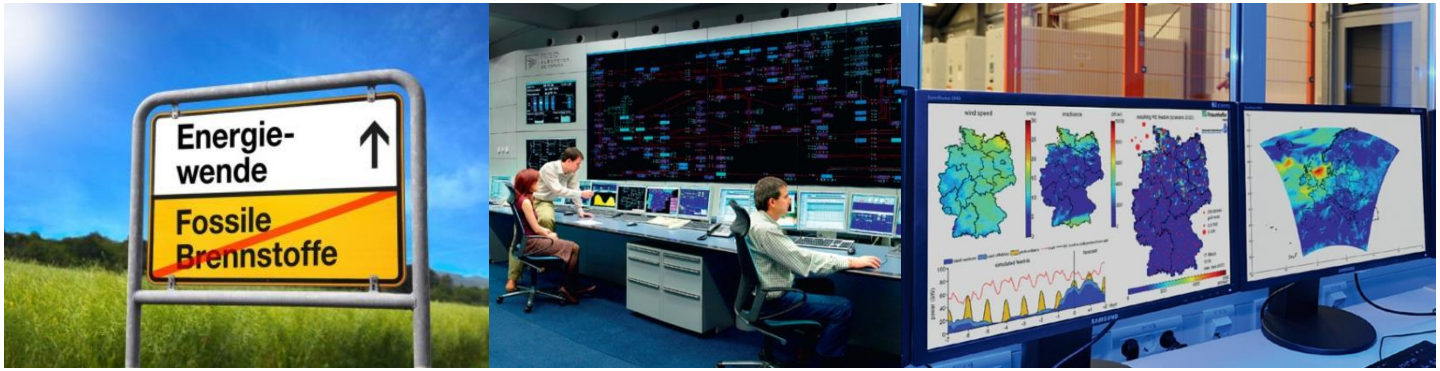
Decentralized Solutions for Challenges in a Future Smart Grid



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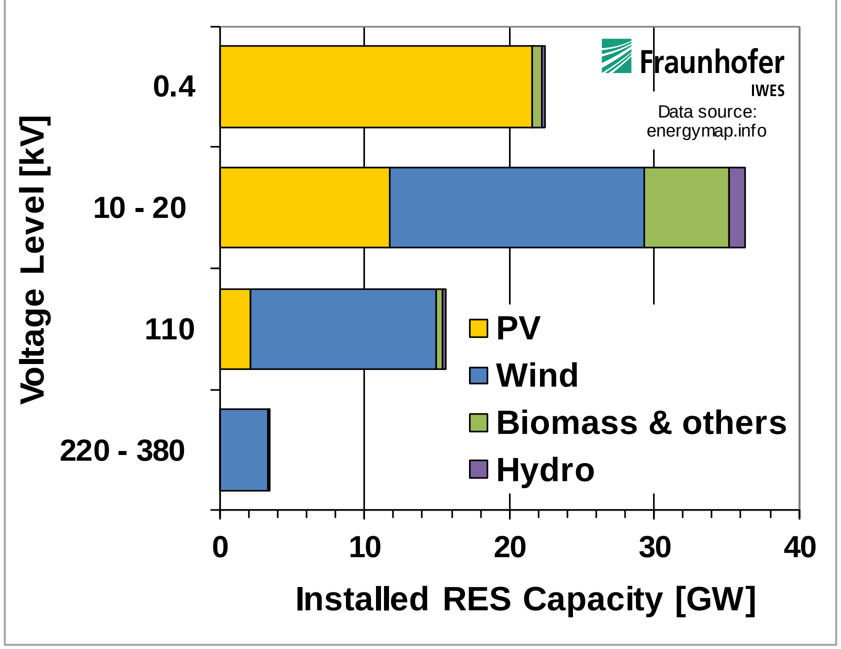
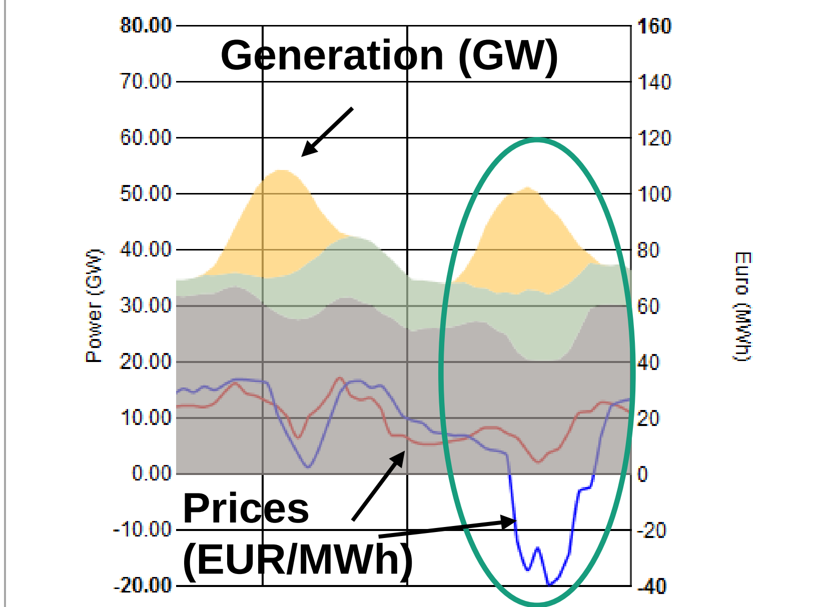
Motivation (1)

The distribution system and the electricity market undergo a huge transition right now.

Distribution of installed RES capacity over different voltage levels in Germany



Electricity production and spot market prices in Germany (Week 16, 2014):*



*Source: Fraunhofer ISE: www.energy-charts.de

Source: Appen et al., IEEE General Meeting, 2014

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Motivation (2)

Self-consumption becomes a viable business case for PV systems in Germany → What is the next step?

PV and storage system prices

Feed-in tariffs

Electricity cost

source: www.multinet-shop.de

Market situation:

Germany:

- ca.15,000 PV battery systems installed*
- ca. 60,000 HP newly installed per year**
- ca. 5,000 CHP newly installed per year***

Worldwide:

- Growing markets in Europe, Japan, Australia and the US

Are there technical and/or economical advantages in coupling the residential heat & power energy-systems using an optimized energy management?

*Source: BSW/ BMWi / *Appen et al., IEEE General Meeting, 2014, **BWP Studie 2010 Prognose 2015, ***trend:research Studie 2011*

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What is the optimal way of operating a decentralized *H*eat-and-*P*ower-*S*torage-System (HPS-System) ?

Max. self-consumption

Smart self-consumption through reduction of PV peaks

Market driven operation via price signals

Grid support: e.g. local voltage control using storage systems

Remote storage operation by DSO

Participation in virtual power plants through central control

Reliable grid operation

Market driven storage operation

Source: based on Kneiske (CEB 2013)

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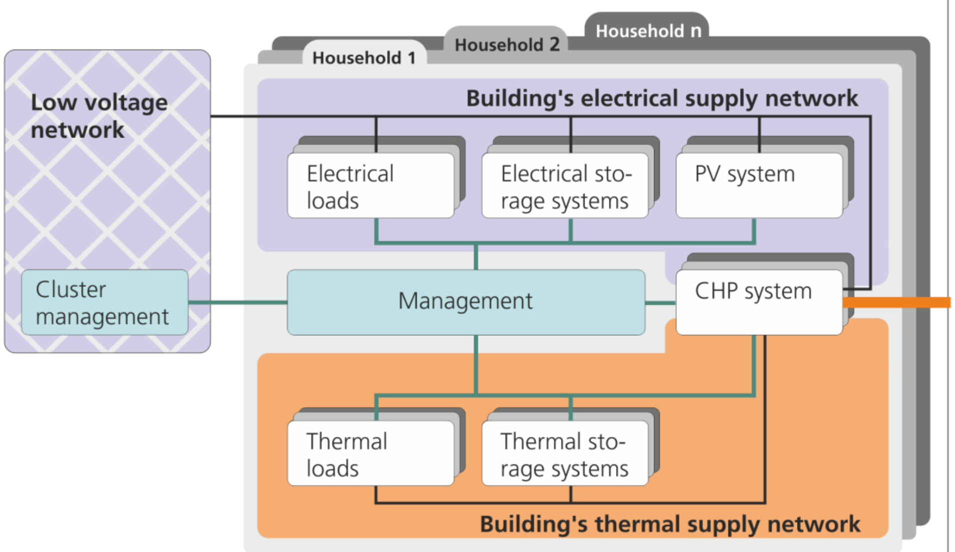
Innovative Use of Storages in Coupled PV-Hybridsystem („Ine-Ves“)

(PV-Hybridsystem = decentralized HPS-System)

