Simulation for Energy Management System development: the Digital Twin Model from UK, applied in the Sharing Cities project

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The Digital Twin

“a virtual model of a process, product or service”

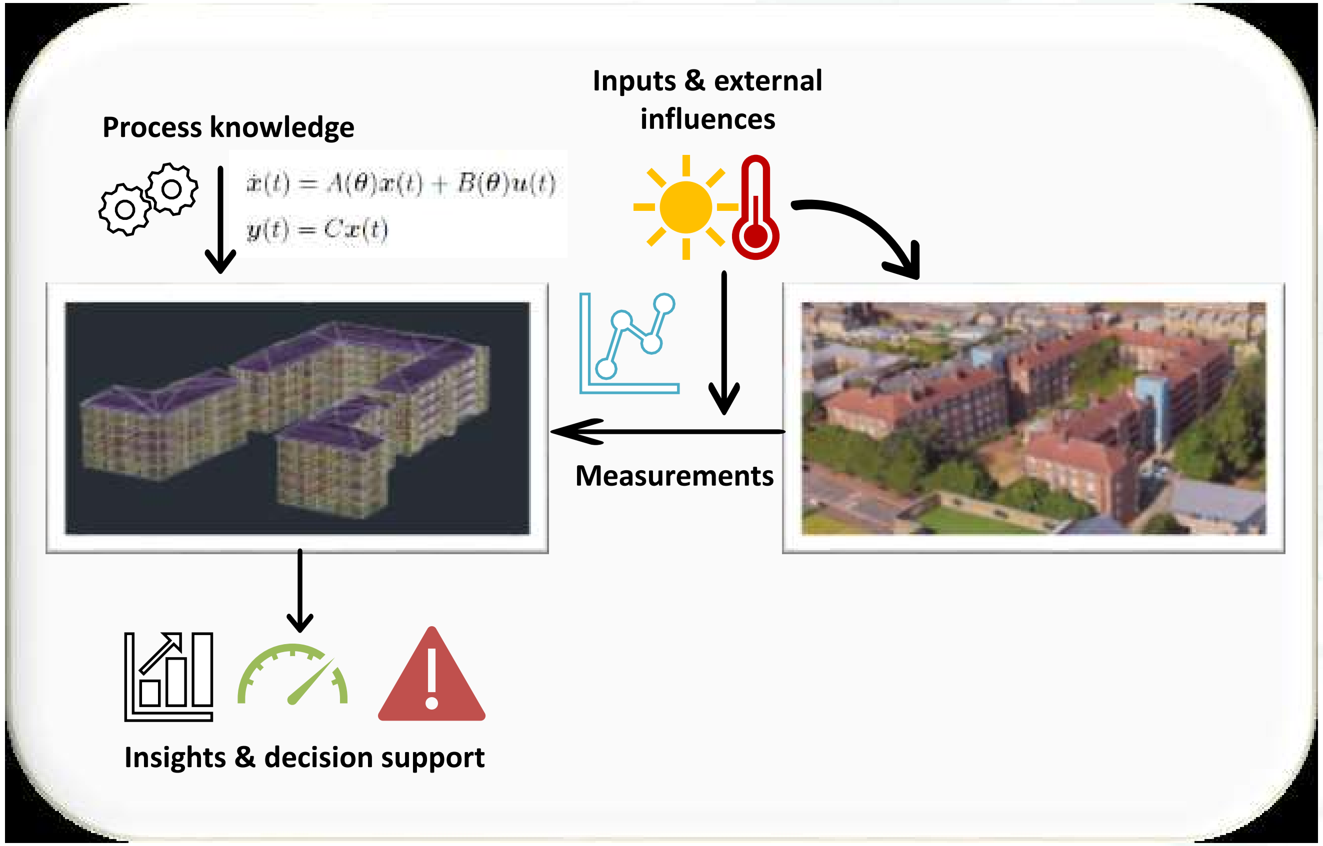
Rationale

Off-line development phase

- Test software interfaces
- Design and analysis of control and operational strategies – *apples vs. apples*
- Evaluation of planned or hypothetical system interventions – *apples vs. apples*
- Rigorous development of benchmarks

