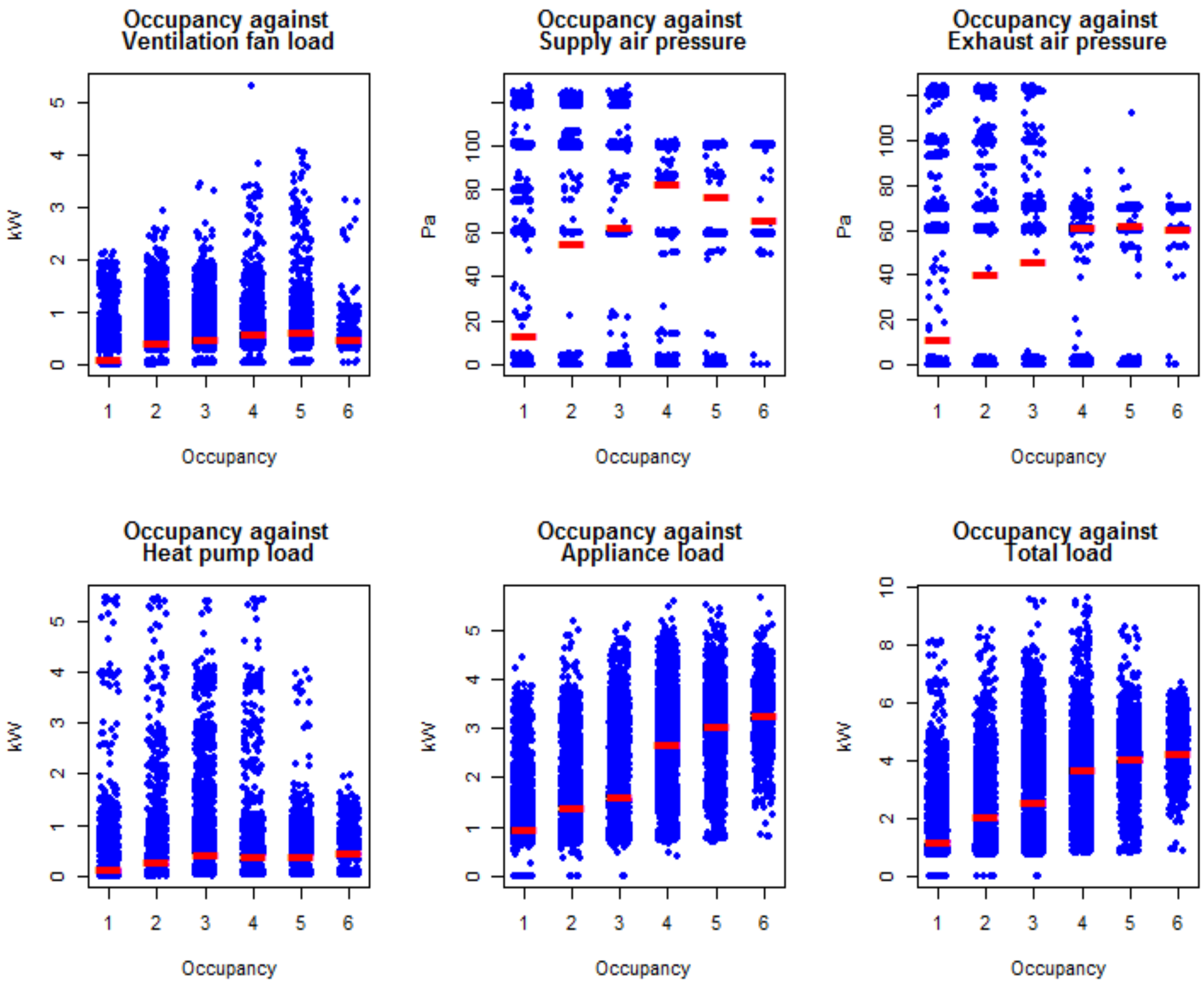


Extra cooling and heat during Monday due to inactive weekend

Seasonal, weekday type, and timing effects on the occupancy

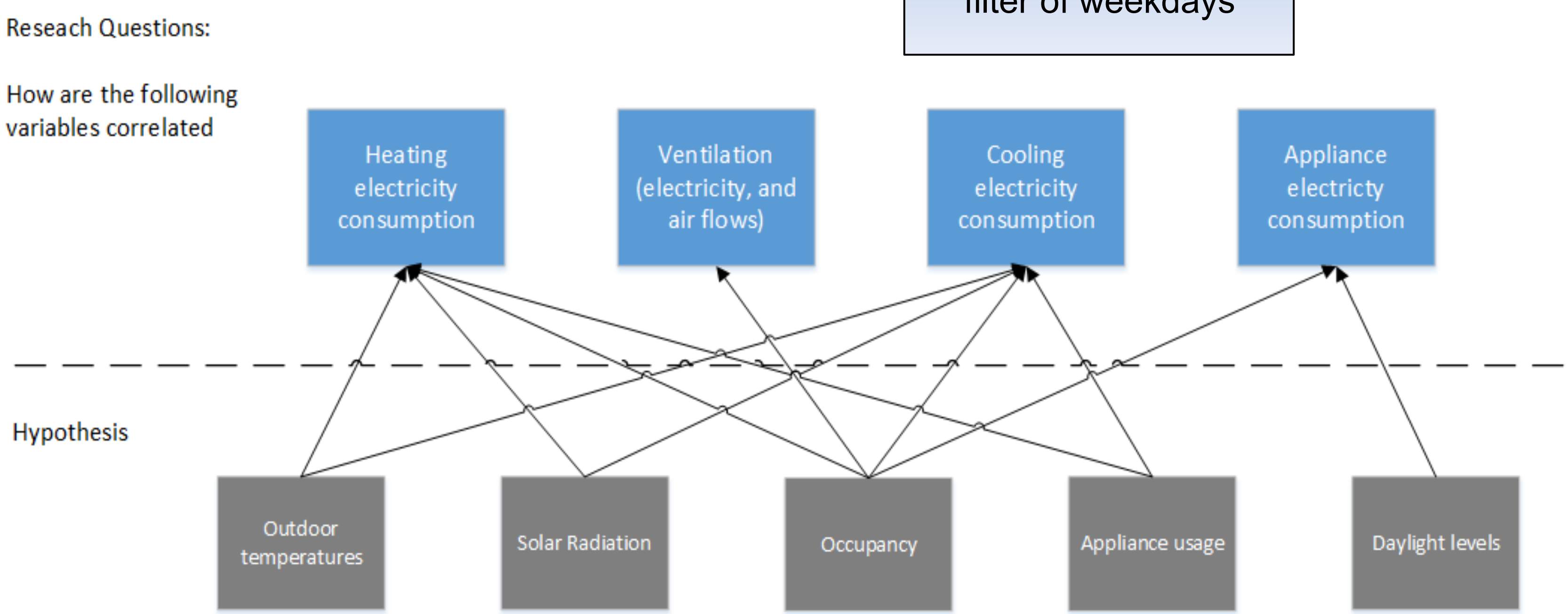


Occupancy correlation to usage per segment



As we speak

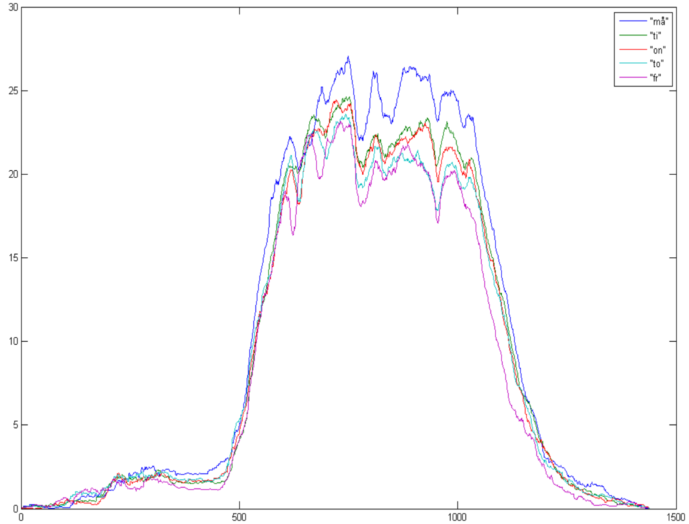
After applying time filter of weekdays

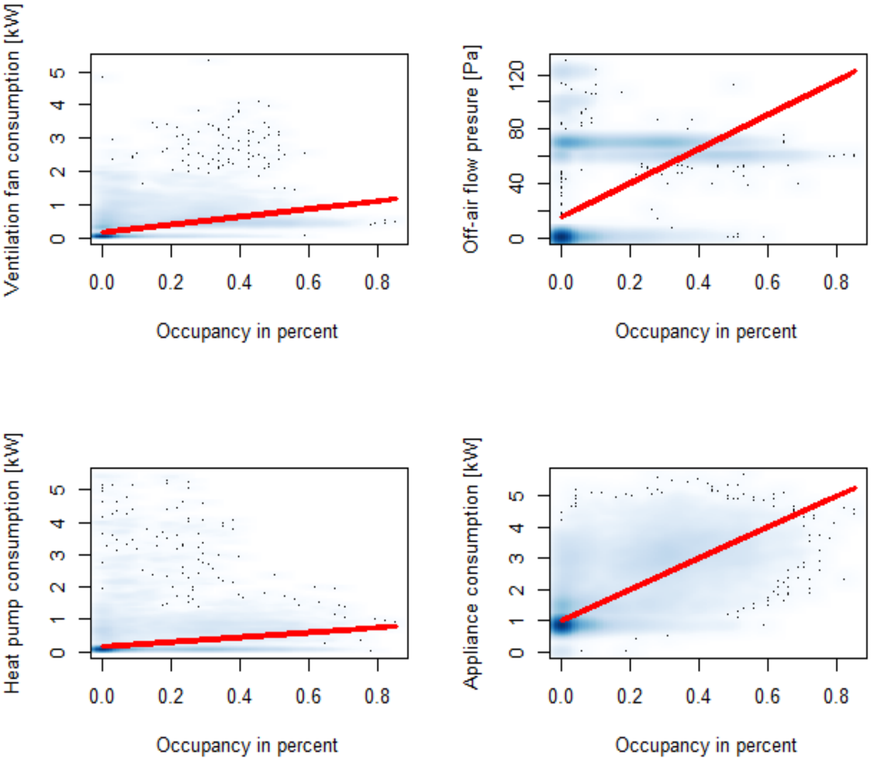


For the simulation model (made assumptions, etc.) it is important to see how the electricity consumption is correlated with occupancy

Early results

Occupancy patterns w.r.t. weekday





Occupancy in correlation
with HVAC and appliance consumption

Next steps

- From the perspective of the Flexibility owner (end-user)
- Focus on markets with geographic coupling

  Hosting Capacity of Renewables

  Voltage Profile and congestion management
- Problem has following characteristics

  Grid operator G: $V_{min}<V(t,b)<V_{max}$

  System operator S: $f_{min}<f(t)<_{fmax}$

  Producer P: Optimise profit from $P_P(t,b)$ and $Q_E(t,b)$

  End-user E: Minimise cost from $P_E(t,b)$ and $Q_E(t,b)$
- There can be several grids per system, enforcing constraints on P & Q
- The following markets determine available control

  Energy market where P & E meet

  System market where P, E & S meet

  Grid market where P, E &G meet

Referenced papers

J. Widén and E. Wäckelgård, “A high-resolution stochastic model of domestic activity patterns and electricity demand,” Appl. Energy, no. 87, pp. 1880–1892, 2010.

J. Widén, M. Lundh, I. Vassileva, E. Dahlquist, K. Ellegård, and E. Wäckelgård, “Constructing load profiles for household electricity and hot water from time-use data—Modelling approach and validation,” Energy Build., no. 41, pp. 753–768, 2009.

