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Forecasting PV Production for Energy Management in Mixed-Use Buildings

New Energy Research Center – Turku UAS

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Agenda

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  - Meteorological data & Electricity Price sources
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- Conclusions

Introduction

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Forecasting **PV production for energy management** in **mixed-use buildings** is crucial for sustainable resource allocation and efficient operations. These versatile structures, encompassing residential, commercial, and industrial spaces, pose unique challenges in **balancing energy supply and demand**.

By employing **forecasting methods**, stakeholders can effectively leverage solar energy to meet diverse energy needs while minimizing environmental impact. This proactive approach ensures the efficient utilization of renewable resources, contributing to the long-term viability and resilience of mixed-use building infrastructure in our sustainable future.

Objective

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- Contribute to the effective **integration of renewable energy sources**, such as solar power, and energy storage systems into mixed-use building infrastructure.
- Develop accurate and **reliable forecasting** methods for photovoltaic (PV) production in mixed-use buildings.
- Enhance sustainability and minimize environmental impact by **optimizing energy usage** through self-consumption improvement as well as reducing the peak level of electricity consumption (peak shaving).
- Integrate **energy storage** utilization to enhance self-consumption and overall energy efficiency.
- Explore electricity **cost reduction** strategies by considering electricity spot prices.

Methodology

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Advanced energy management system which includes advanced processes. Developed with the aim for an easy implementation/replication to achieve the integration of renewable energy resources.

Processes included:

- PV power production forecast
- Electrical consumption forecast
- Energy flow optimization based on accurate predictions
- Optimization of electricity cost and peak shaving
- Energy storage control based on optimization results

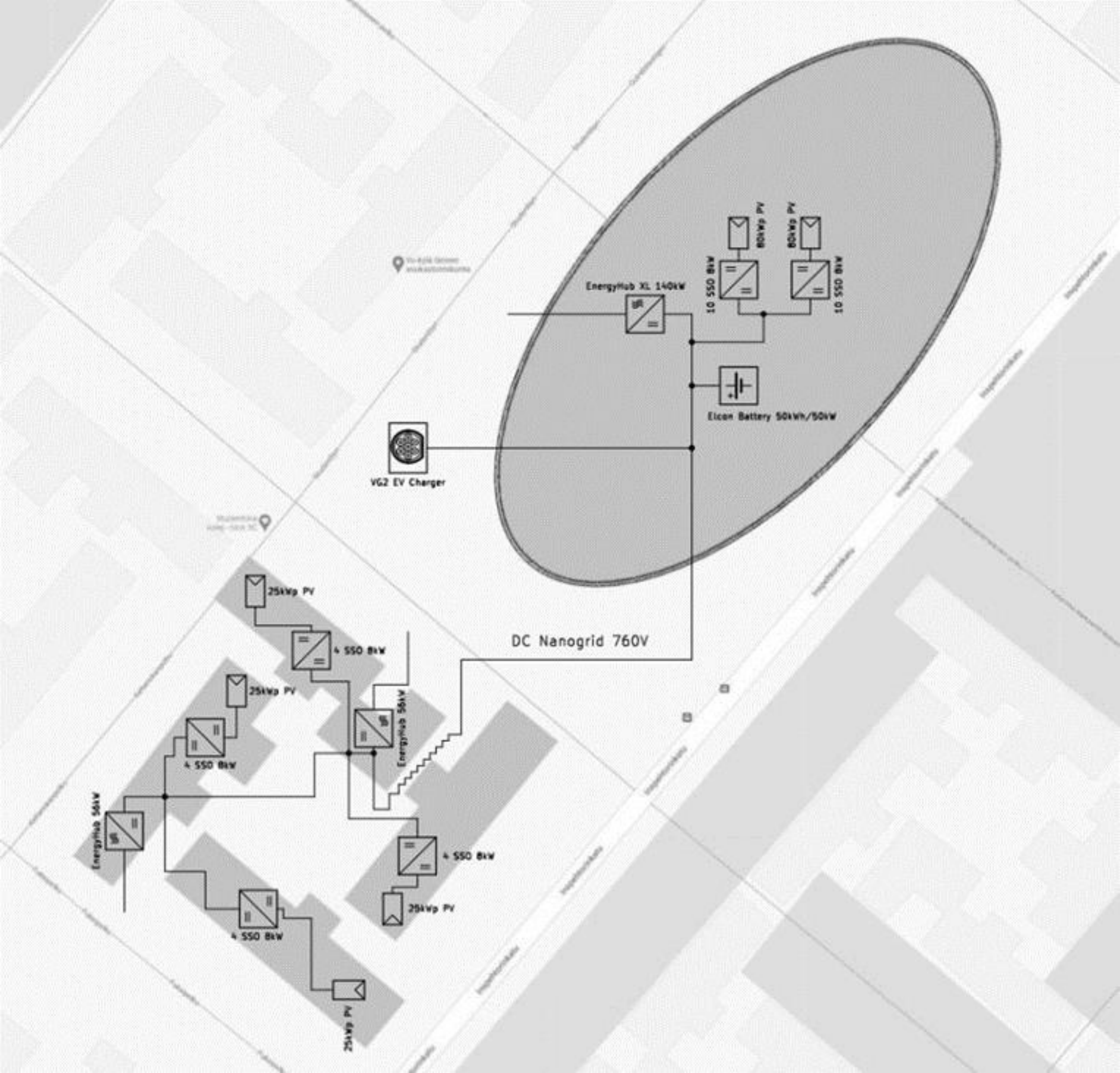
Students' village, Tyyssija. Mixed-use building.