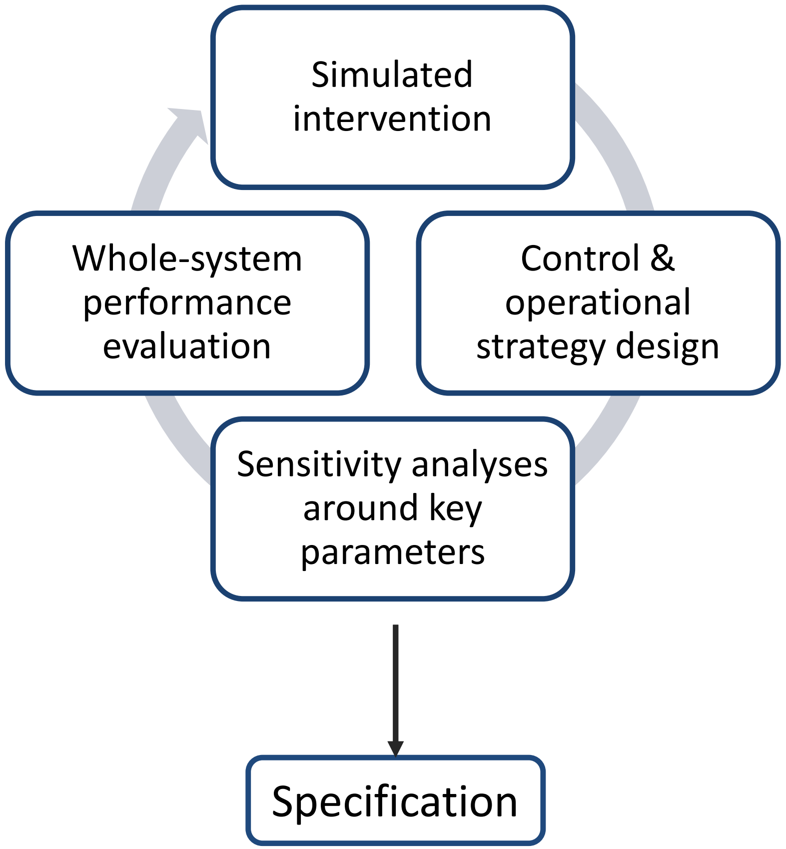
On-line operational phase

- Deeper insight into operational performance
- Prediction-based optimisation of system at multiple hierarchical layers
- Detection of anomalous behaviour & identification of faults



