Modelling and optimization of renewable energy supply for electrified vehicle fleet

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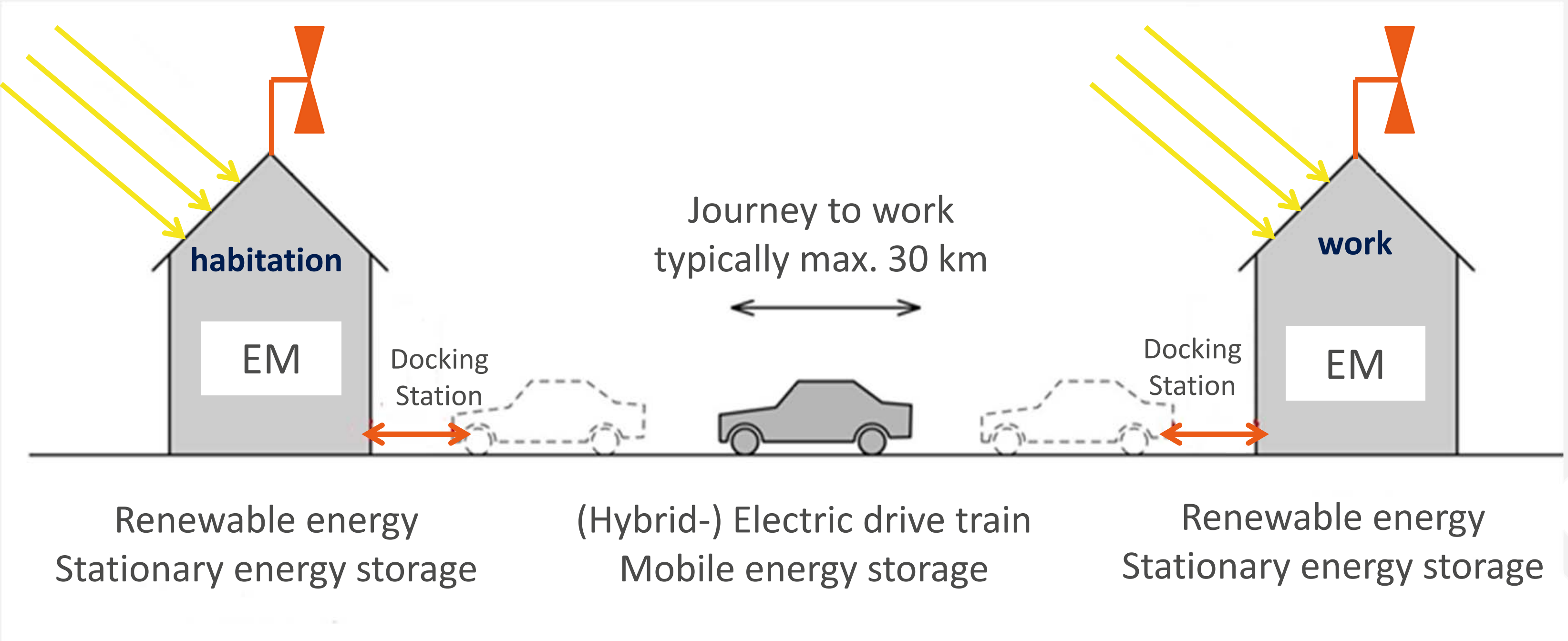
optimizing your energy applications

Outline

- Introduction and Motivation
- Modelica-based simulation environment ‘Green Building‘
- Coupling vehicle and building systems simulation
- Simulation examples and results
- Summary and outlook

Introduction and Motivation

Changed situation – residence and mobility



- Former situation: People commuting to work, energy supply to buildings (grid, etc.) seperated from energy supply to vehicles (petrol station)
- Future situation: Electrified vehicles, energy supply to buildings and vehicles connected (electricity), renewable energy producers, local storage systems

Introduction and Motivation

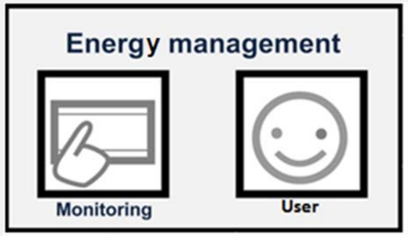
Holistic energy system design requires simulation

Human behavior

Charging of electric Vehicles

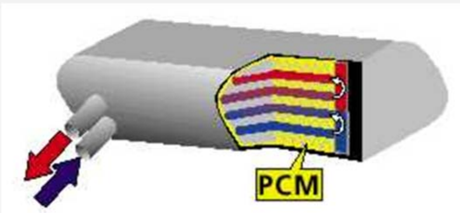
source: [TUDEA]

Energy management



source: [EA]

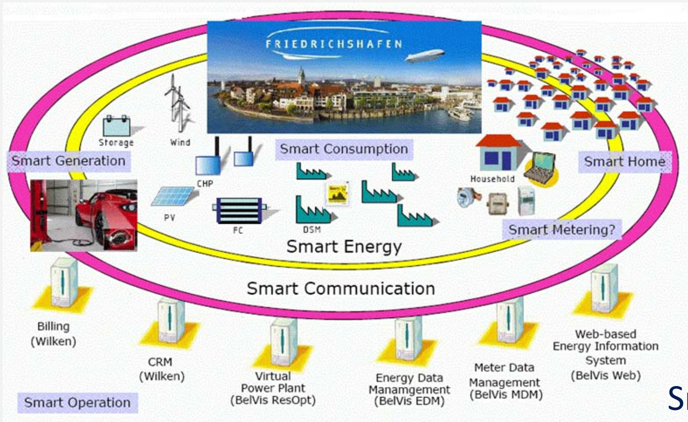
Phase change memories (PCM)



source: [Hac02]

Batteries – non-linear characteristics, aging, costs

source: [Sch09]

