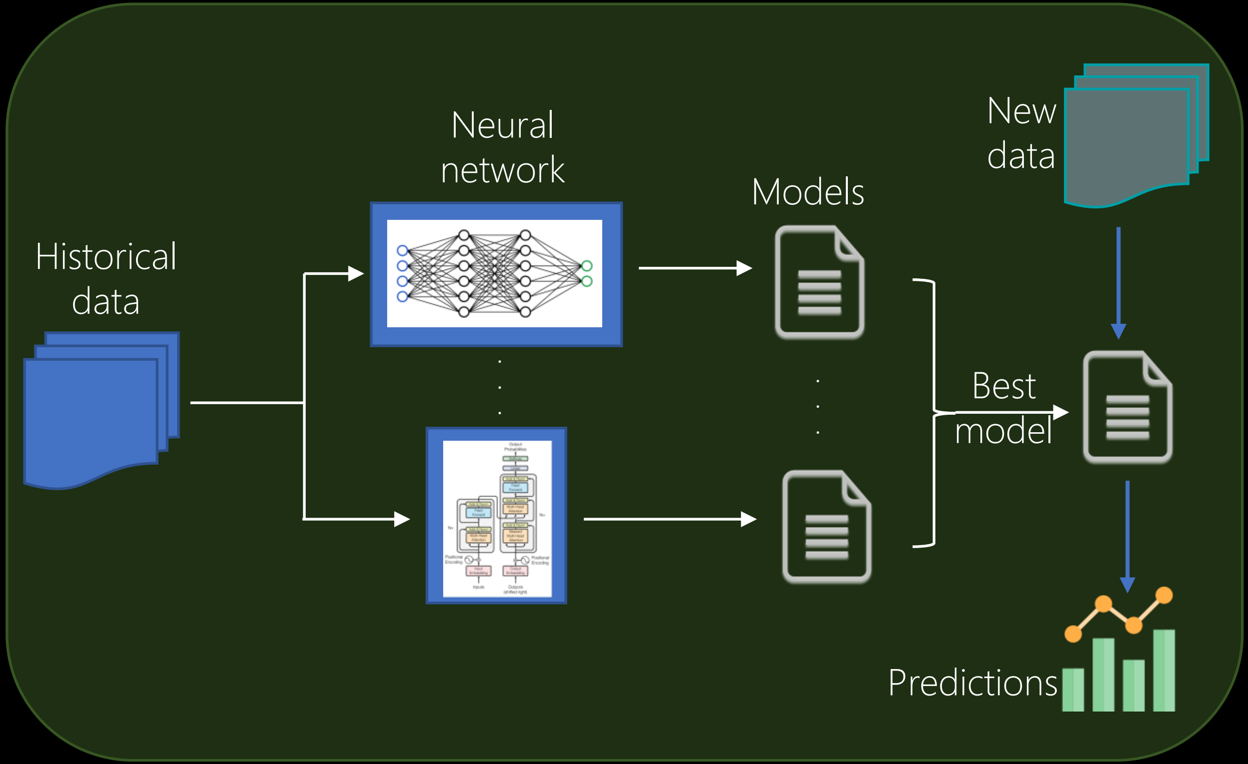
Outline

- FCR-N Market price forecasting
- IEC 104 & REST API for Virtual Power Plants
- Asset capacity forecasting - Photovoltaics / Solar Panels
- Asset capacity forecasting - Building Automation
- Energy Consumption forecasting
- MLOps for FCR-N market forecasting

Prediction with Neural network

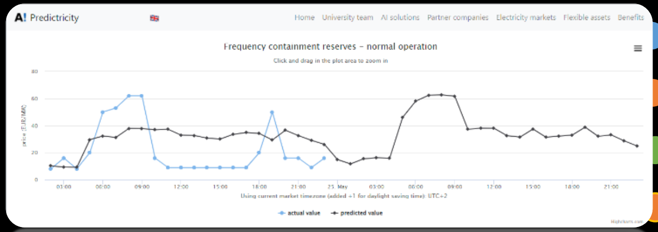


FCR-N Market price forecasting

FCR-N Market price forecasting

Previous work & background

- Previous work:
  - Researched the best model
  - Web UI , REST API & Running on CSC
- Current scope:
  - Increase accuracy
  - Automate ML lifecycle



FCR-N market price forecasting

- Data collection
- Train ML model
- Predict day ahead price
- Display results, REST API interface

"In machine learning, performance metrics (Error measures) are used to compare the trained model predictions with the actual (observed) data from the testing data set"

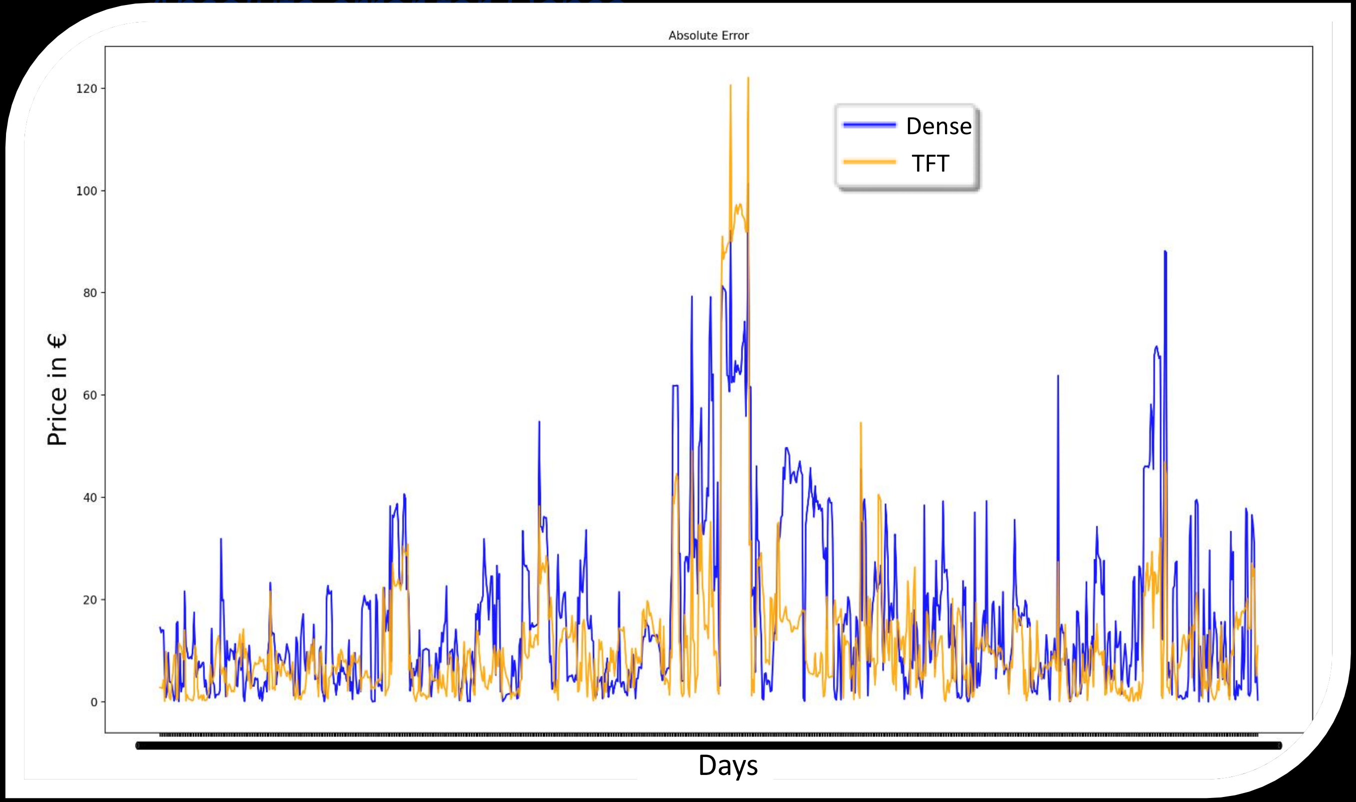
Different error metrics

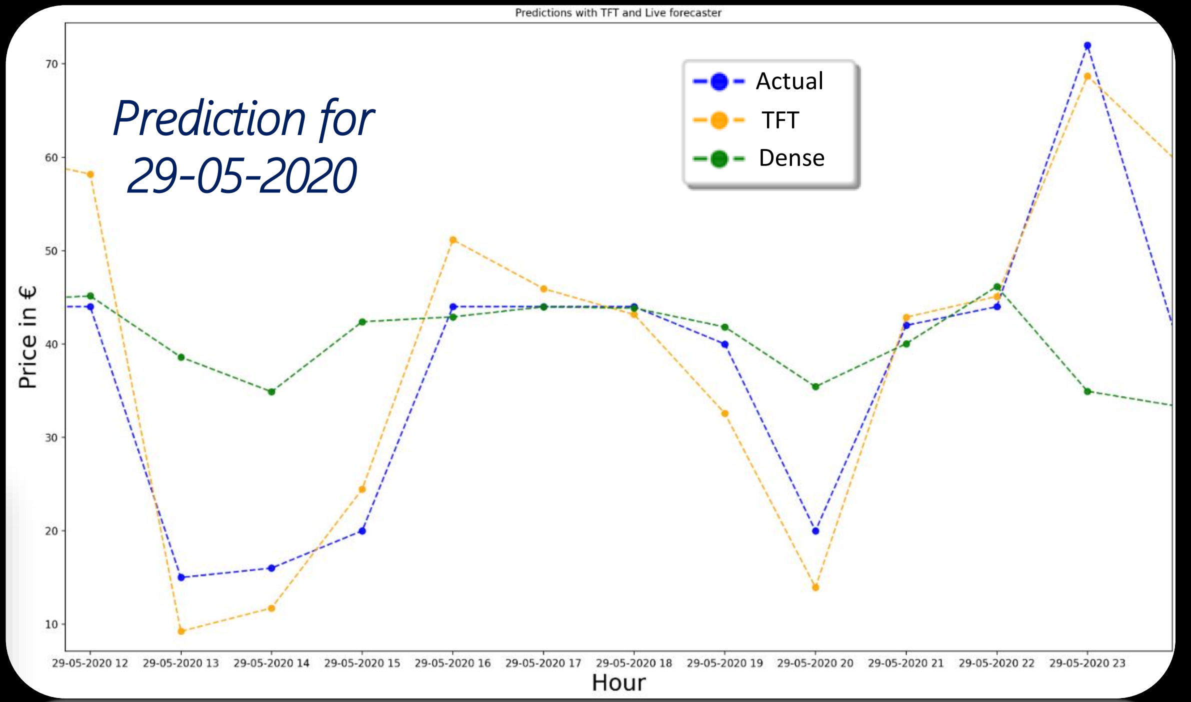
Absolute Error - AE	Mean Absolute Error - MAE	Mean absolute percentage error - MAPE	Mean Square Error - MSE
Amount of error in forecast without considering the direction	The average magnitude of the errors in the forecasts, without considering the direction	How many percentage points the forecasts are off	The smaller the Mean Squared Error, the closer the fit is to the data

