Impact of incentive-based demand response on urban low-voltage grid operation

12. Symposium Energieinnovation,
16.02.2012, Graz, Austria

Dr.-Ing. Jan Ringelstein
Division Engineering and Grid Integration
Fraunhofer IWES, Königstor 59, D-34119 Kassel
jan.ringelstein@iwes.fraunhofer.de

Fraunhofer IWES

Agenda

- Introduction and Project SHSG
- Considered grid area and software simulation
- Simulation Results
- Conclusions and further work

SHSG Project Partners

Research

TNO

Fraunhofer Institute for Wind energy and energy system technology

Fraunhofer IWES

Institute of Com-munication and Computer Systems

ICCS-NTUA

Industry

MVV Energie

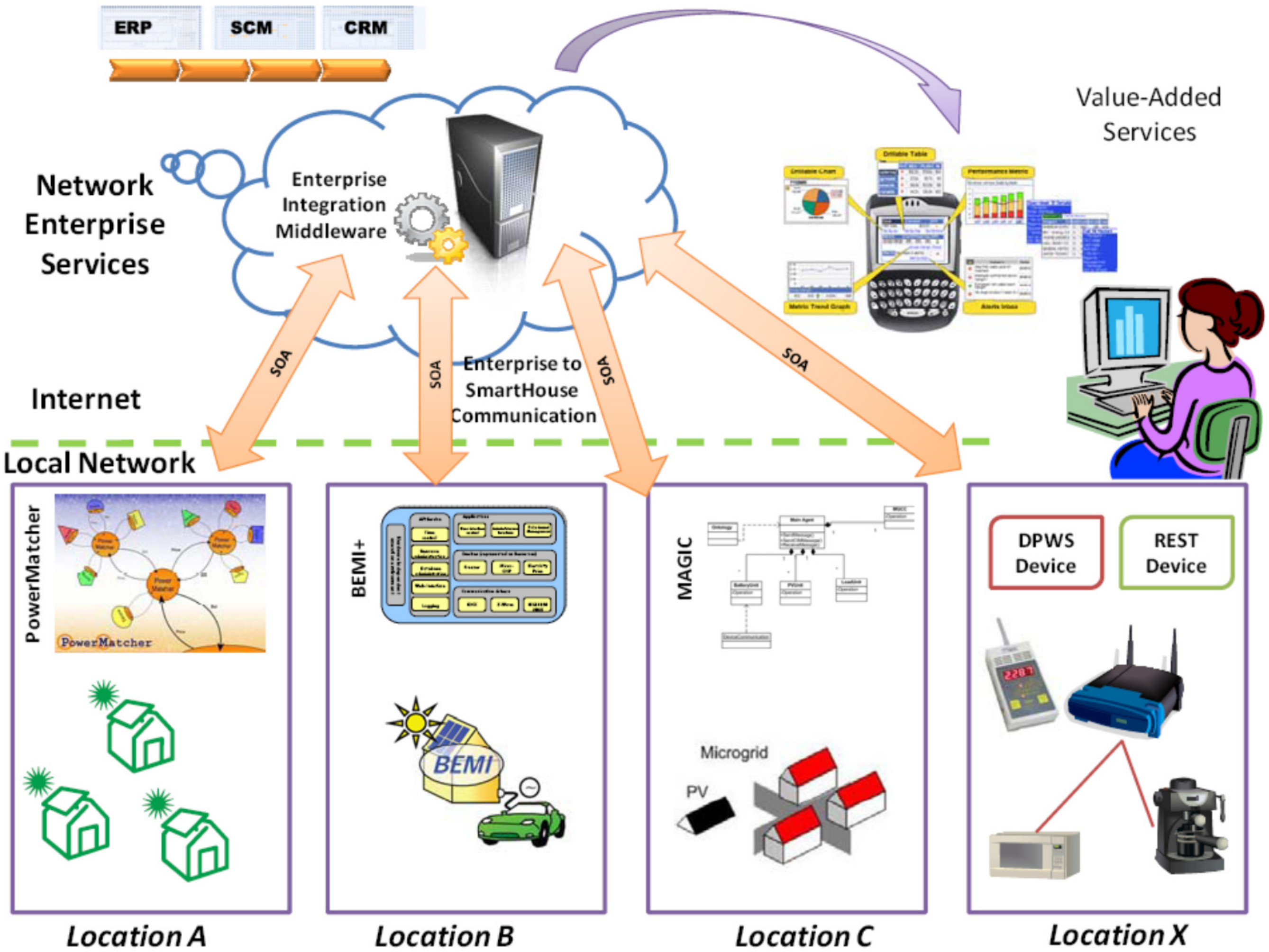
SAP

ΔΕΗ

Public Power Corporation (PPC) S.A.