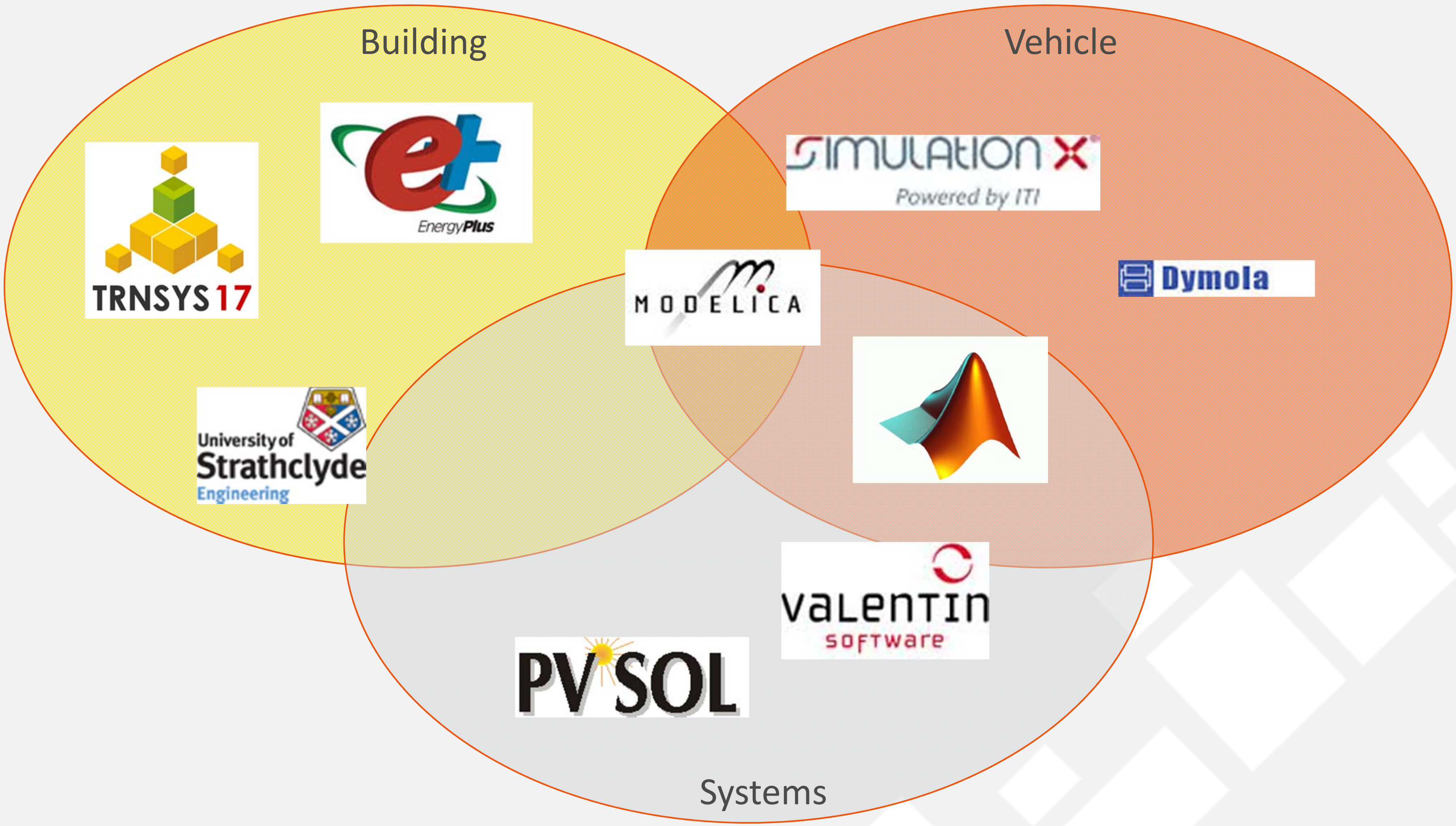


source: [Soc10]