RESPONSE

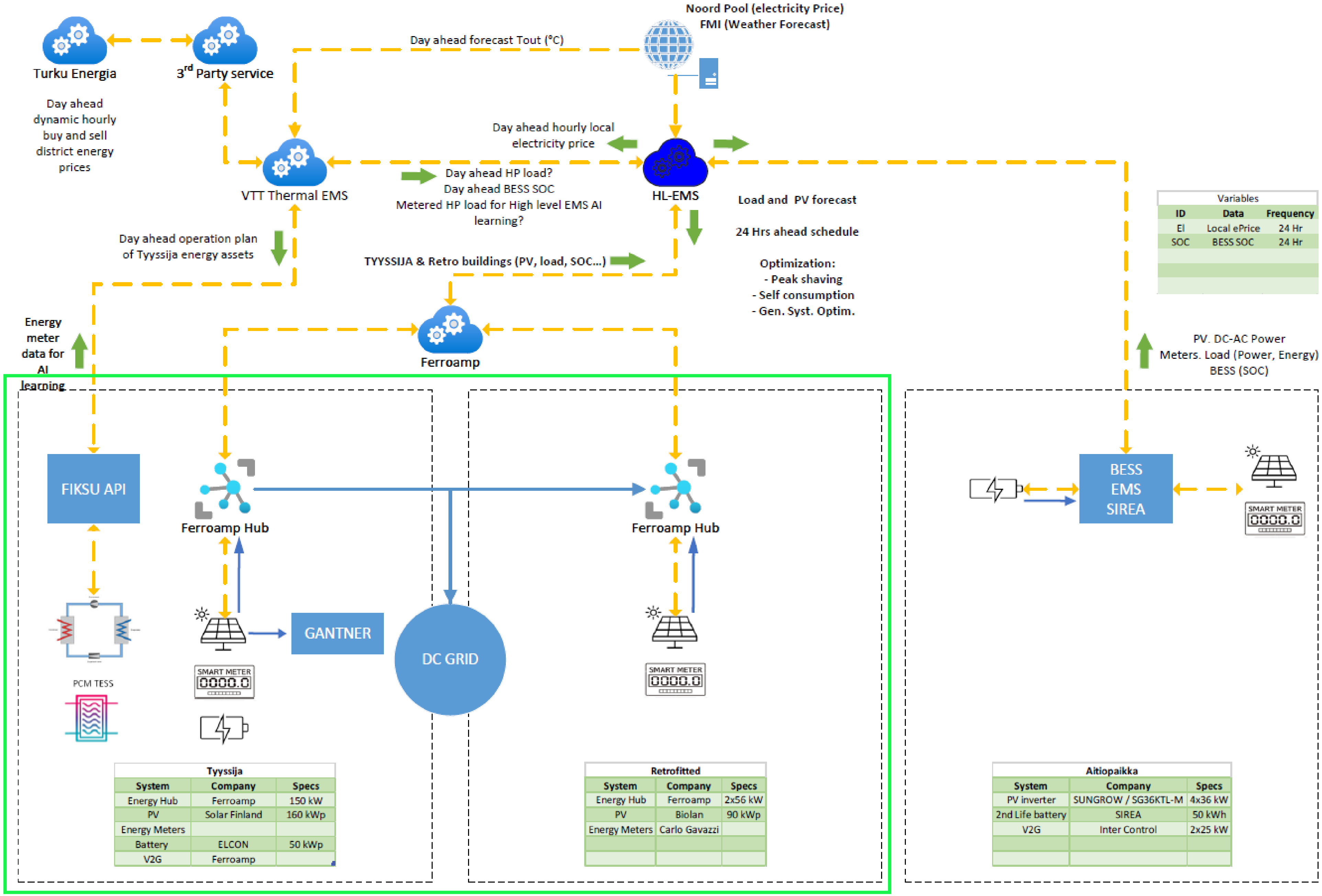
INTEGRATED SOLUTIONS FOR POSITIVE ENERGY AND RESILIENT CITIES

Pilot site – TYS

- ~**140 kWp** bifacial PV modules in Tyyssija’s rooftop
- Twenty 8kW Solar String Optimizers in Tyyssija
- **50kWh/ 50kW** DC coupled battery energy storage system
- 140kW Energy Hub XL bidirectional AC/DC converter in Tyyssija
- Fast V2G charging stations DC coupled
- **Four 25kWp** monofacial PVs in Retrofitted buildings
- Sixteen 8kW Solar String Optimizers in retrofitted buildings
- Two 56kW EnergyHub bidirectional AC/DC converter in retrofitted buildings (5B and 5C)