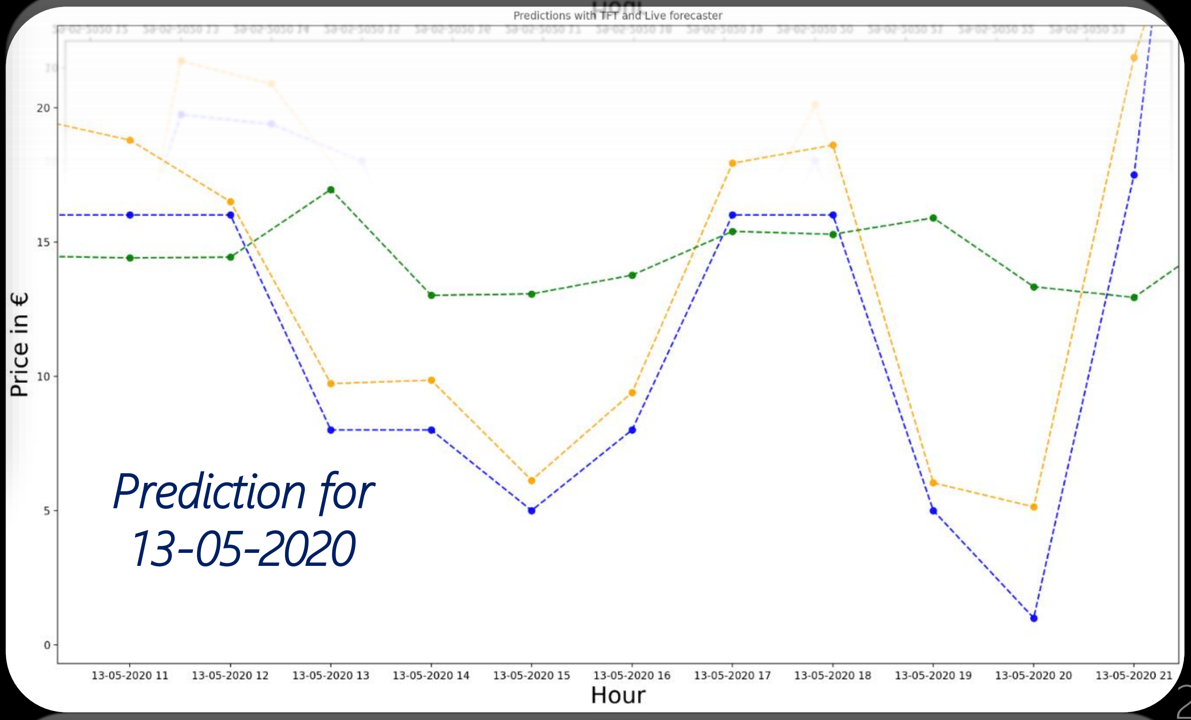
FCR-N Market price forecasting

Dense vs TFT

- Data sources: Fingrid, Finnish Meteorological Institute, Calendar features
- Dense (Three-layer classic NN) = Old model.
- TFT (Temporal Fusion Transformer) = Current research model



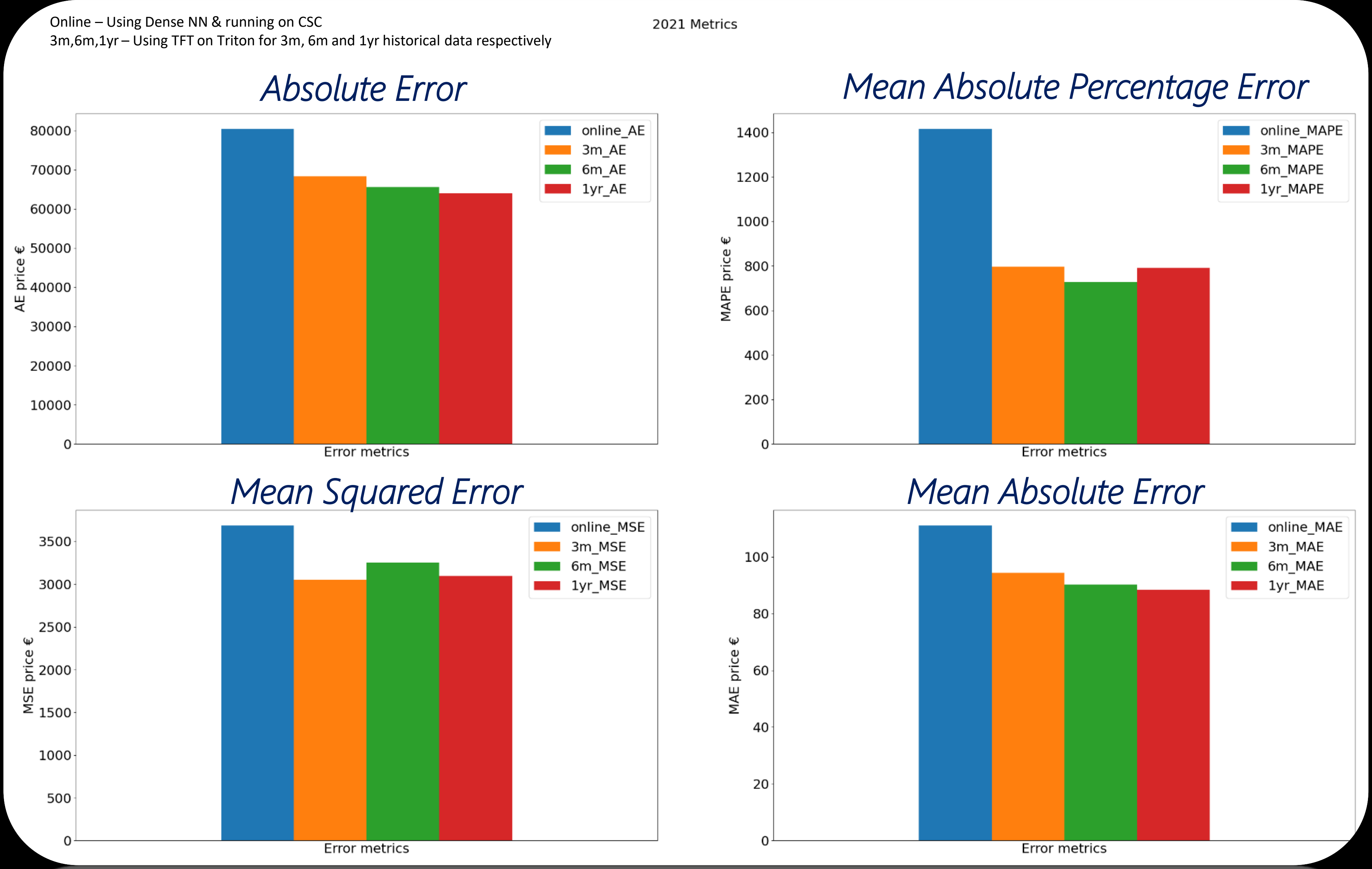




FCR-N Market price forecasting

Dense vs TFT

- Error Comparison
- Four metrics
- Three different training periods for TFT
  - 3 Months – 3m
  - 6 Months – 6m
  - 1 Year – 1yr
- Similar result for 2020 and 2022
- TFT performs better than existing model



IEC 104 & REST API for Virtual Power Plants

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Engineering

IEC 104 & REST API for VPP

Background

- VPP:
  - Manage energy resources that are not co-located (DER)
  - Lack of research: Cloudification & multi-tenancy
  - Need: Interoperability via cloud computing
- IEC 60870-5-104 (IEC 104)
  - Well-established standard for telecontrol in automation applications
- IEC 104 Role:
  - VPP interoperability & Cloudification.
  - Third-party integration (as SaaS clients)
    - Internet of Things-enabled Distributed Energy Resources
    - Electricity market information systems

Interfacing Third Party Cloud Services to a Virtual Power Plant

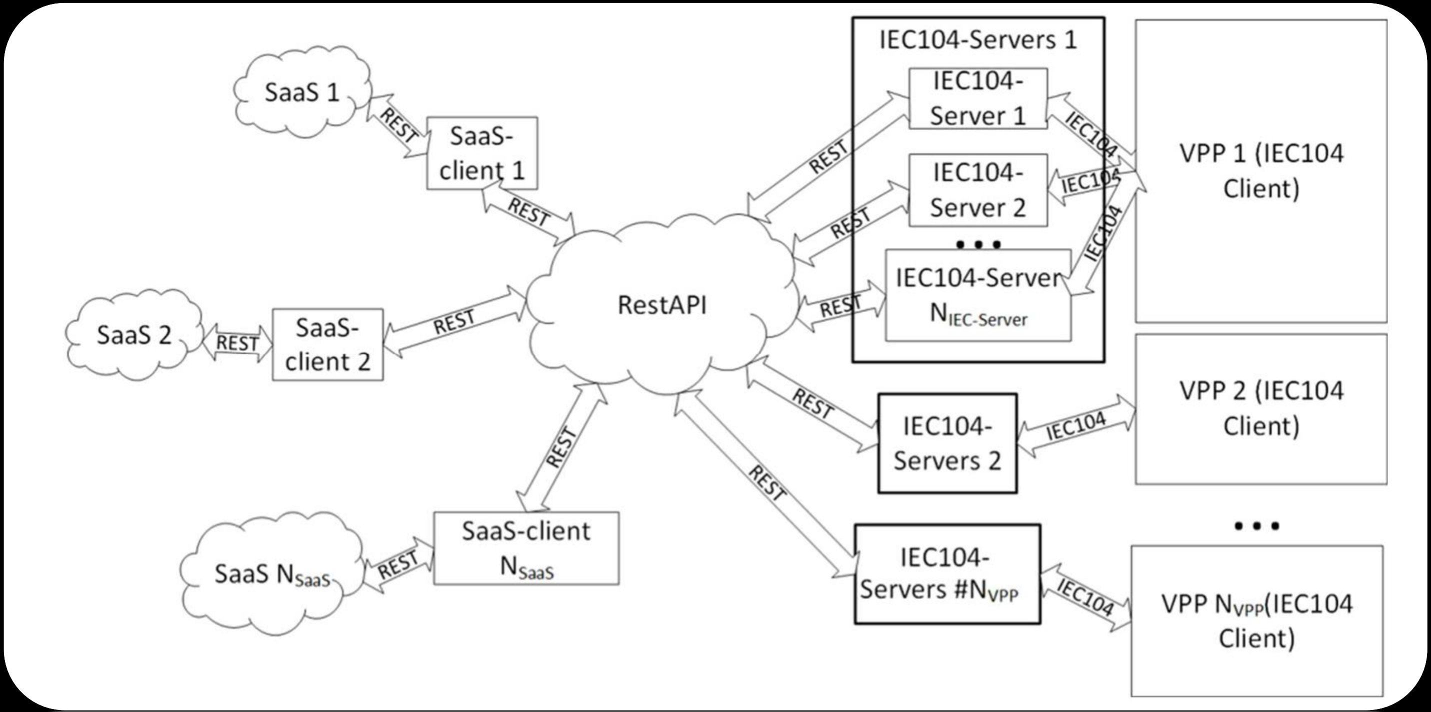
Publisher: IEEE Cite This PDF

Rakshith Subramanya ; Seppo Sierla ; Matti Yli-Ojanperä ; Henri Makkonen ; Mahdi Poura...

- Integration with Siemens Virtual Power Plant (VPP).
- Used for: Data imports from VPP and perform forecasts on the data.
- **Publication: https://ieeexplore.ieee.org/document/9640200**