SmartGrid

Introduction and Motivation

Great variaty of existing simulation tools and systems

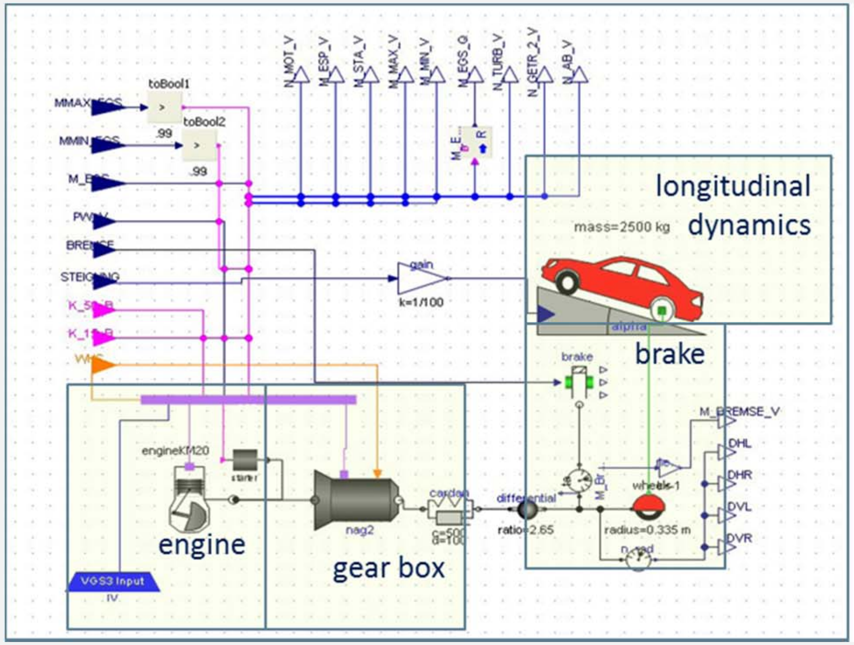


Modelica-based environment ‘Green Building‘

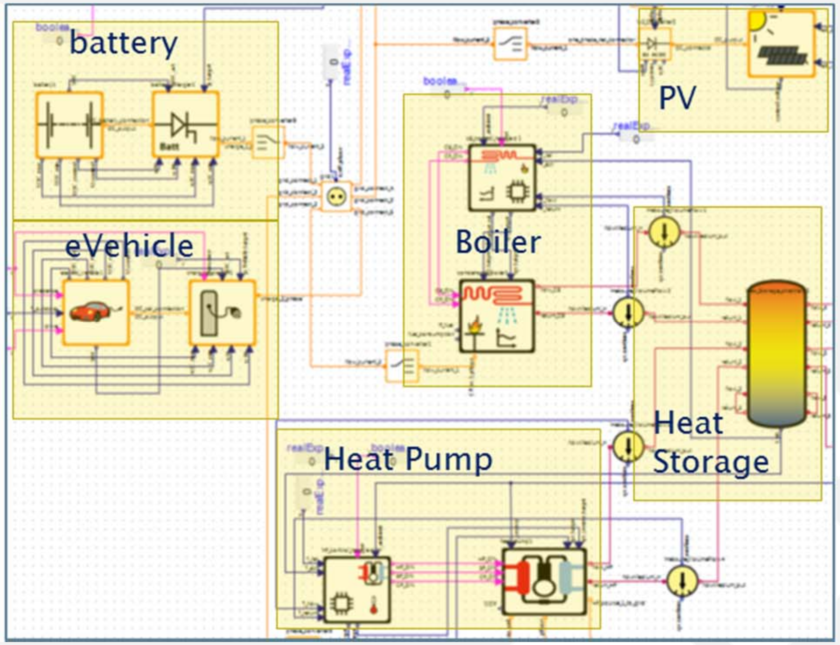
Approach from automotive industry

Modelica:

- Non-proprietary, object-oriented, non-causal, equation-based language to model complex, domain-overall physical systems



Modelica car model with engine, braking system, gearbox etc.



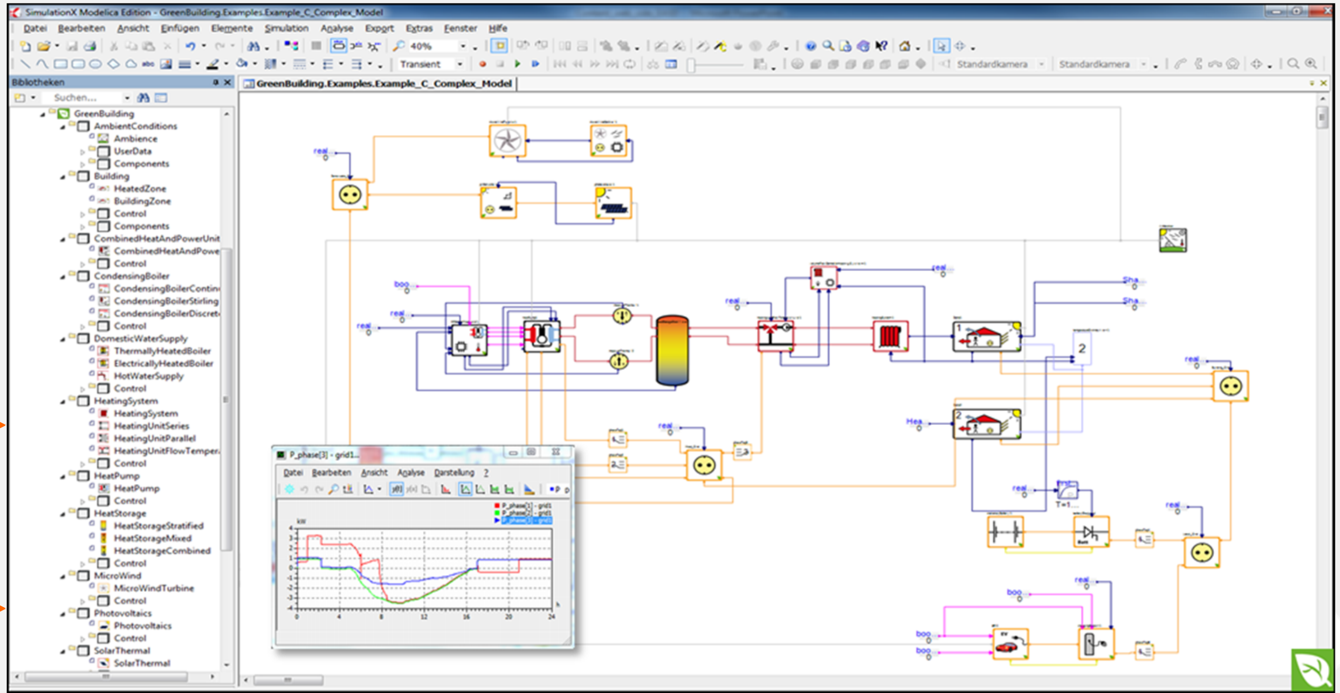
‘Green Building‘ building energy system model including heat storage, photovoltaic, battery, heat pump, boiler and eVehicle

Modelica-based environment ‘Green Building‘

Inputs, outputs and usage of simulation environment

Inputs

- Location, climate
- Energy prizes
- Building and system configuration
- Inhabitants and requirements
- *eMobility*



Model library

- Energy producers and consumers
- Storages
- Ambience and Grid
- *eVehicles*

Test and optimization

- Fast → 1h per year with short step size
- Simulated characteristics instead of references
- Optimization for “real-world“ conditions
- Synthetic statistics