Source: http://www.smarthouse-smartgrid.eu/index.php?id=147

Amalgamated smart grid architecture



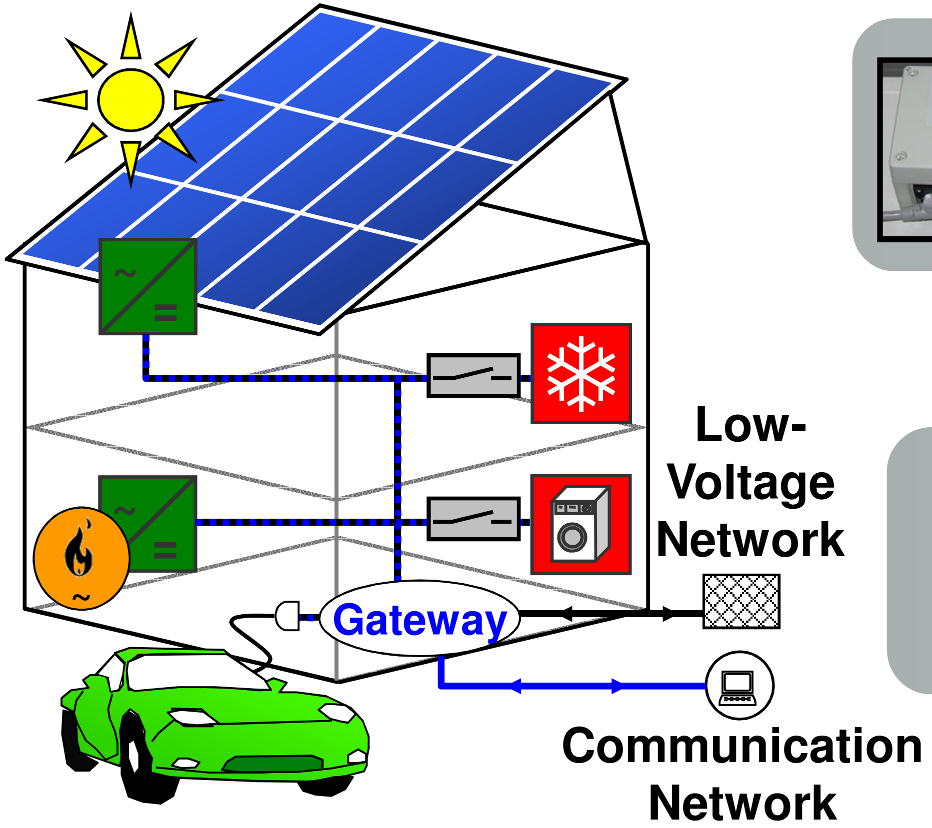
Source: the SH/SG team, 2010

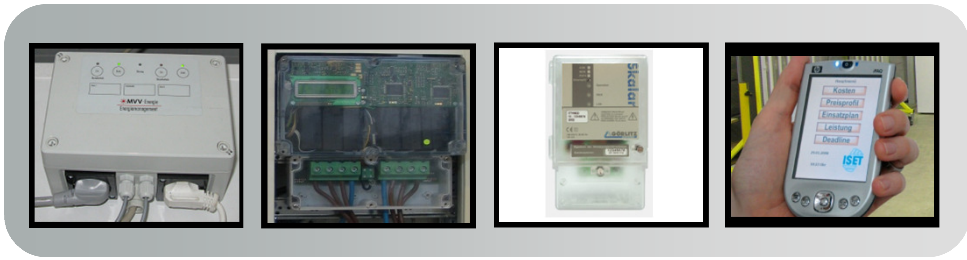
Fraunhofer IWES

BEMI Coordination Algorithm Concept

Bidirectional **E**nergy **M**anagement **I**nterface

- Concept of decentralized decision
- based on central and decentralized information





ISET-*BEMI+*® Functions

Device Types

Fraunhofer IWES

Practical relevance of Simulations

- The final structure of the future smart grid is yet unknown
- Grid assets must be procured today for lifetimes of > 30 years
- The beginning energy system transition influences daily grid operation

Smart Grid simulations should…

- Allow for developing Smart Grid processes
- Assess applications of Energy Management Systems (EMS) in grid operation
- Quantify influence on grid operation parameters, i.e. line loadings, voltages and line losses
- Provide a tool for grid operation and future grid design
- Allow for consideration of grid deconstruction scenarios
- Complement field tests and measurements

Simulation studies in SHSG WP4

A: ECN/TNO

- Study I: PowerMatcher improving integration of wind power generation in a cluster of 3.000 Smart Houses.
- Study II: PowerMatcher impact on grid losses within a single LV feeder

B: IWES/MVV

- Impact of 300 Smart Houses equipped with BEMI on grid operation parameters for three realistic LV grid topologies (MA-Wallstadt)
- MVV studied impact of DG within real LV networks in Mannheim, Offenbach, Kiel (voltages, line loadings)