Response project – HL EMS

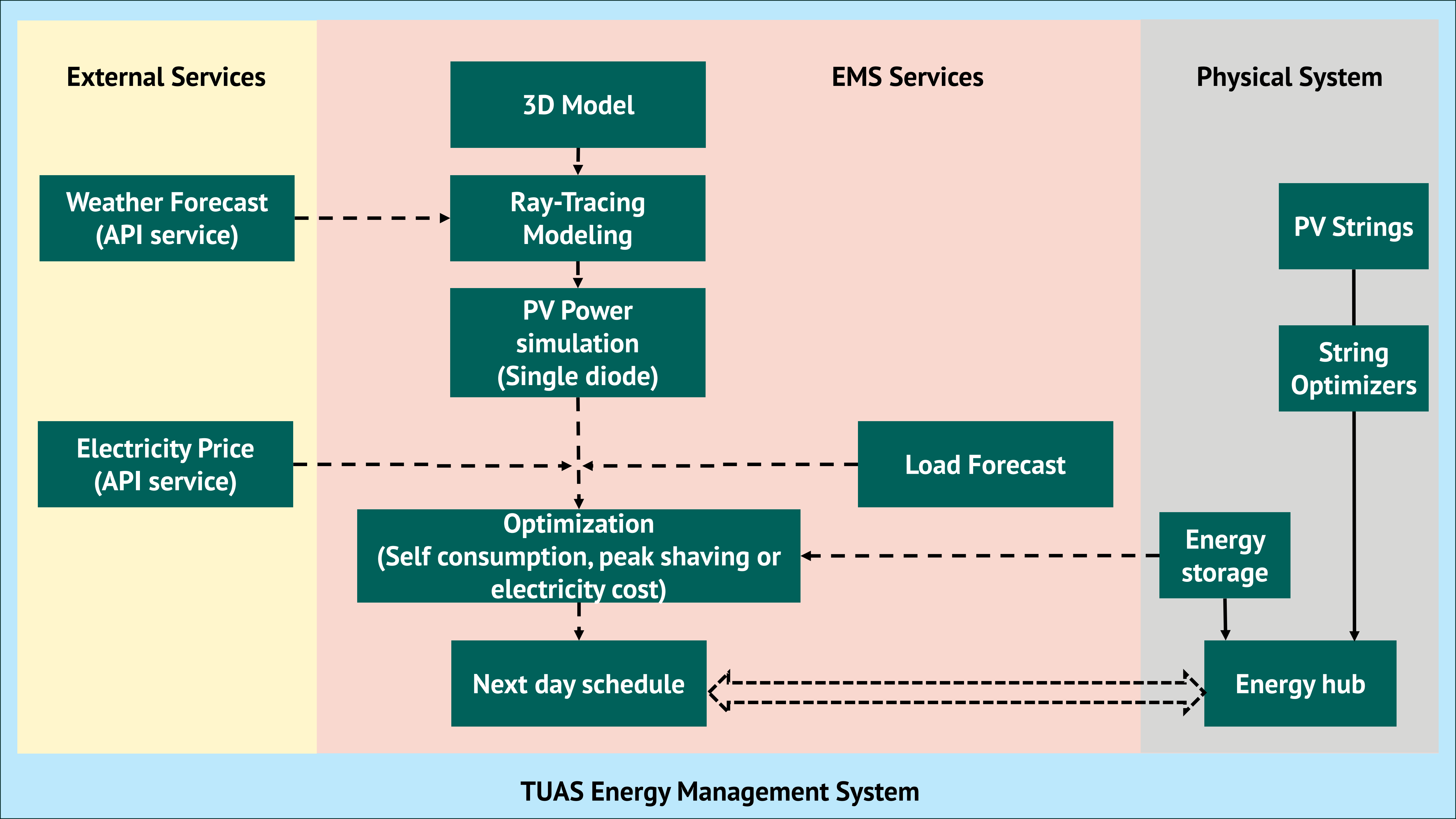


Variables		
ID	Data	Frequency
El	Local ePrice	24 Hr
SOC	BESS SOC	24 Hr

Tyyssija		
System	Company	Specs
Energy Hub	Ferroamp	150 kW
PV	Solar Finland	160 kWp
Energy Meters		
Battery	ELCON	50 kWp
V2G	Ferroamp	