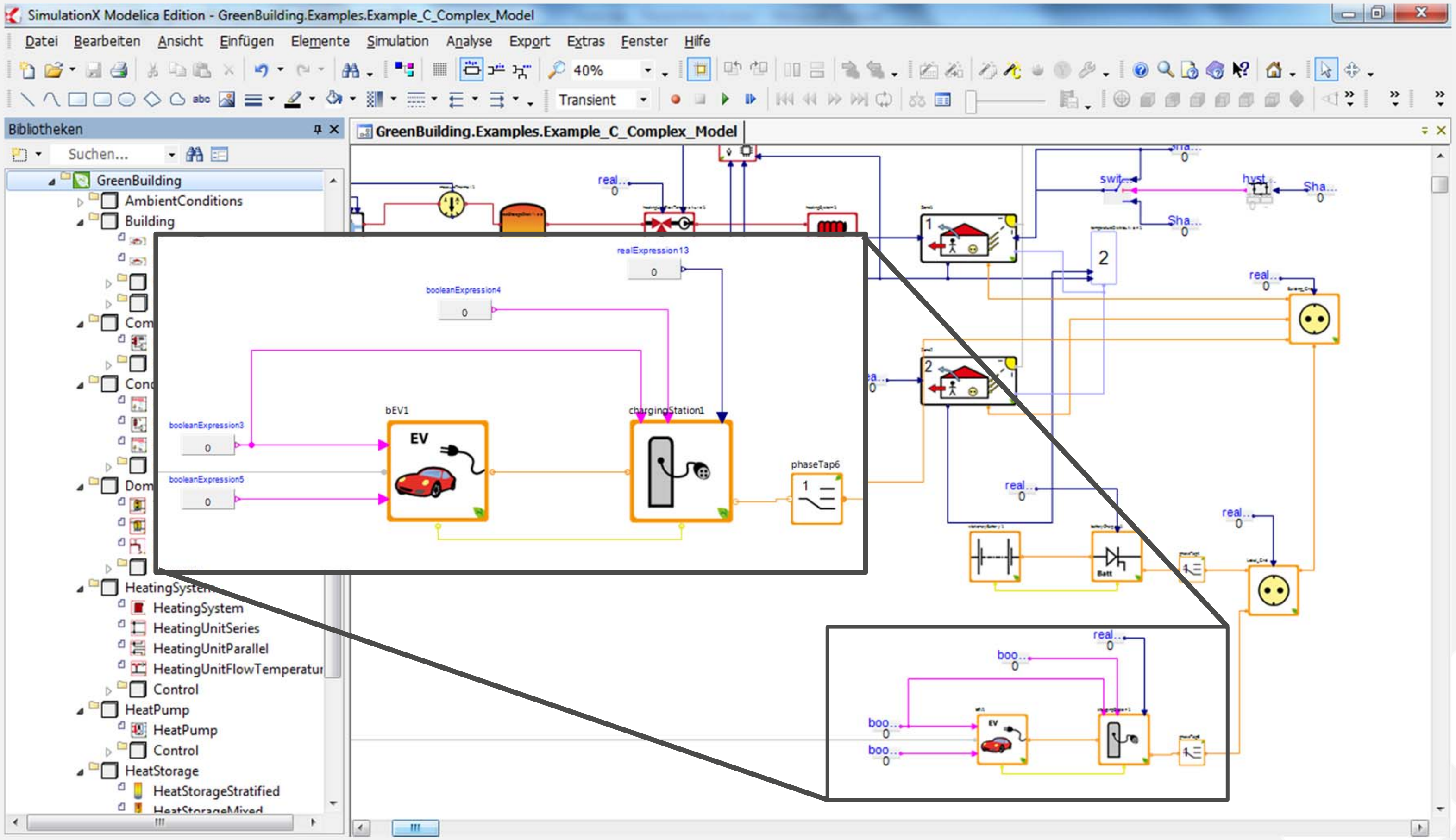
Outputs

- Gains and Consumption
- Dimensions and feasibility
- Costs and profitableness
- Strategies for energy management and storage

‘Green Building‘ simulation package, distributed by ITI GmbH, Dresden

Coupling vehicle and building simulation

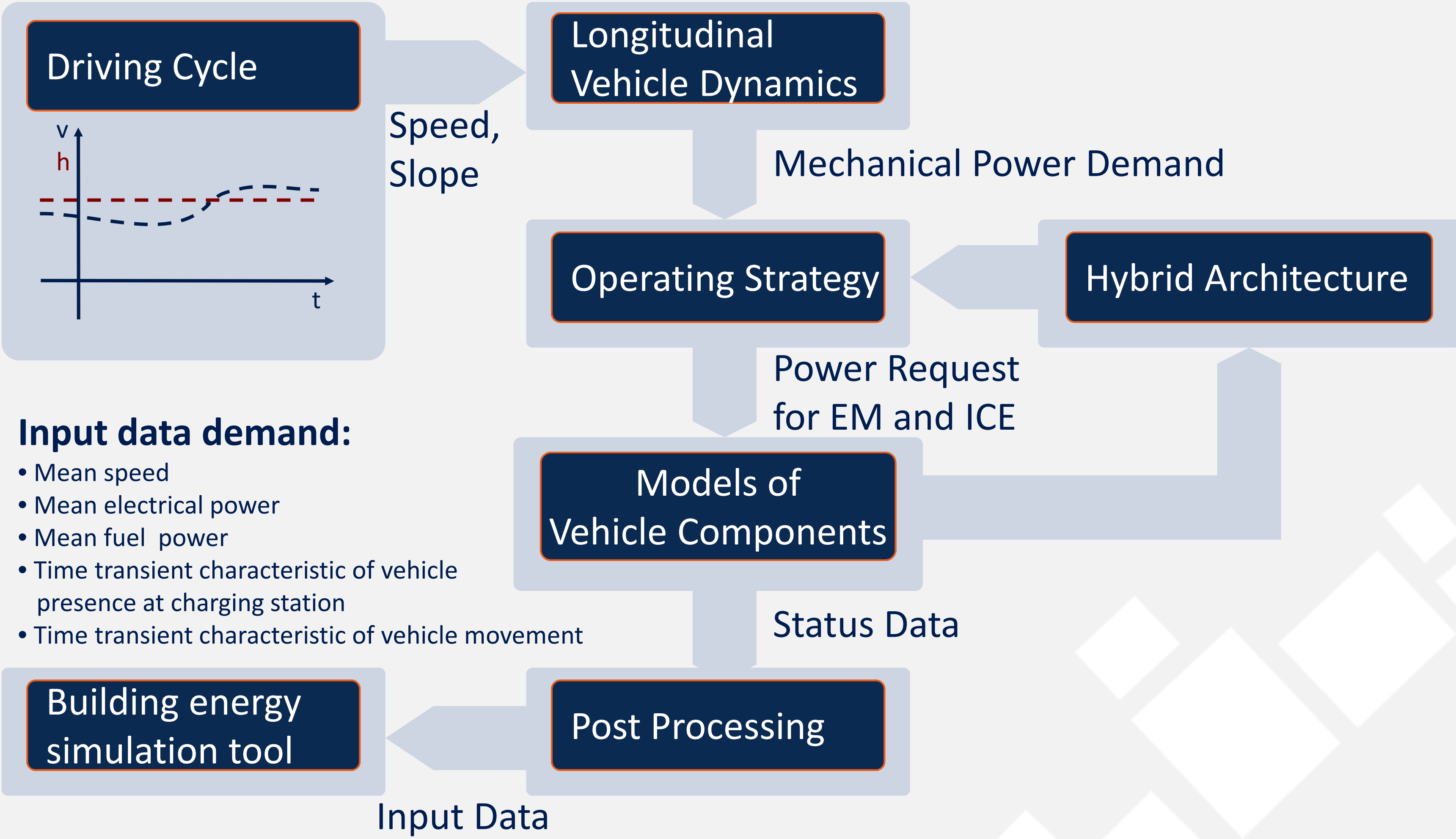
eVehicles as a part of bulidung energy system model