Simulation environment

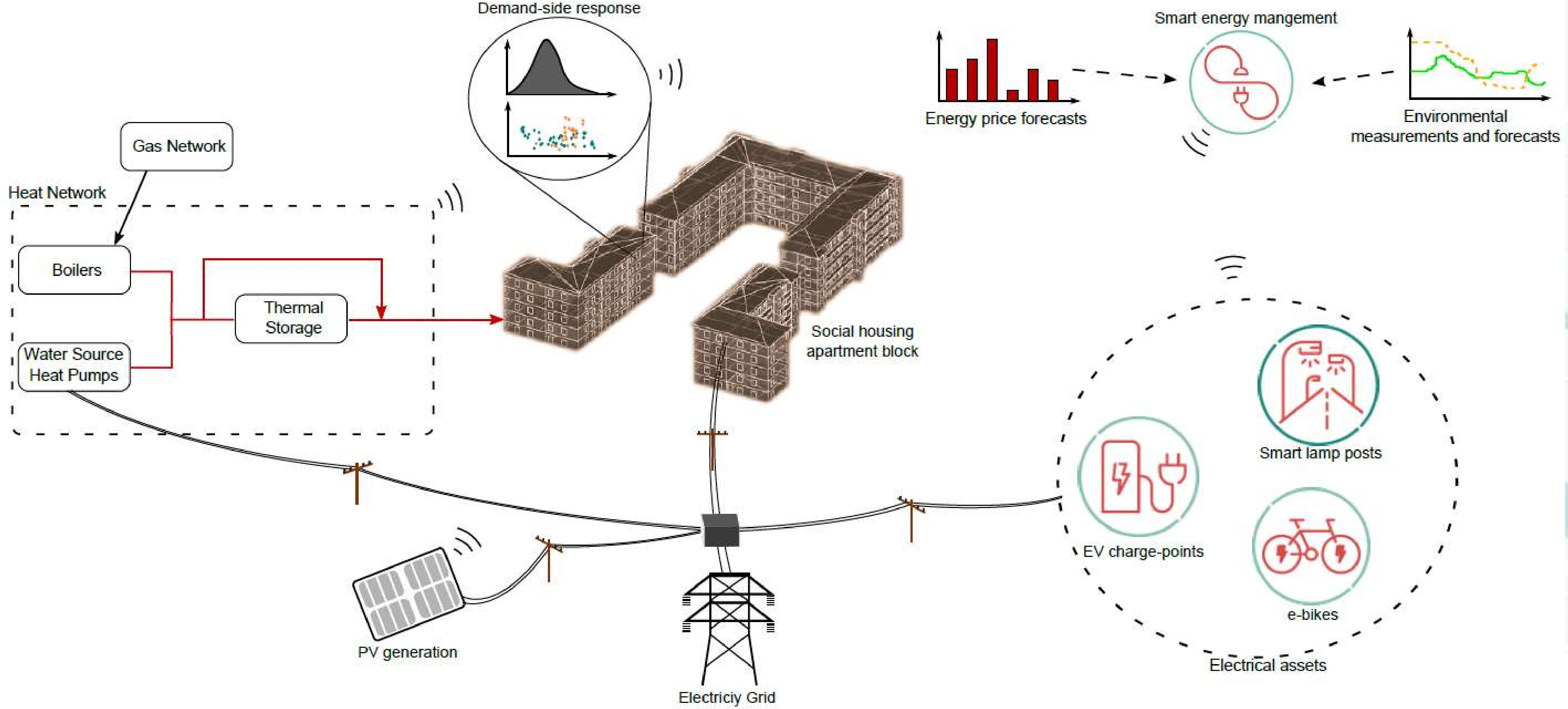
Desired purpose



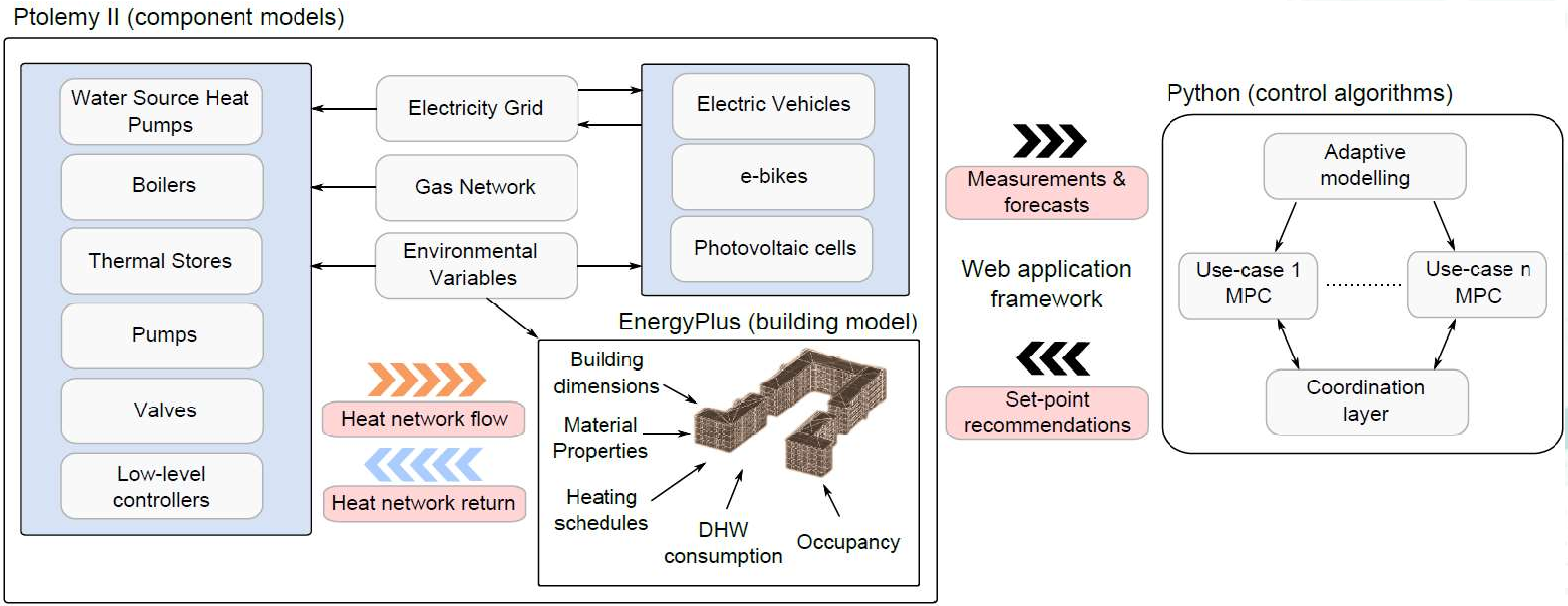
Design challenges

- Calibration & validation: does it match measured data?
- Adaptability & scalability: Generic vs. specific
- Open-source: Possible? Necessary?
- Appropriate complexity
- Appropriate granularity
- Modularity of design