System Overview



Gefördert durch:

Bundesministerium für Wirtschaft und Energie

Innovation

Household:

- **Coupled** electrical and thermal energy grids inside the house using a CHP
- Optimized energy storages & management
- Including additional thermal and electrical energy sources and loads

Grid:

- EEG feed-in
- **Grid-active** electrical storages, realizing grid relief via cluster management

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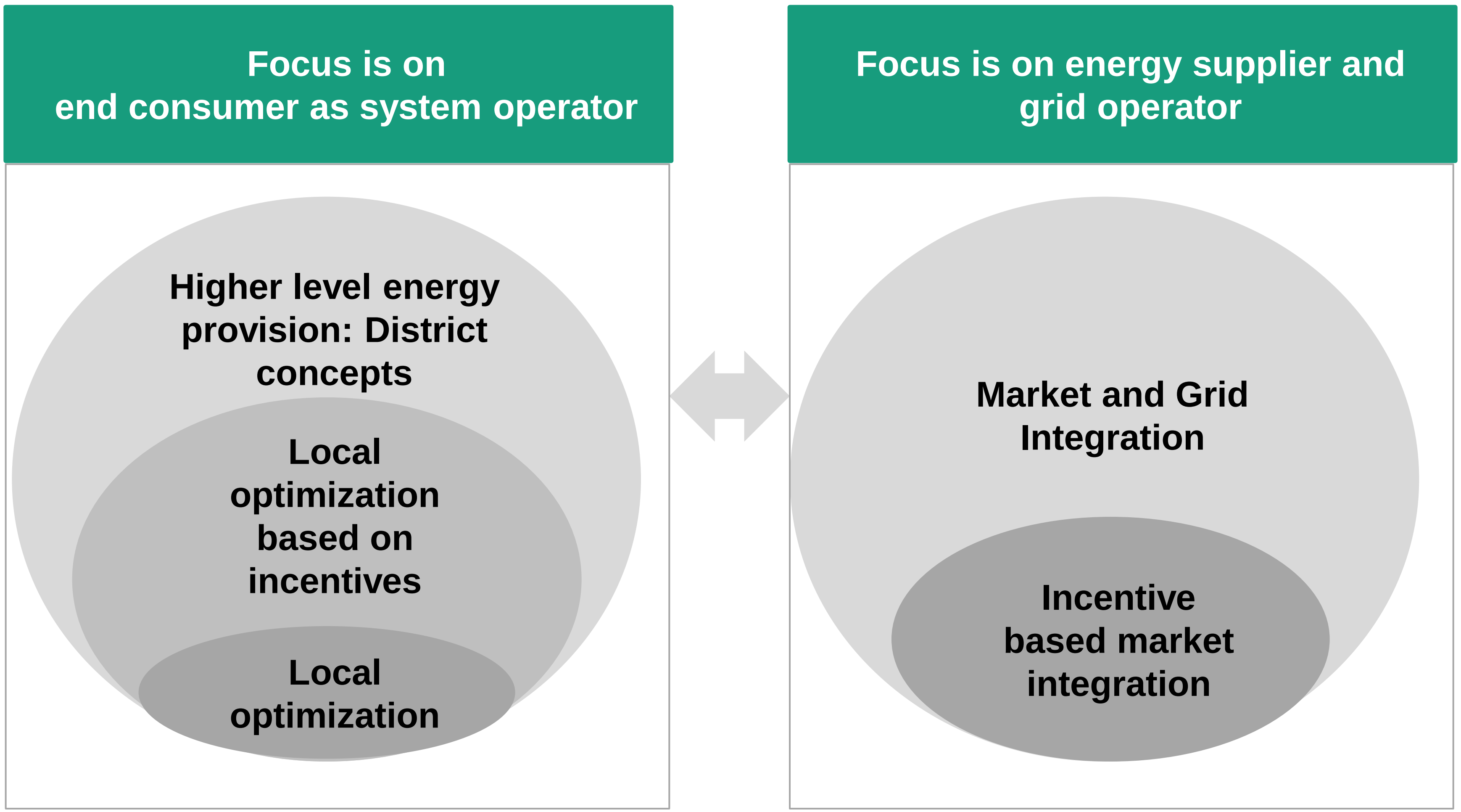
Scenarios and Use-Cases



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Steps towards an innovative decentralized HPS-System

Investment decision	▪ Tool for economically-efficient sized DER and storage systems (OptIn)
System operation	▪ Optimization of system operation based of detailed models and including PV-production load and forecasts
Performance test	▪ Implementing the optimized operation in an EMS ▪ Tests and demonstrations in the laboratory and/or in the field

➡ **Economical and technical excellent HPS-System**

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Sizing of decentralized HPS-Systems (OptIn)

Simulation and investment decision (including uncertainty)

Input
- User
- Load and generation profile
- Storage system parameters
- Market conditions and grid constraints
- Investment and operation cost

Optimization

Objective/ control strategy

depending on use-case

Results
- Sizing of storage systems
- Economic KPIs
- System and storage operation

Source: Appen et al., Staffelstein, 2015, contact: jan.vonappen@iwes.fraunhofer.de

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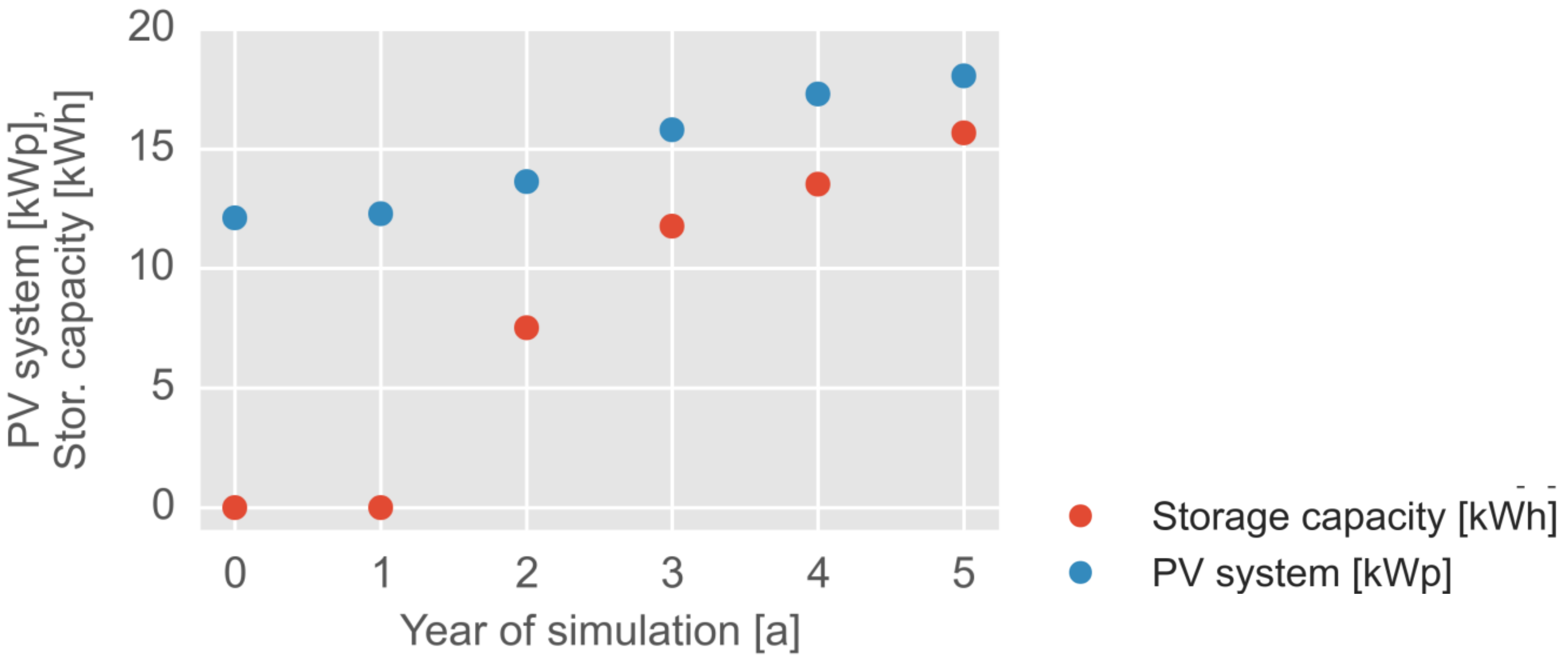
Example: Sizing of PV storage system

Optimization results in an self-consumption-oriented control strategy.

