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Digital Twin Modelling of Energy Systems

SDU Center for Energy Informatics

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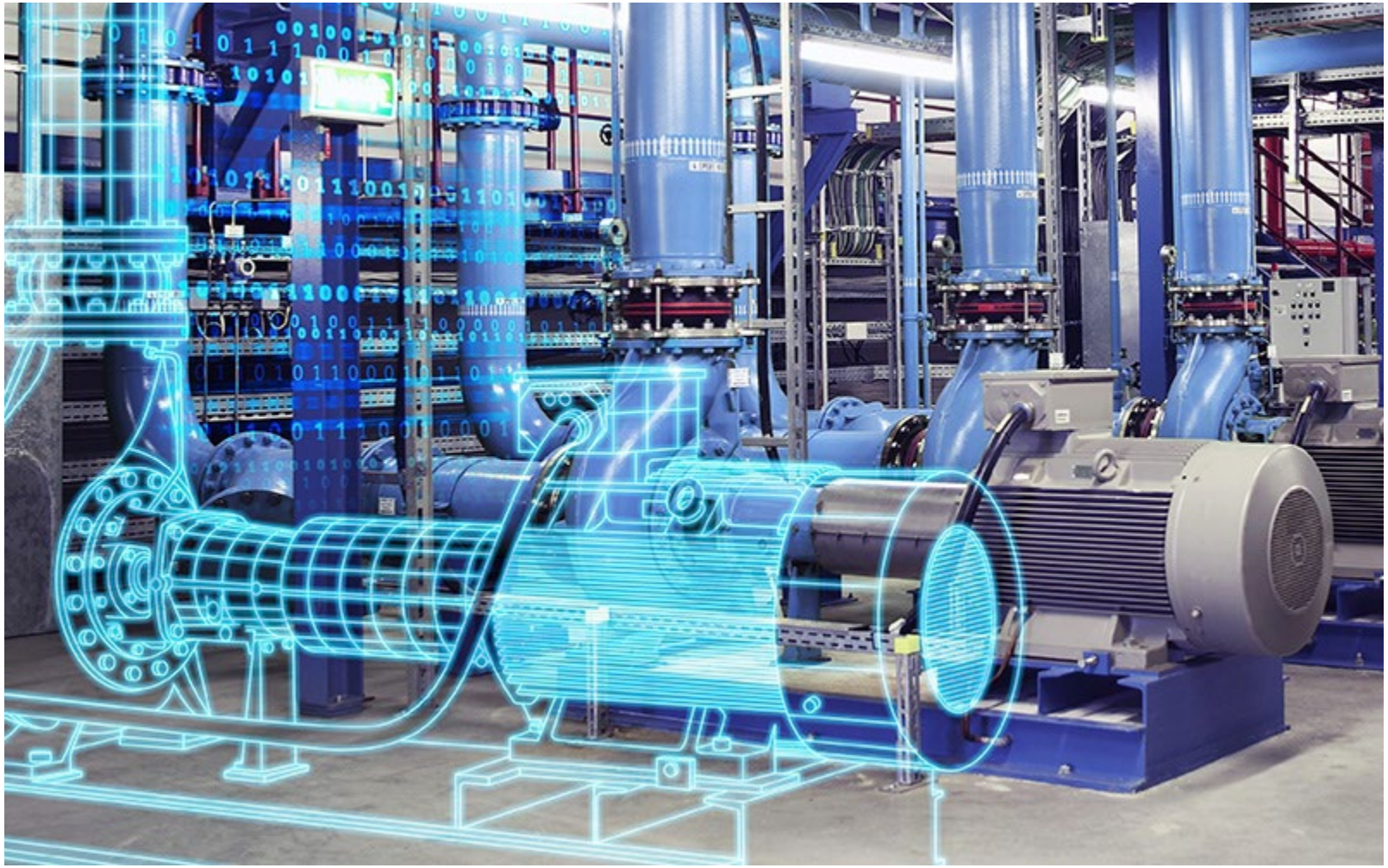
What is a digital twin



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Definitions

"A Digital Twin is an integrated multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin." NASA, 2013

"A digital twin is a composition of software artifacts – linked to a specific cyber-physical system (physical twin) – with a specific goal of improving real-time insights, decision making and/or operation of the physical twin." SDU-CEI, 2022

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Purposes

- Monitoring
- Prediction
- Optimization
- Control
- Simulation

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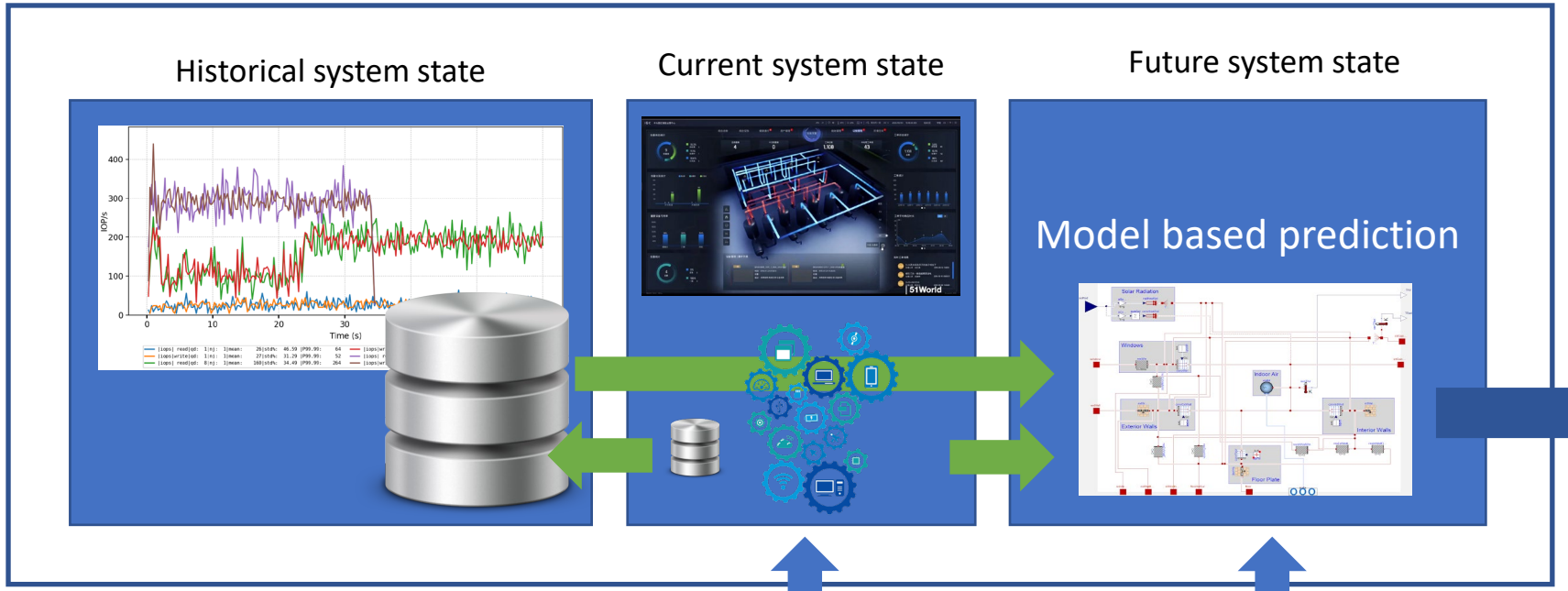
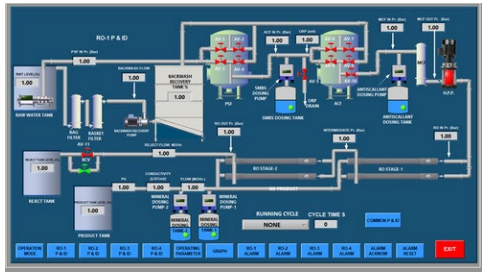
Application domains

- Manufacturing and production
- Buildings
- Aviation
- Logistics
- Mechanical engineering
- Healthcare
- Power grids
- Smart cities