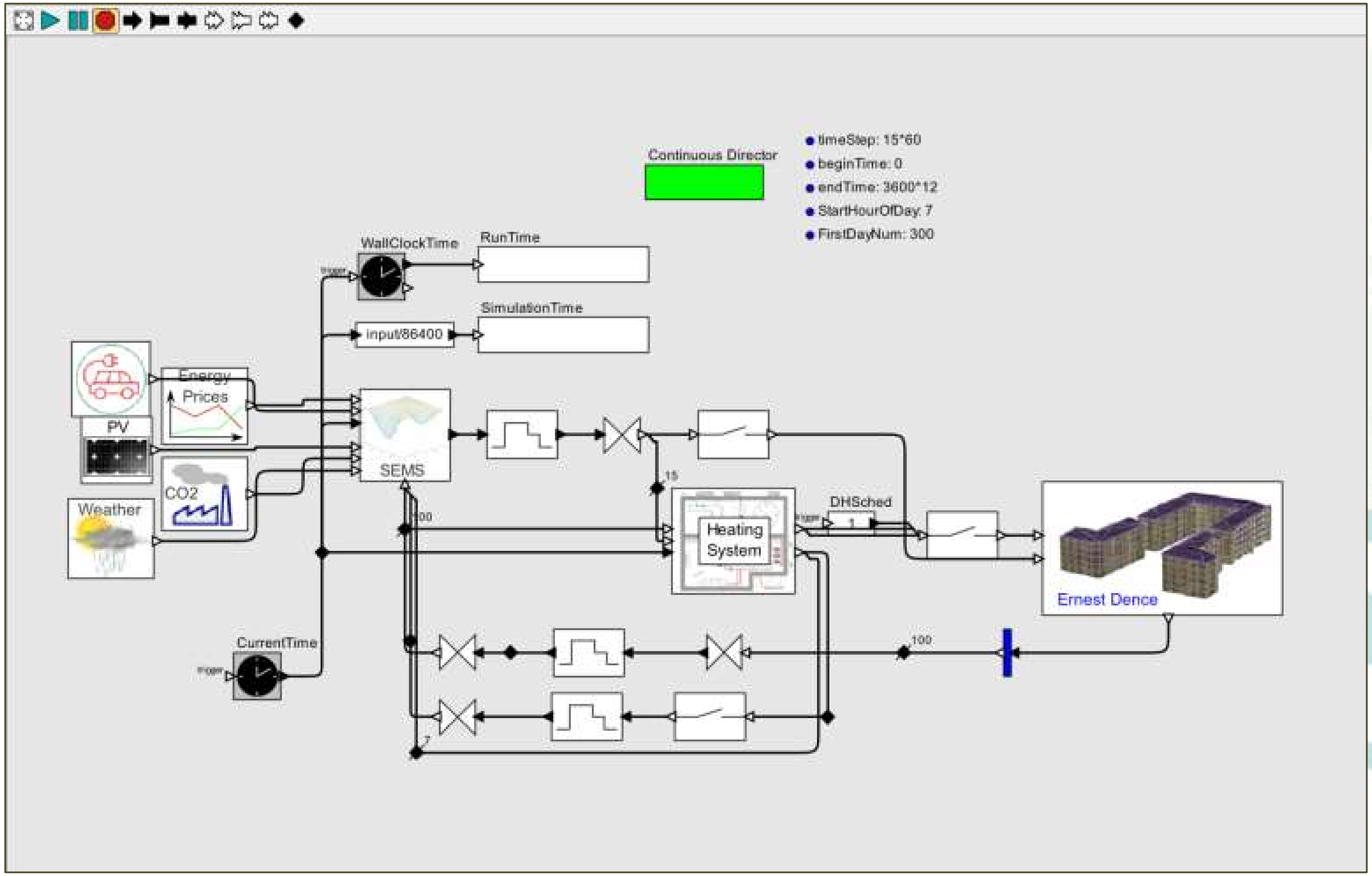
Sharing Cities:
The Greenwich Example



Simulation Architecture



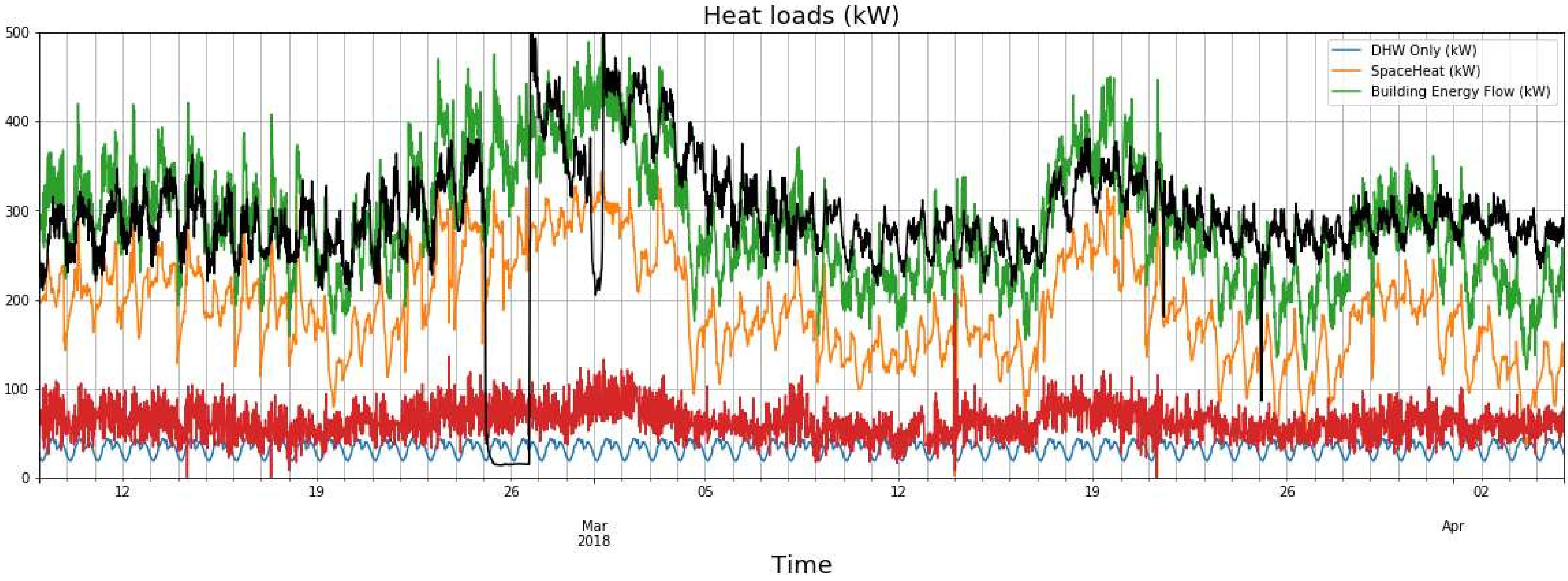
Interface



Continuous Director
timeStep: 15*60
beginTime: 0
endTime: 3600*12
StartHourOfDay: 7
FirstDayNum: 300
WallClockTime
RunTime
SimulationTime
input/86400
Energy Prices
PV
CO2
Weather
SEMS
Heating System
DHSched
Ernest Dence
CurrentTime