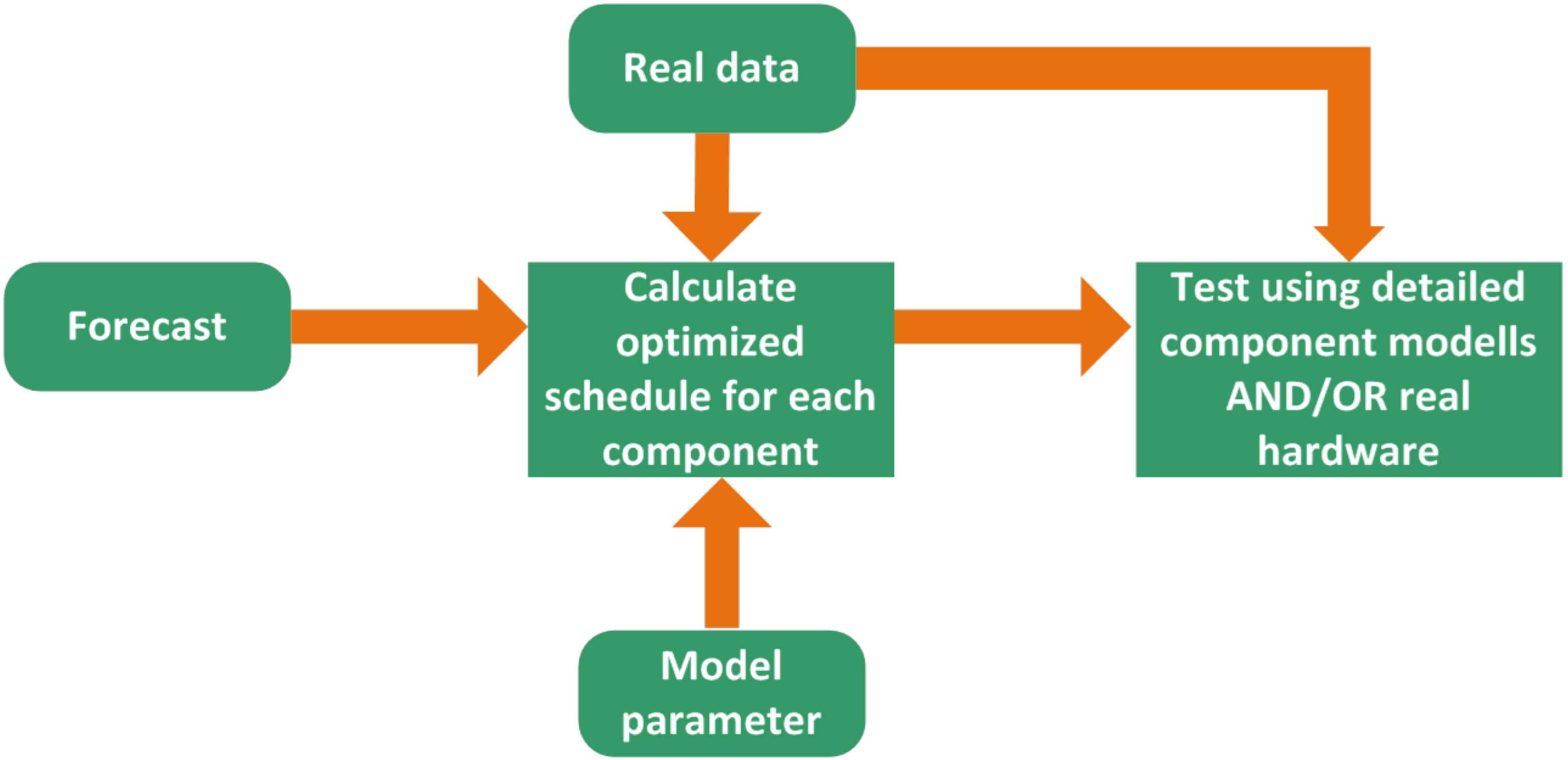


Including the uncertain development of electricity and storage system prices in the investment decision changes the optimal system sizing.

Source: Appen et al., Staffelstein, 2015, contact: jan.vonappen@iwes.fraunhofer.de

Optimized operation concept

The operation software can be used to calculate theoretical optimized operation schedules, but also implemented in an energy management system (like OGMEA) for laboratory and field tests.



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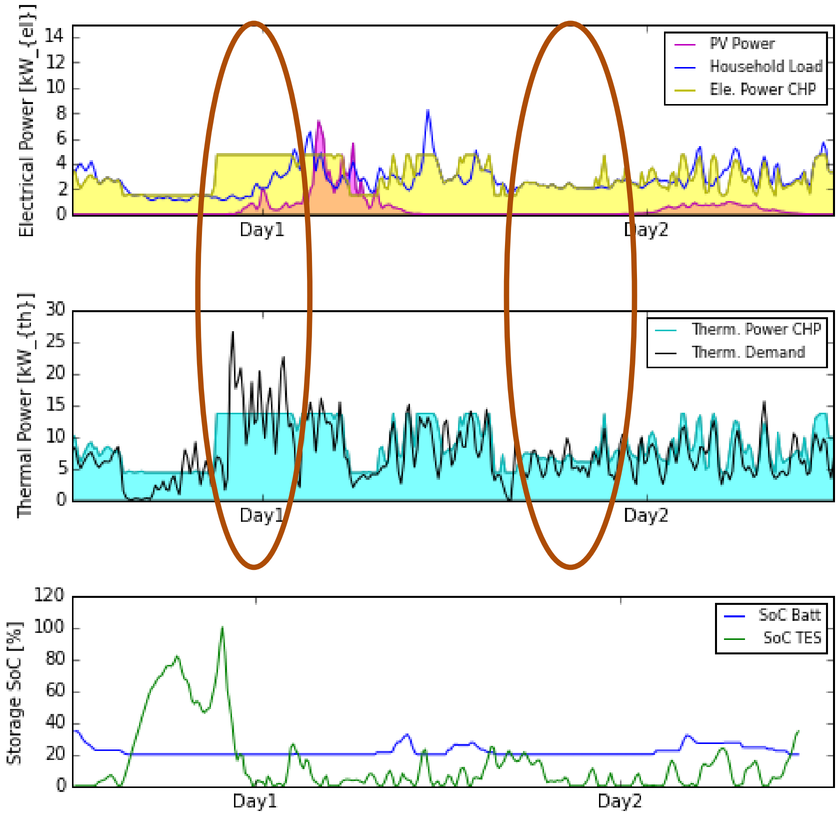
Example: Operation schedules for a HPS-System

Optimized operation of a PV-CHP-System including a thermal storage and a battery



CHP operation changes from heat-led operation to electricity-led operation, depending on the load profiles and storage SOCs.

Source: Diego Hidalgo

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Energy management system (EMS) OGEMA 2.0

Java based open-source platform: Apps can be developed independently by producer/distributor and added to the OGEMA 2.0 environment.