- From Building's point of view: eVehicle is additional consumer/storage
- Interesting system states: SOC of battery when vehicle is available at charging station as well as average energy consumption when driving – preprocessing required

Coupling vehicle and building simulation

Calculation/simulation of vehicle energy consumption



Input data demand:

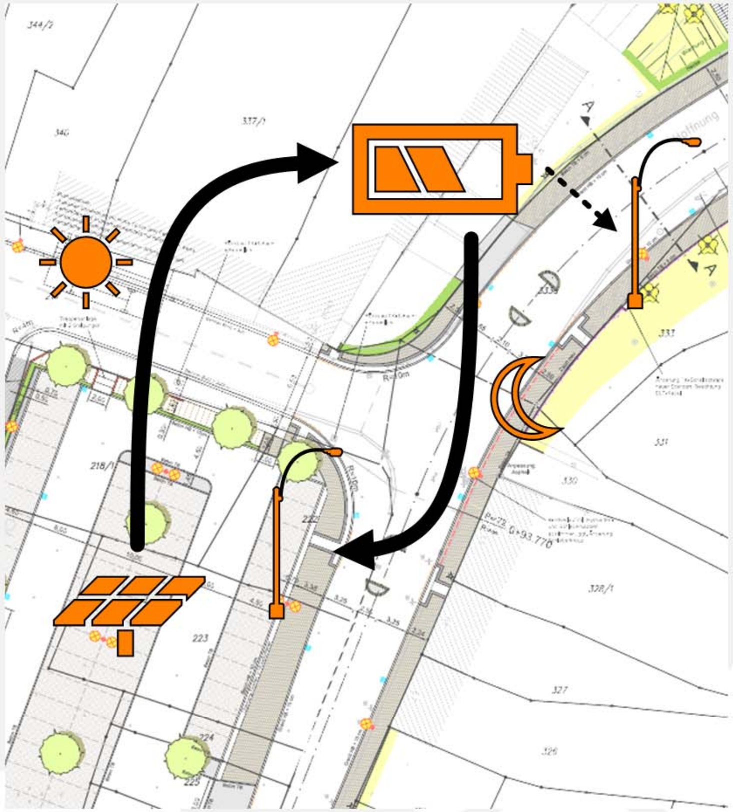
- Mean speed
- Mean electrical power
- Mean fuel power
- Time transient characteristic of vehicle presence at charging station
- Time transient characteristic of vehicle movement