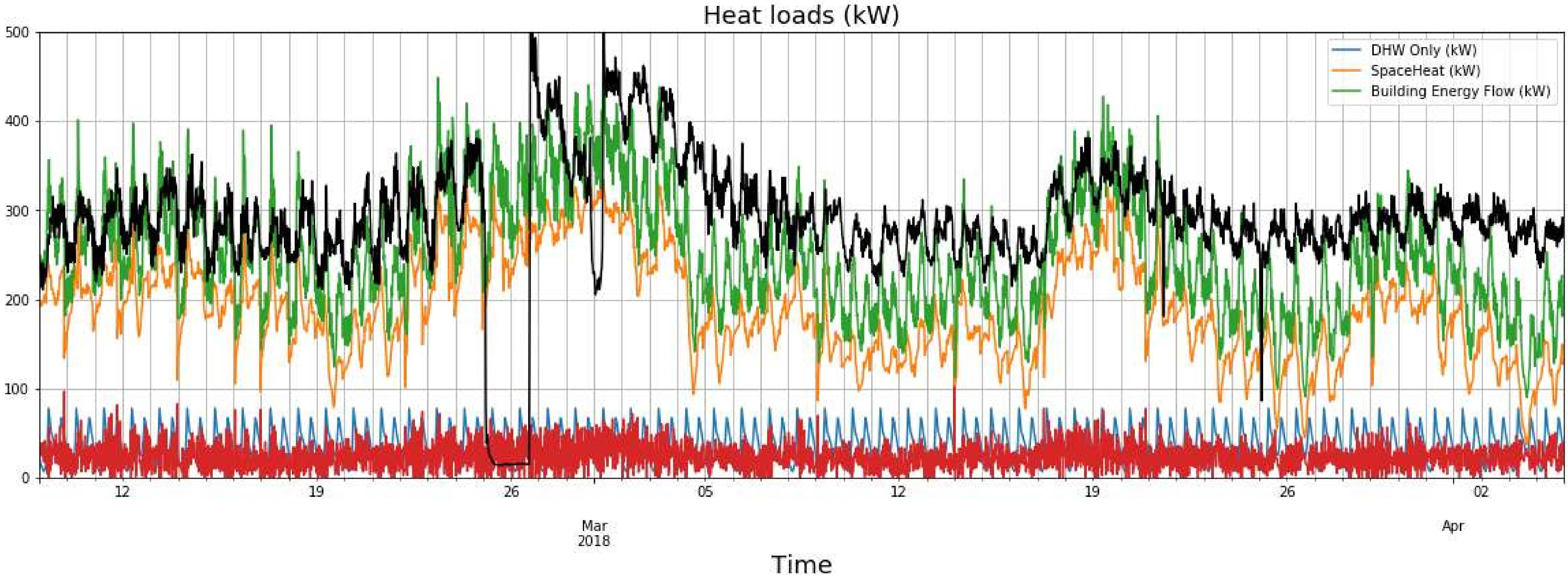
Illustrative Examples I

Modelled Case Vs Measured Case: No changes to building



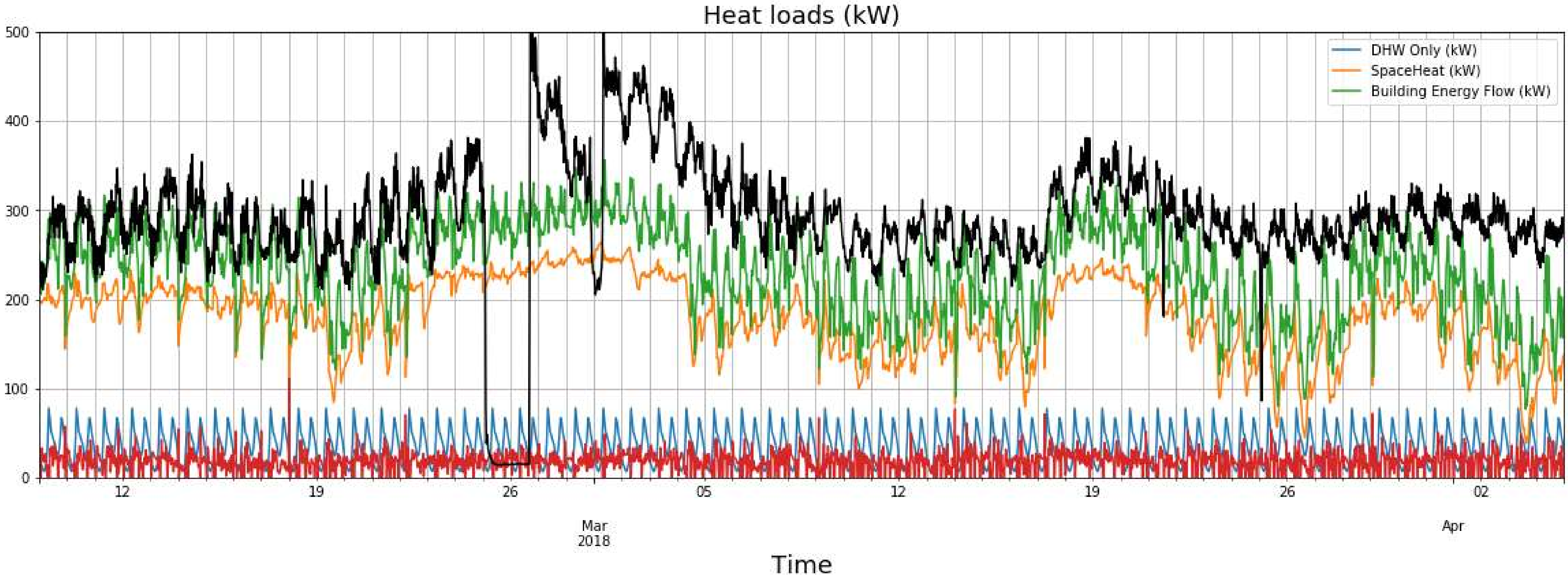
Illustrative Examples I

Modelled Case Vs Measured Case: Retrofitted building, boiler supply



Illustrative Examples I

Modelled Case Vs Measured Case: Retrofit + HP + Energy Management