IEC 104 & REST API for VPP

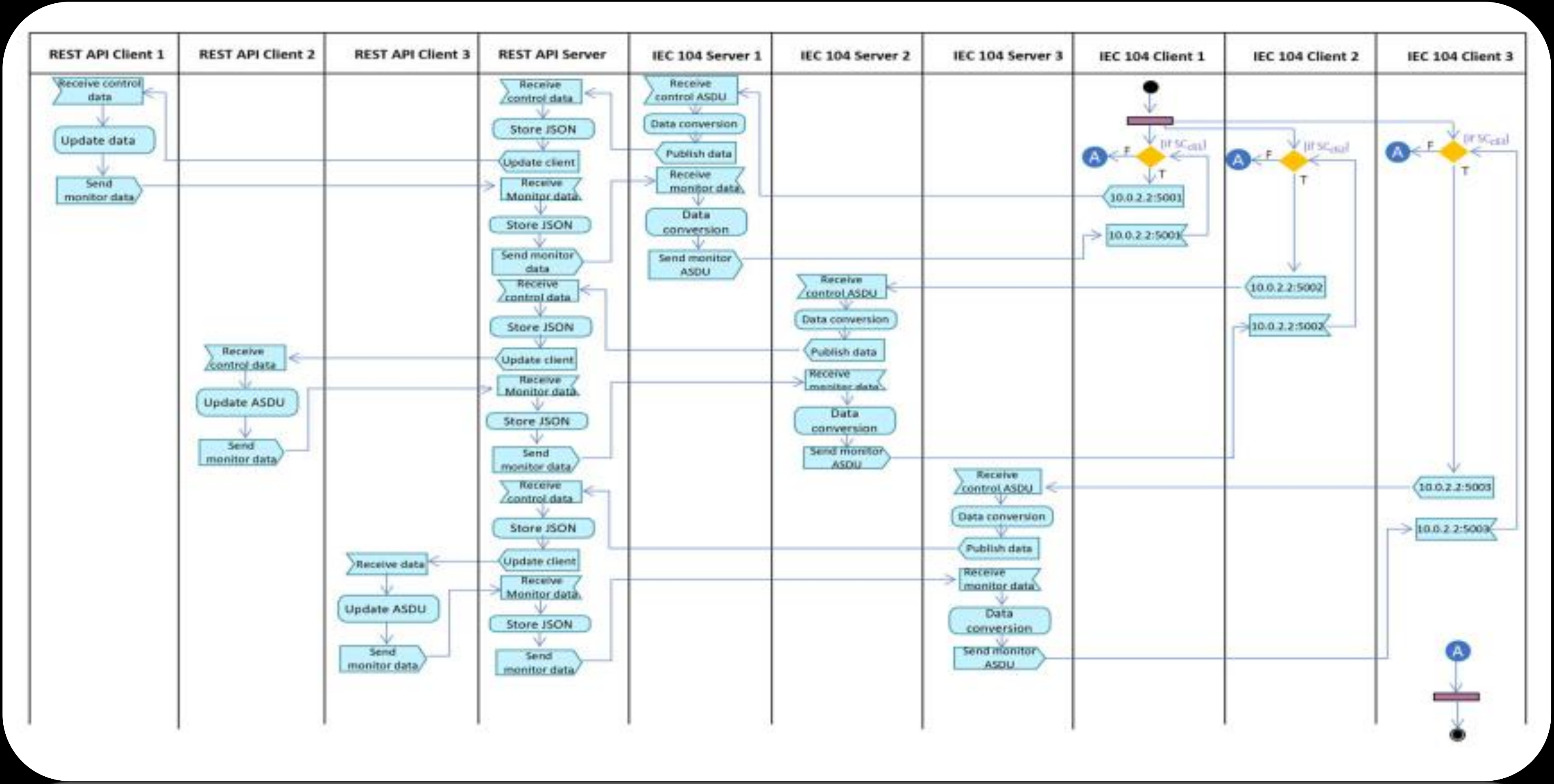
Architecture



- Smart grid: VPP interfacing via IEC-104
- Software as a Service – SaaS architecture
  - IEC 60870-5-104 / 104
  - REST (Representational State
  - Transfer)
  - APIs (Application Programming Interfaces).
  - Multitenancy (For scaling)
  - SaaS clients: Connected to assets like photovoltaic panels / EV charging stations via the REST API

IEC 104 & REST API for VPP

Multitenant Architecture Implementation



- Multiple SaaS (REST API) clients
- Multiple IEC 104 Clients
- Single REST API server
- Both monitor and control signal communication
- Security: Request authentication

Asset capacity forecasting

Photovoltaics / Solar Panels

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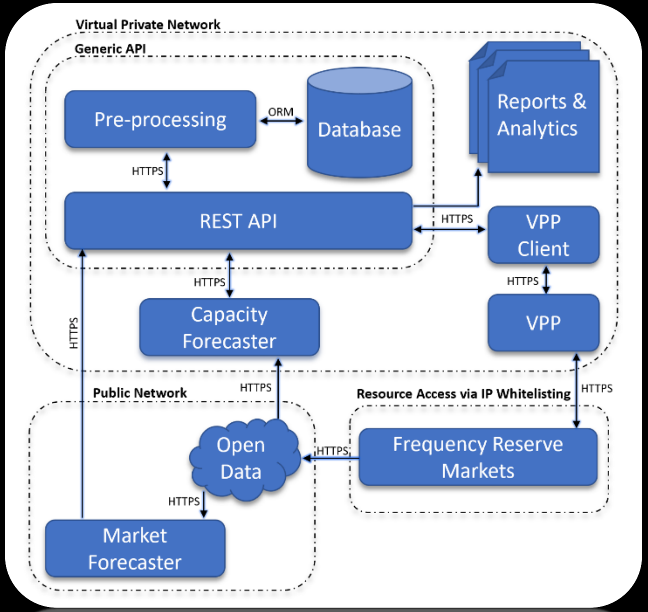
Engineering

Asset capacity forecasting : PV

Sello usecase : Introduction

- Penetration of Photovoltaic (PV) power generation in PFR (Primary Frequency Reserves).
- For VPP, asset capacity forecast is useful due to the minimum capacity of one bid in the PFR markets.
- PV data is collected from Siemens VPP for forecasting.
- Dense model (Three-layered classical neural network).
- Data sources: Finnish Meteorological Institute, Calendar features

- Publication: https://www.mdpi.com/1996-1073/14/5/1242



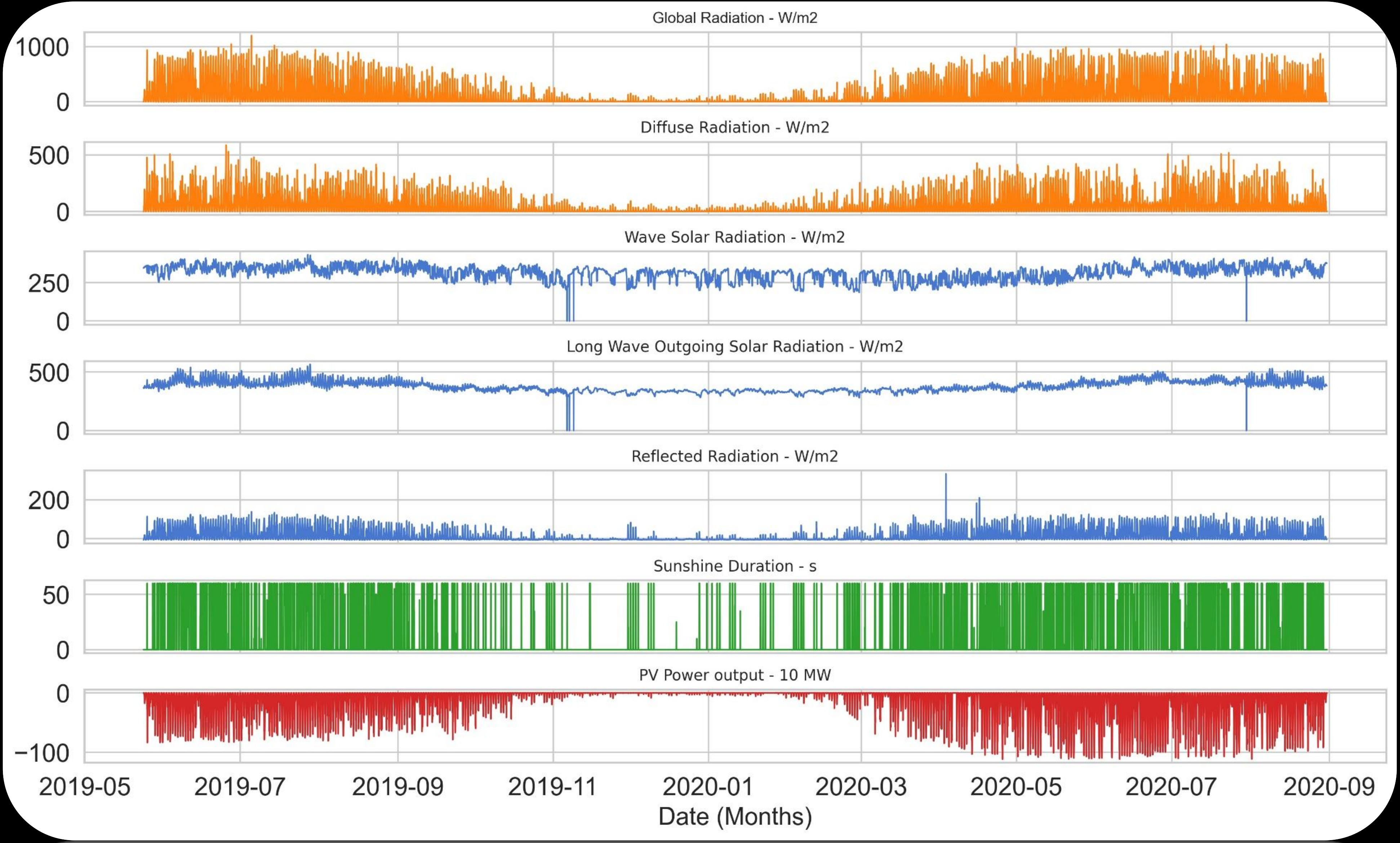
A Virtual Power Plant Solution for Aggregating Photovoltaic Systems and Other Distributed Energy Resources for Northern European Primary Frequency Reserves

by Rakshith Subramanya [1,*], Matti Yli-Ojanperä [1], Seppo Sierla [1], Taneli Hölttä [1], Jori Valtakari [2] and Valeriy Vyatkin [1,3,4]