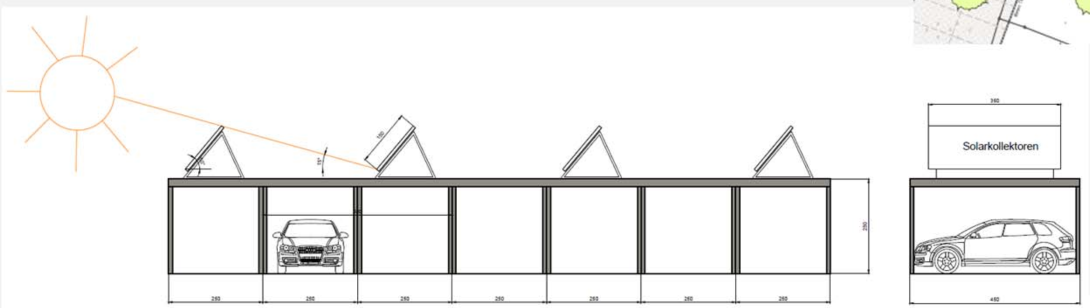
Simulation examples and results

Simulation of renewable parking lot

- optimal PV peak power
- angle and inclination
- battery size

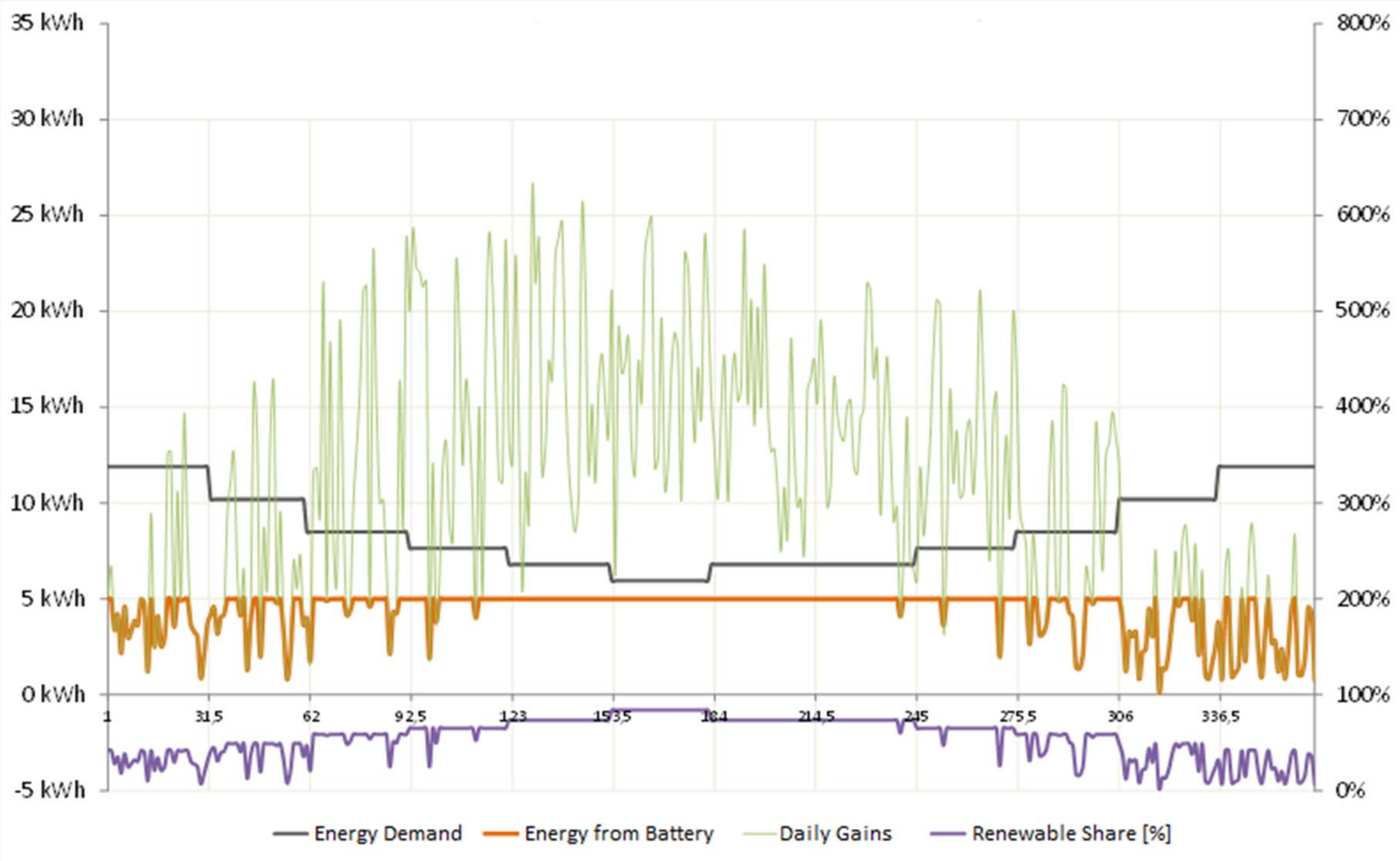
- cost efficiency
- renewable energy share





Simulation examples and results

Renewable energy share of a renewable parking area lighting



Example: 5 kWh battery, 4 kWp photovoltaic optimal alignment (south, inclination 35°)

Simulation examples and results

Layout of battery capacity for renewable parking area lighting

- Variants calculation for photovoltaic system size and battery capacity layout – layout target: highest annual share of renewable energy (south, inclination 50˚)
- Low coverage in winter in case of cheap PV-system and storage combinations
  - Few sunshine
  - Long light-on times
- System oversizing in summer even in case of small PV-systems and storage capacities
- Optimum: Layout regarding transitional time and cost aspects
- This way: „optimal“:
  3-4 kWp PV-system
  4-10 kWh battery capacity

December

27%	1	2	3	4	5	6	7	8	9	10
2	7%	11%	13%	14%	15%	15%	16%	16%	17%	17%
4	7%	14%	19%	22%	24%	26%	27%	28%	29%	30%
6	7%	14%	21%	26%	30%	32%	35%	37%	38%	40%
8	7%	14%	22%	28%	34%	38%	41%	43%	46%	48%
10	7%	14%	22%	29%	36%	41%	45%	49%	52%	54%
12	7%	14%	22%	29%	36%	43%	48%	53%	56%	60%
14	7%	14%	22%	29%	36%	43%	50%	55%	59%	62%
16	7%	14%	22%	29%	36%	43%	50%	56%	60%	64%
18	7%	14%	22%	29%	36%	43%	50%	57%	62%	66%
20	7%	14%	22%	29%	36%	43%	50%	58%	63%	68%

June

84%	1	2	3	4	5	6	7	8	9	10
2	33%	34%	34%	34%	34%	34%	34%	34%	34%	34%
4	61%	67%	67%	67%	67%	67%	67%	67%	67%	67%
6	71%	98%	99%	100%	100%	100%	100%	100%	100%	100%
8	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
10	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
12	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20	72%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Oversizing