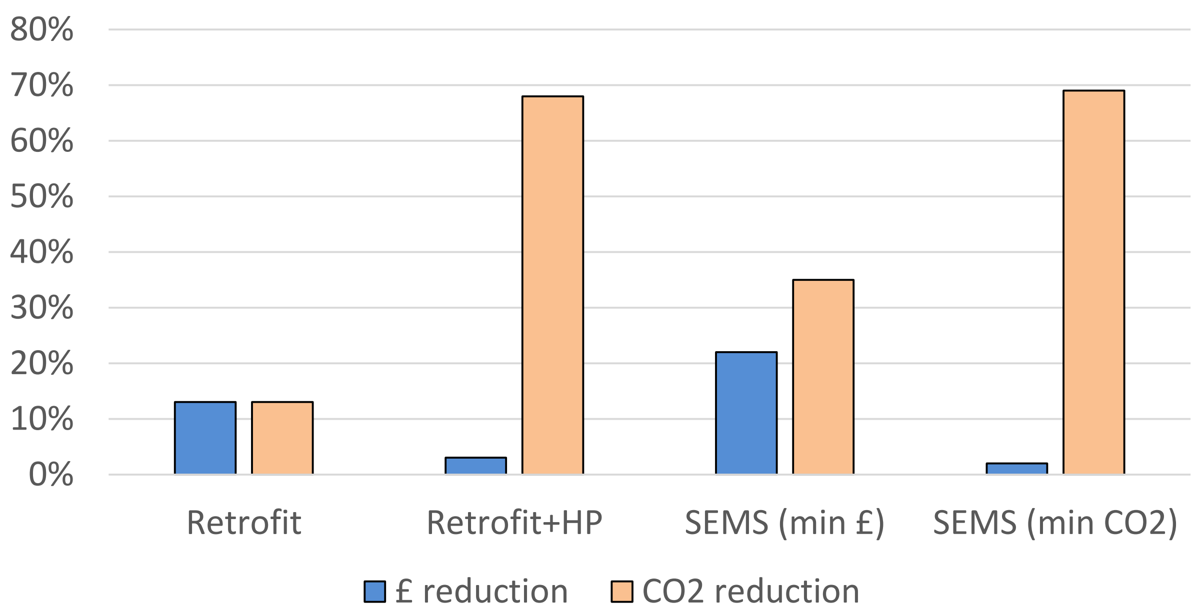
Illustrative Examples I

Control strategy impact

- Advanced control enables system to be optimised towards economic, environmental and/or resilience objectives
- Impact of different strategies can be clearly illustrated – environmental goals may conflict with financial goals
- Multiple stake-holders must be considered