Asset capacity forecasting : PV

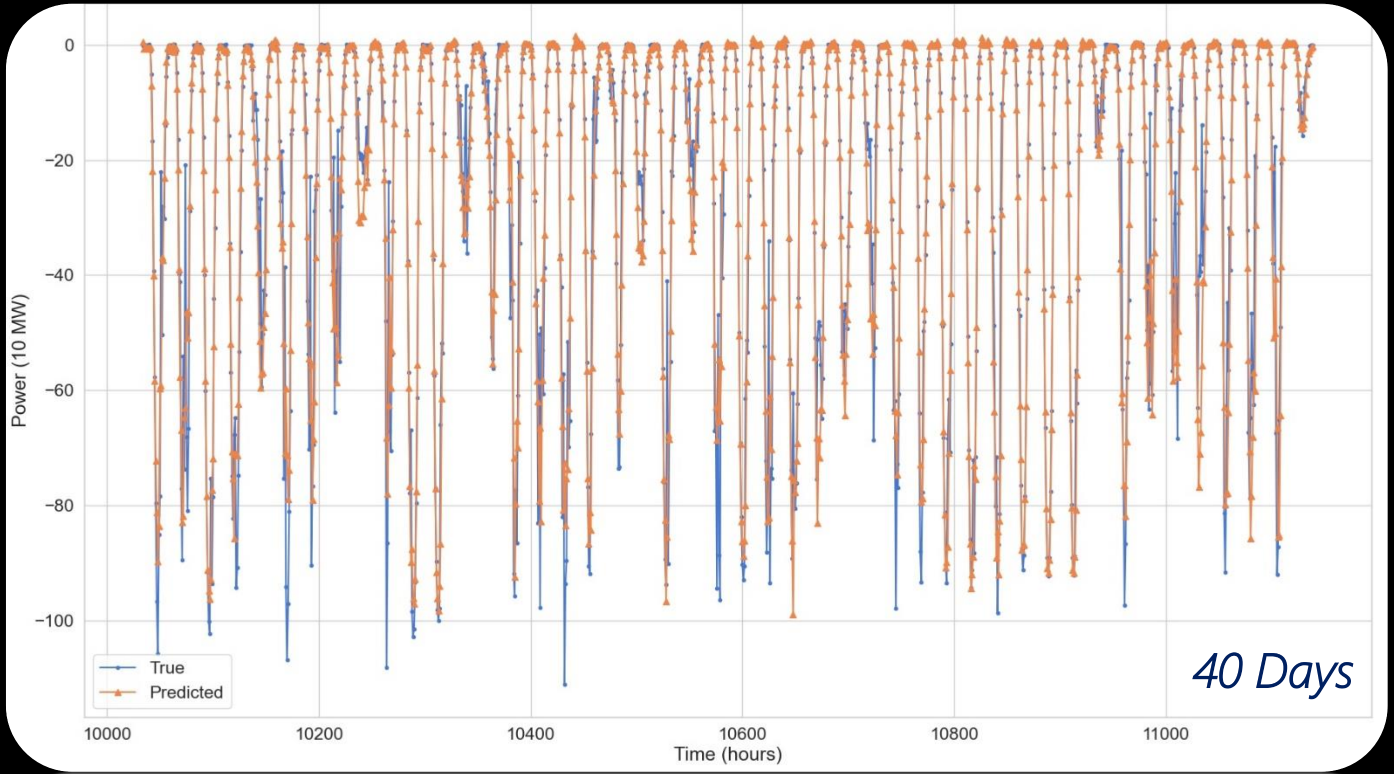
Sello usecase

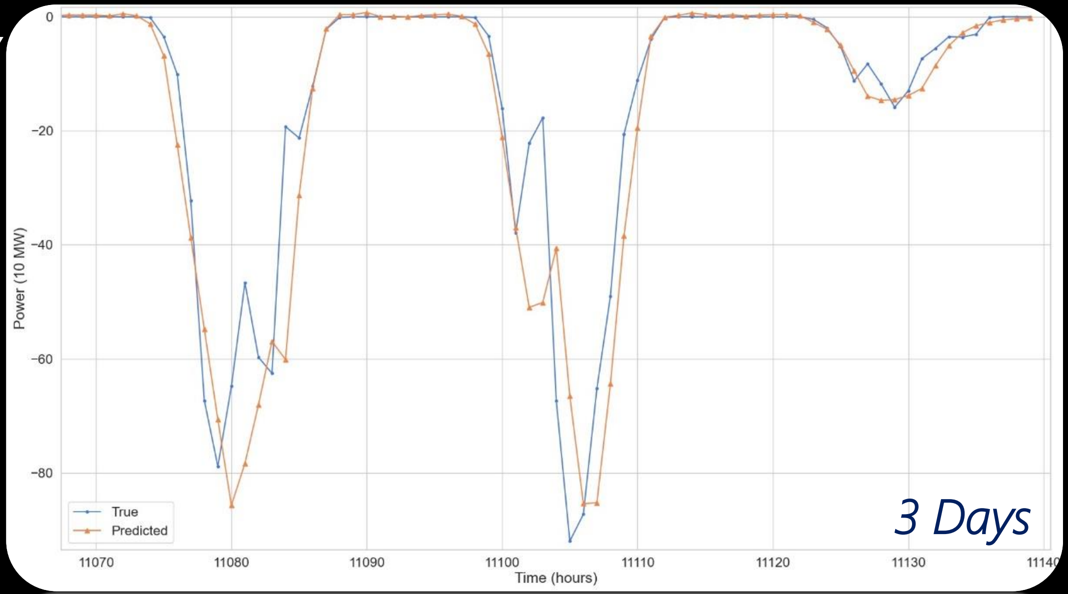
Data used for prediction

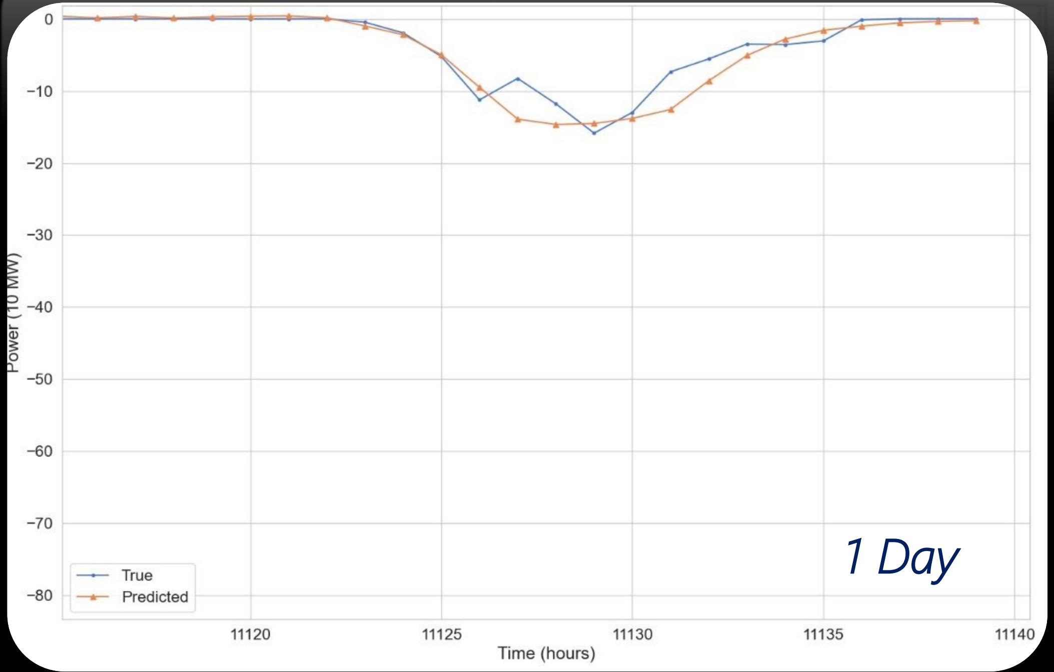


Asset capacity forecasting: PV

Sello usecase - Prediction results







Negative capacity: Adjustable curtailable power production.

Asset capacity forecasting

Building Automation

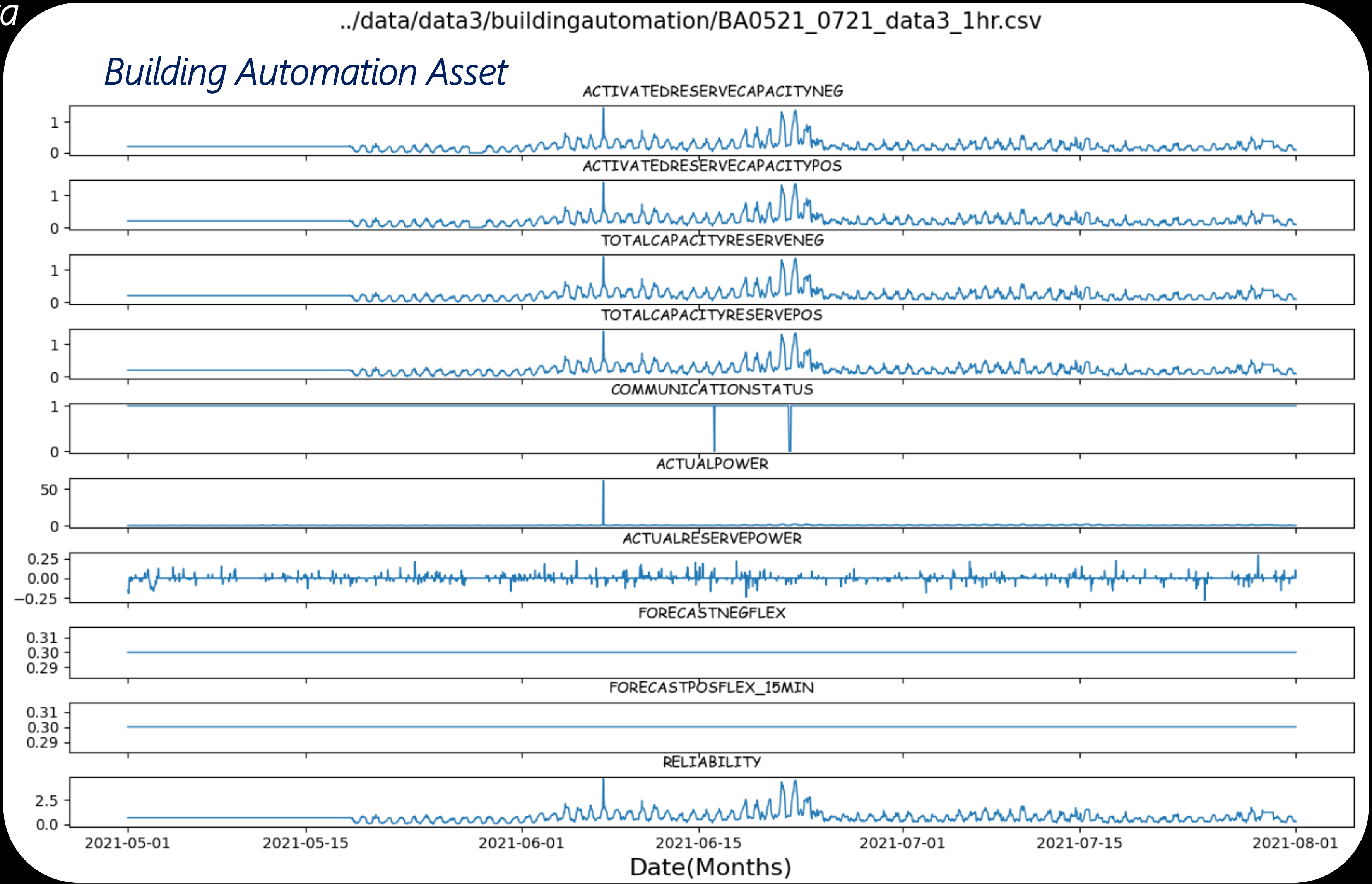
Asset capacity forecasting : Building Automation

Sello usecase – Building Automation

- Forecasting different asset capacities:
  - Building automation
  - Diesel generation
  - Battery storage
- Asset data is collected from Siemens VPP for forecasting.
- Data Sources:
  - BuildingAutomation data + Calendar features + Fingrid features (FCR) + Mall operating hours.
  - Researched with previous PV data for increasing accuracy.
- Auto Machine Learning (AutoML) is used for determining the optimal learning parameters.
- Types of networks used:
  - Three-layered classical neural network - Dense
  - Temporal Fusion Transformer - TFT
  - Convolutional Neural Networks - CNN