C. Sandels, U. Franke, and L. Nordström, “Vehicle to Grid system reference architectures and Monte Carlo simulations,” Int. Journal. on Vehicle. Autoomousn. Systems., vol. 11, no. 2, pp. 205–228, 2011.

C. Sandels, K. Zhu, and L. Nordström, “Analyzing fundamental aggregation functions in power systems,” in 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies Europe 2011, 2011, Manchester, UK.

C. Sandels, J. Widén, and L. Nordström, “Forecasting household consumer electricity load profiles with a combined physical and behavioral approach,” Applied. Energy, vol. To appear, 2014.

P. Stoll, N. Brandt, and L. Nordström, “Including dynamic CO2 intensity with demand response,” Energy Policy, vol. 65, pp. 490–500, Feb. 2014.

C. Sandels, M. Hagelberg, and L. Nordström, “Analysis on the profitability of demand flexibility on the swedish peak power reserve market,” in IEEE PES Innovative Smart Grid Technologies (ISGT), 2013,

Backup slides

Summary

- So is there any value in Demand Response?
  - + There is value in flexibility (& storage)
  - + Large scale units have an easier time participating
  - - Value is locked in by market models
  - - Costs for equipment must be shared or ”embedded”
  - - End-user participation must be incentivised and automated

- For certain markets, regulation sets the value
- For certain markets geography is critical
  - E.g. Congestion management, Voltage control

Lars Nordström – in brief

2011 Professor Information Systems for Power System Control

2008 Assoc. Professor, KTH

2006 Director of EKC^2 – Swedish Centre on Electric Power

2004 Researcher at KTH, Program manager ICT for Power program

2002 CEO & Founder LB Software – mobile GIS software

1998 Consulting AU-System (SCADA, Control Systems)

Senior Member IEEE

Member CIRED, Cigre

IEC TC57 Sweden chairman, IEC Strategic Smartgrid group member

EU Task force Smartgrids expert group member

PI/Co-PI for 1,2 MEUR annual

Two start-ups in Demand response & Information Modeling

100+ publications

- Wide Area Monitoring & Control
- Distributed control
- Demand Response

Father of three great kids!

www.ee.kth.se/psmix

School of Electrical Engineering

- One of ten schools at KTH
- EE School in numbers
  - 70 Faculty across 10 departments
  - 230 PostDocs & PhD Students
  - 800 BSc & MSc Students.
- Focus areas
  - Power Systems, Power Electronics, Control Systems, Signal Processing, Communication Systems

QS WORLD UNIVERSITY RANKINGS

#31 Electrical Engineering

Power groups at EE School

Power markets, system performance and regulation

Söder, Hesamzadeh, Amelin,

Power system stability and control, Hybrid AC/DC system control and operation

Ghandhari, Vanfretti, Berggren(ABB)

Communication & Control for Power Systems, Cybersecurity, Distributed control

Nordström, Ekstedt, Ericsson (SvK), Wang(ABB)

Power System reliability, Reliability centered asset management

Bertling, Hilber

Power Electronics, Multi-level converter technologies, HVDC applications

Nee, Norrga, Harnefors (ABB)

Electric drives for hybrid applications, permanent magnet drives, electric traction,

Wallmark, Soulard, Leksell, Östlund, Dijkhuisen(ABB)

Multiphysics modeling, EMC electromagnetic compatibility, lightning

Thottapillill, Månsson, Becerra, Norgren

Highvoltage, Insulation materials, Electromagnetic modeling,

Engdahl, Edin

Power Systems Management & Related Information Exchange

Group lead: Nordström
Affiliated: Ekstedt, Ericsson(SvK), Wang (ABB)
Post-Docs: Saleem, Chenine
7 PhD students + 2 Industrial PhD @ ABB
8 MSc Students

Educational Activities:

- Communication & Control for Power Systems
- Computer Applications in Power Systems
- Circa 20 Masters & Bachelor projects annual

Research Areas:

- Reliable and High-performing ICT infrastructures
- Distributed Control of Power Systems
- Novel Market Models for Active Power Systems

Funding:
1,2 MEUR Annual
58% External
Main sources:
FP7, Swedish Energy Agency ABB, SvK.