Difference Vs. Baseline

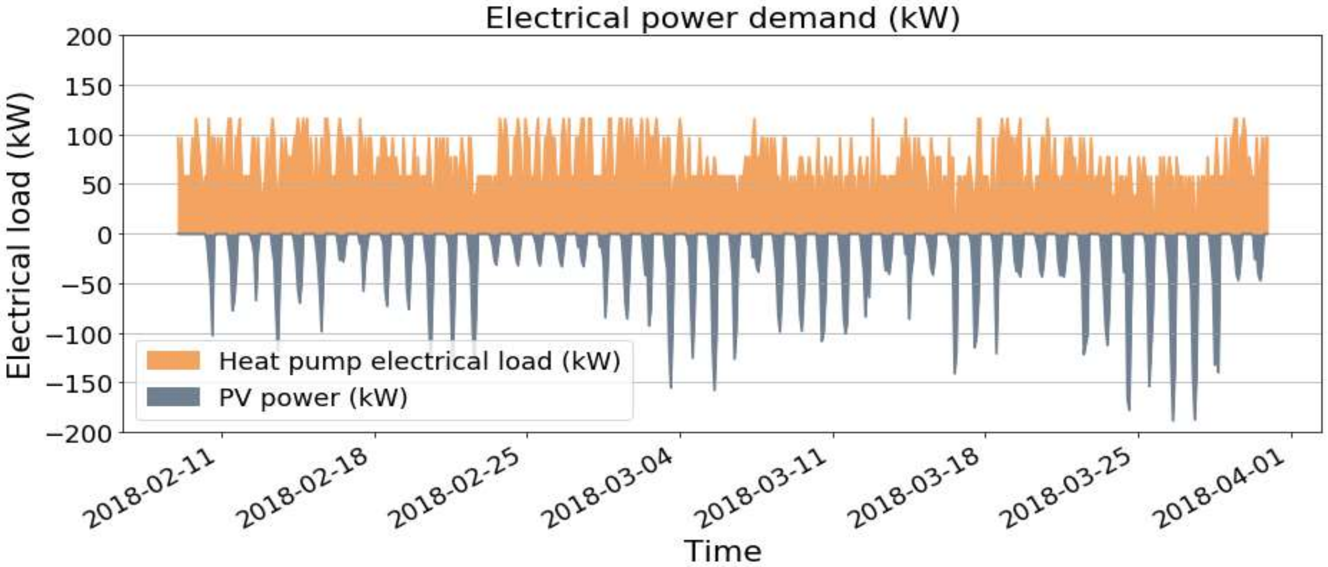
	Cost	CO_2
Retrofit	13%	13%
Retrofit + Heat Pump	3%	68%
SEMS (min £)	22%	35%
SEMS (min CO2)	2%	69%

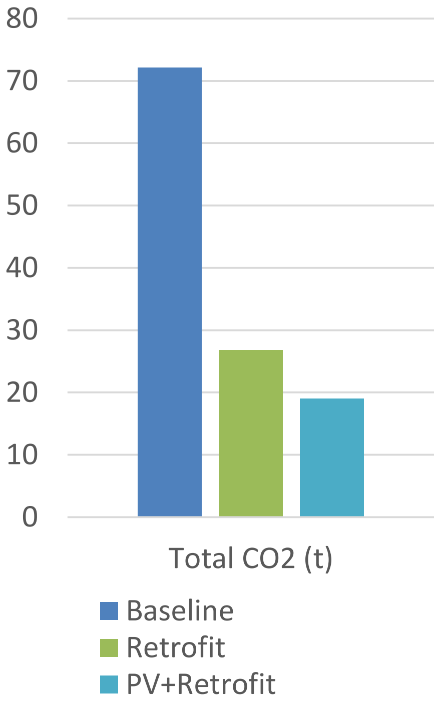


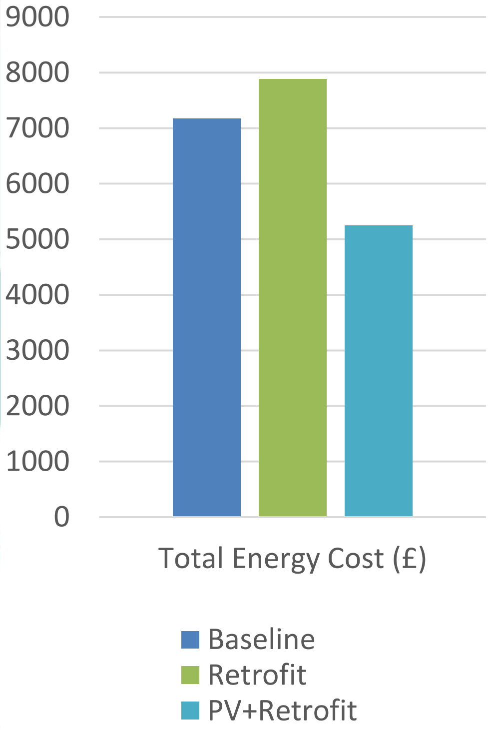
Illustrative Examples II

Wider system impact

- The wider system can be considered – particularly when
- Example: presence of PV panels can influence control of heat network – can influence the decisions around infrastructure design & operational strategy development
- Power network constraints can be considered – electrification of heat & transport may lead to grid stress