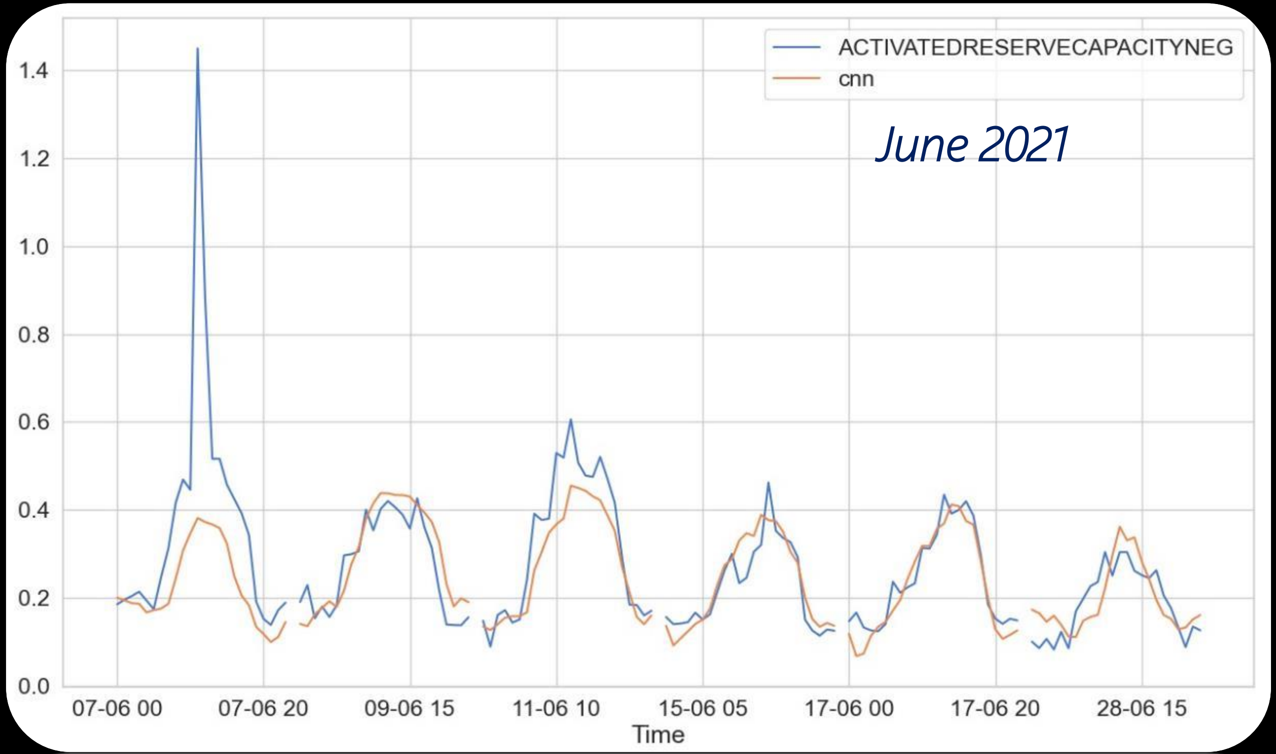
Asset capacity forecasting

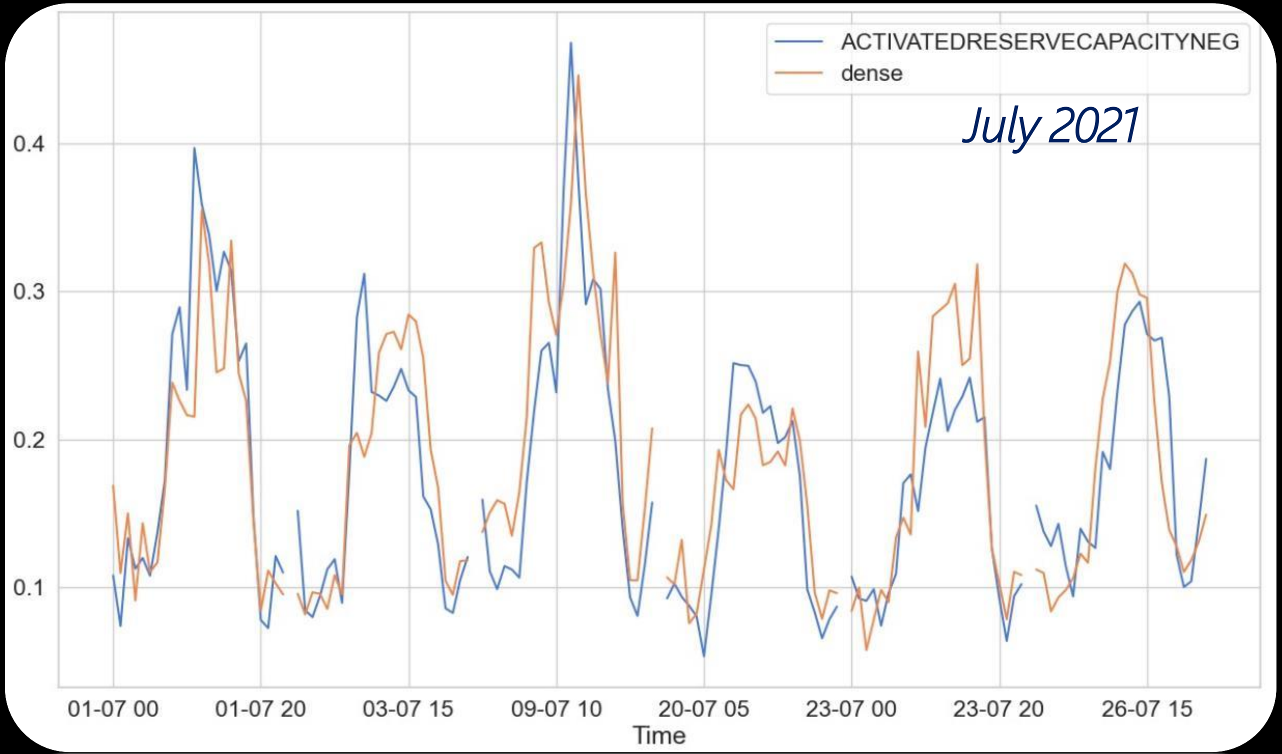
Sello usecase – The data



Asset capacity forecasting

Sello usecase – Prediction results





Prediction with CNN Model leads to slightly higher accuracy

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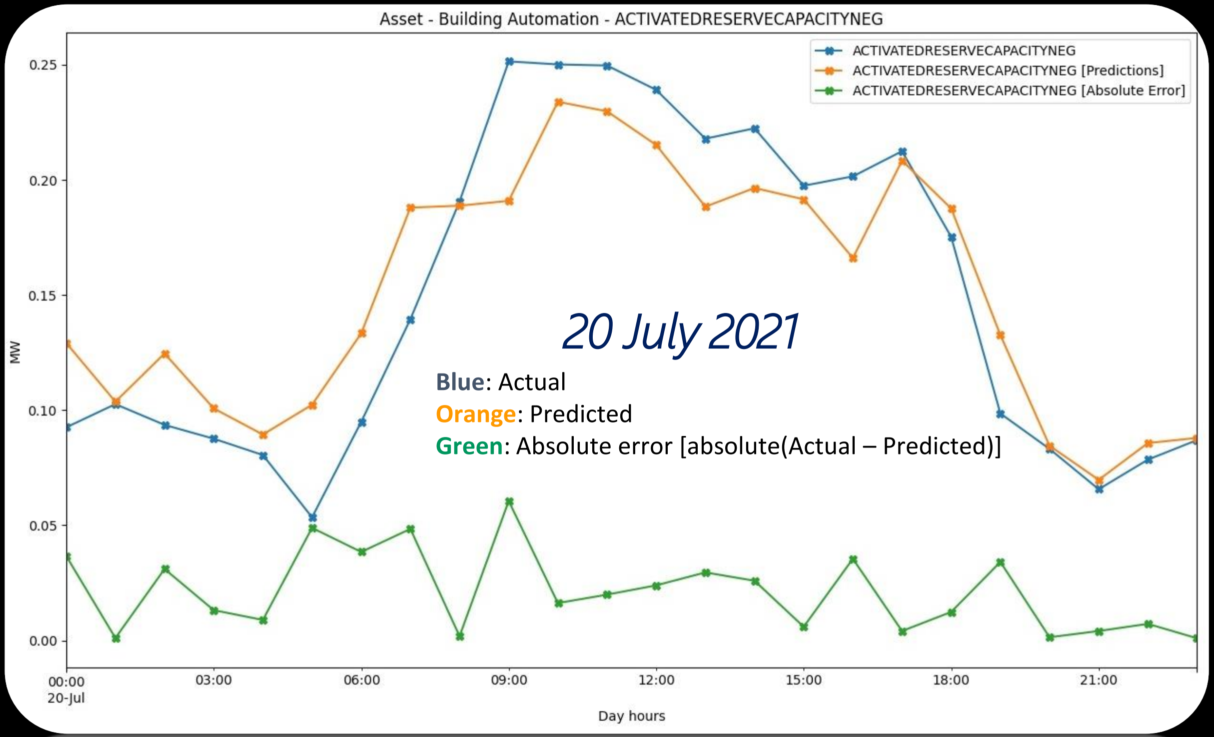
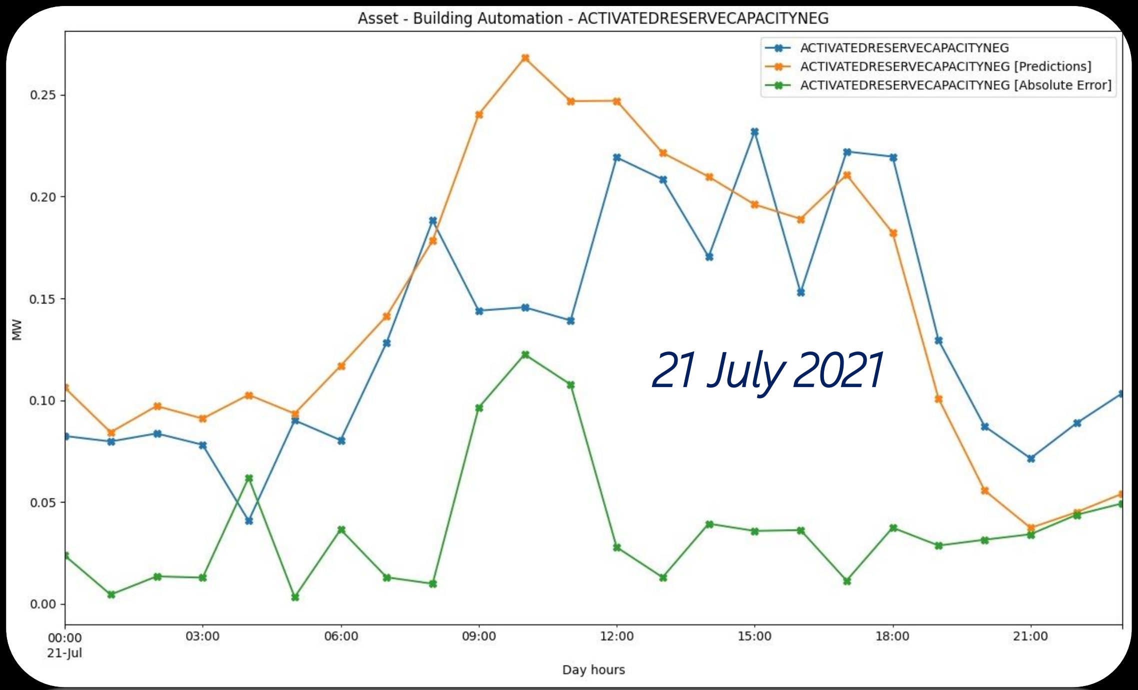
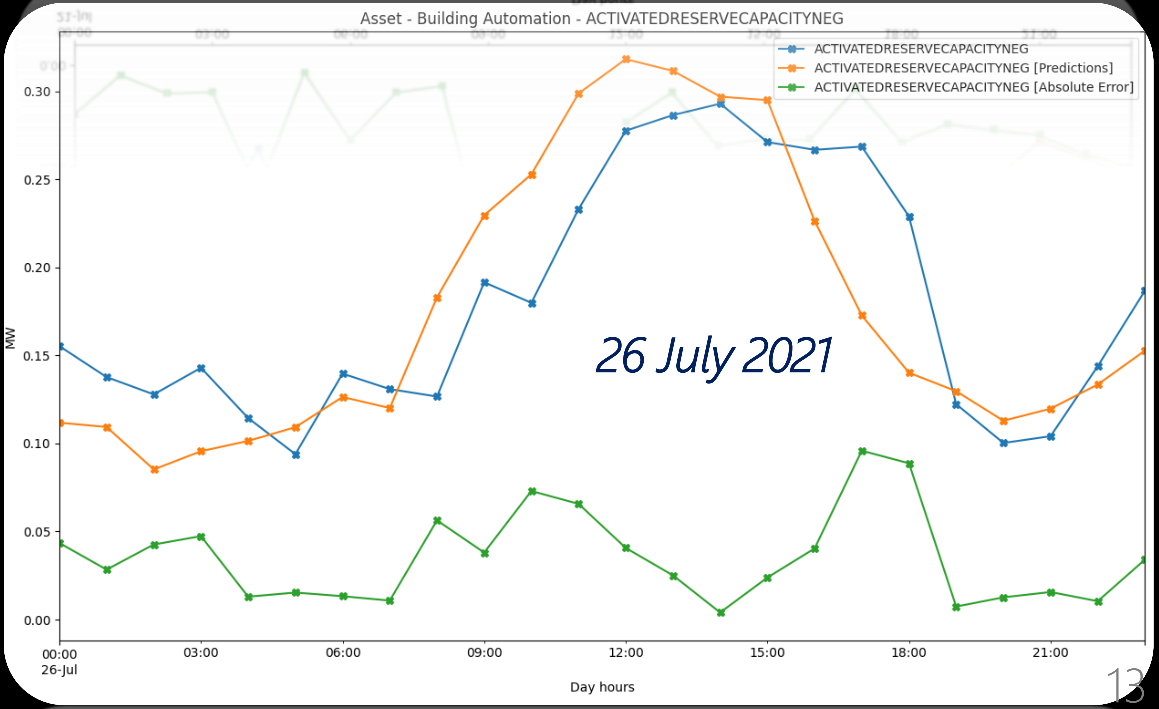
Asset capacity forecasting