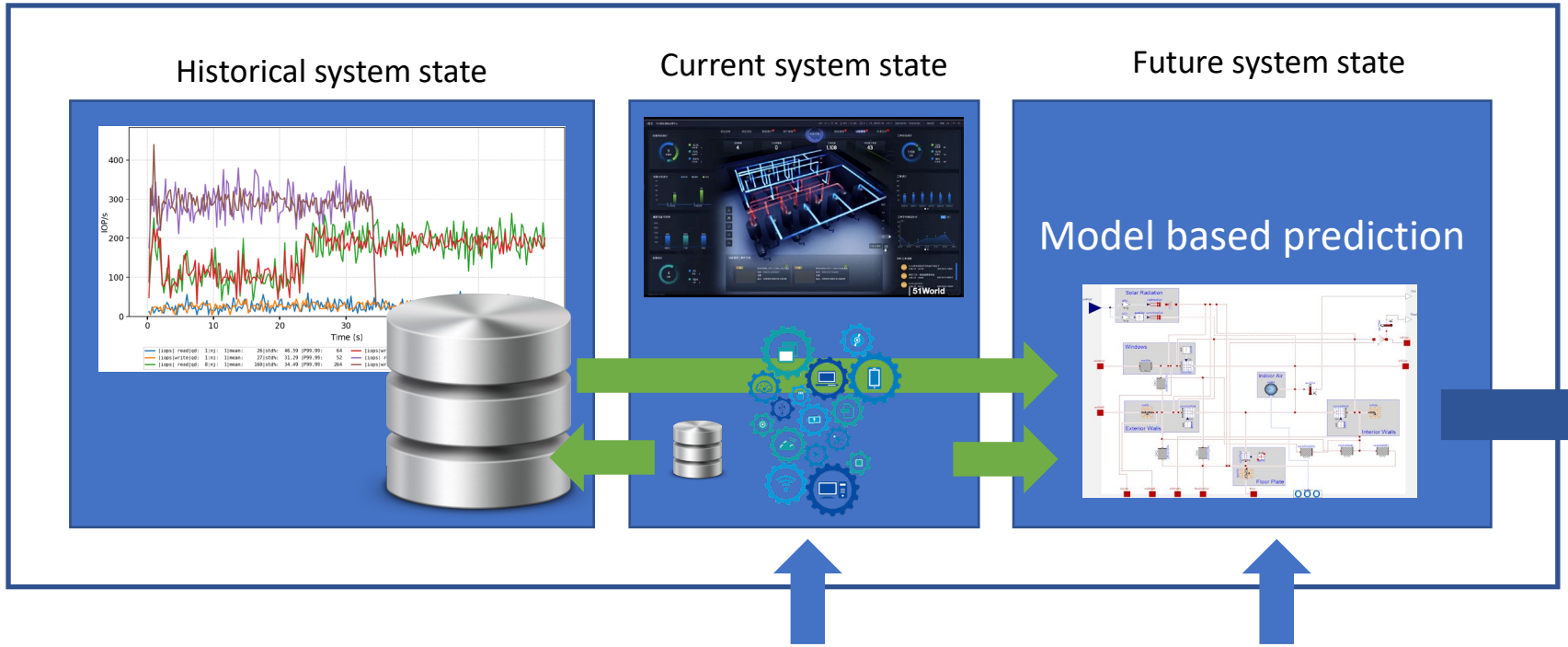
Digital twin architecture for active control



Output
- Setpoints to SCADA system



Digital twin architecture for decision support



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Smart buildings

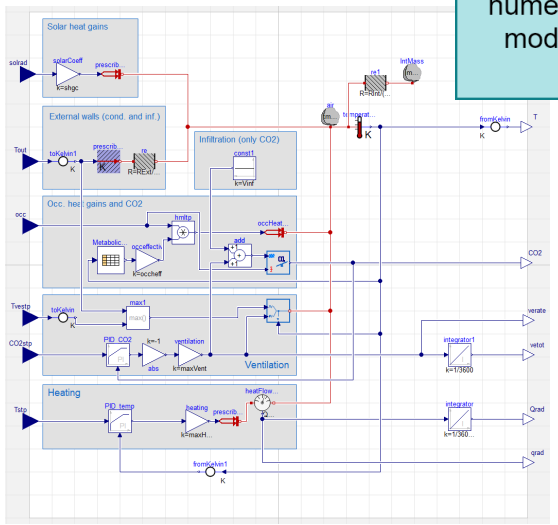
SDU Smart building lab – OU44

- Construction year 2014 to 2015
- Floor area 9600 m^2 (103333 ft^2)
- 3 levels, plus basement
- 190 thermal zones (class rooms and offices)
- Danish low energy class 2020
- BMS control of all building systems
- Metering infrastructure
  - 71 Electricity submeters
  - 12 heating submeters
  - 4 water meters
- Sensors: Temp., CO^2, Humidity, PIR, Lux
- Stereo vision occupancy sensors
- Ventilation system heat recovery
- Rooftop photovoltaic
- Weather station

EcoStruxure™ Innovation At Every Level

Building Analytics

SDU Smart building lab – OU44 Digital Twin



Optimizer (MOGA)

sMAP

Archiver

Custom drivers

Forecasts (weather, occupancy)

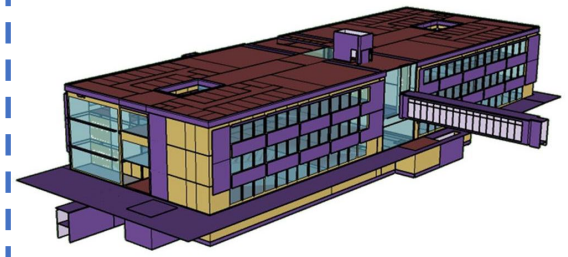
FMI

sMAP

Simplified numerical models

Building management system

Virtual building simulator



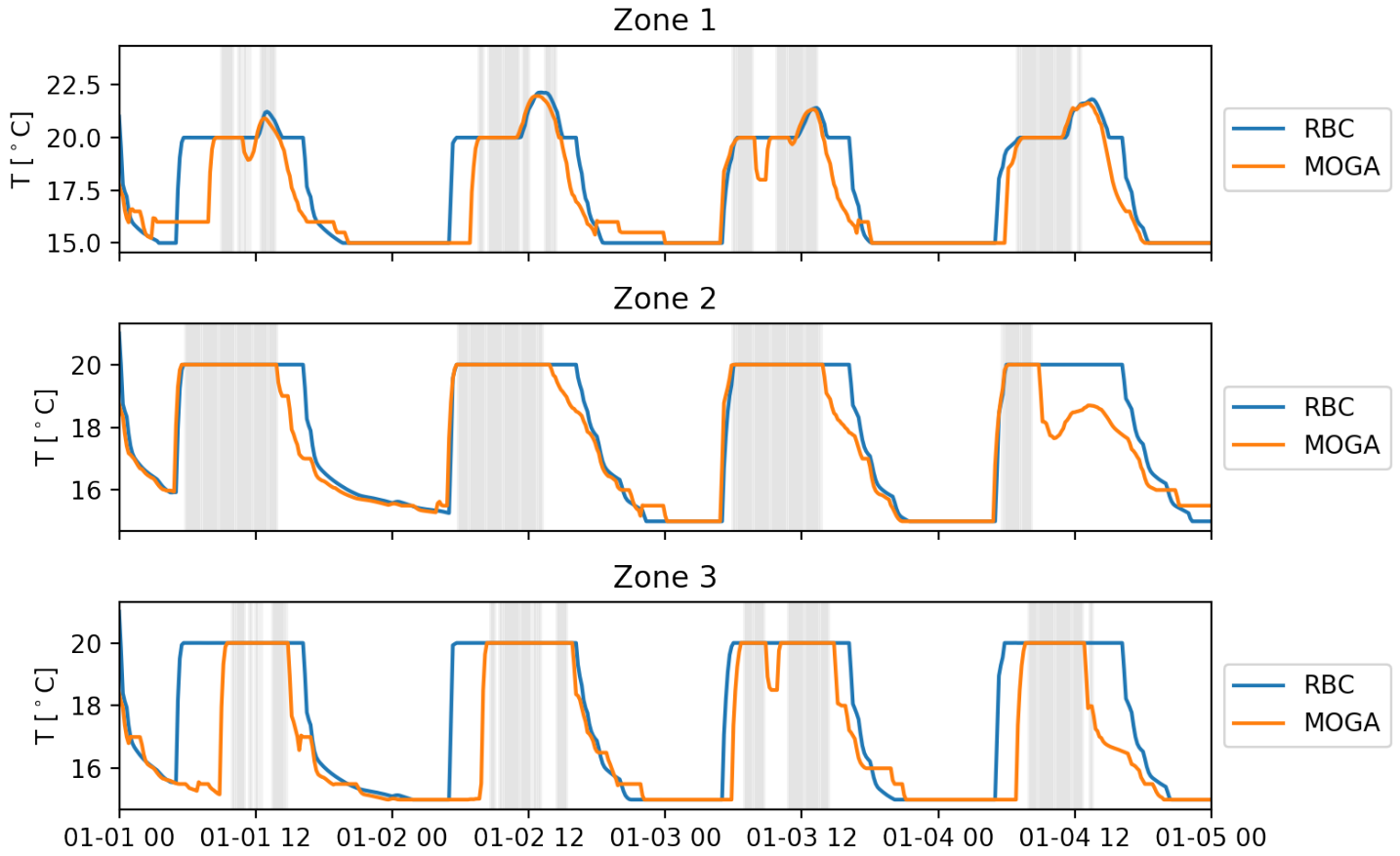
SDU Smart building lab – OU44 Digital Twin