Retrofitted		
System	Company	Specs
Energy Hub	Ferroamp	2x56 kW
PV	Biolan	90 kWp
Energy Meters	Carlo Gavazzi	

Aitiopaikka		
System	Company	Specs
PV inverter	SUNGROW / SG36KTL-M	4x36 kW
2nd Life battery	SIREA	50 kWh
V2G	Inter Control	2x25 kW



External Services
EMS Services
Physical System
3D Model
Weather Forecast (API service)
Ray-Tracing Modeling
PV Strings
PV Power simulation (Single diode)
String Optimizers
Electricity Price (API service)
Load Forecast
Optimization (Self consumption, peak shaving or electricity cost)
Energy storage
Next day schedule
Energy hub
TUAS Energy Management System

External services

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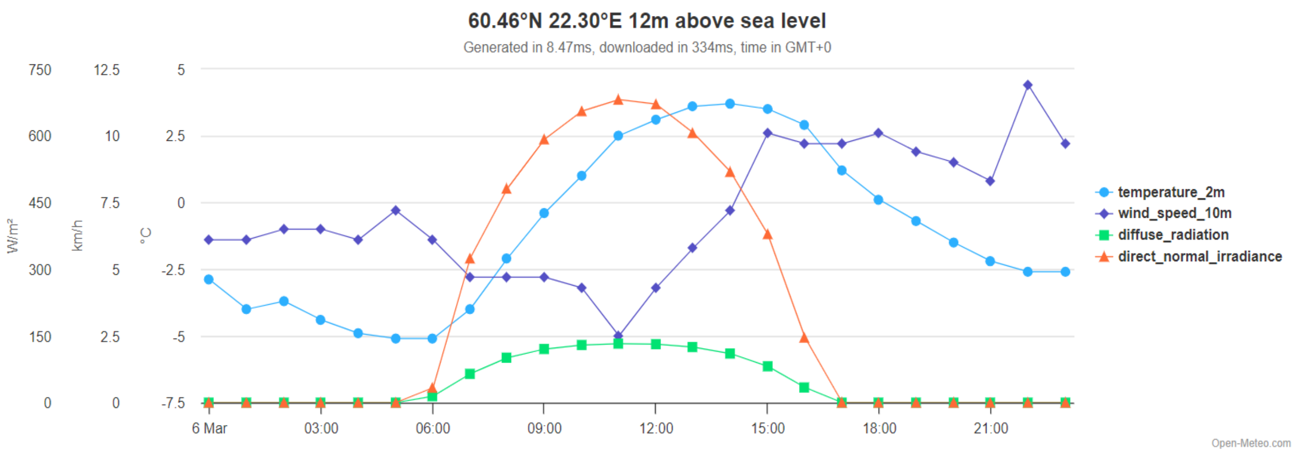
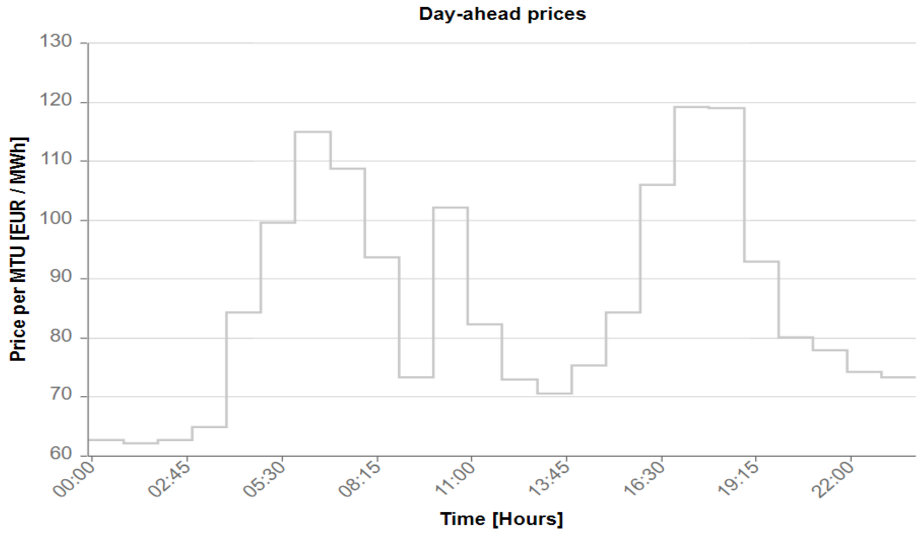
Weather forecast and electricity prices



Meteorological data predicted for the next day
-Finnish Meteorological Institute (FMI)
-MET Norway API

Electricity Prices
Finnish Electricity Prices for the next day

entsoe
Transparency Platform



https://en.ilmatieteenlaitos.fi/ https://open-meteo.com/ https://transparency.entsoe.eu/dashboard/show