Sello usecase – Prediction results

Prediction with CNN Model



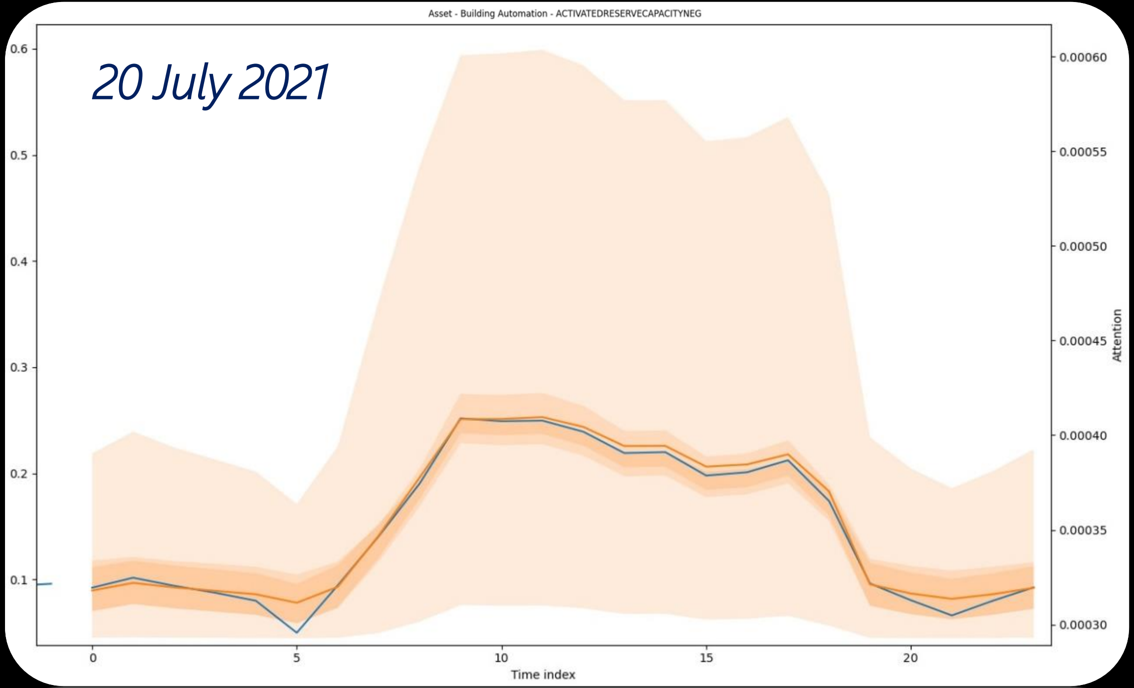


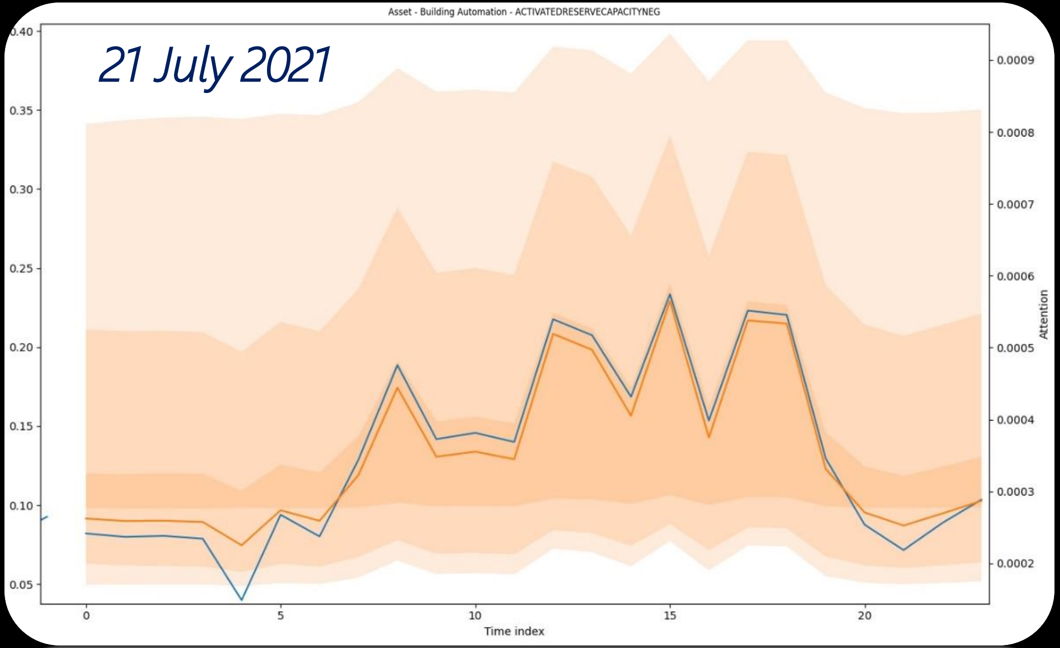


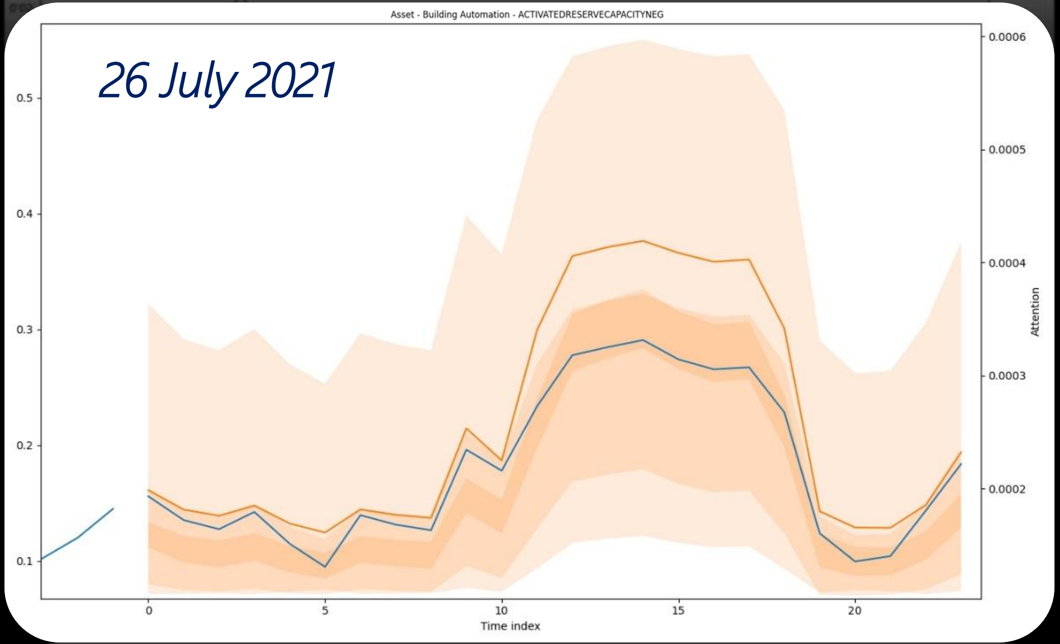
Asset capacity forecasting

Sello usecase – Prediction results

Prediction with Temporal Fusion Transformer (TFT) Model







Prediction with TFT Model leads to higher accuracy than CNN

Energy Consumption forecasting

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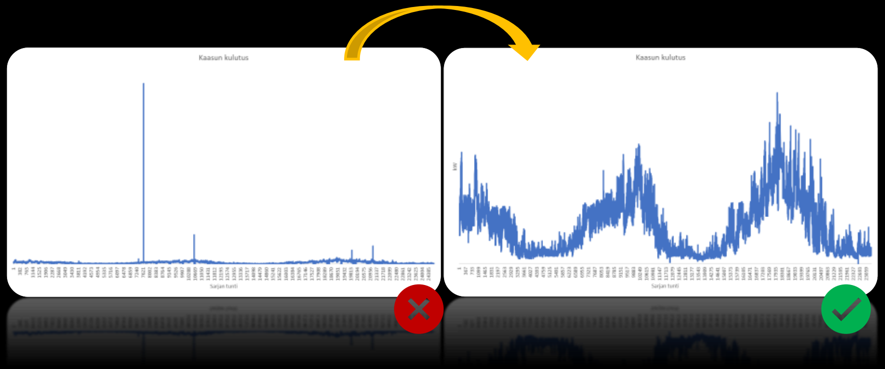
Engineering

Lempäälän Lämpö energy consumption forecasting

Background

- Prediction of:
  - Solar production
    - 2 Solar power plants
  - District heating consumption
    - Fire station, school, sports hall, service building
  - Electricity consumption
  - Gas consumption
  - Goal was to use AI under the 'Leading energy community' program.
  - Main tasks:
    - Exploratory data analysis - Data Cleaning
      - Fixing: Timestamp, double entries, missing series data, data format.
    - Forecasting using the Dense model (Three-layered classical neural network).



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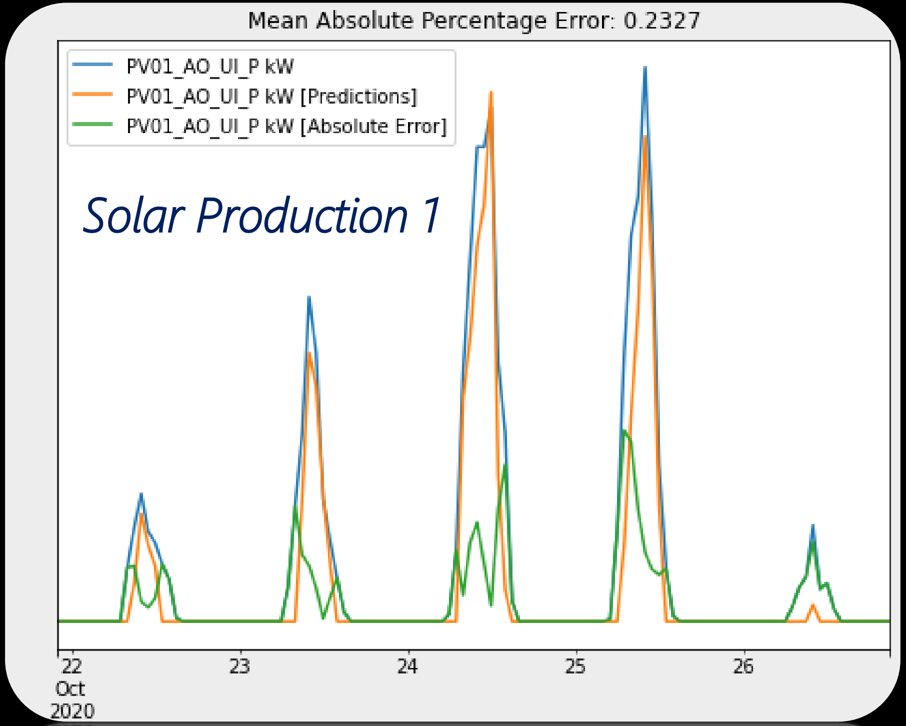
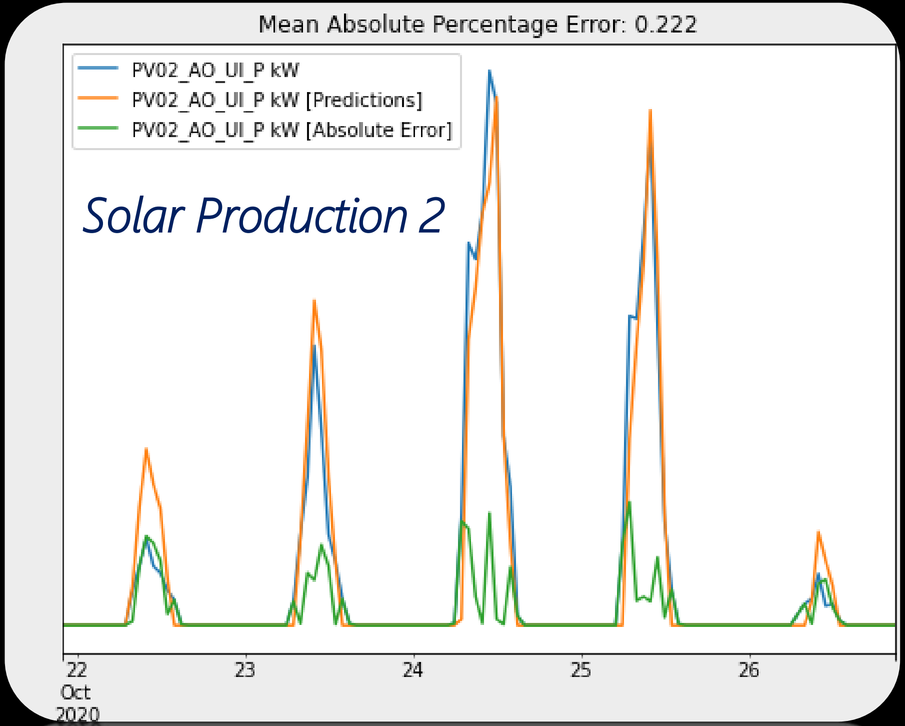
Lempäälän Lämpö energy consumption forecasting