MOGA vs. rule-based control (RBC):
1-month simulation on virtual building

Result	MOGA	RBC
Heating energy [kWh]	4050.43	5368.66
Comfort violation [Kh]	42.18	287.85

Summary:

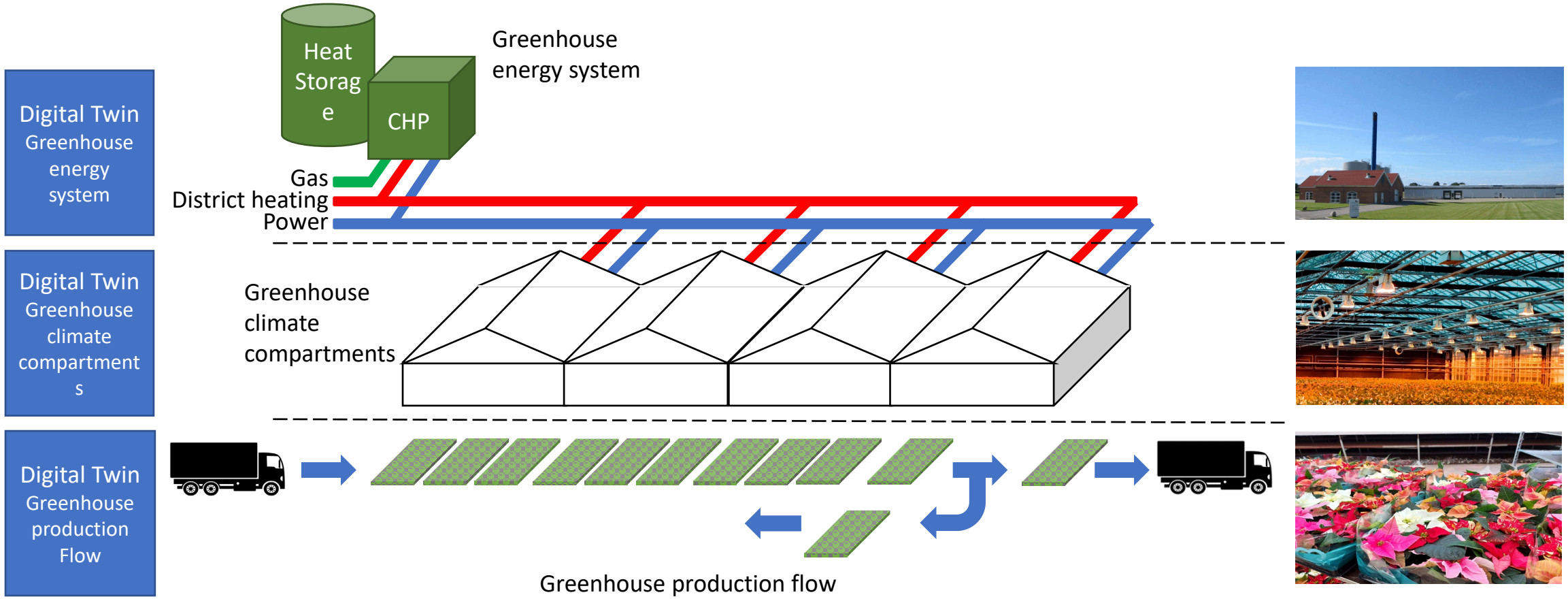
- ≈25% of energy saved
- increased thermal comfort
- energy consumed only when it's actually needed



Indoor temperature profiles across zones:
MOGA adapts indoor temperature to occupancy periods (shaded in gray)

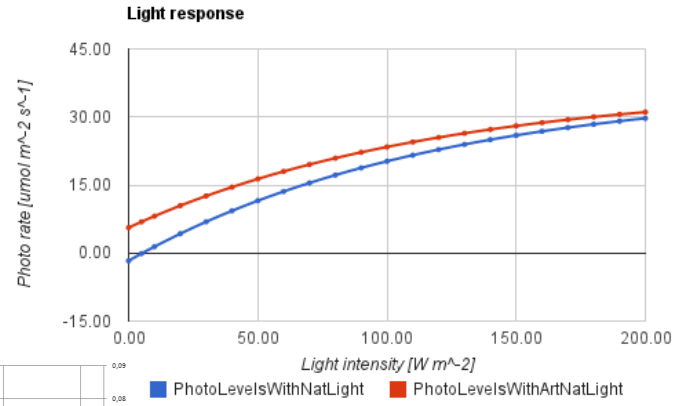
Smart Horticulture

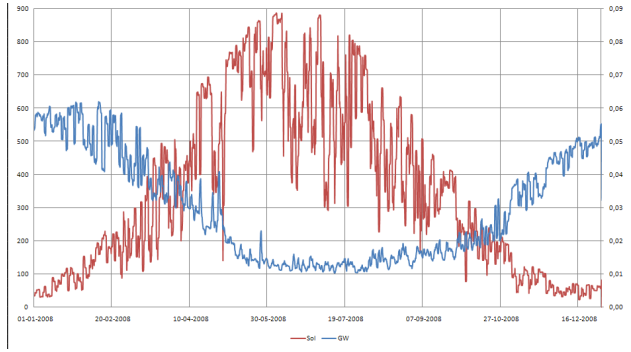
Smart-grid integration of flexible energy consumption



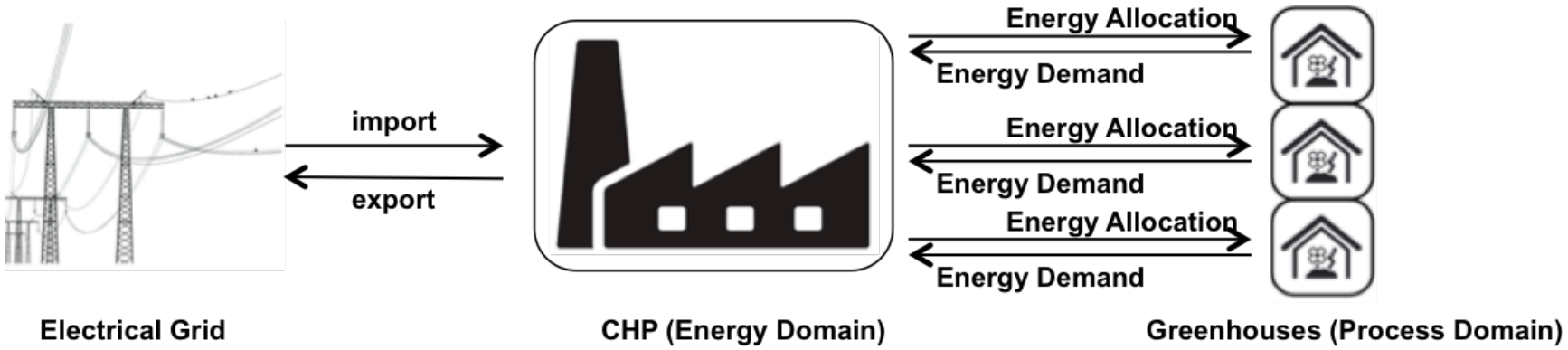
Multi-objective optimization based on flexibility

- Domain requirements
  - Growth targets
  - Ornamental qualities
  - Energy efficiency
  - Cost efficiency
  - Demand response
- Process parameters
  - Temperature
  - Light
  - CO_2
  - Humidity

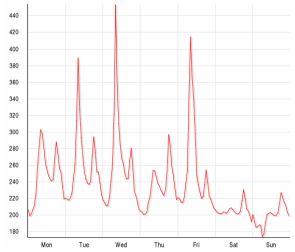


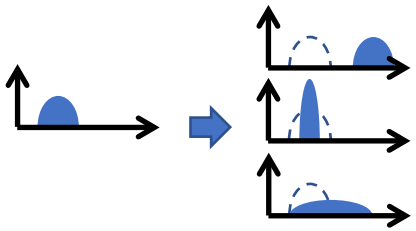


Greenhouse energy system integration



Virtual Power Plant (VPP)