PV system modeling

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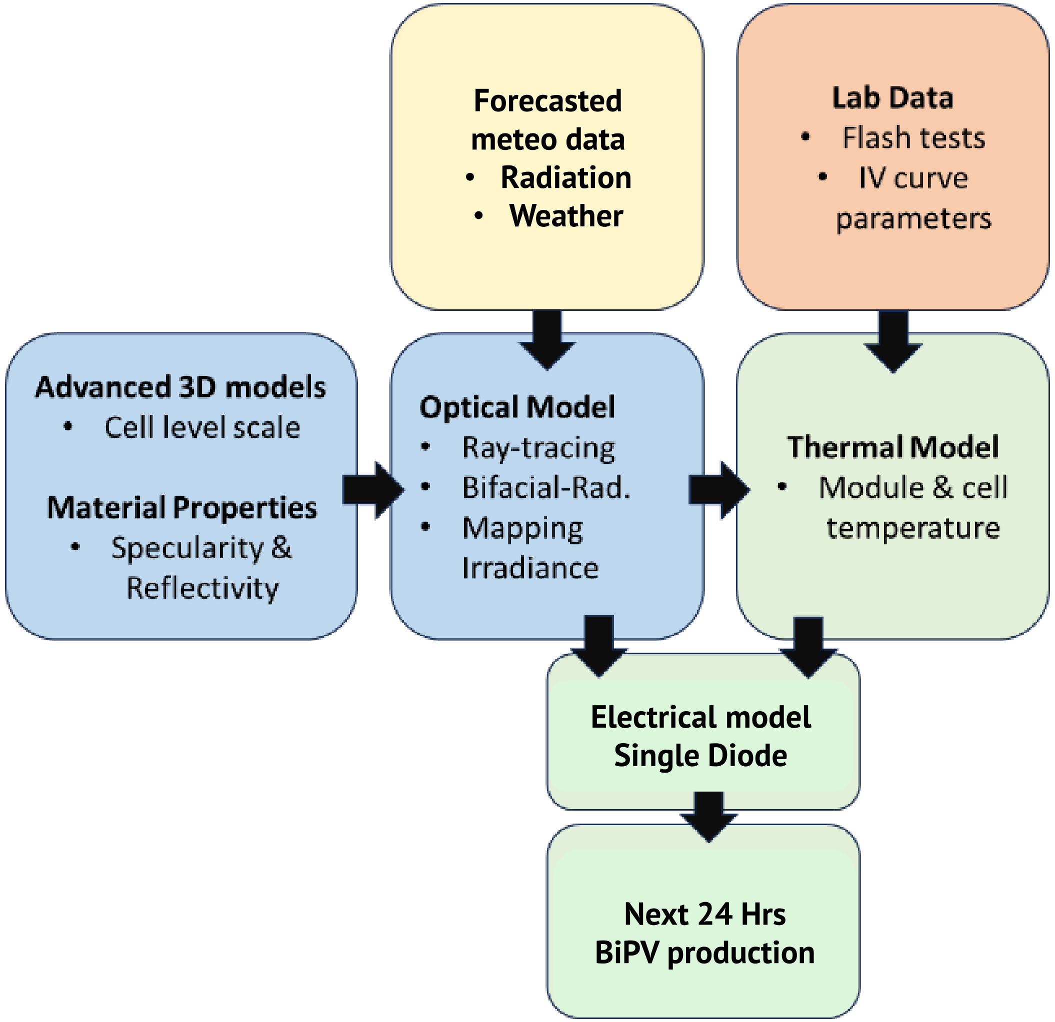
Ray Tracing modeling

Using two methodologies:

1. 3D software (NX), Bifacial-Radiance, Radiance software (CPU based)

2. 3D software (NX), Bifacial-Radiance, Accelerad software (GPU based)



EU PVSEC 2023. Bifacial PV Systems at High Latitude: Modeling and Validation with Monitoring Data. Huerta et al.

PV system modeling cont.