Solar production forecasting

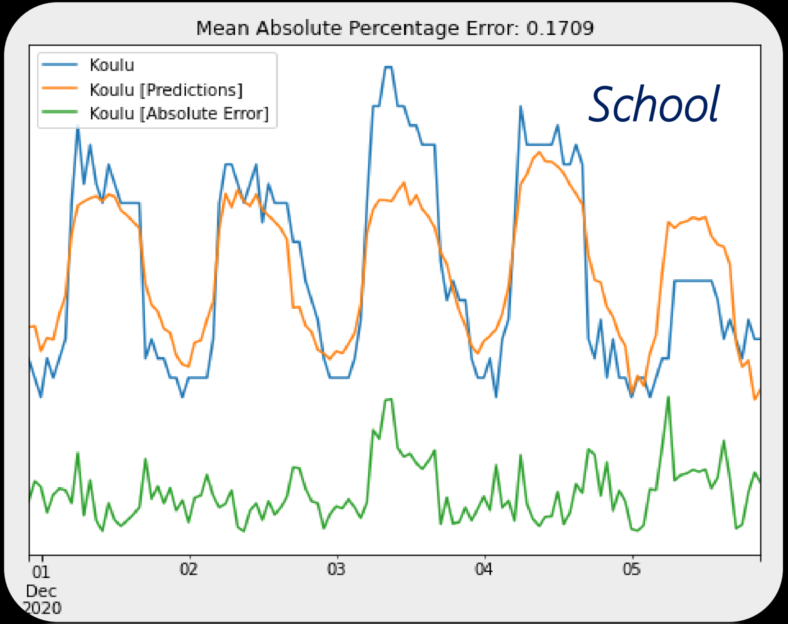


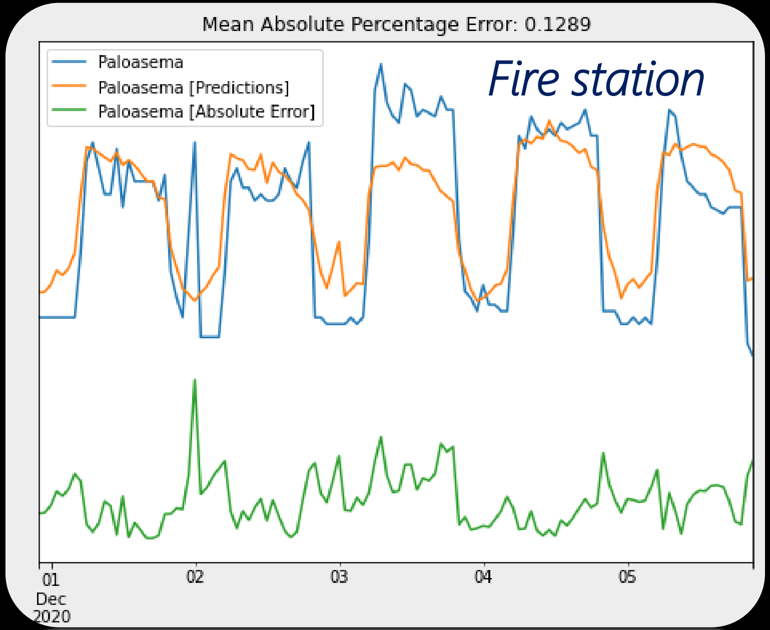


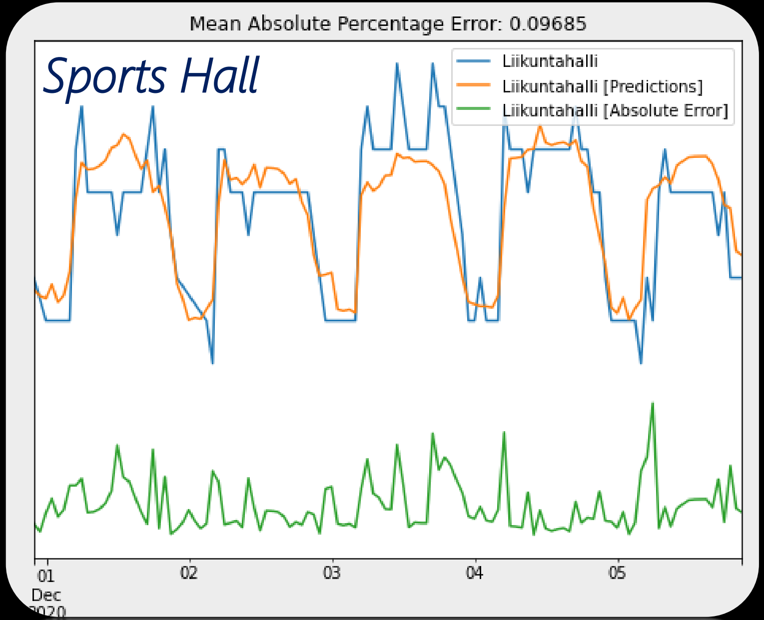
Data Sources : *Calendar features, Solar data (From LL)*

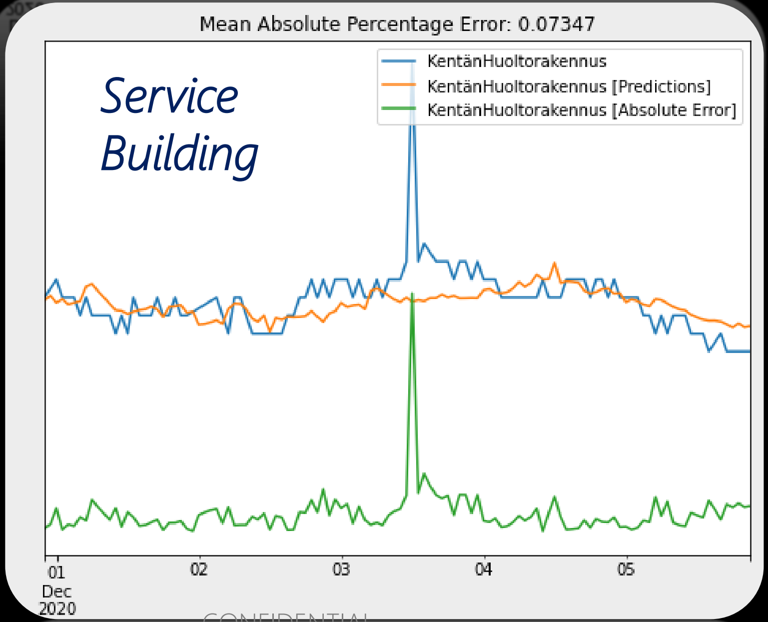
Lempäälän Lämpö energy consumption forecasting

Forecasting District heating consumption





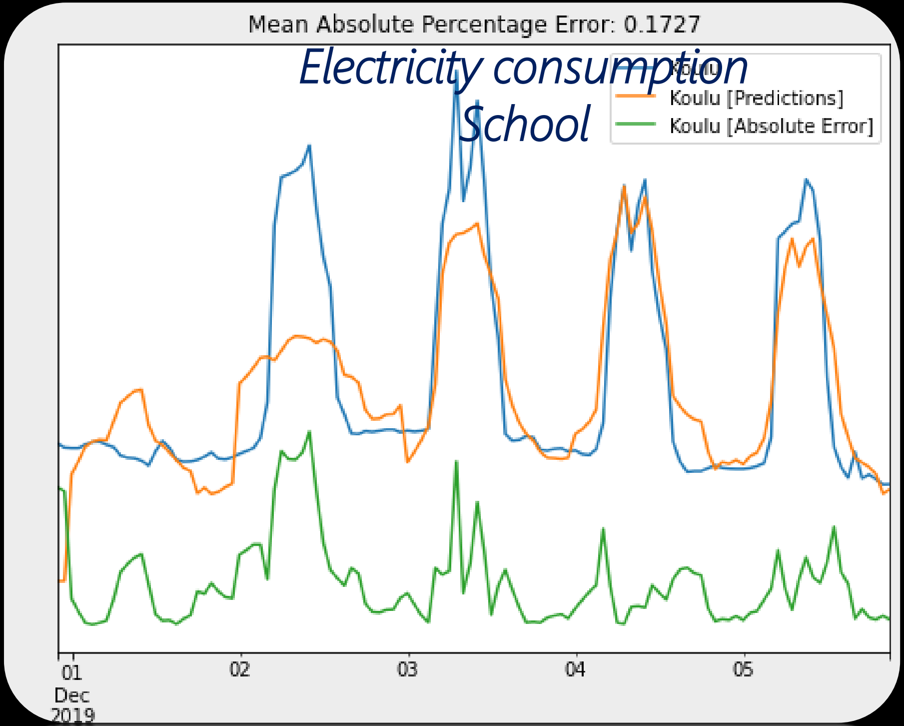


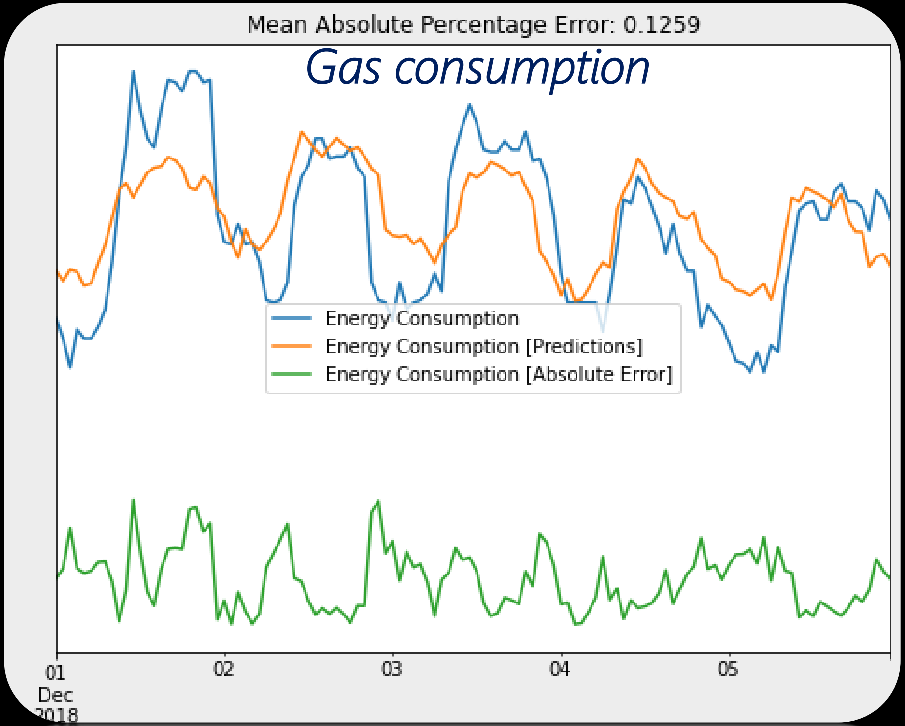


Data Sources : *Calendar features, Solar data (From LL), Finnish Meteorological Institute*

Lempäälän Lämpö energy consumption forecasting

Forecasting electricity and gas consumption





Forecast Summary

Asset Type	MAE	MAPE
Solar production Power plant 1	33.80%	23.30%
Solar production Power plant 2	25.90%	22.20%
District heating School	15.30%	17.10%
District heating Fire station	11.70%	12.90%
District heating Sports hall	9.30%	9.70%
District heating Service building	7.70%	7.30%
Electricity consumption School	17.50%	17.30%
Electricity consumption Sports hall	12.10%	12.50%
Electricity consumption Fire station	10.70%	11.20%
Gas consumption	11.70%	12.60%

Data Sources : *Calendar features, Energy consumption (From LL), Finnish Meteorological Institute*

MLOps for FCR-N market forecasting

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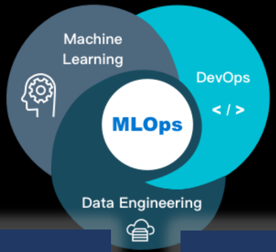
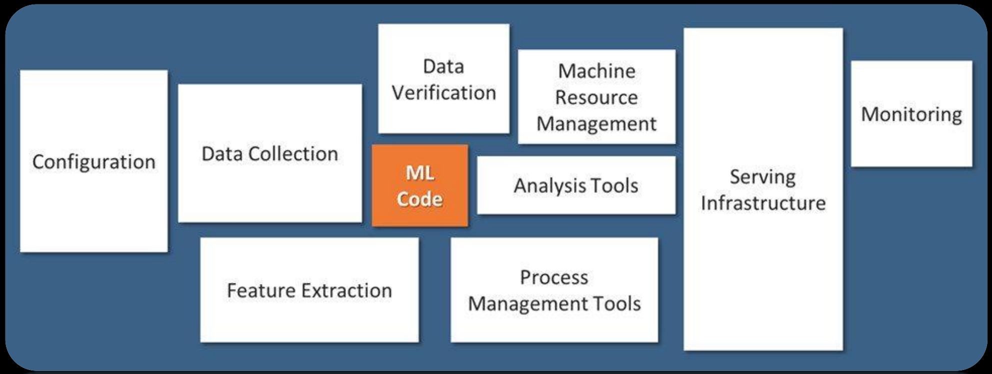
MLOps for FCR-N market forecasting