Smart grid

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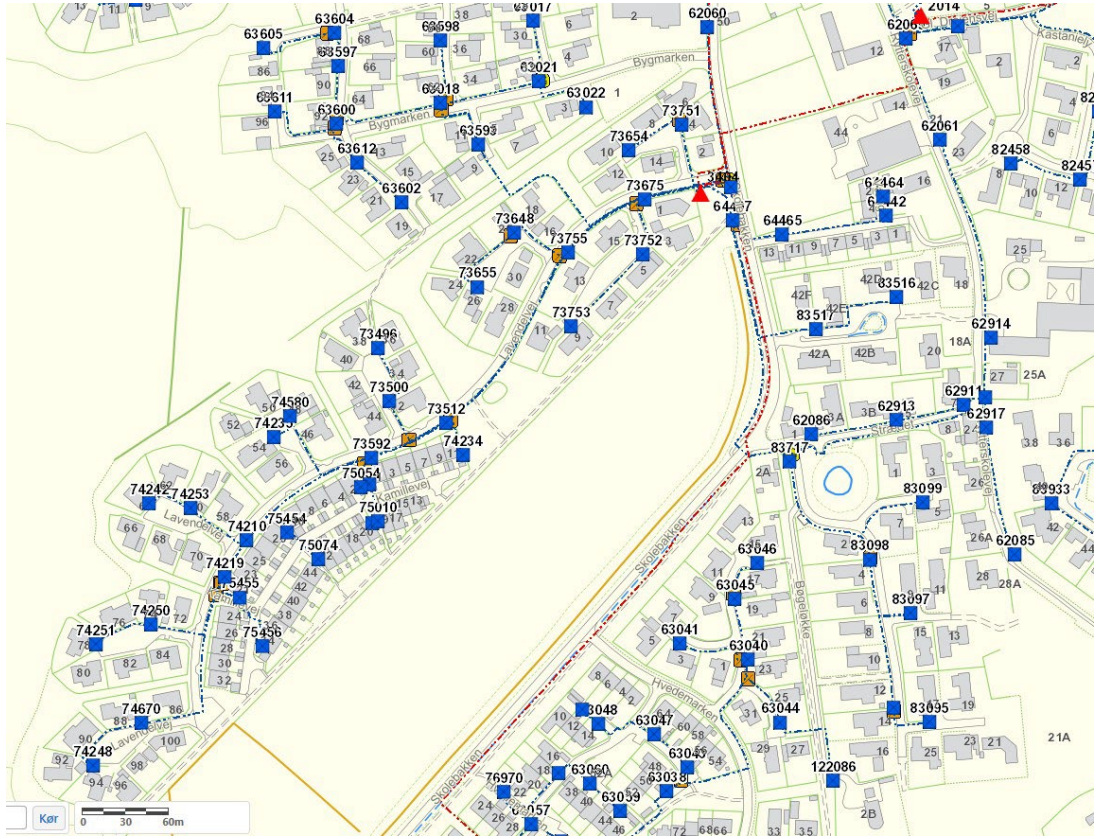
Smart electrical vehicles charging

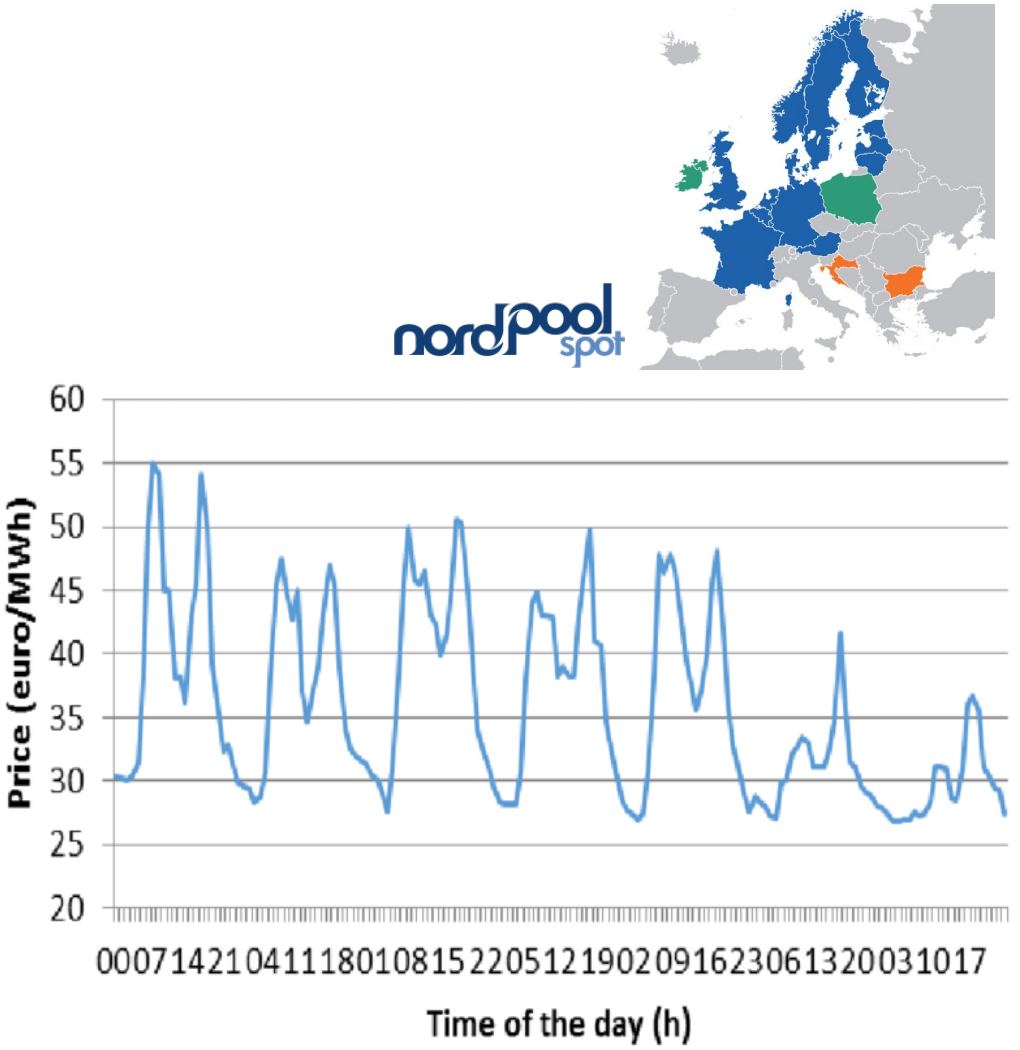
- Simple charging VS smart charging
  - **Simple charging** when plugged in, will cause high peak load when people return home from work
  - **Smart charging** is claimed to solve this problem, by shifting the peak due to vehicle charging away from the peak due to other consumption, but is that true?



FED FLEXIBLE ENERGY DENMARK

Smart charging

- Respond to hourly electricity pricing - charge at cheapest hours (during night)
- However, what happens if everybody use the same charging strategy?