OGEMA

Weather App

Component Apps

Smart Grid Apps

Optimizer

Component driver

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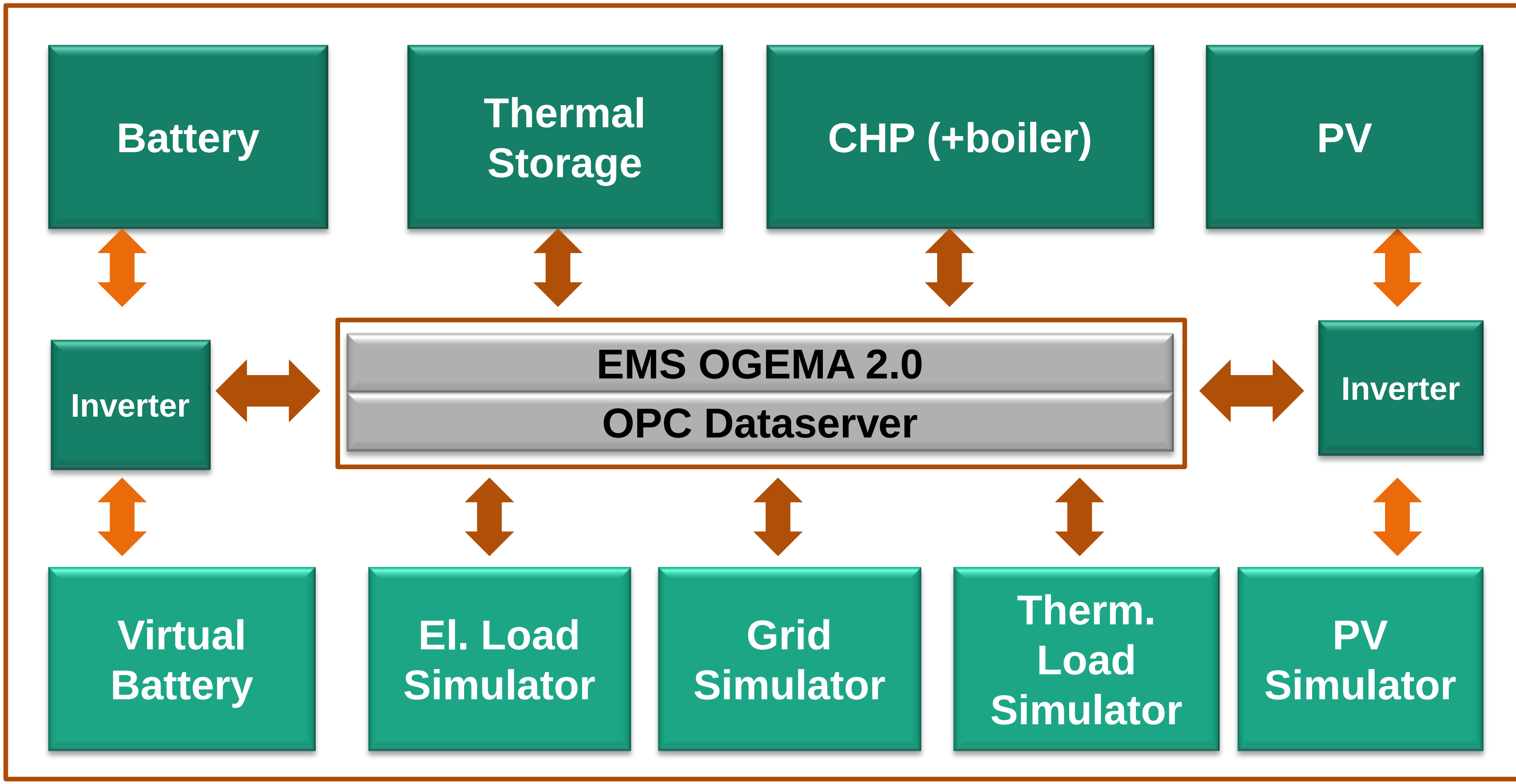
Demonstration structure - Modular concept

Real hardware components can be combined with simulators.



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Demonstration - Performancetest

Vaillant components

SMA components
with SAFT Battery

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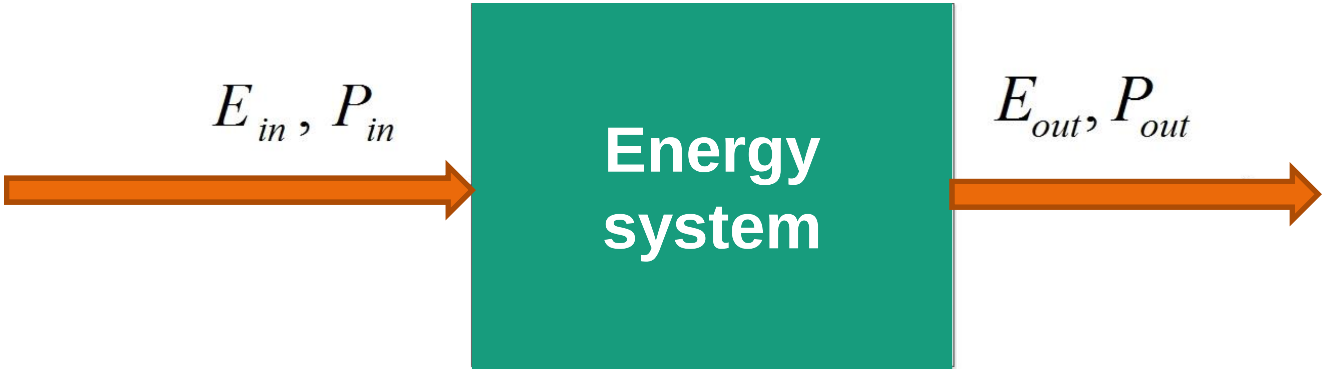
Performance test



Efficency

$$n = \frac{E_{out}}{E_{in}}$$

DEUTSCHE NORM

Dezember 2013

DIN EN 50530
(VDE 0126-12)

DIN

Diese Norm ist zugleich eine **VDE-Bestimmung** im Sinne von VDE 0022. Sie ist nach Durchführung des vom VDE-Präsidium beschlossenen Genehmigungsverfahrens unter der oben angeführten Nummer in das VDE-Vorschriftenwerk aufgenommen und in der „etz Elektrotechnik + Automation" bekannt gegeben worden.

VDE

Vervielfältigung – auch für innerbetriebliche Zwecke – nicht gestattet.

ICS 27.160

Ersatz für
DIN EN 50530
(VDE 0126-12):2011-04
Siehe Anwendungsbeginn

Gesamtwirkungsgrad von Photovoltaik-Wechselrichtern;
Deutsche Fassung EN 50530:2010 + A1:2013

Overall efficiency of grid connected photovoltaic inverters;
German version EN 50530:2010 + A1:2013

Efficacité globale des onduleurs photovoltaïques raccordés au réseau;
Version allemande EN 50530:2010 + A1:2013

- The regular approach is not sufficient to determine the performance of decentralized HPS-System systems
- Beside the normal losses within the energy system, the quality of the energy-management and the storage operation are important factors for the system performance

Source: Fabian Niedermeyer, CEB 2015, fabian.niedermeyer@iwes.fraunhofer.de

Performance Tests: Application Test Approach

Objective:

Assessment of the performance in an exemplary application of the system

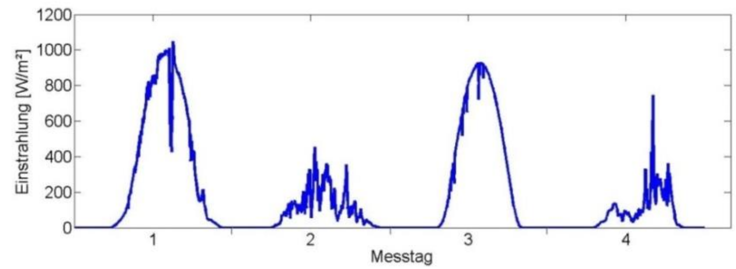
Calculation of three performance indicators:

- system efficiency
- system control
- self-sufficiency

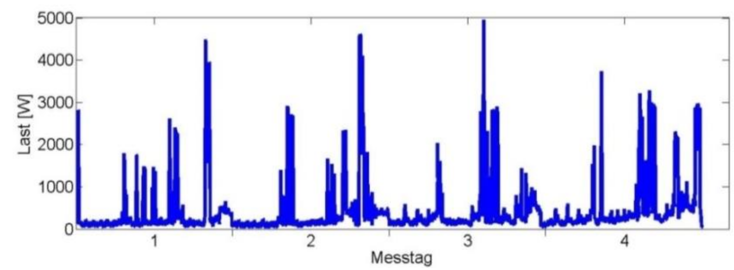
Selection of test profiles:

- 4 day profiles: irradiation & el. load
- Selection of profiles based on an analysis of long-term measurements
- Implementation in laboratory in 1-sec resolution
- Emulation of typical operation states

Test profile PV



Test profile el. load



Source: Fabian Niedermeyer, CEB 2015, fabian.niedermeyer@iwes.fraunhofer.de

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Performance Tests: Modular Test Approach

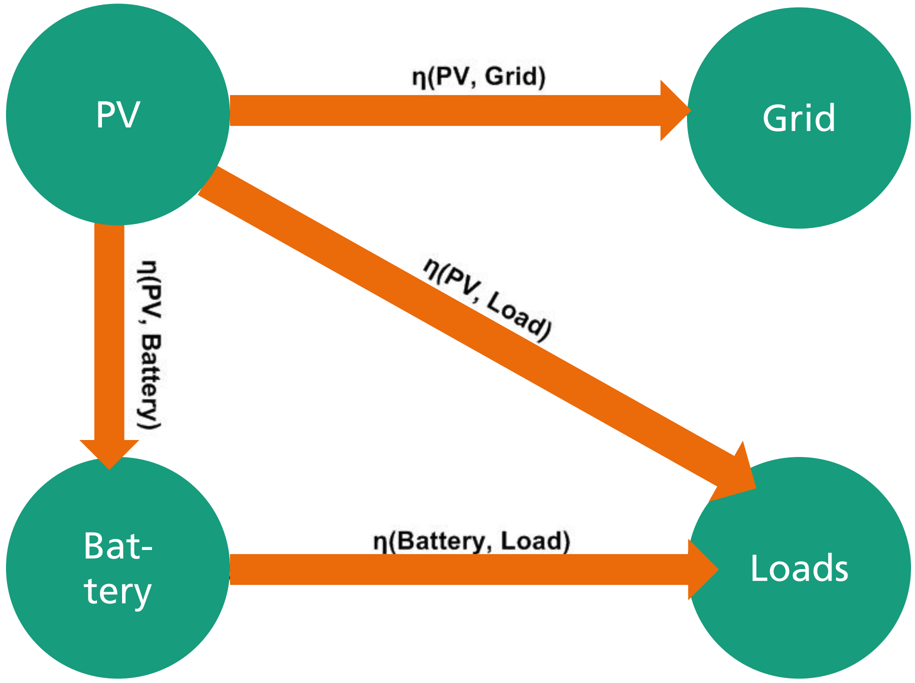
Objective:

Determination of the system performance in use-cases which are very different to the application test

Measurement of static energy conversion efficiencies

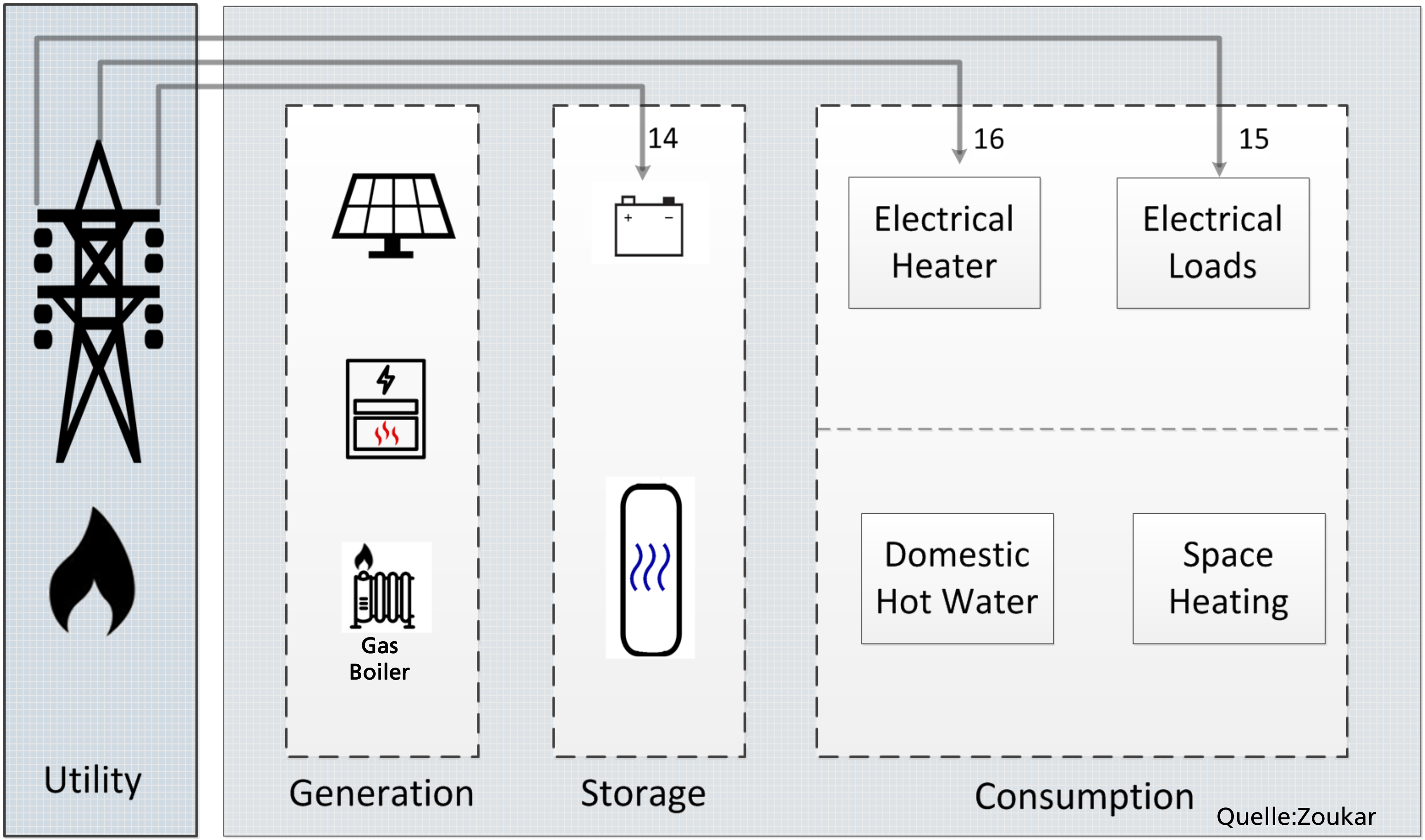
- PV → Battery
- PV → loads
- Bat→ loads

Determination of losses in different operational states and power levels



Contact: Fabian Niedermeyer, fabian.niedermeyer@iwes.fraunhofer.de

Grid → Electrical loads



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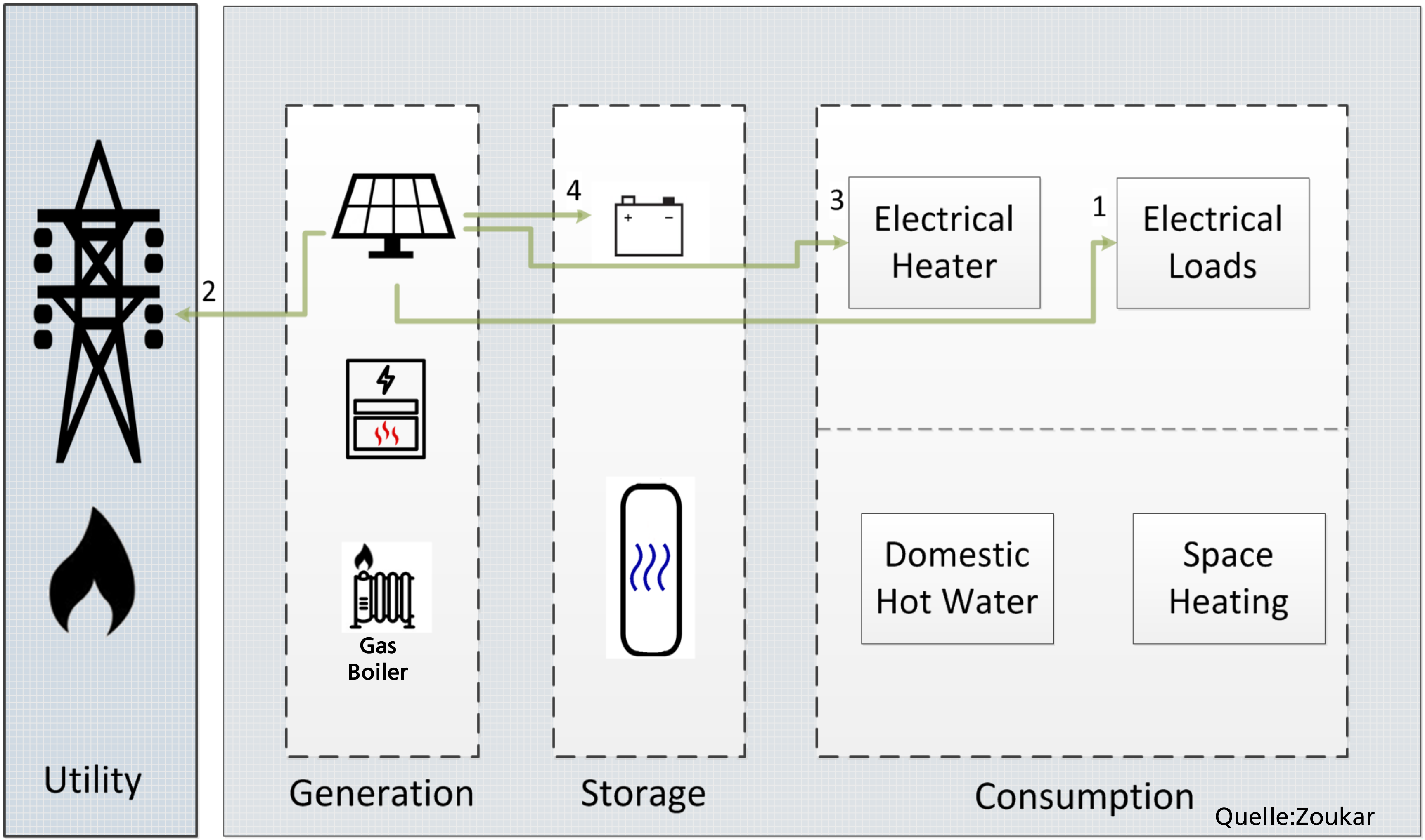
PV → Electrical loads