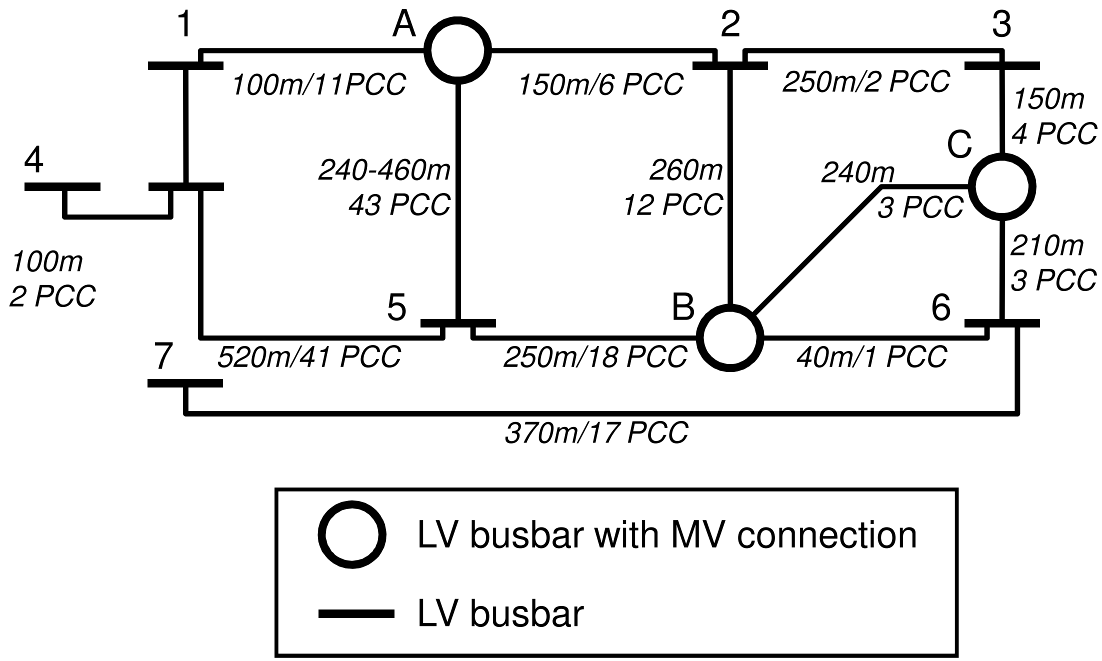
C: ICCS/PPC

- Considering MAGIC application for island system operation (Crete)
- Study I: steady-state simulation considering load controller impact on grid operation parameters (peak load, losses, CO2 emissions, cost)
- Study II: transient simulation in grid disturbance scenario (frequency stabilization)