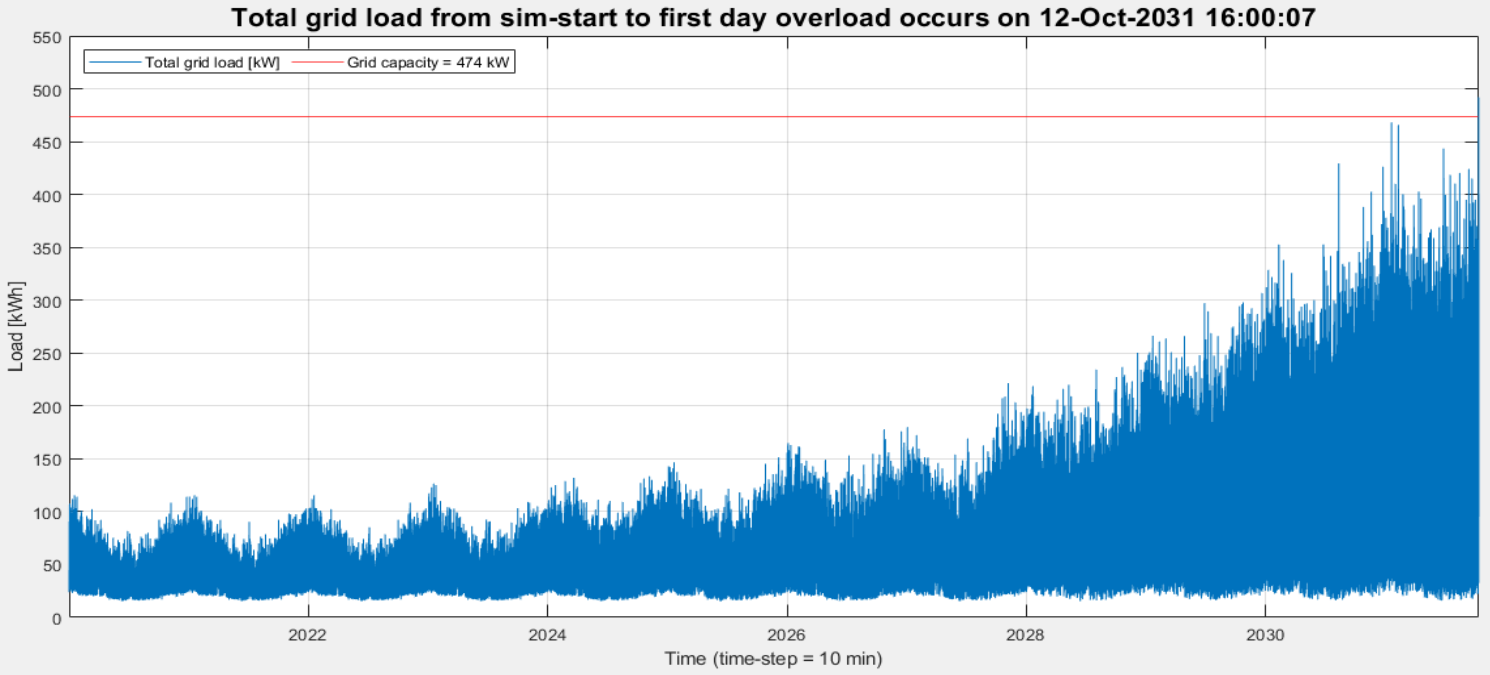


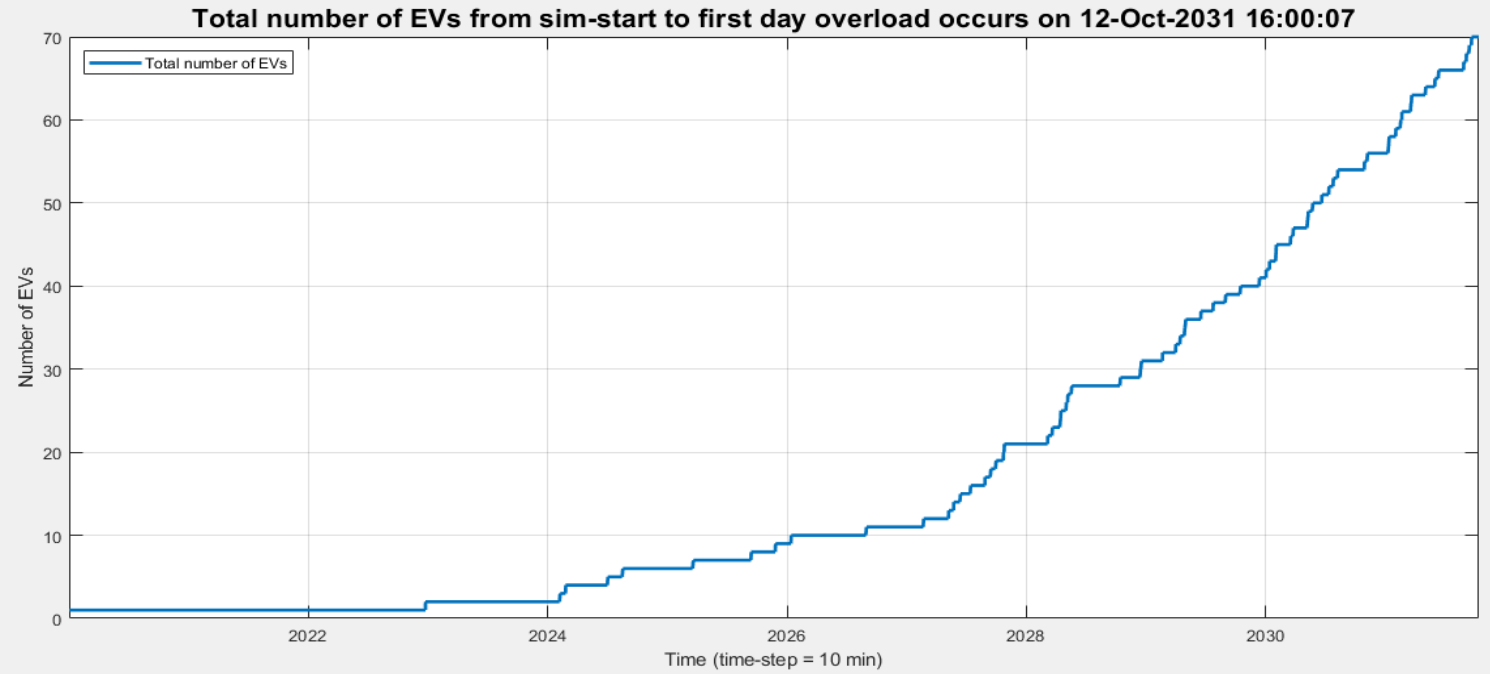
Nord Pool Spot prices during an average week (Monday to Sunday)