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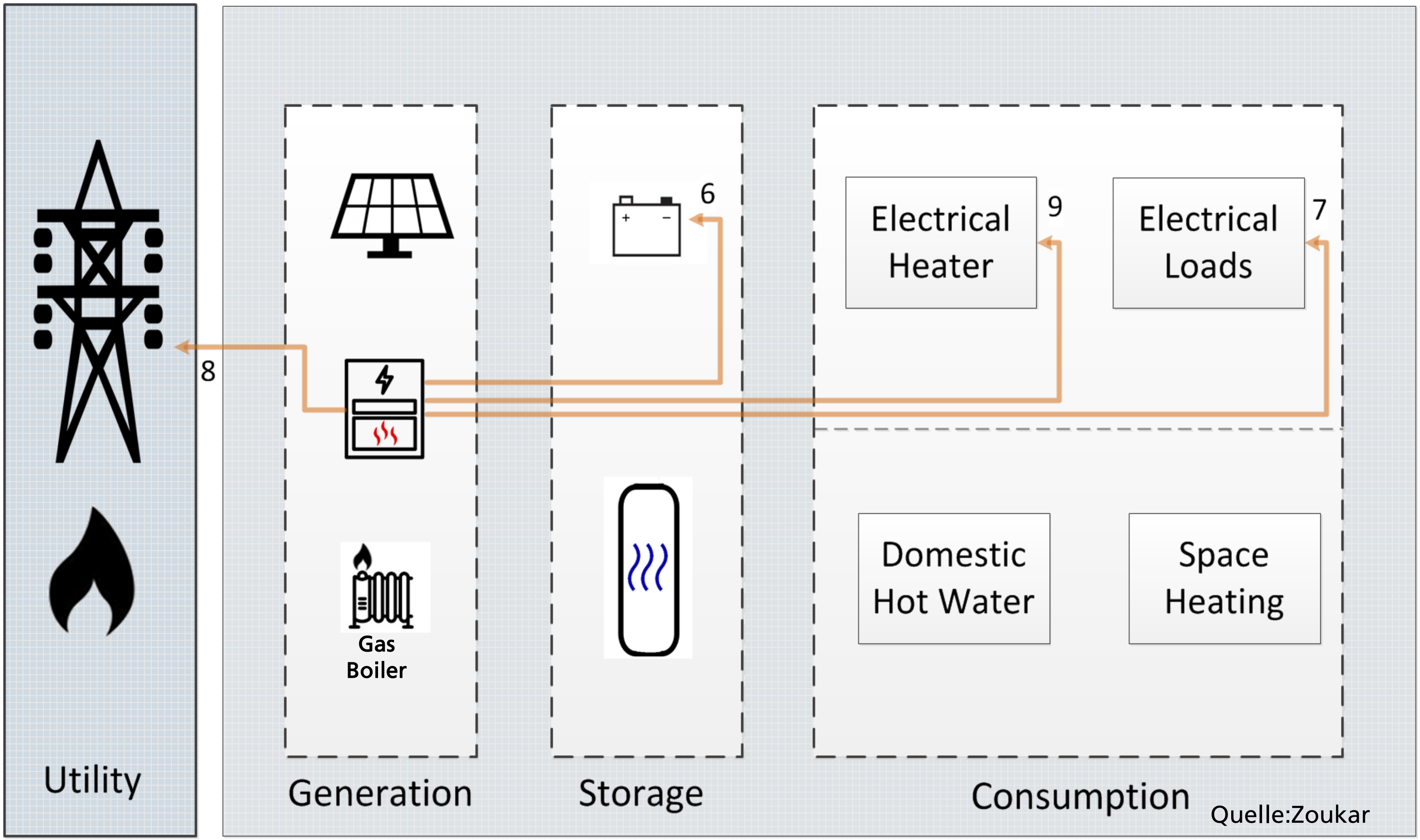
CHP → Electrical loads



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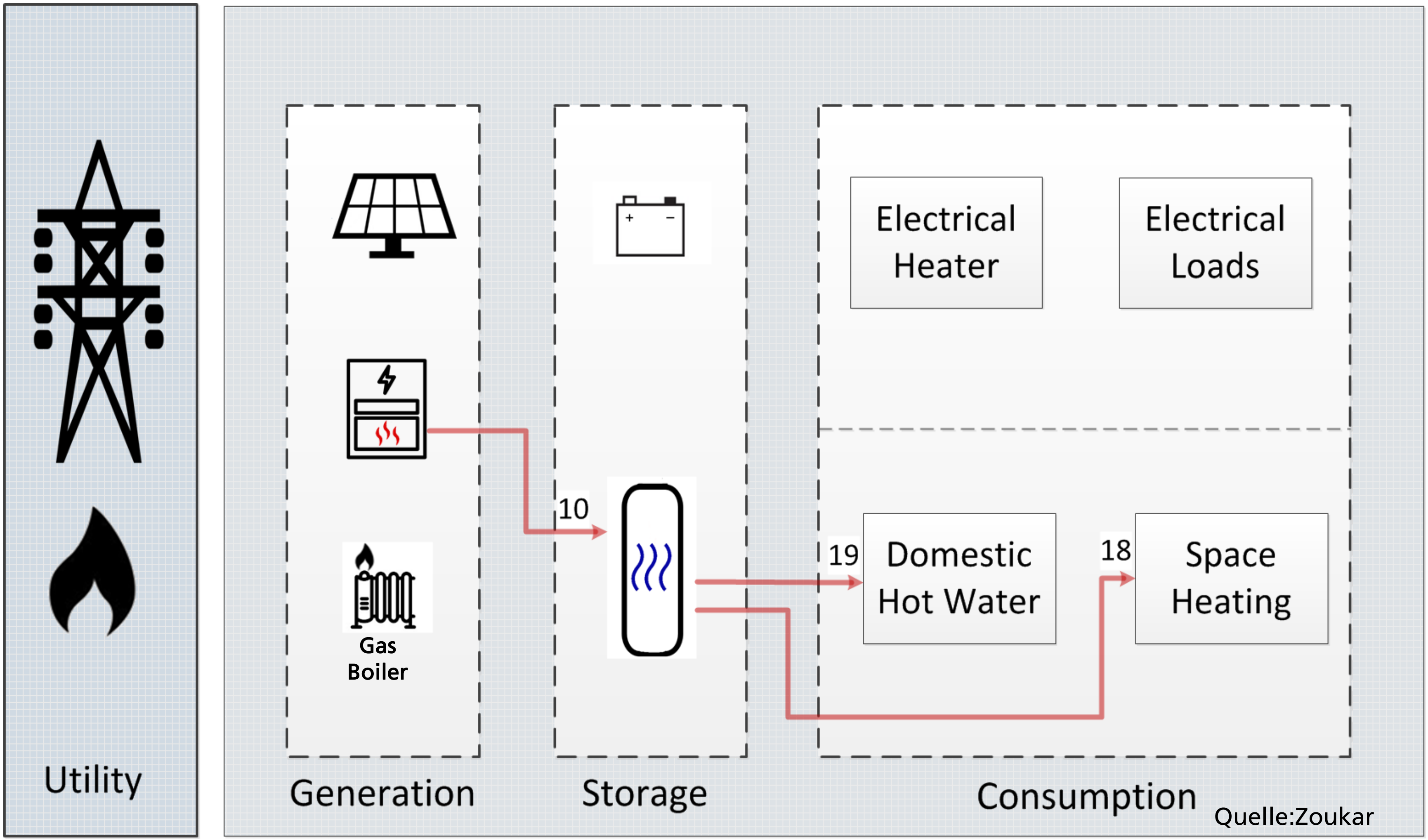
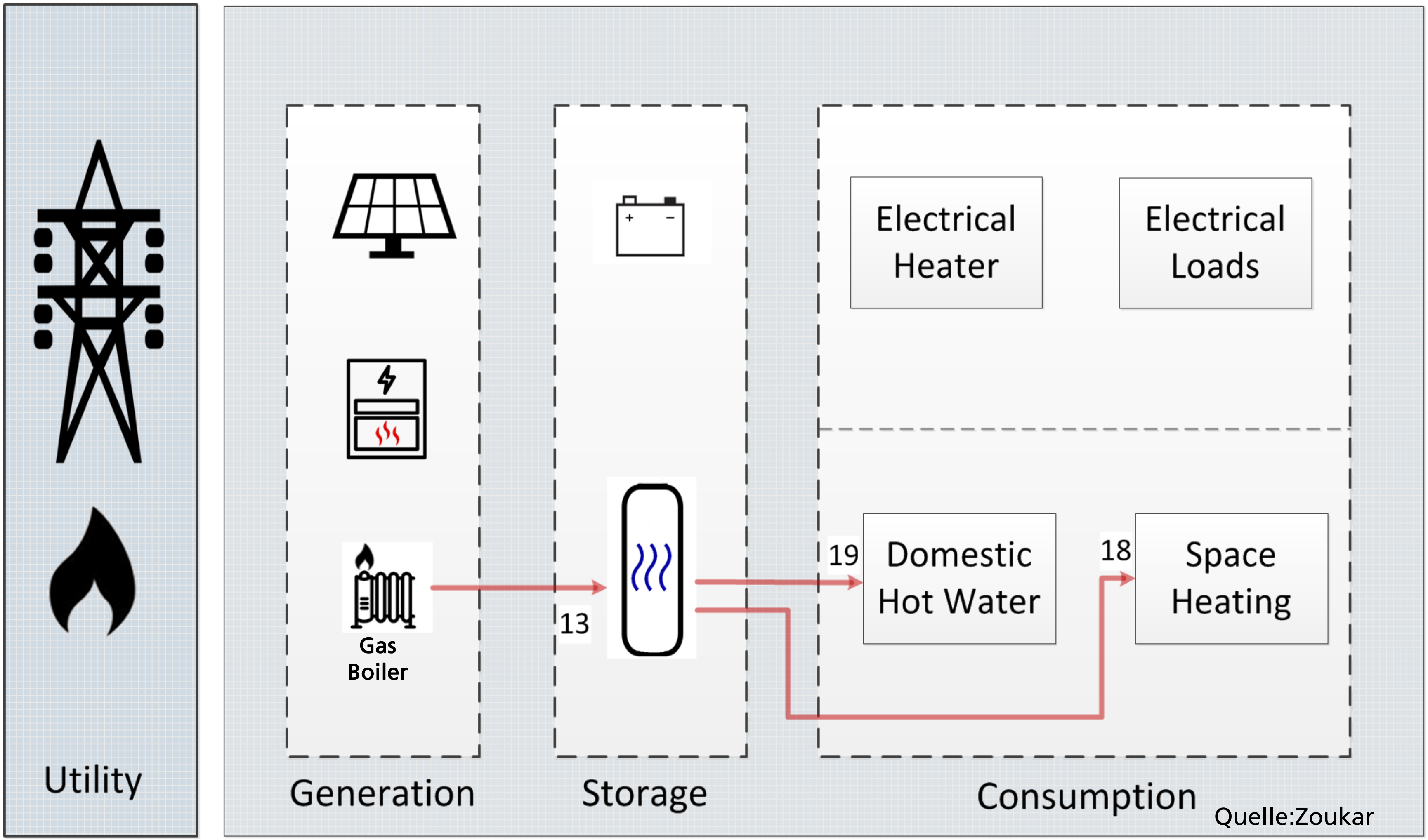
CHP → Thermal loads