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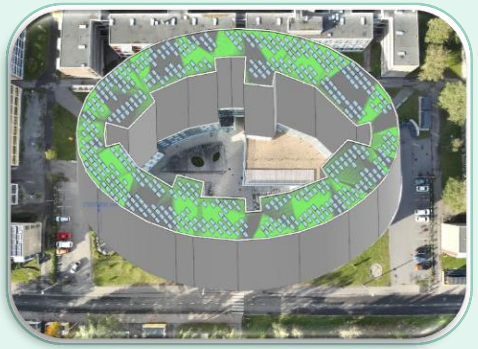
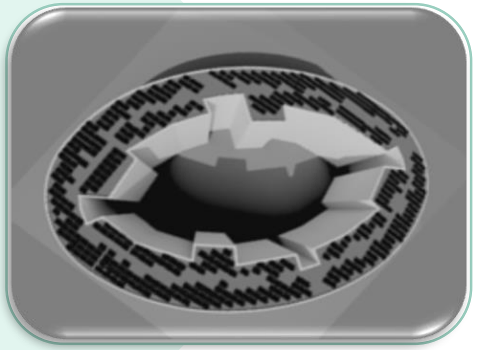
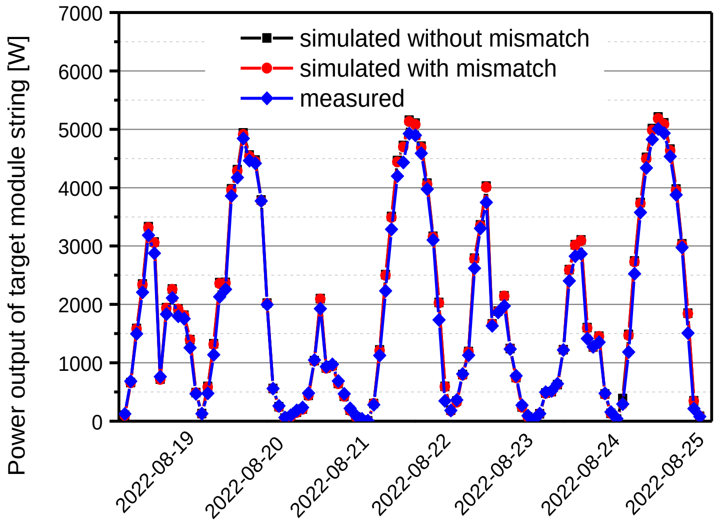






Simulation results vs. measured data. Ray tracing.

EU PVSEC 2023. Bifacial PV Systems at High Latitude: Modeling and Validation with Monitoring Data. Huerta et al.

Optimization

The optimization of the system is based on Linear Programming.

Minimizes or maximizes an Objective function (Cost of electricity)

Requirements:

- Electricity Spot price
- PV production forecast
- Load Forecast model-NN Model. Trained.
- - To predict load 24 hrs ahead
- Storage system parameters

$$\min_{x} f(x),$$

subject to

$$G_i(x) = 0 \quad i = 1, \ldots, m_e$$

$$G_i(x) \leq 0 \quad i = m_e + 1, \ldots, m$$

$$x_l \leq x \leq x_u,$$

Implementation and preliminary results

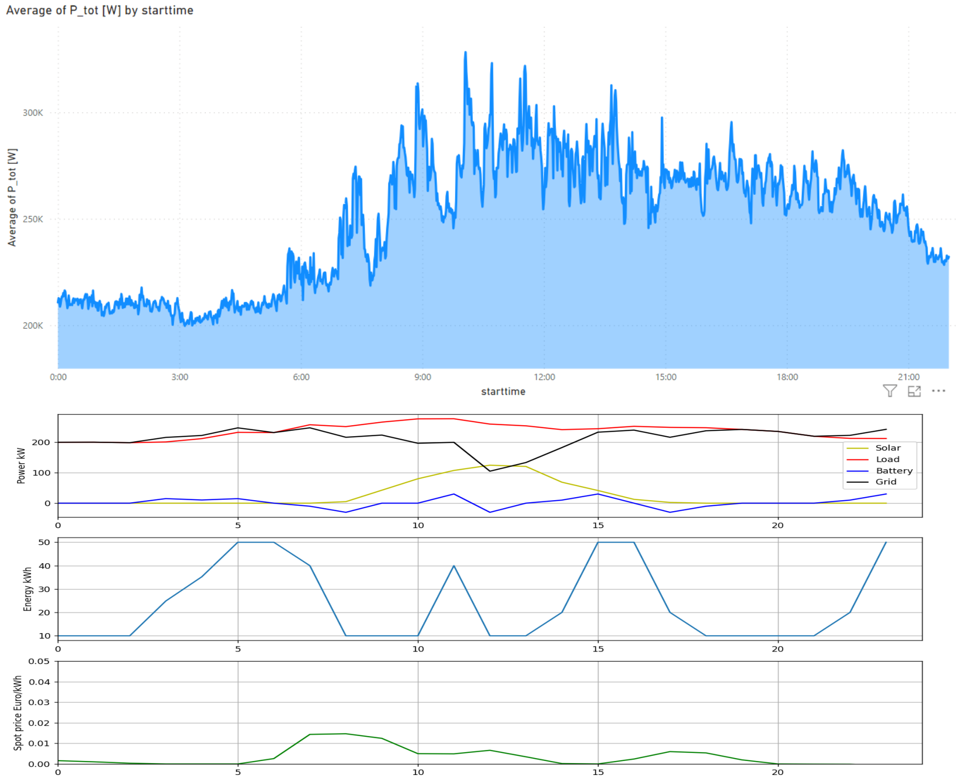
The EMS is up and running with some of the functionalities in operation. The system's architecture consists of several processes running simultaneously 24/7. The main processes consist of:

Data Services

- Acquisition
- Monitoring
- Management

Control Services

- Forecasting/Predicting
- Modeling
- Optimization
- Scheduling



Monitoring building's consumption(top), optimization (bottom)

Implementation and results, cont.