Results - Simple charging

Using real parameters setting

- October 12, 2031
- Total of 70 EV





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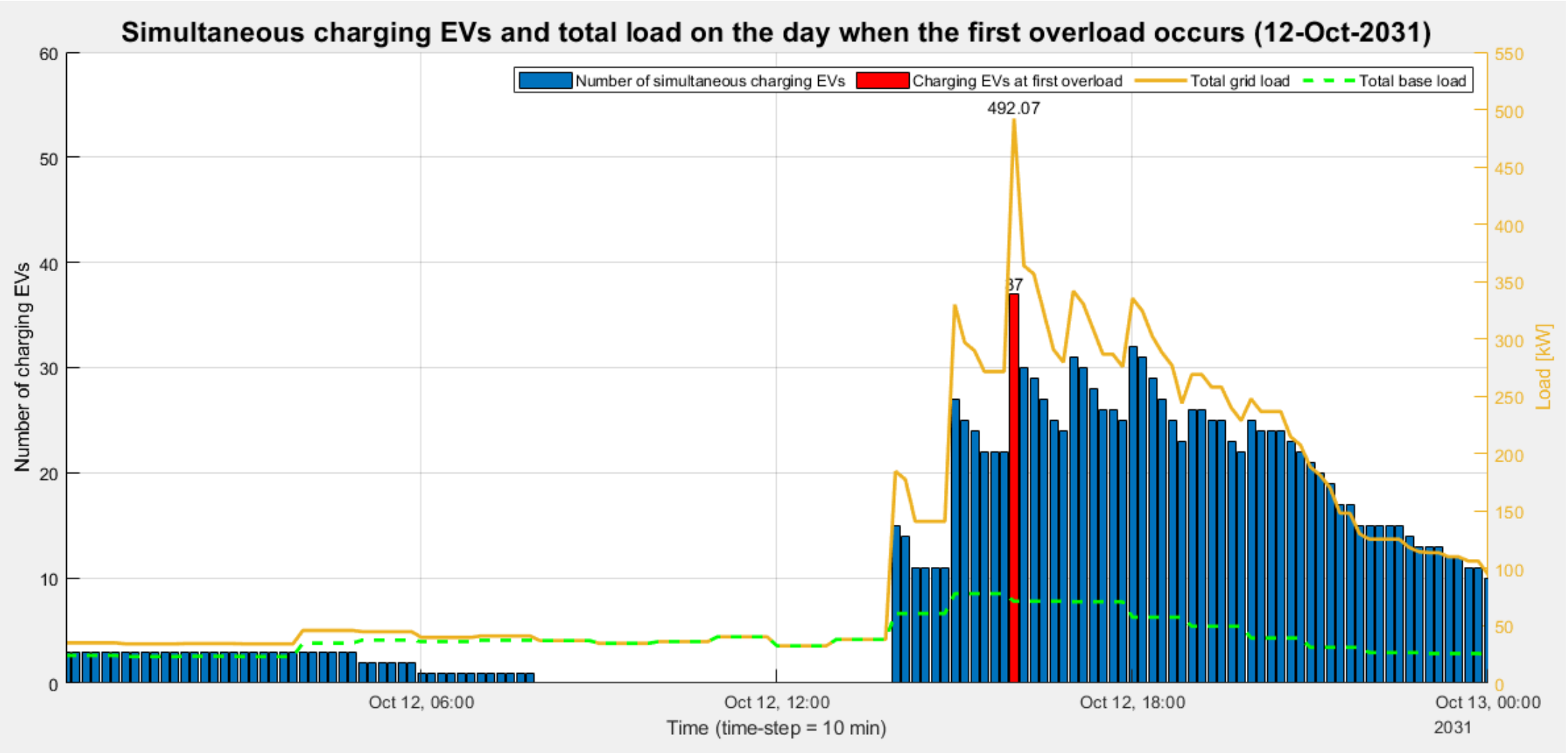
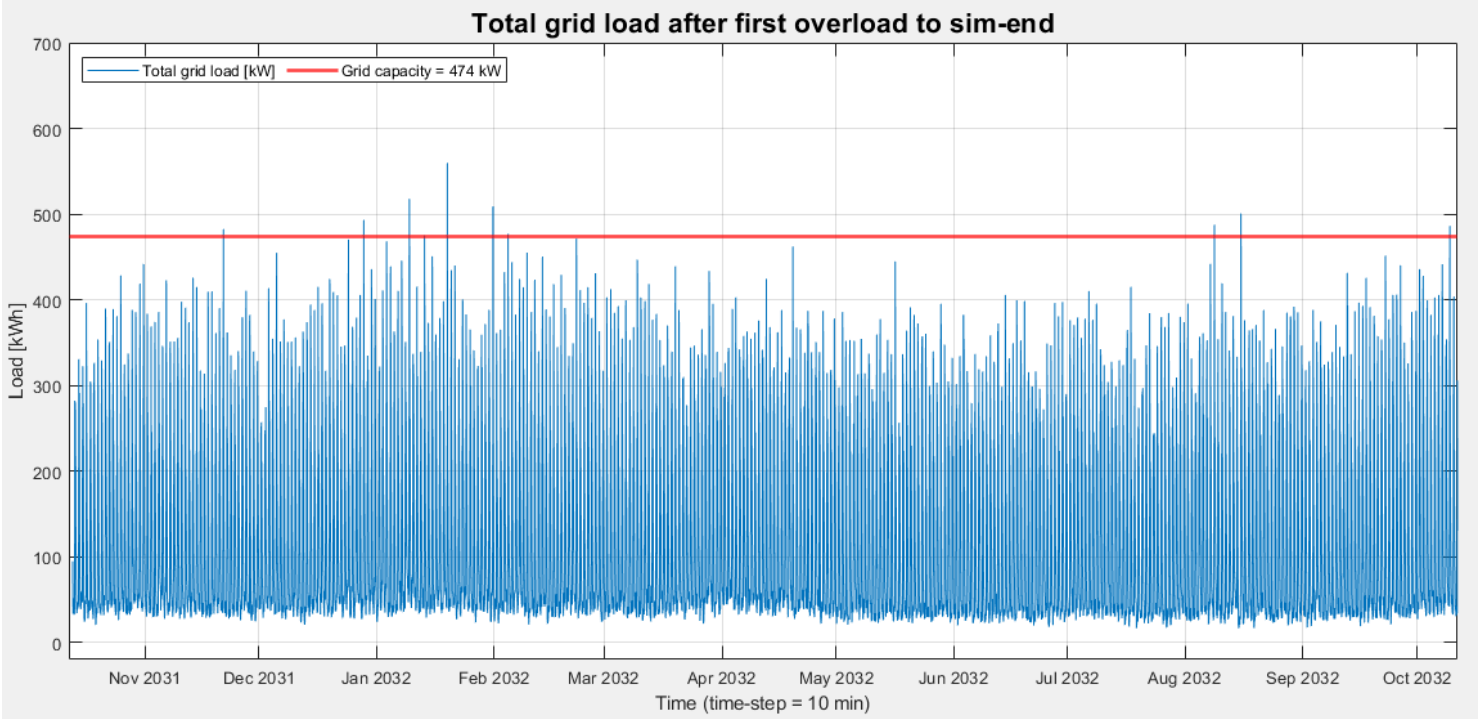
Results - Simple charging

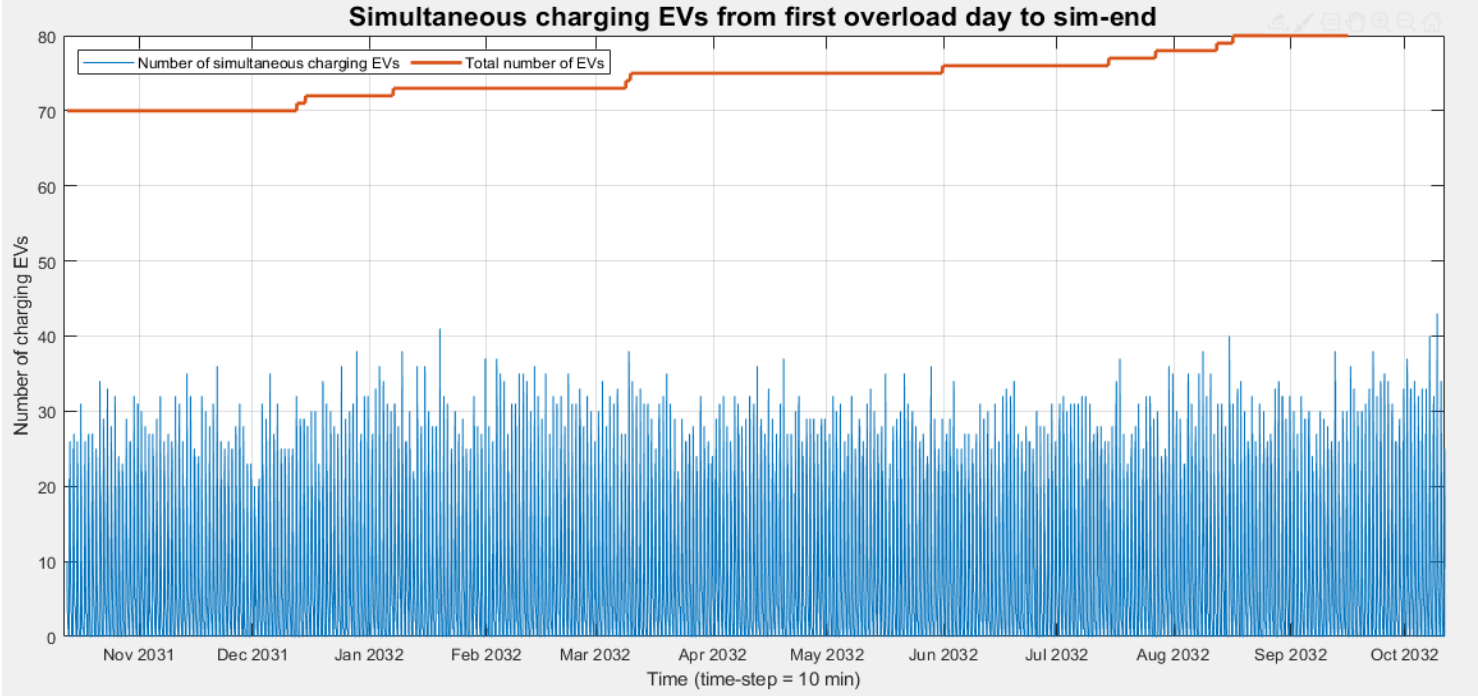
- 37 simultaneously charging EVs
- Overload of 18.07 kW