Gas-boiler → Thermal loads



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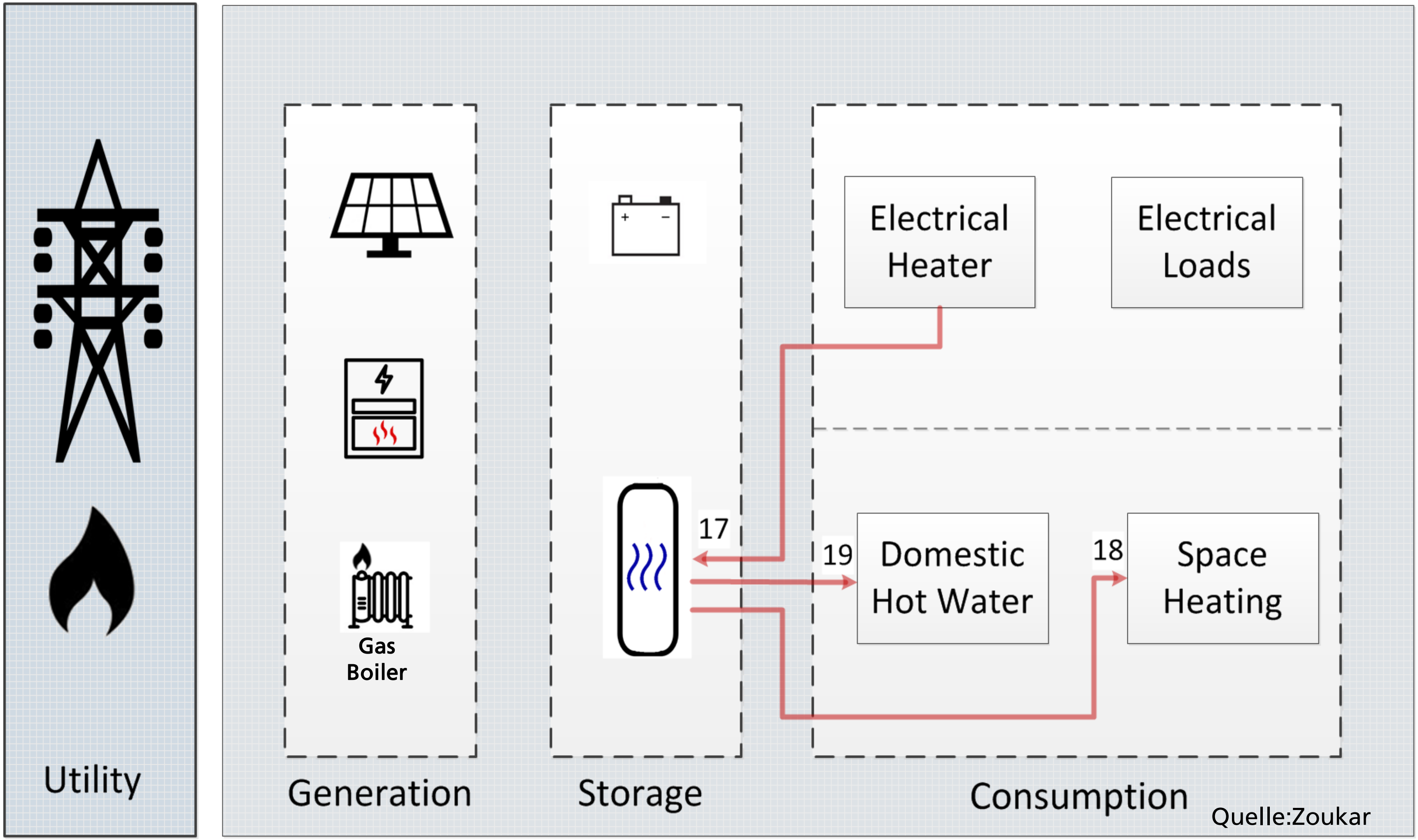
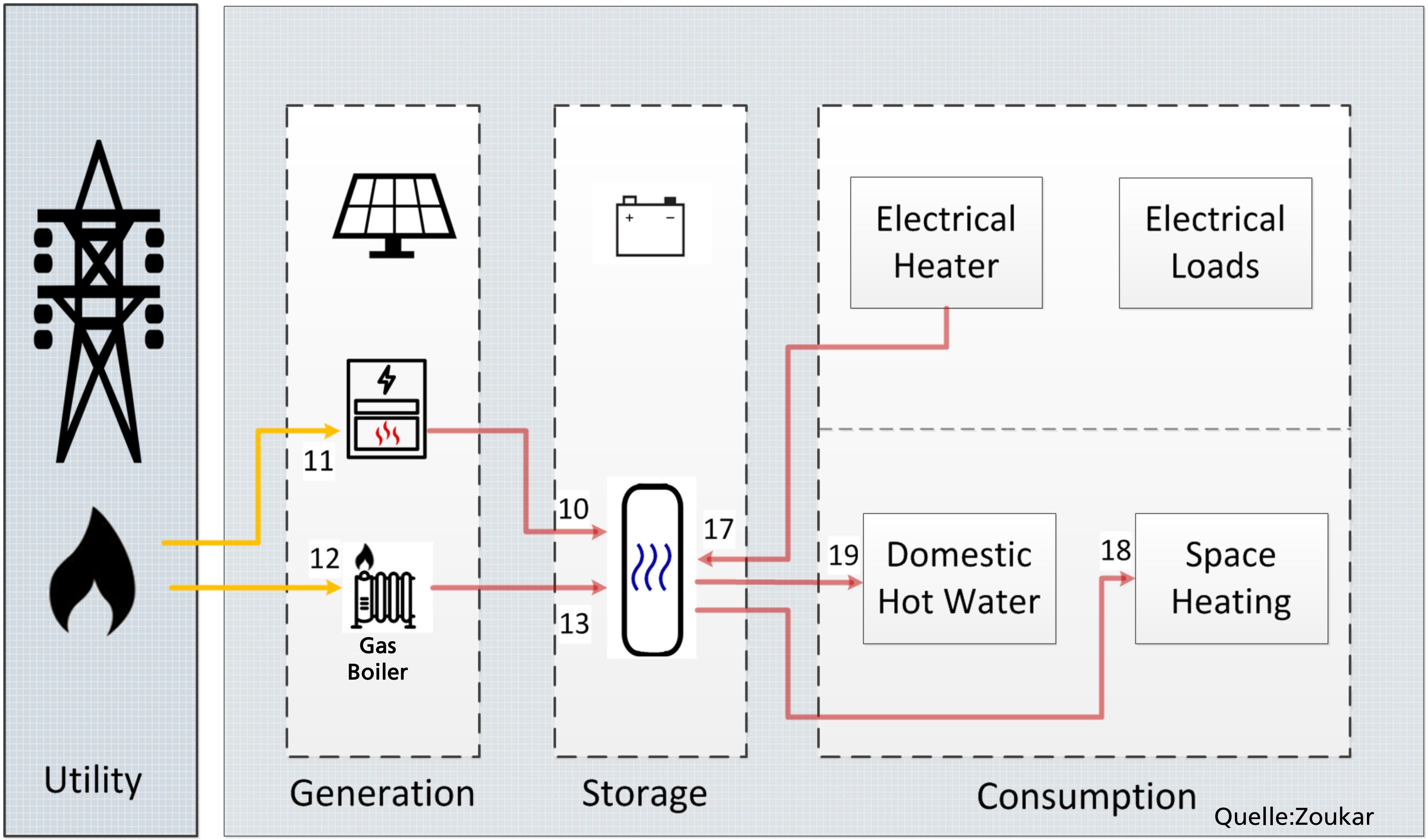
Electric heater → Thermal loads