STRONgrid

iTesla

GRID4EU INNOVATION FOR ENERGY NETWORKS

High Voltage Valley

DISCERN

eit KIC InnoEnergy

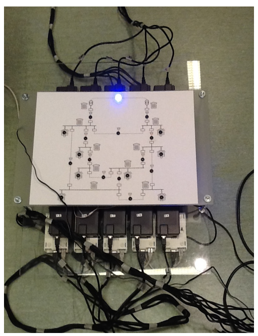
Collaboration & Funding

- **ValueFlex**, project on Demand response flexibility forecasting and decision support 100 k€,
- **DISCERN**, EU FP7 observability and controllability of activ distribution grids, 2013-2016, 400 k€
- **Grid4EU** EU FP7 Active Low Voltage grids, 200k€
- Real-time control of **Hybrid AC/DC grids**, 400 k€
- **Swegrids** – Swedish centre for Smart Grids and Energy storage, 1200k€.

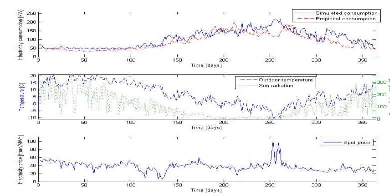
- **INSTINCT**, ICT Solutions for Active Distribution Networks and Customer Interaction 150 k€
- **Stronggrid**, Transmission system control and security. 280 k€
- **Vinnova** project on ICT Architectures for Smartgrids and Electric Storage, 300 k€
- **STandUP** Strategic Researc newable Energy and Smart grids, 1000 k€

Recent Highlights

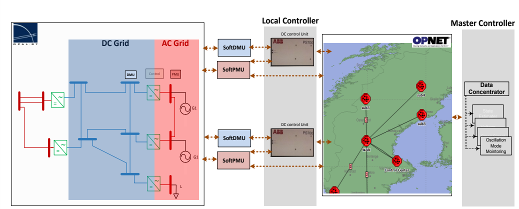
Implemented a distributed algorithm for self-healing grids using wireless communication. Article in revision for IEEE Transactions