Considered LV grid area, Mannheim - Wallstadt

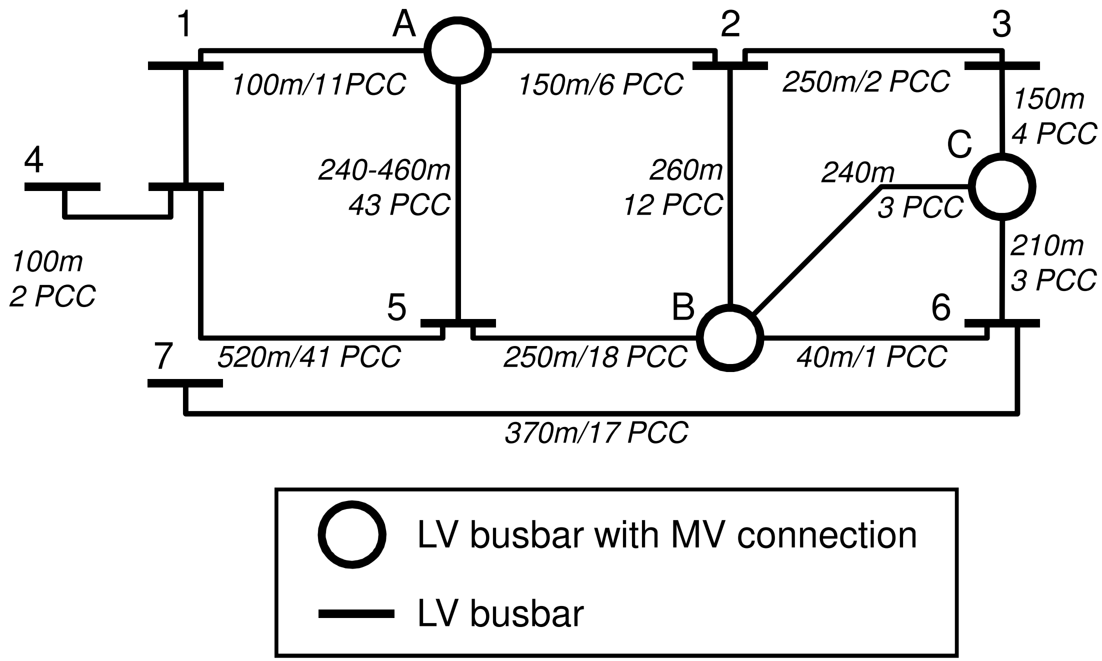
Source: http://www.maps.google.de, 2011

Network for SH/SG Simulations



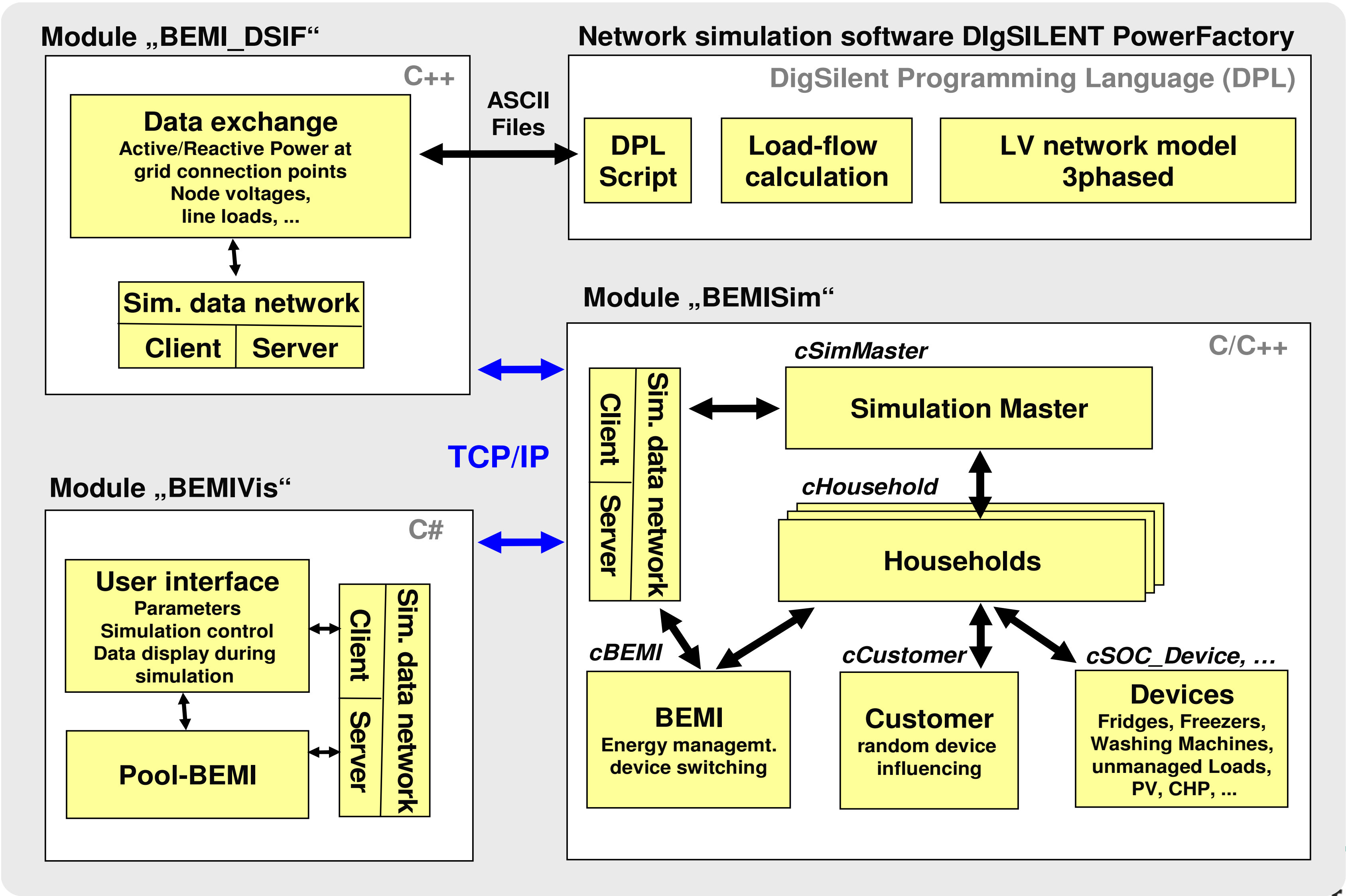
- 162 PCCs, 309 Households
- neighbour LV cell interconnections near nodes 1, 4 and 6
- Node 4 is subject to maximum voltage deviations

Network for SH/SG Simulations
Considered topologies



Topology Nr.	LV-LV connections	LV-MV connection
1	All open	All closed
2	All open	B&C closed
3	All open	A&C closed

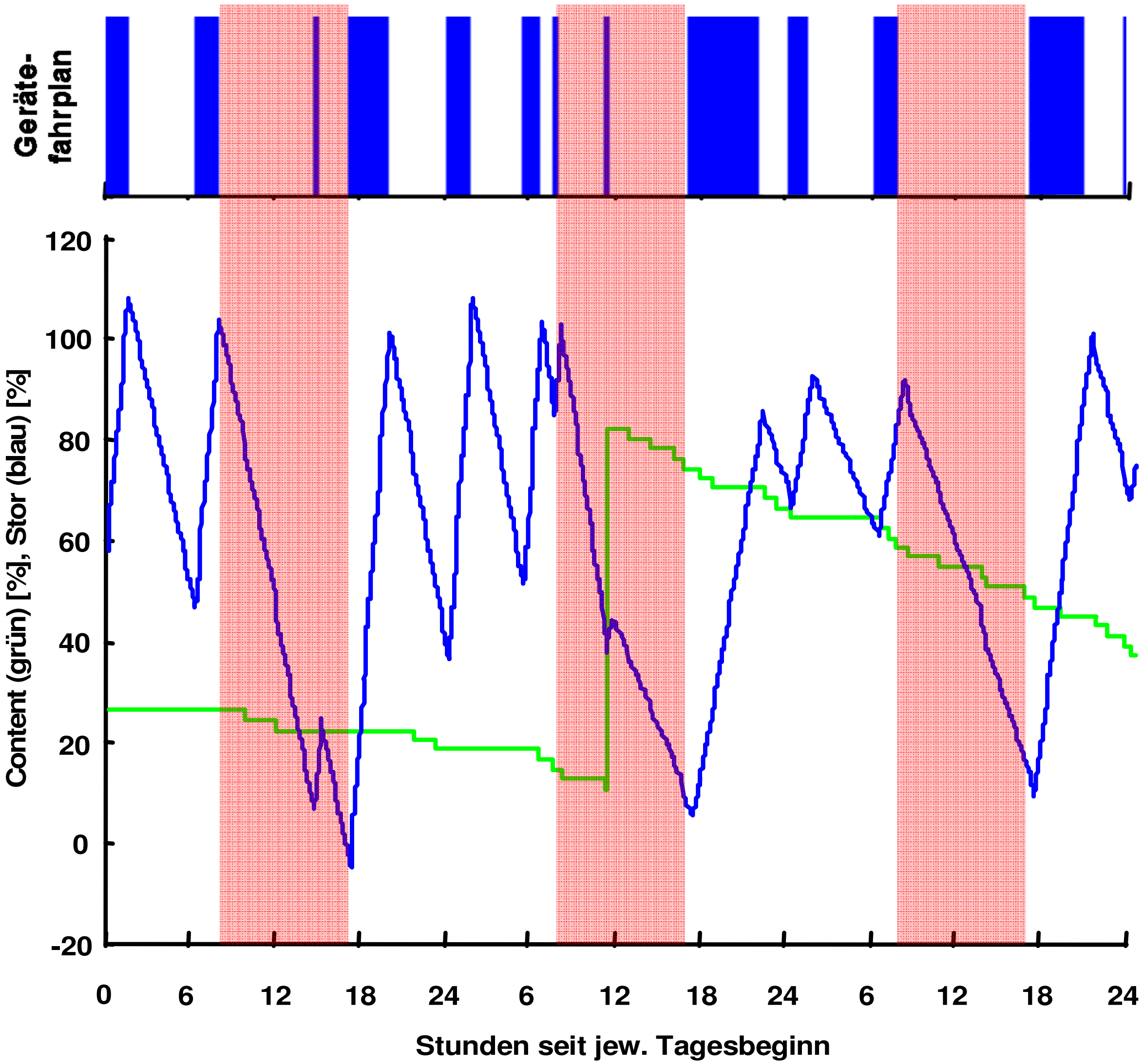
IWES Simulation system as used for SH/SG