Results - Simple Charging

- 11 days with overload
- 11 timesteps of overload





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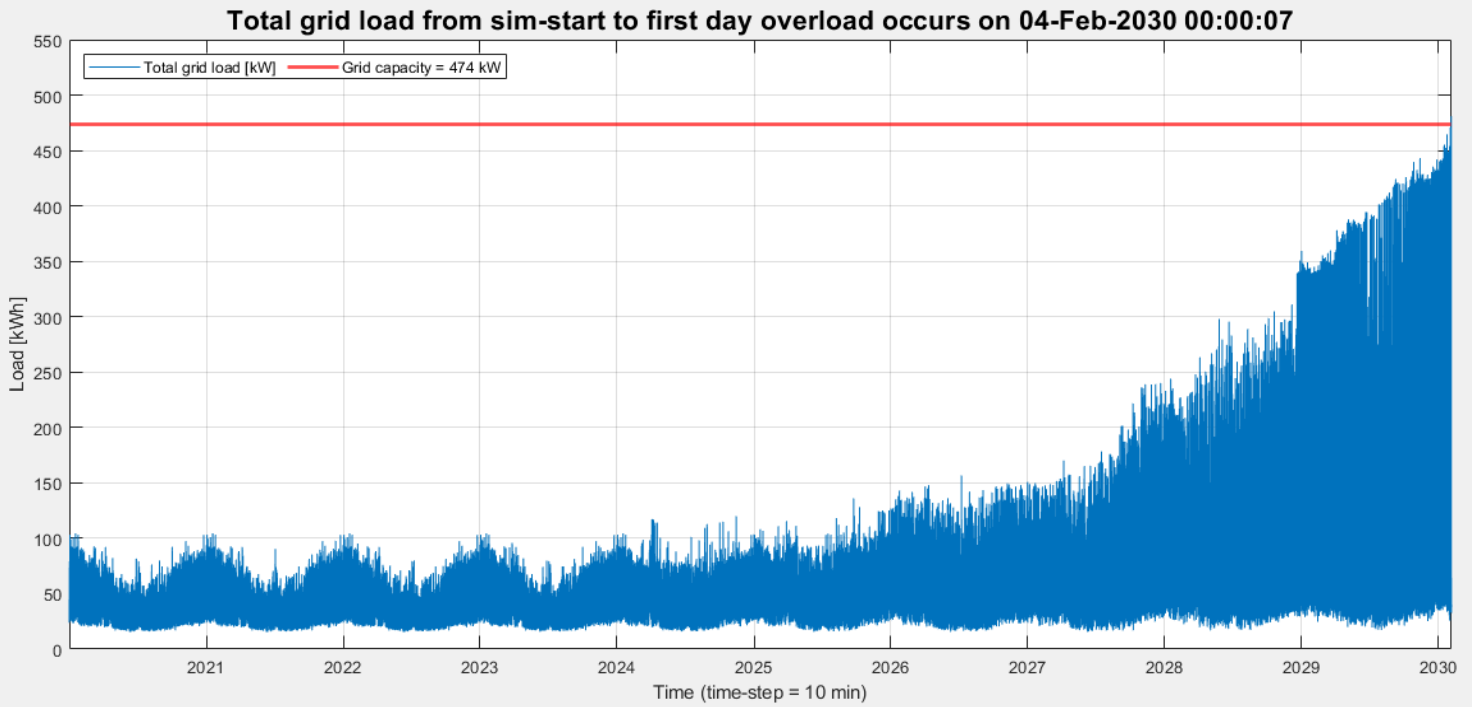
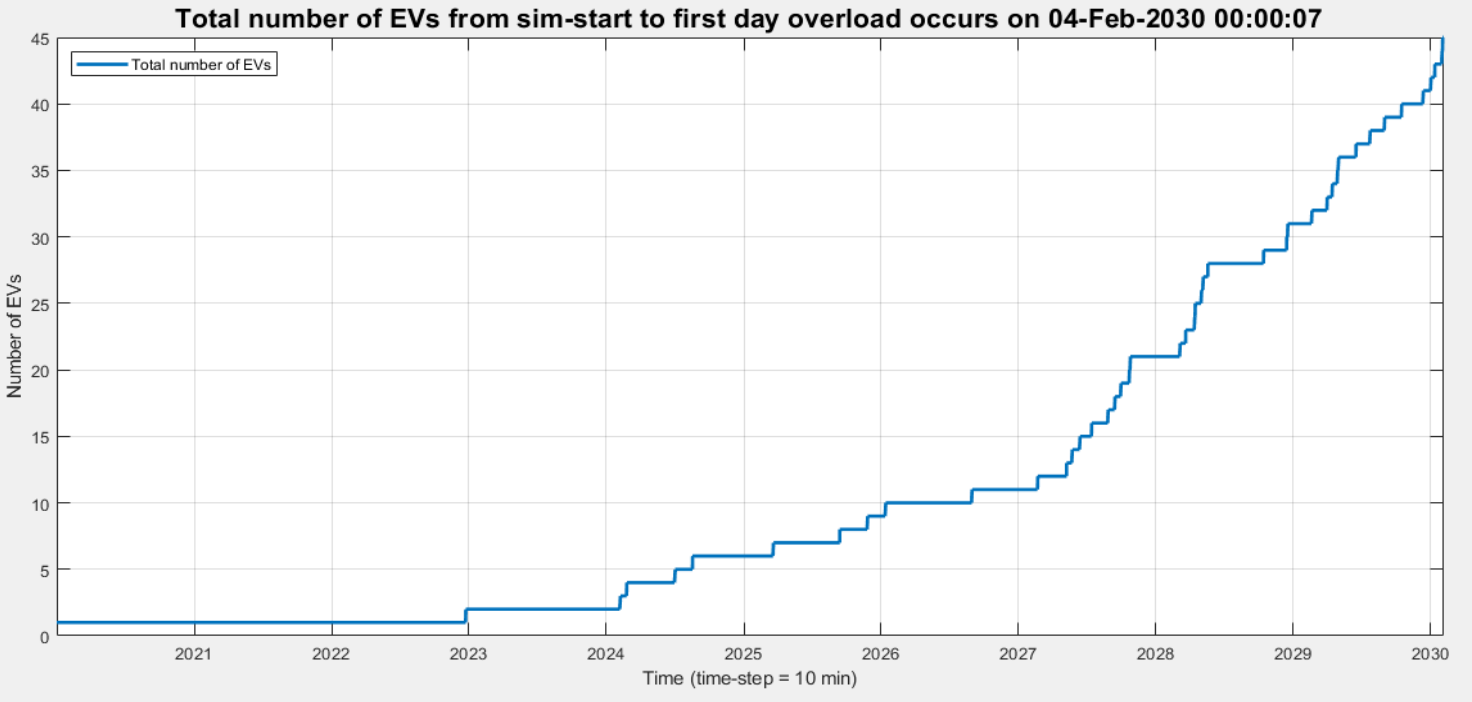
Results – Smart charging