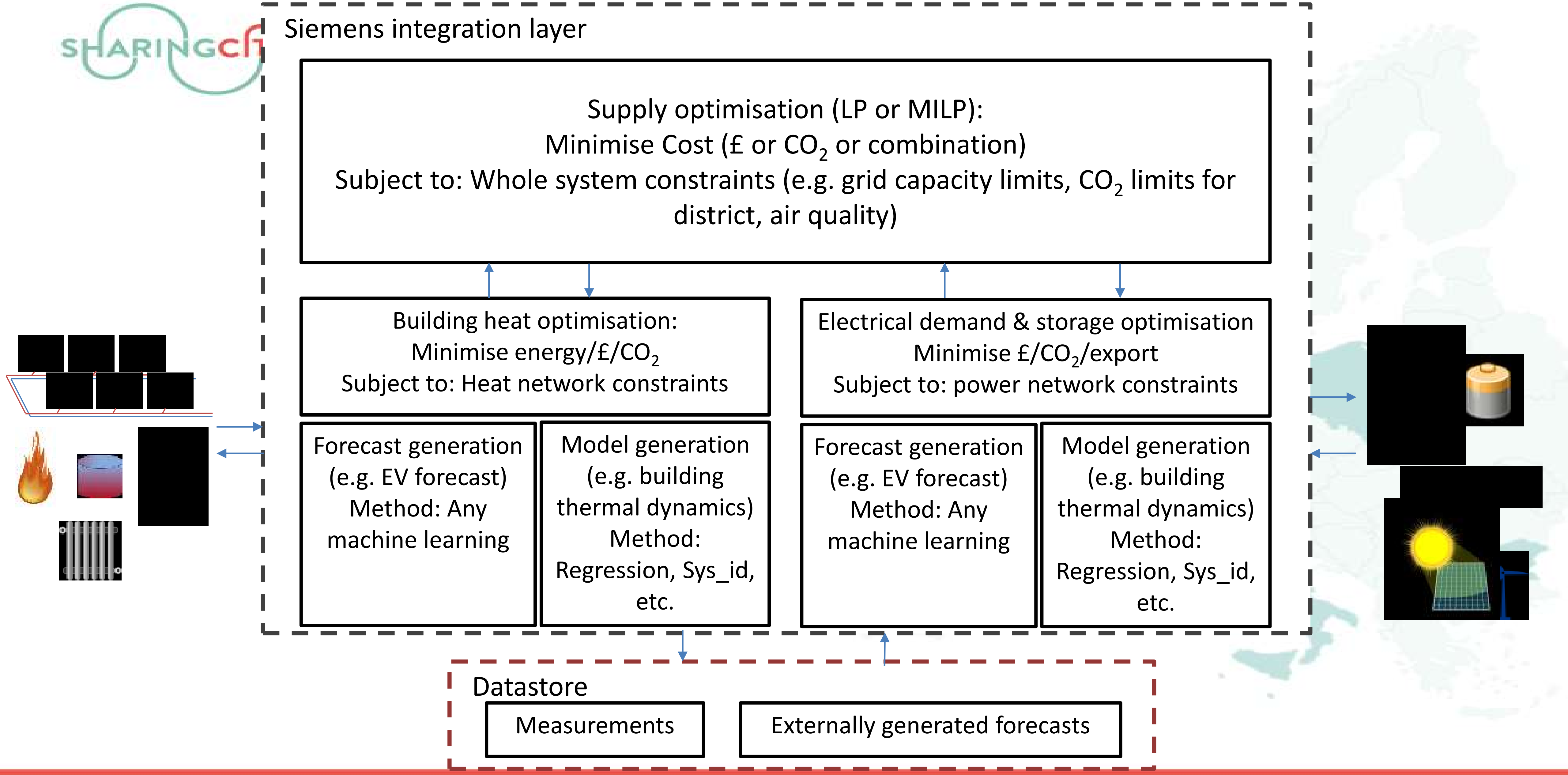






Lessons Learned

- An over-specified approach will not scale – every scenario is different
- An under-specified approach is not useful – system interactions can change the business case
- Explanations make more sense with numbers: energy domain comprises multiple stakeholders, multiple system layers & multiple objectives. Everything interacts with everything else!



Siemens integration layer
Supply optimisation (LP or MILP):
Minimise Cost (£ or CO_2 or combination)
Subject to: Whole system constraints (e.g. grid capacity limits, CO_2 limits for district, air quality)
Building heat optimisation:
Minimise energy/£/CO_2
Subject to: Heat network constraints
Electrical demand & storage optimisation
Minimise £/CO_2/export
Subject to: power network constraints
Forecast generation (e.g. EV forecast) Method: Any machine learning
Model generation (e.g. building thermal dynamics) Method: Regression, Sys_id, etc.
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Datastore
Measurements
Externally generated forecasts