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Energy Management System API 0.5 OAS 3.1

/api/openapi.json

Project RESPONSE - Turku student village

API developed to perform the Energy Management System (EMS) in Turku's student village.

Functionalities

Servers

/api

Authorize

- commands
- devices
- KPI
- measurements
- MQTT
- Optimization
- predictions
- programs
- Solar
- sensors
- Spot_price
- users

Implementation. Example 1 – Low ePrice

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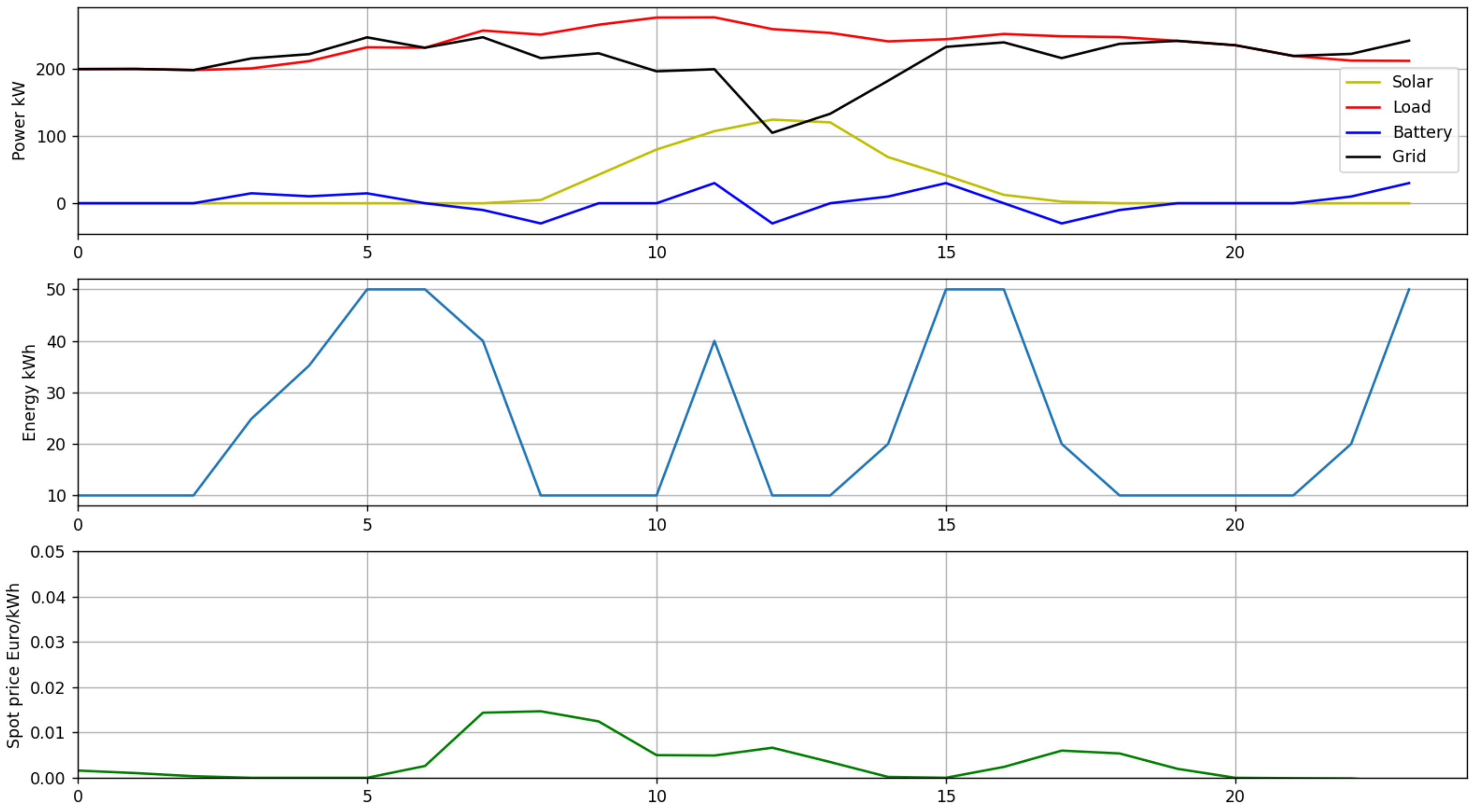