Charging when electricity price is lowest

- February 04, 2030
- Total of 45 EV





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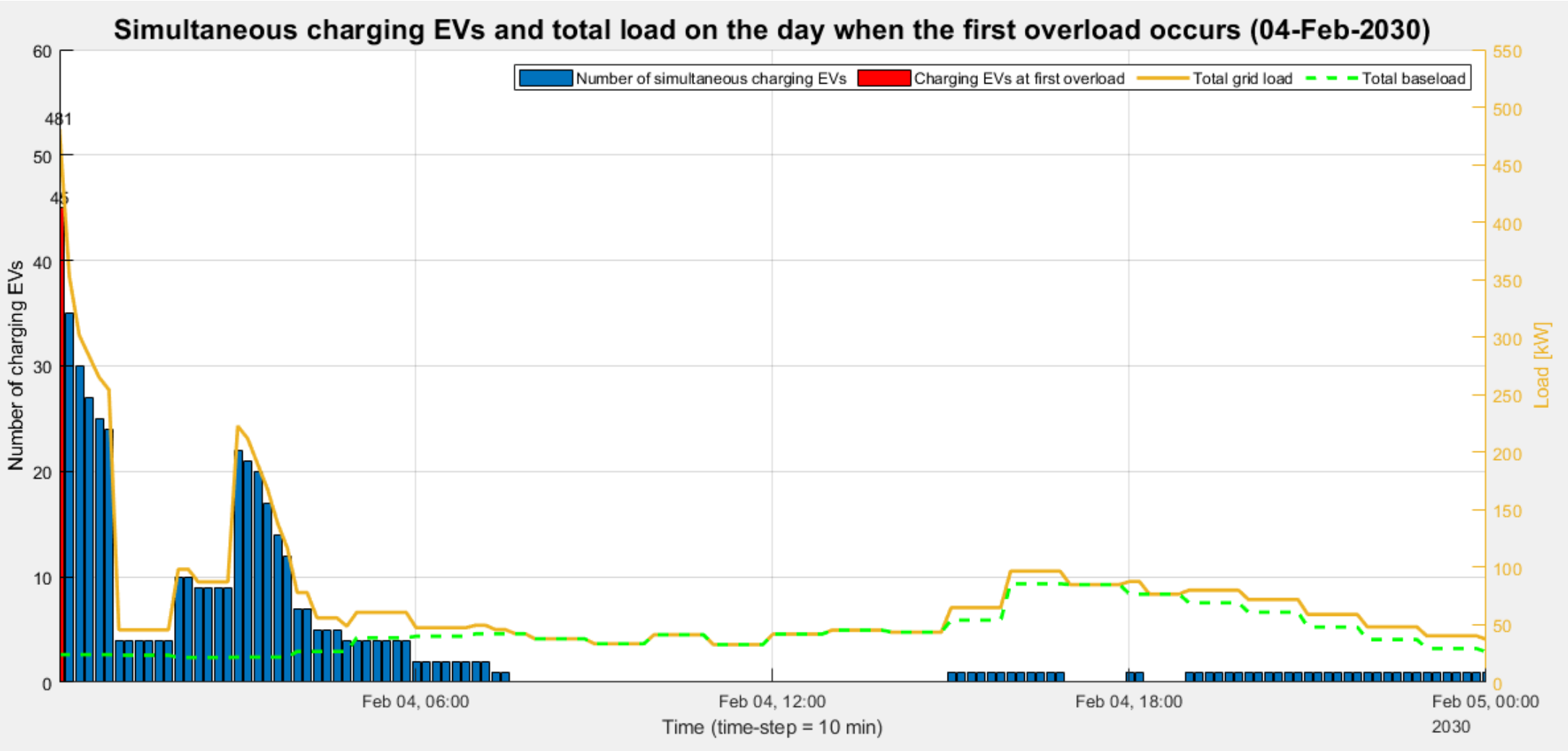
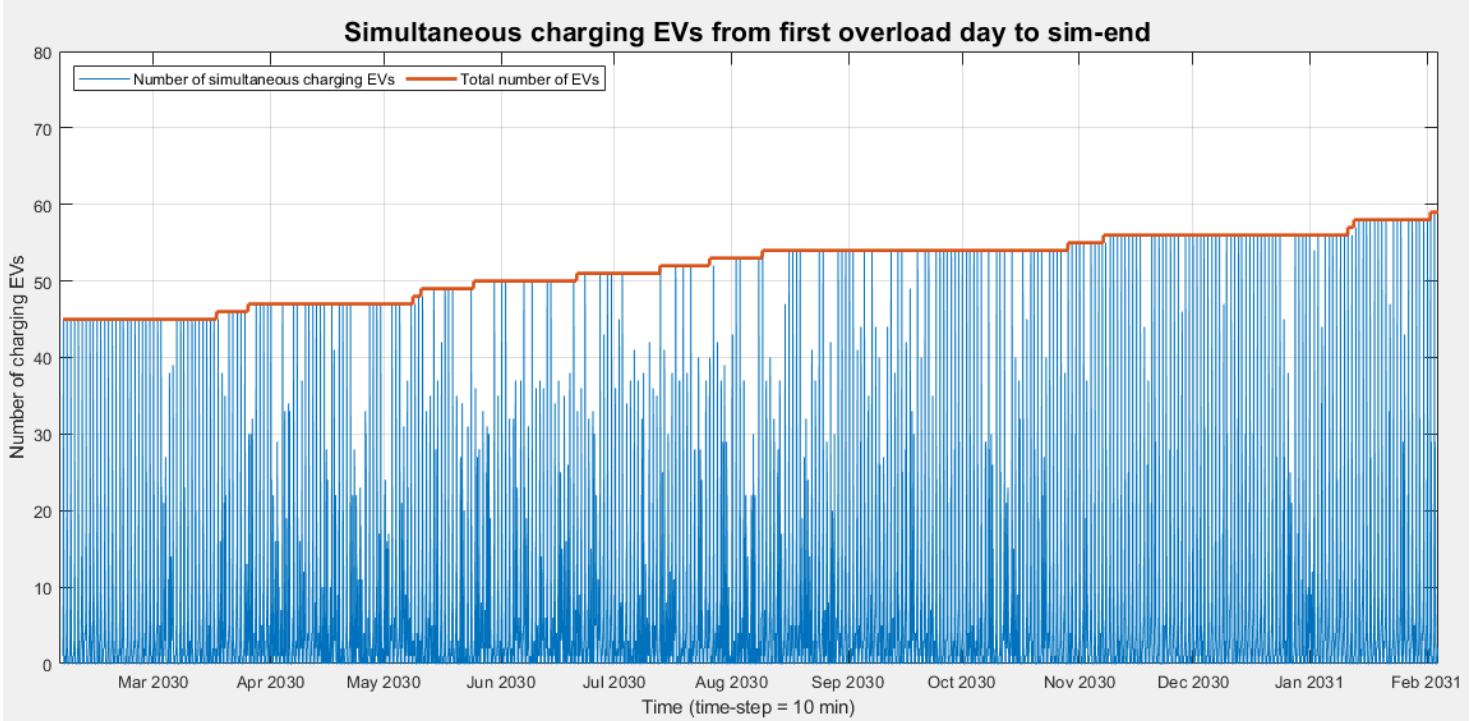
Results – Smart Charging

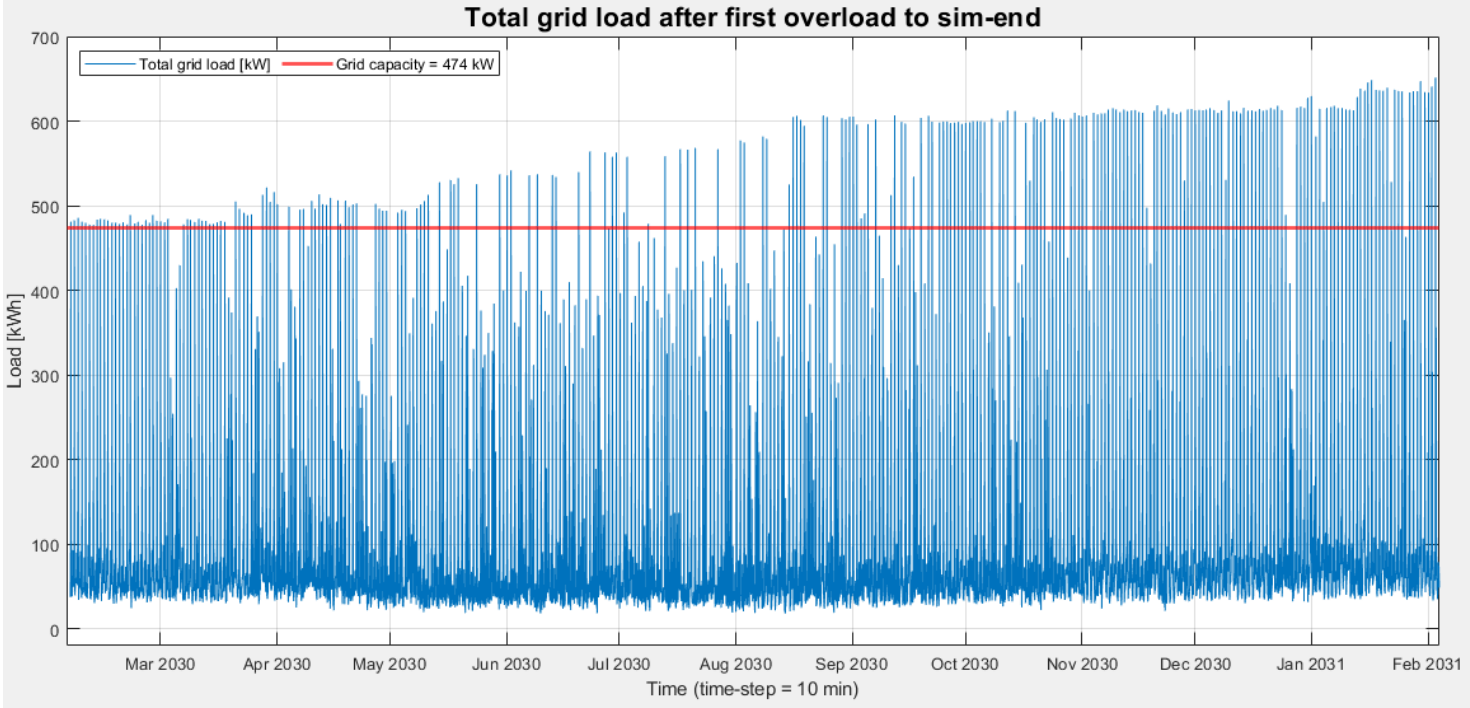
- 45 simultaneously charging EVs
- Overload of 7 kW



Results – Smart charging

- 235 days with overload
- 401 timesteps of overload





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Simple vs. Smart charging

Simple charging

- October 12, 2031
- Total of 70 EV
- 37 simultaneously charging EVs
- First overload of 18.07 kW
- 11 days with overload
- 11 timesteps of overload

Smart charging

- February 04, 2030
- Total of 45 EV
- 45 simultaneously charging EVs
- First overload of 7 kW
- 235 days with overload
- 401 timesteps of overload

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