March

PV-system in kWp

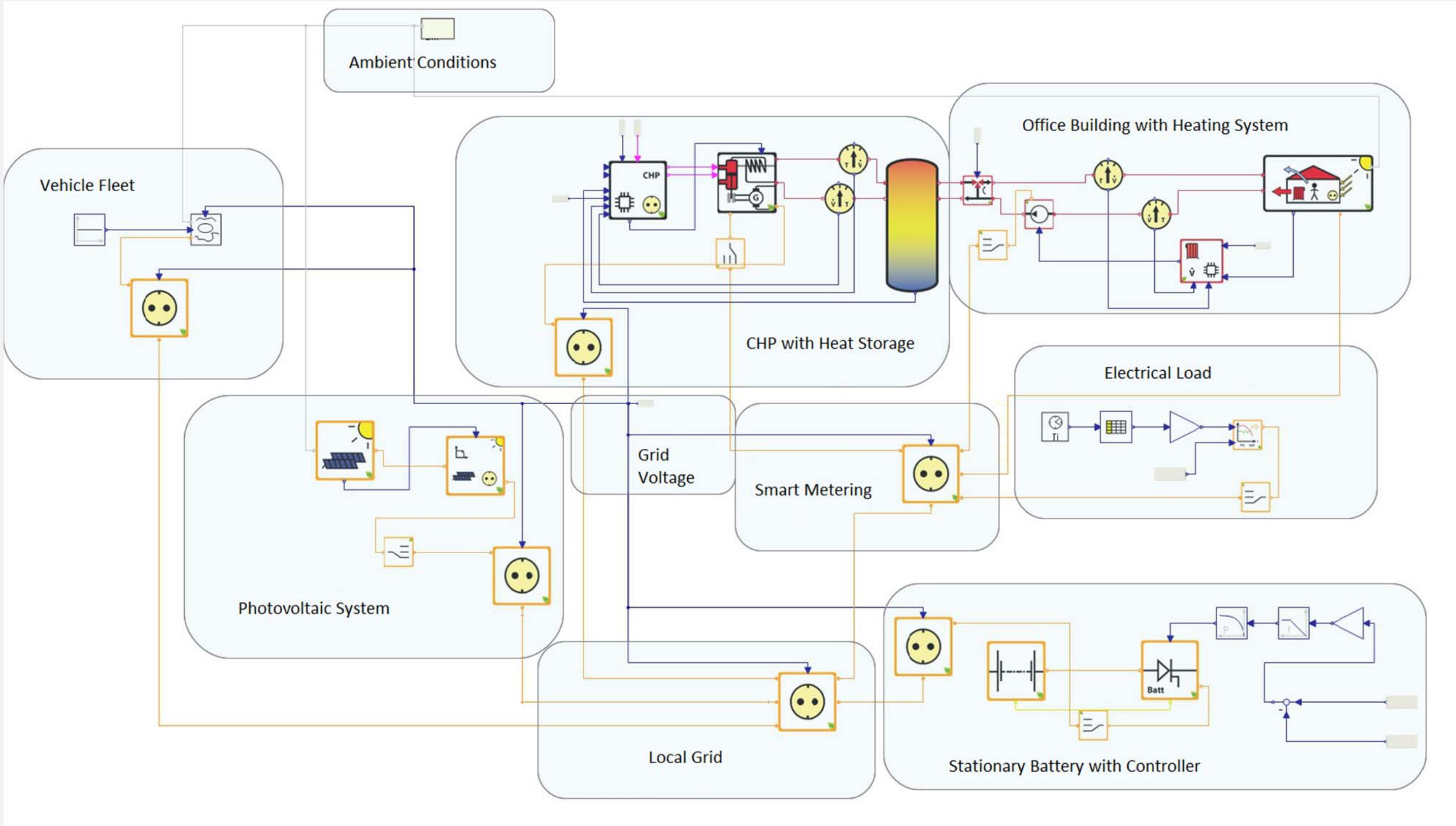
Battery Capacity in kWh

57%	1	2	3	4	5	6	7	8	9	10
2	20%	23%	23%	23%	24%	24%	24%	24%	24%	24%
4	29%	39%	43%	45%	46%	46%	47%	47%	47%	47%
6	33%	51%	59%	63%	66%	68%	69%	69%	69%	70%
8	33%	59%	72%	79%	83%	86%	89%	91%	91%	92%
10	33%	62%	78%	85%	90%	93%	95%	97%	98%	98%
12	33%	64%	82%	89%	92%	94%	96%	98%	98%	99%
14	33%	64%	85%	90%	93%	95%	97%	98%	99%	100%
16	33%	64%	87%	92%	94%	96%	97%	99%	100%	100%
18	33%	64%	88%	93%	95%	97%	97%	100%	100%	100%
20	33%	64%	89%	94%	96%	97%	97%	100%	100%	100%

High Investment Costs

Simulation examples and results

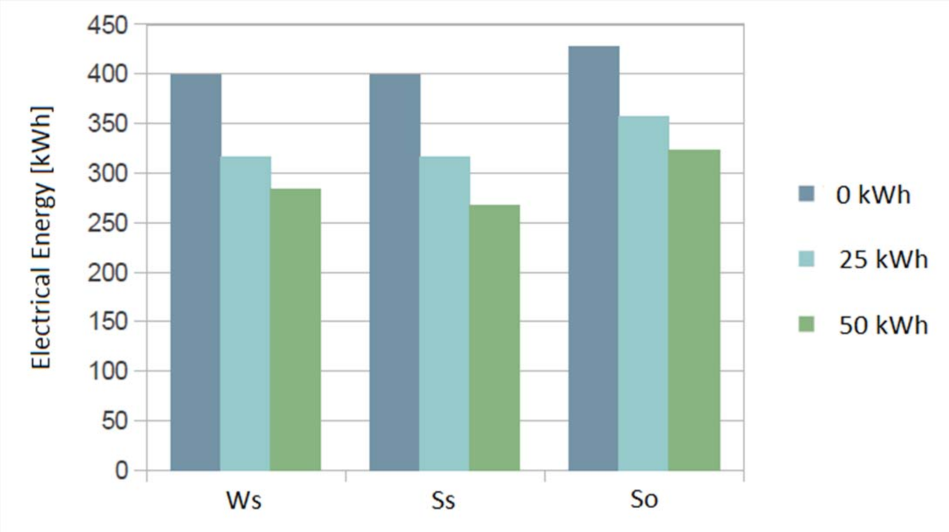
Complex example – Office building with vehicle fleet