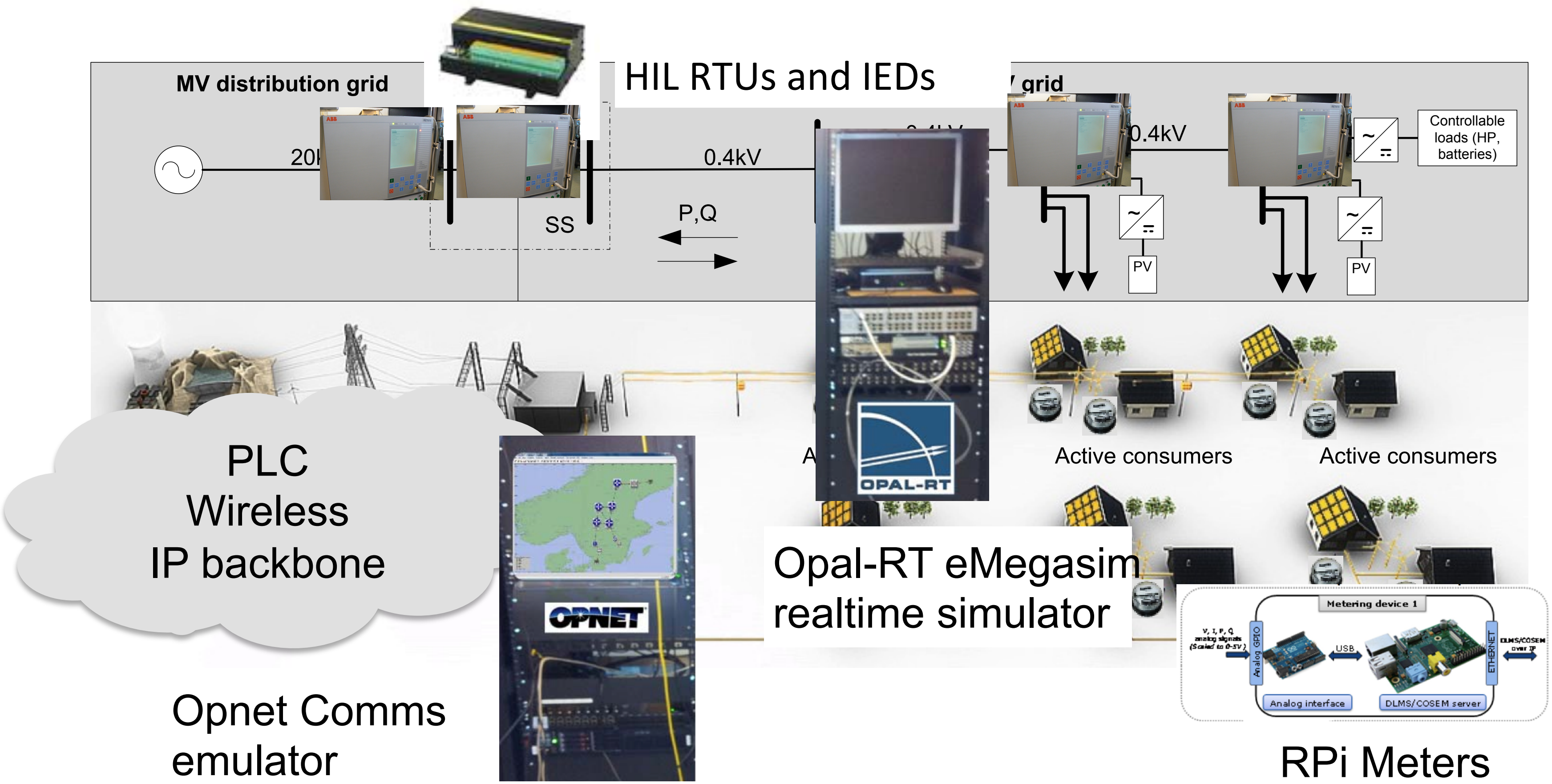
Markov chain based residential flexibility forecasting for demand response developed, and tested in Smartgrids Gotland demo project Article in revision for Elsevier Journal