Optimization results using low electricity prices

Implementation. Example 1 – High ePrice

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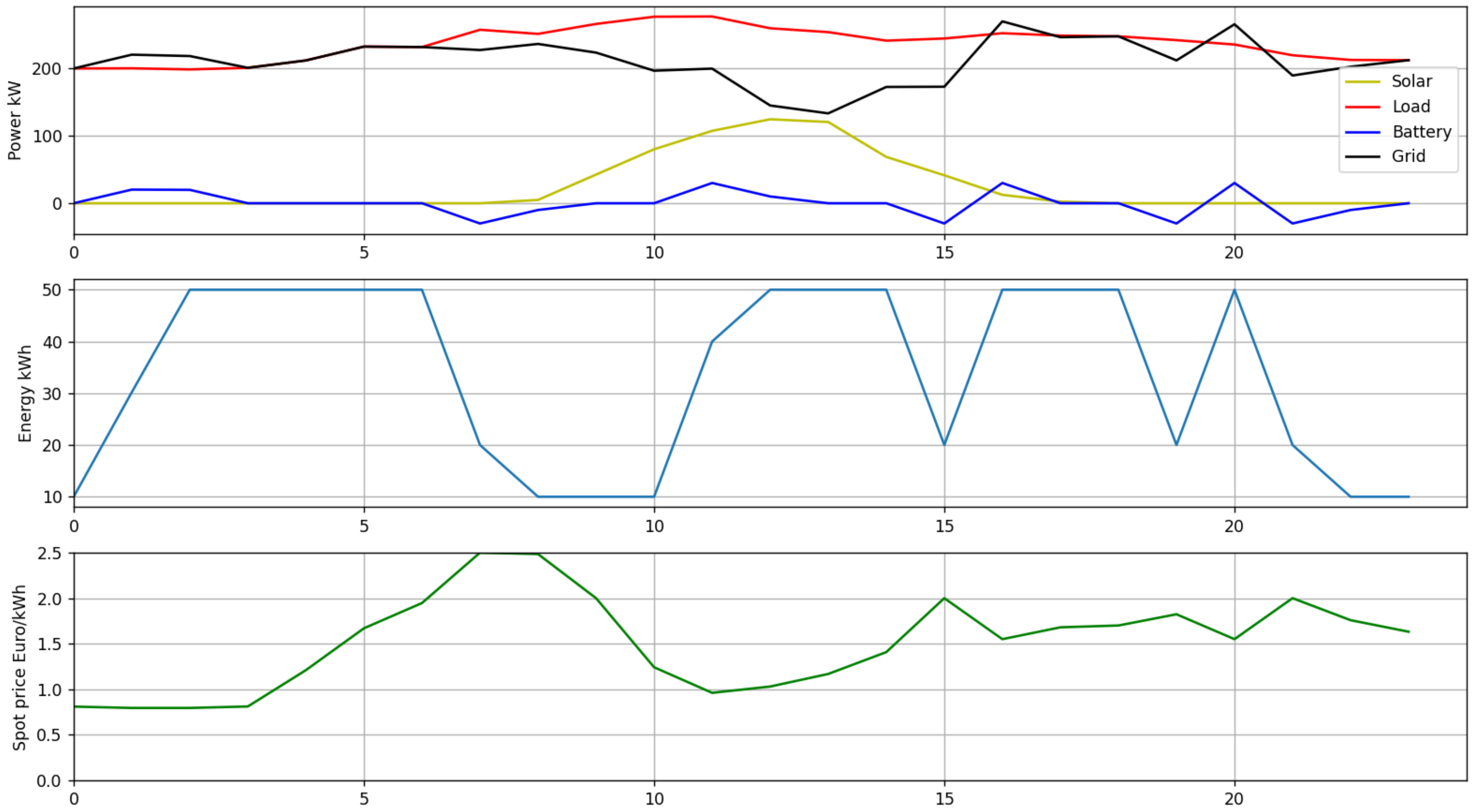

Optimization results using high electricity prices.

Conclusions

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PV production forecast

- Modeling complex 3D structures together with the PV systems is relatively easy, and the methodology has been well defined in the research group.
- Modeling irradiance conditions for the PV systems using Ray Tracing technique has been proved and validated in the past, therefore, can be used with confidence.
- Using forecasted Meteo data have shown good results when compared to measured values, however, more evaluation is needed.
- PV forecast is critical for implementing the EMS in order to improve the energy usage.

Energy Management System

- The TUAS EMS is still under development and some of the features have been tested with a smaller system at the NERC's laboratory.
- The EMS is in operation and collects critical data for its future implementation, consumption, meteo data, and electricity price, to name a few of them. Historical data will be used soon to train models and implement the optimization in the building once all the connections are finished.
- EMS can be used to reduce cost of electricity, maximize self-consumption as well as peak shaving depending on the needs.