Gas → Thermal loads



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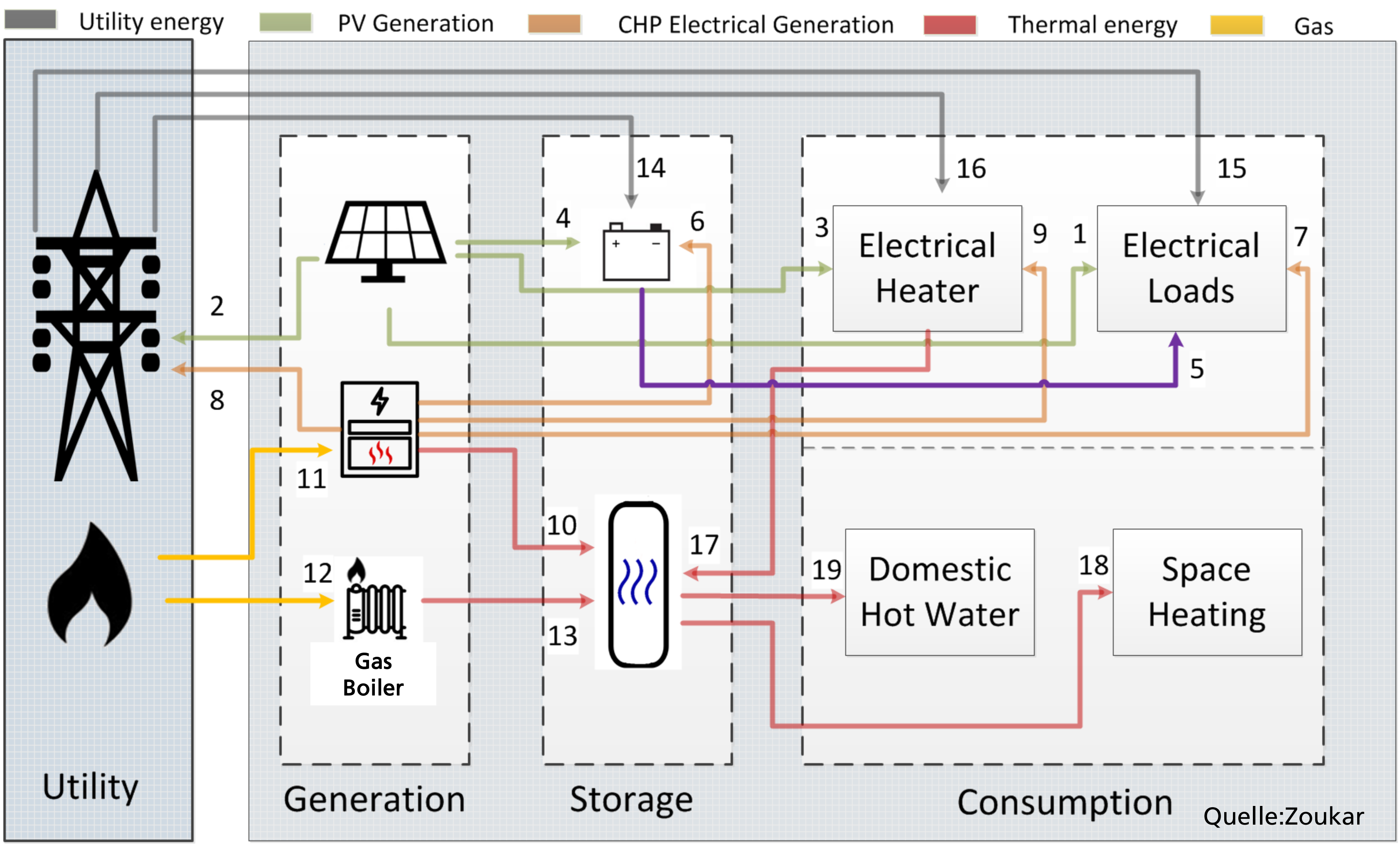
How can a Performancetest be done ?



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Summary

Question	▪ What is the optimized use of an HPS-System?
Investment decision	▪ Optimize sizing of system components (objective)
Operation optimization	▪ Optimize system operation and scheduling (objective)
Demon-stration	▪ Technical validation – Performancetest
Answer	▪ There is no general answer. ▪ There is an individual solution for each business case !

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References and Literature Suggestions

- Thomas Stetz, Jan von Appen, Fabian Niedermeyer, Gunter Schreibner, Roman Sikora and Martin Braun, “Twilight of the grid”, IEEE power and energy Magazin 2015
- J. Appen, T. Stetz, M. Braun, A. Schmiegel, “Local Voltage Control Strategies for PV Storage Systems in Distribution Grids,” *IEEE Trans. Smart Grids,* under Review 2013.
- J. Appen, M. Braun, T. Kneiske, A. Schmiegel, “Einfluss von PV-Speichersystemen auf das Niederspannungsnetz,” in *Proc. 2013 28. Symposium Photovoltaische Solarenergie*, pp. 1-12.
- J. Appen, A. Schmiegel M. Braun, “Impact of PV storage systems on LV grids,” in *Proc. 2012 27th European PV Solar Energy Conf.*, pp. 3822-3828.
- M. Braun, K. Büdenbender, D. Magnor, A. Jossen, “Photovoltaic Self-Consumption in Germany,” in *Proc. 2009 24th European PV Solar Energy Conf.*, pp. 3121-3127
- M. Braun, T. Stetz, A. Oehsen, Y.-M. Saint-Drenan, “Vorstudie zur Integration großer Anteile Photovoltaik in die elektrische Energieversorung,“ Report for BSW – German Solar Industry Asso., May 2012.
- D. Hidalgo et al. "Development of a Control Strategy for mini CHP Plants for an Active Voltage Management in Low Voltage Networks," *in Proc. IEEE ISGT Europe 2012*.
- T. Kneiske “Potenzial & Wirtschaftlichkeit von Stromspeichern kleinerer und mittlerer Leistungsklassen,“ CEB, Feb. 2013.
- Electricitcy Storage Association, “Technology Comparison,“ http://www.electricitystorage.org/technology/storage_technologies/technology_comparison, Mar. 2013.
- A. Arteconi et al. “*State of the art of thermal storage for demand-side management*“ in Applied Energy 93. 2012
- J. Appen, M. Braun, T. Stetz, K. Diwold, D. Geibel, “Time in the Sun”, *IEEE Power & Energy Mag.*, vol.11, pp.55-64, March 2013.
- J. Appen, M. Braun, R. Estrella, “A Framework for Different Storage Use Cases in Dist. Syst.,” in *Proc. 2012 CIRED* , Paper no. 318.
- J. Appen, M. Braun, T. Kneiske, “Voltage Control using PV Storage Syst. in Dist. Systems”, in *Proc. 2013 CIRED*, Paper no. 1396.
- T. Stetz, M. Braun, F. Marten, “Improved LV Grid-Integration of PV Systems in Germany,” *IEEE Trans. Sust. Energy,* vol. 99, pp. 1-9.
- T. Stetz, M. Kraiczy, M. Braun, S. Schmidt, “Technical and economical assessment of voltage control strategies in distribution grids,” *Prog. Photovolt: Res. Appl.*. doi: 10.1002/pip.2331.

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