SOC Model: Parameters used for SH/SG

Refrigerator	*MaxOnTm*	**4800 sec +- 20 %**
	MaxOffTm	**7200 sec +- 20 %**
Freezer	*MaxOnTm*	**3430 sec +- 40 %**
	MaxOffTm	**8100 sec +- 30 %**

SOC Model: Example



Load and Generation within the network

Distributed Generation

- peak generation of ~350 kWp
  from PV installed at every PCC (evenly distributed)
- used PV irradiation measurements from Kassel (5 min resolution)

Load

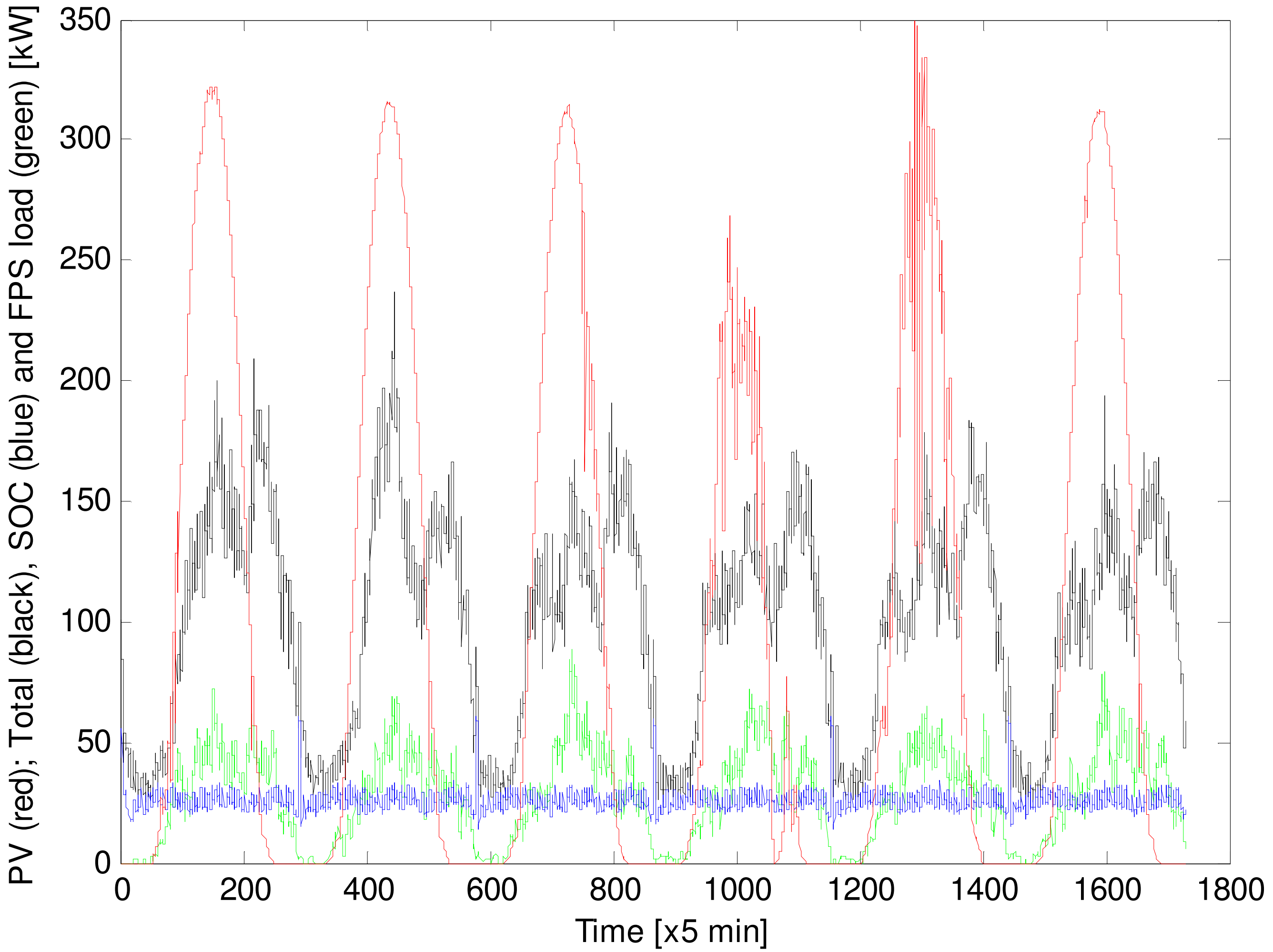
- Peak consumption ~200 kW in grid area
- 3.300 kWh / a consumption per household