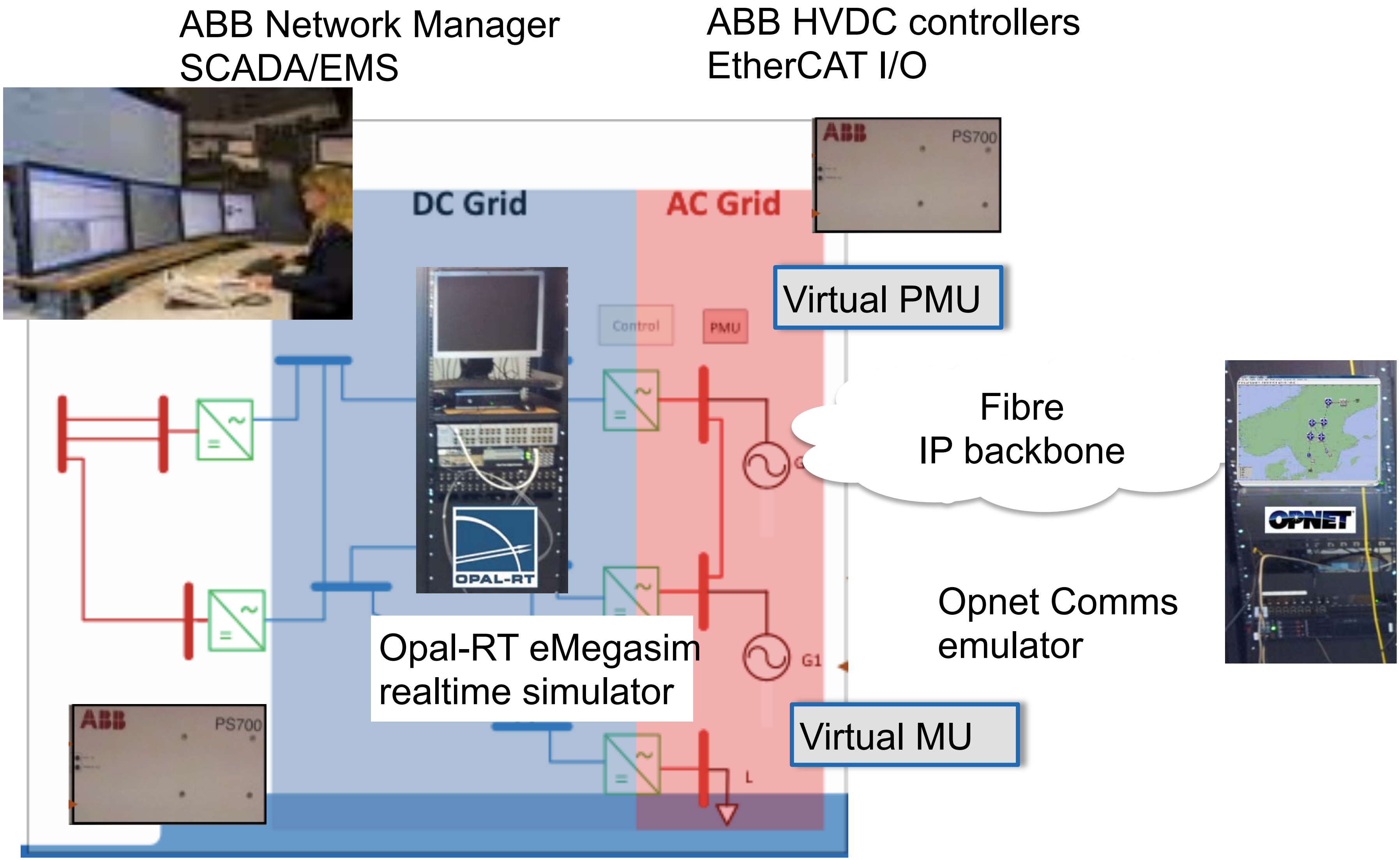
Multi-agent control strategy for DC voltage control in MT-HVDC grids, published and introduced to ABB, presently implementing prototype in ABB controllers.



Research infrastructure – Distribution



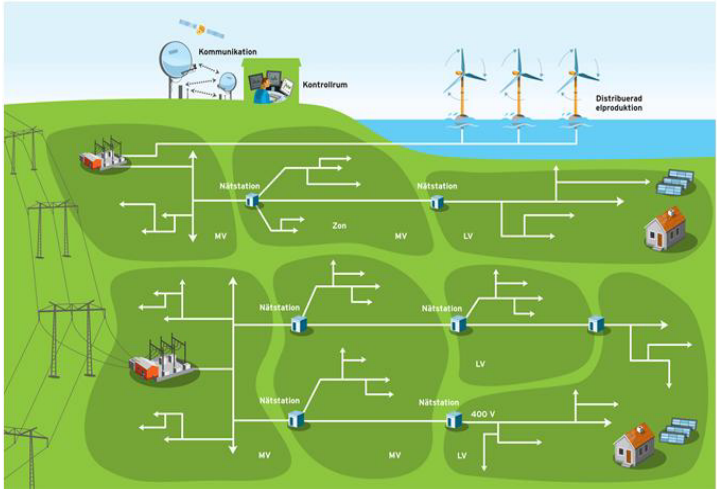
Research infrastructure - Transmission



Research Infrastructure – Smartgrids Gotland

Maximise Wind utilisation, minimise export to mainland

Consumer engagement via price incentives directly to smart devices



Improve power quality (interruptions and voltage)

Cost reductions at utility and minimised risk for QoS failure charges

GEAB VATTENFALL ABB SVENSKA KRAFTNÄT Schneider Electric Energimyndigheten KTH