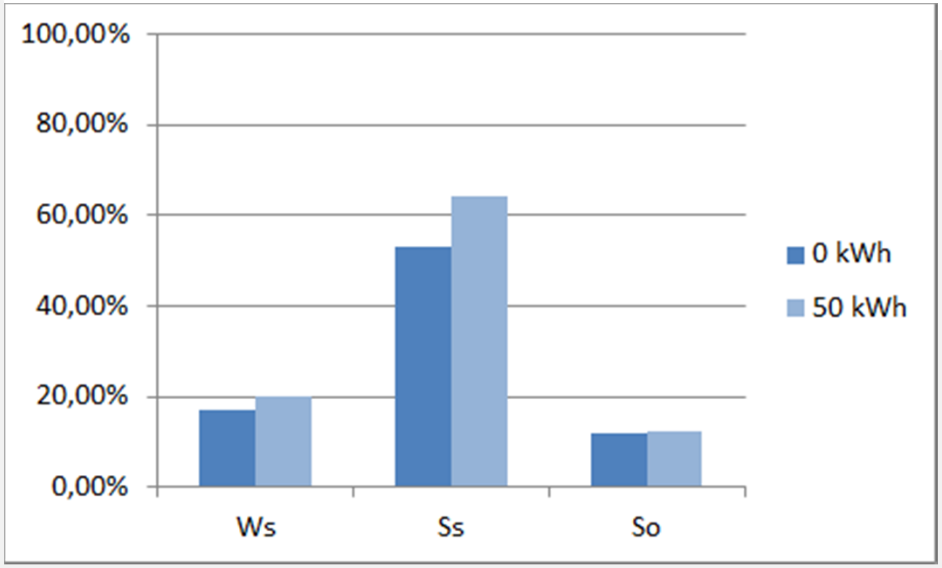


Office Building (1.500 m^2), Electrical energy consumption 50 kWh/m^{2}a, CHP (40 kW$_{th}$), PV-system 8.5 kWp

Simulation examples and results

Complex example – Results



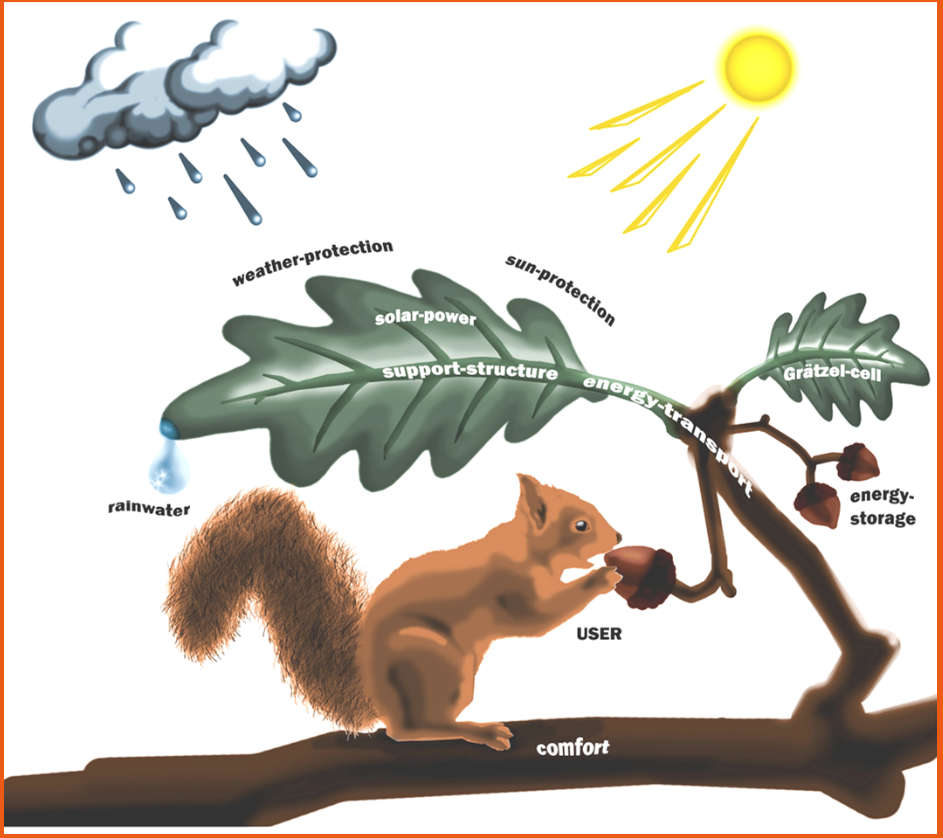


- Difference between electrical energy consumption and grid-feeding depending on battery capacity with eight vehicles
- Comparatively low battery size reduce electrical energy balance (high renewable enery production)
- Low differences between summer and winter (PV – summer, CHP – winter)
- Renewable energy share of electricity consumption of a fleet with 4 vehicles depending on stationary battery size
- Battery size especially important at sunny days – storage of photovoltaic energy at noon when vehicles cannot be recharged (usage scenario)

Summary and outlook

- Holistic energy system layout requires simulation approaches (static calculations are not feasible any more)
- Vehicles and building energy systems have to be considered together (renewable energy usage for eVehicles)
- Modelica enables users to simulate different domains together (heat, electricity, etc.) – base of 'Green Building'
- Combined simulation of vehicle-building-system requires sufficient precalculations (differing time constants – vehicles (milli-seconds-seconds) – building (hours-days))
- Simulation examples chosen to evaluate vehicle fleet behavior – vehicle fleet first fields for eVehicle usage (range, costs, routes)
- Sufficient energy system layout needed to avoid high running costs (electricity consumption) and to reduce emissions (electricity production in power plants)

Any Questions?



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