Application	Relative consumption	Absolute Consumption [kWh/a]
Fridges	11%	363
Freezers	11%	363
Washing Machines	7%	231
Dish Cleaners	7%	231
Tumble Dryers	10%	330
Non-controllable	54%	1.782
Sum	100%	3.300

Simulation Runs

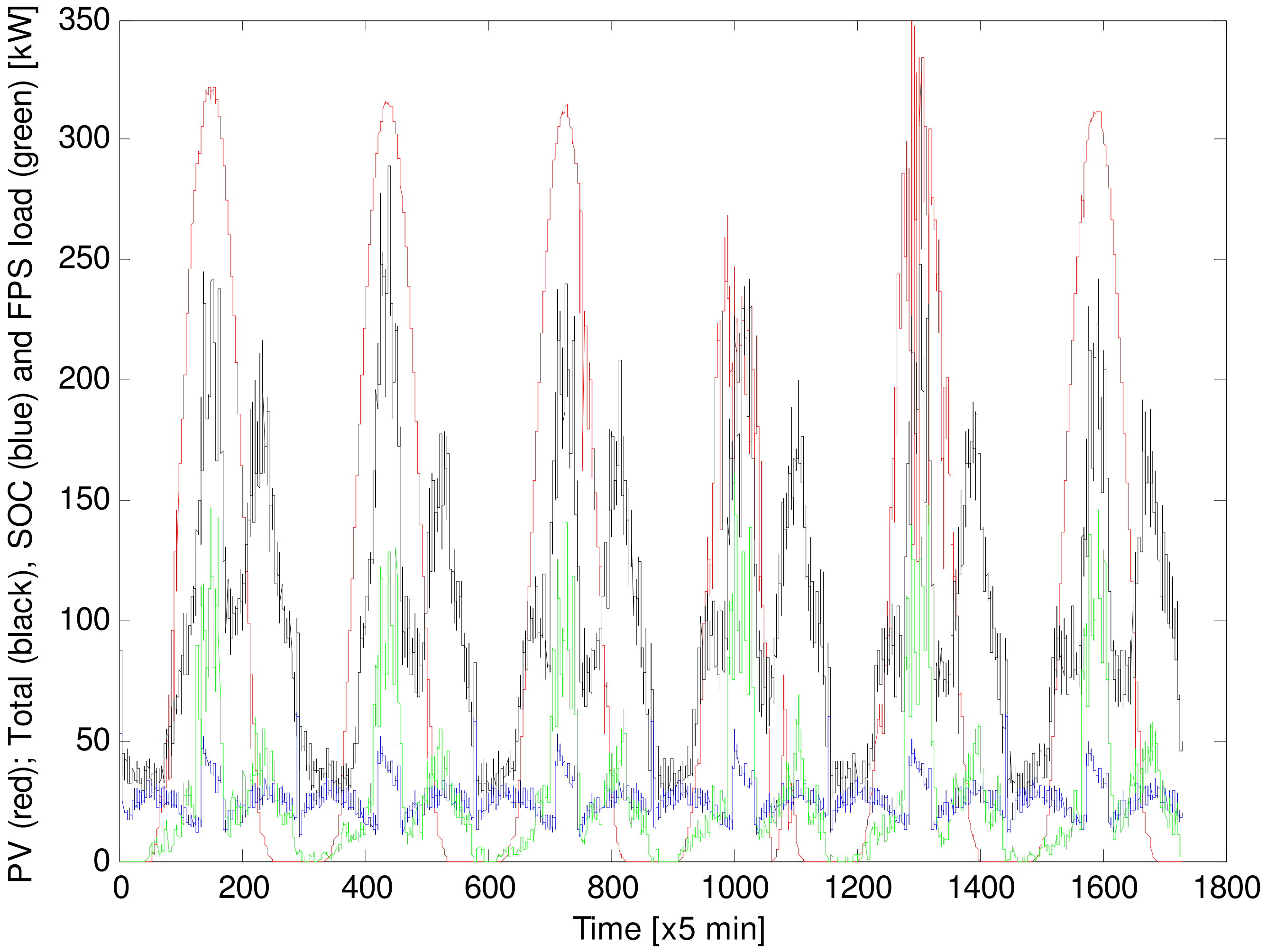
- 6 days in June were simulated in each run
- 5 min simulation stepwidth
- Each run is done for a flat tariff and a PV tariff
- PV tariff designed for incentivizing load switch-on during high PV infeed:
  - three price groups à 103 households
  - Price group 1: 15 ct/kWh 11:00-12:59, else 20 ct/kWh
  - Price group 2: 15 ct/kWh 11:00-13:59, else 20 ct/kWh
  - Price group 3: 15 ct/kWh 11:00-13:59, else 20 ct/kWh
- Repetition for each topology → 3 x 2 simulation runs

Example result topology 3: load and generation (flat tariff)

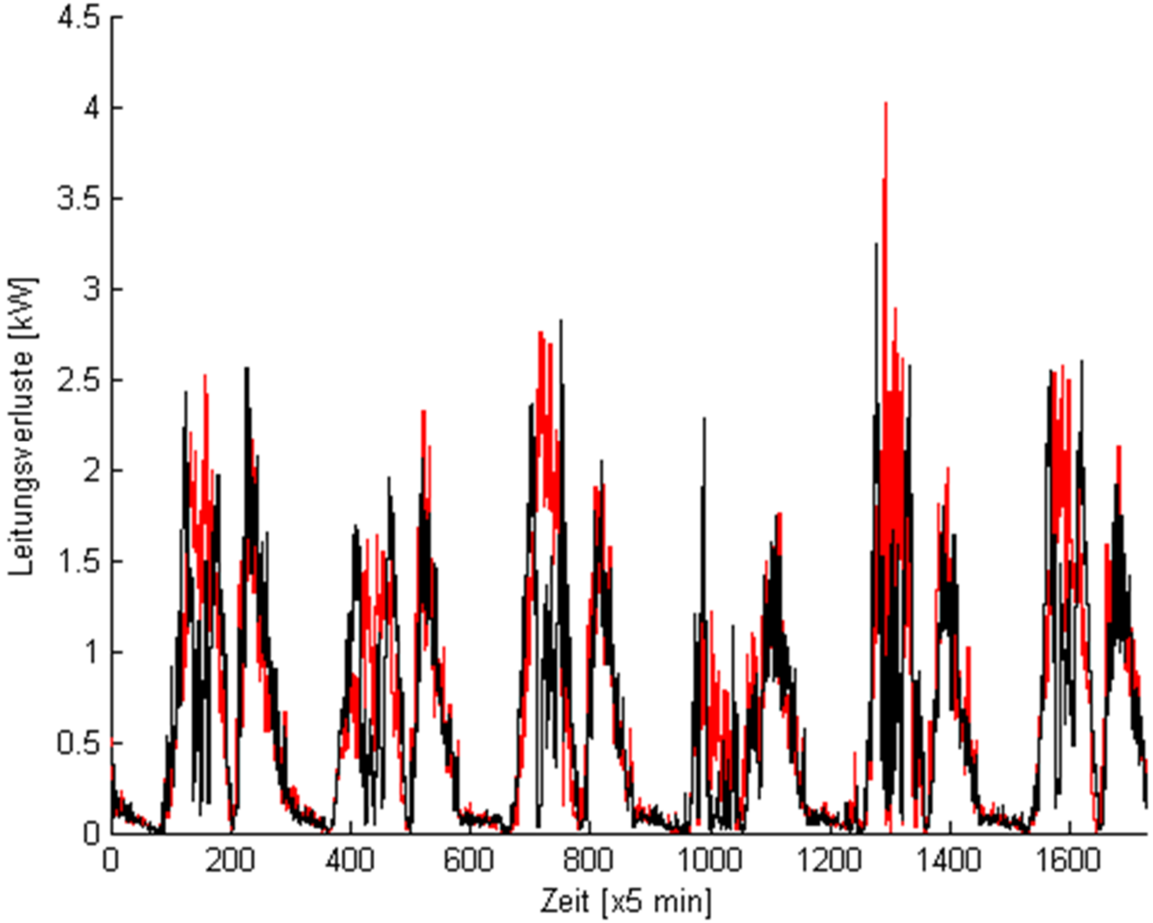


Fraunhofer IWES

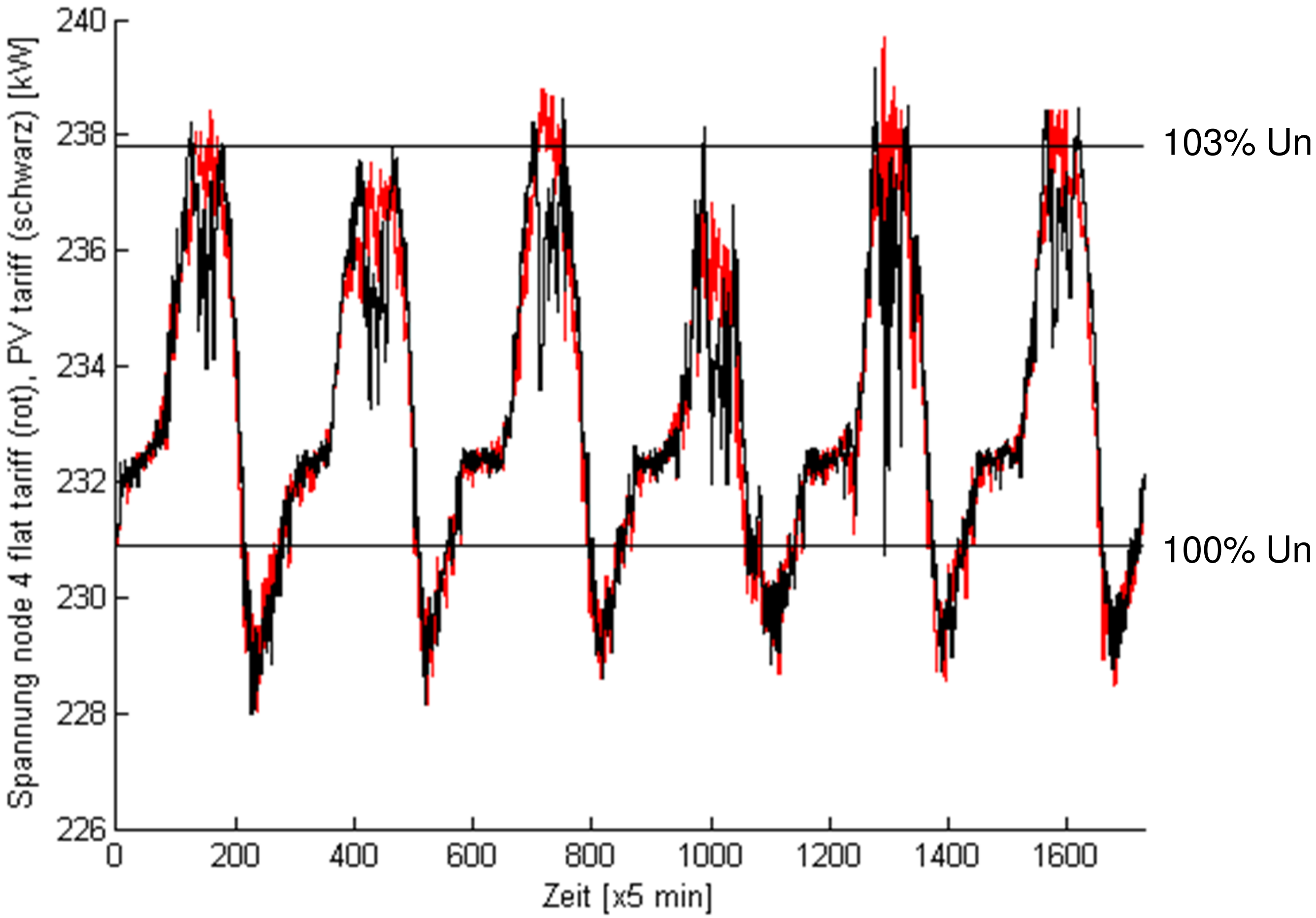
Example result topology 3: load and generation (PV tariff)



Example result topology 3:
active power line losses (red: flat tariff, black: PV tariff)



Example result topology 3:
voltage at node 4 (red: flat tariff, black: PV tariff)



Result summary

Characteristic value	Change	
Imported energy	avg. -3,7 %	marginal effect due to restriced load shifting potential and short low-price period
Locally used PV energy	avg. +3,7 %	
Line losses	**-8 .. -9 %**	lower than ECN/TNO due to different loads
Transformer losses	appr. -1 %	Note: tr. loss ~ lne. loss x 8 .. 2 (top. 1 .. 3)
Avg. Voltage node 4		
during 11:00-14:00	**-1 .. -1.8 V**	Peaks reduced by 0.8 .. 1.4 V
else	+0.1 .. +0.3 V	Caused by load switch-off at HI-price times*
Avg. Line loading		
during 11:00-14:00	**-3.2 .. -6.2 %**	Note: peaks are not occuring in this time
else	+0.1* .. +0.4 %	Causing increase of peaks by up to 1.2 %
Avg. Transformer loading		
during 11:00-14:00	**-7.1 .. -9.7 %**	Note: peaks are not occuring in this time
else	appr. +0.6 %	Causing increase of peaks by up to 2 %

* Attribution to tariff effect uncertain

Conclusions and further work

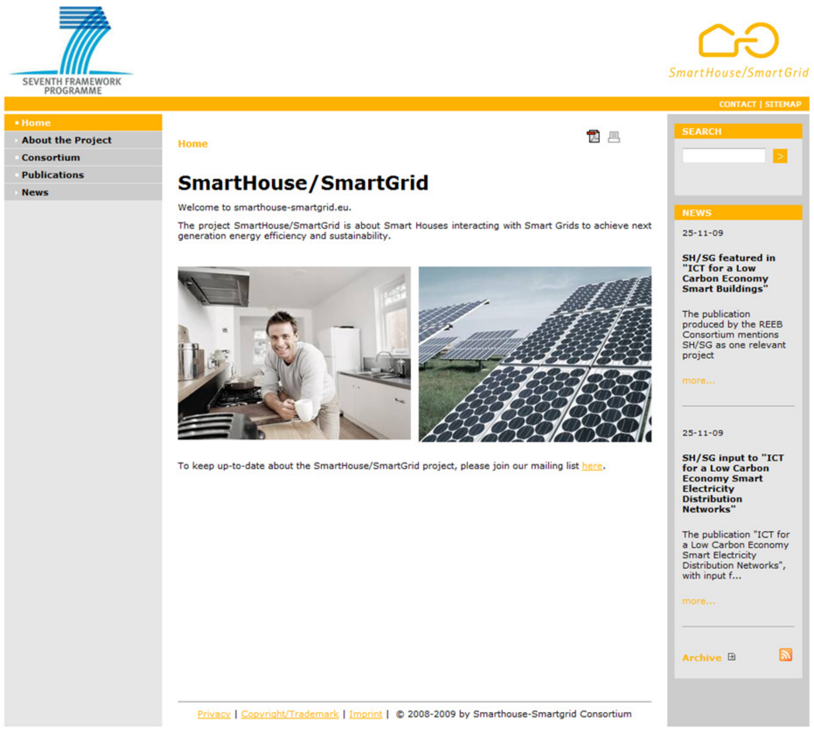
- Loadings and voltages are uncritical in any case
- PV tariff changing char. values as expected, but in some cases merely marginal. Reasons: low LM potential, tariff design
- Significant reduction of line losses due to PV tariff design
  → Tariff design needs to be goal oriented
- Significant reduction of voltages, line & transformer loading during LO-price times only
- Weaker grids benefit more from tariff effects

- Further Research: Model improvements, study other tariff designs, MV studies and practical applicability considerations
- The work continues in project „Modellstadt Mannheim“

SHSG project website

All publications and public final report at:

http://www.smarthouse-smartgrid.eu



Fraunhofer IWES

Thank you for your attention!

Dr.-Ing. Jan Ringelstein
Fraunhofer IWES, Königstor 59, D-34119 Kassel,
Tel.: +49 561 7294 – 208, Email: jan.ringelstein@iwes.fraunhofer.de

This report is based on a research project partly funded by the EU FP7 project SmartHouse/SmartGrid (Grant no.: FP7-ICT-2007-224628).
The authors are responsible for the content of this publication.

Fraunhofer IWES