Background

- Core ML (e.g., in FCR-N) is only a small part
- ML applications are more experimental in nature
    - Tracking, debugging
- Usually works with other software systems
    - Web applications, Mobile API
- Continuous software engineering practices
- Production: Accessibility, Scalability, Security



Real-world application with ML code



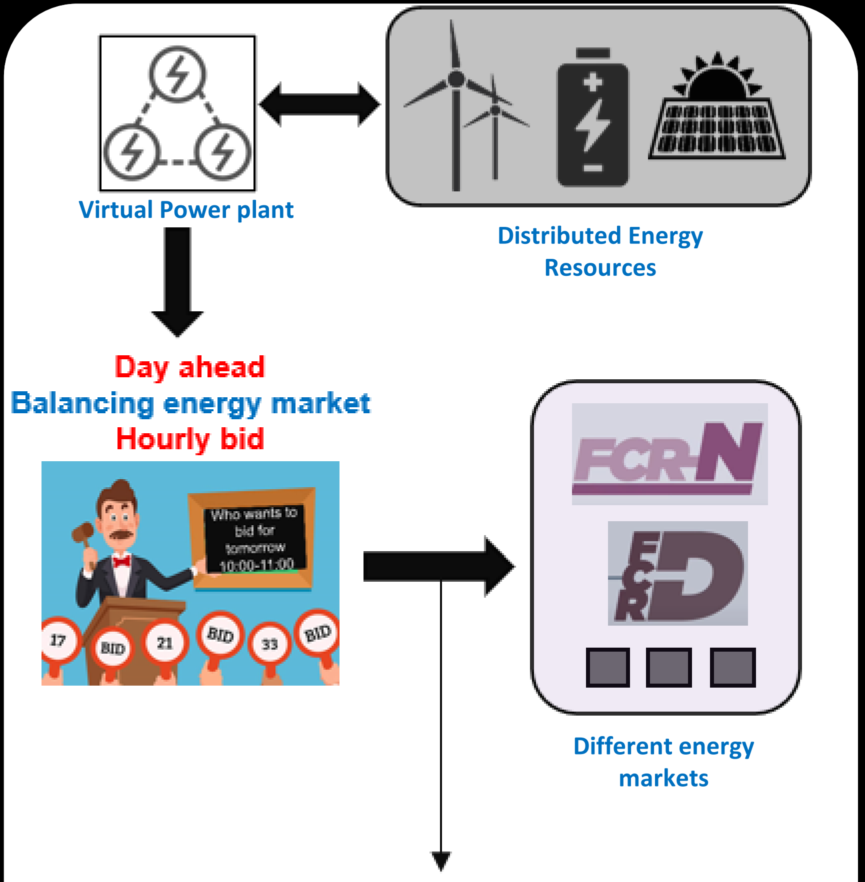
Publication: WIP

1. Reproducible Must be able to reproduce the predictions with the same model & data to within few % error	2. Accountable Must be able to trace back from model in production to its provenance
3. Collaborative Must be able to do asynchronous collaboration	4. Continuous Must be able to deploy automatically & monitor statistically

MLOps for FCR-N market forecasting

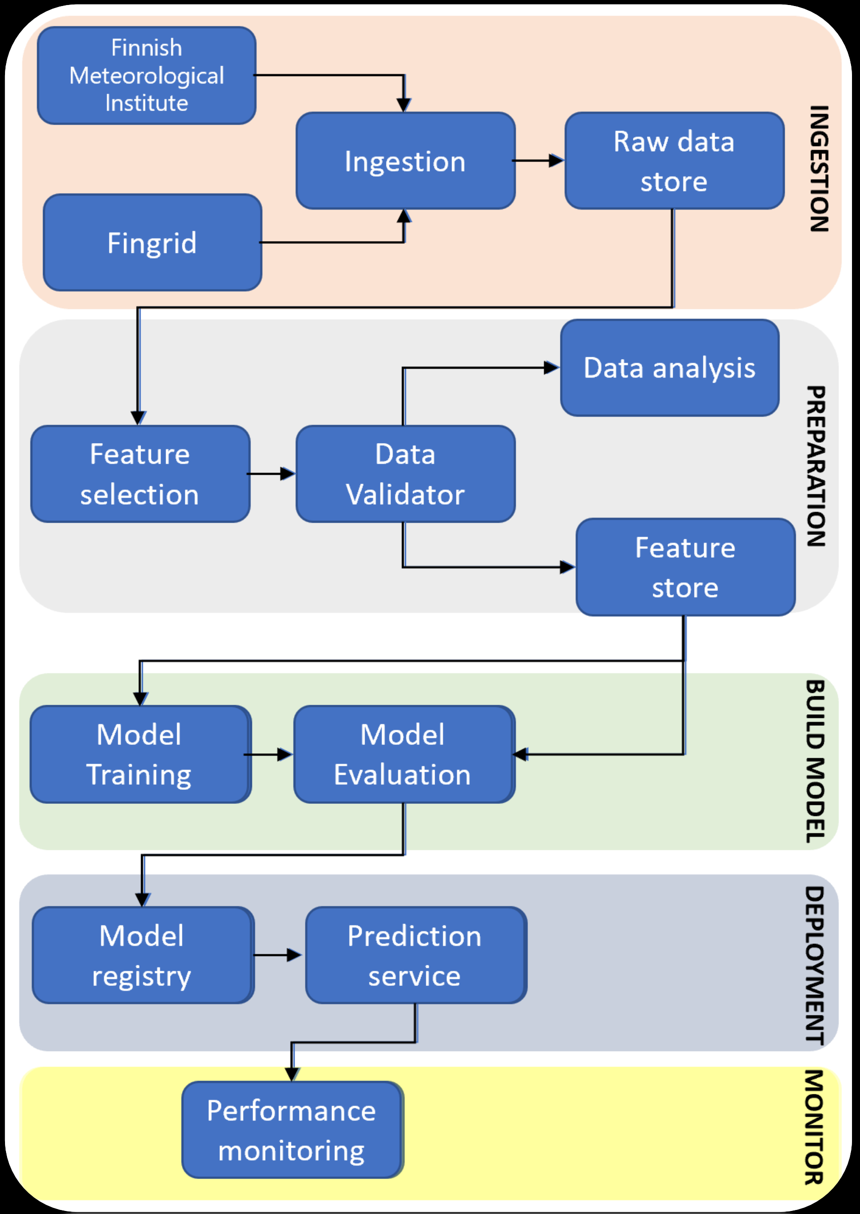
Usecase

FCR-N market



Owner	Capacity	Participation Hour	Market	Price
Asset Owner 1	I promise to p..	09:00 - 10:00	FCR-D	n €
Asset Owner 2	I promise to provide x MW capacity	10:00 - 11:00	FCR-N	m €
Asset Owner 3	I promise to p..	11:00 - 12:00	FCR-N	p €

MLOps pipeline



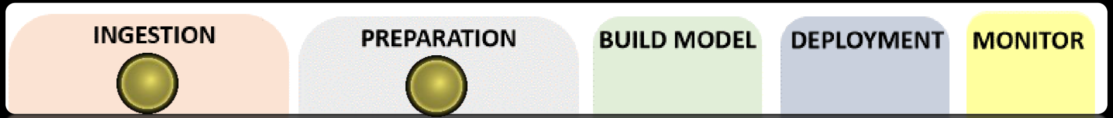
MLOps for FCR-N market forecasting

Ingestion, Preparation

Jenkins — Pipelines | Administration | Logout

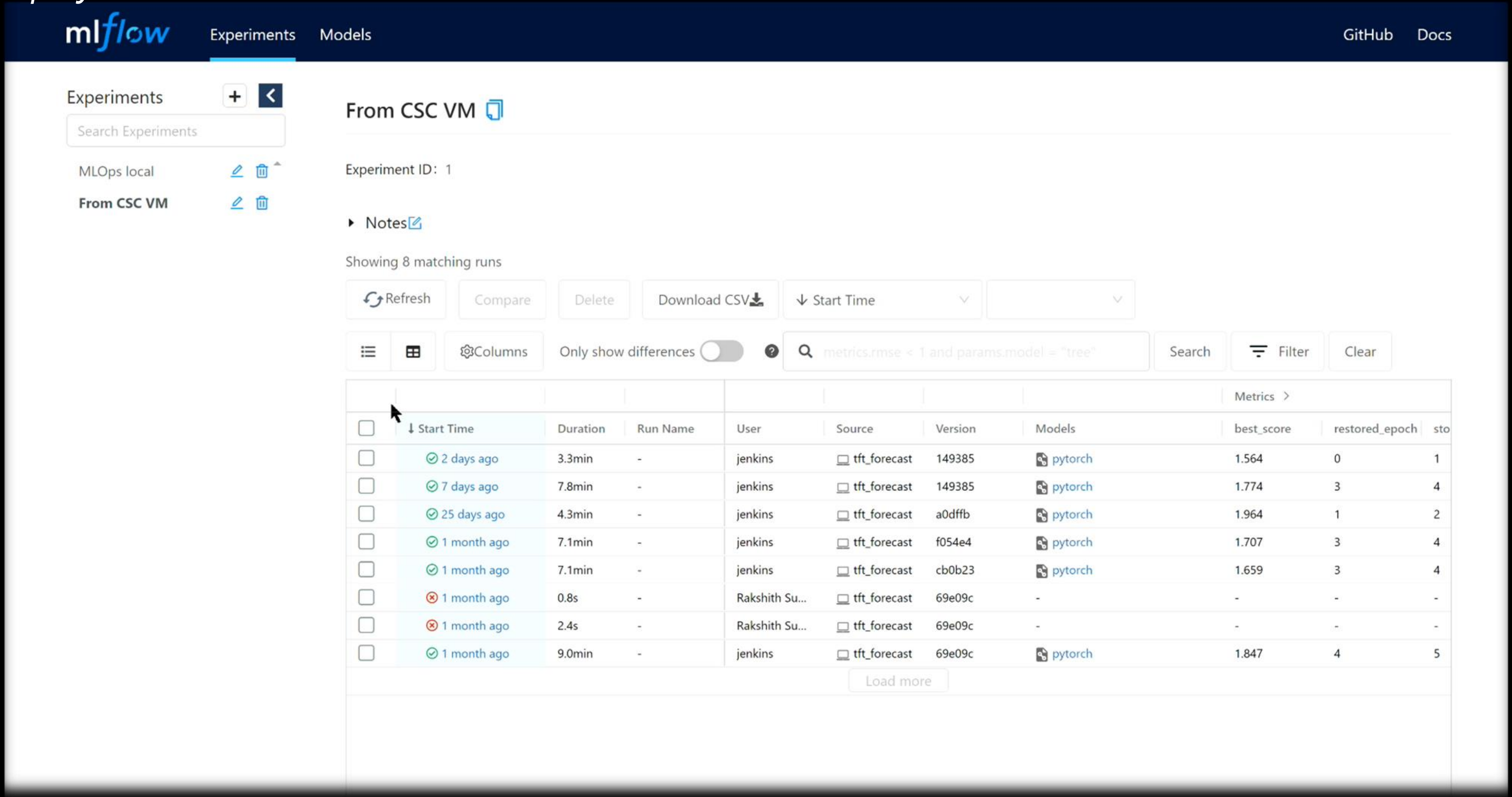
mlops_tft_gitlab — Activity | Branches | Pull Requests

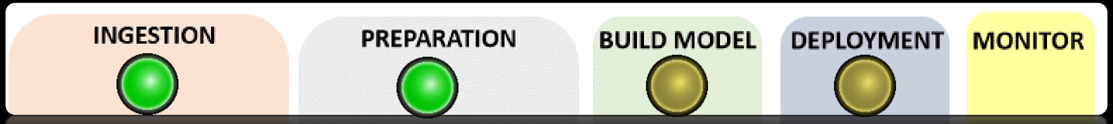
STATUS	RUN	COMMIT	BRANCH	MESSAGE	DURATION	COMPLETED
✓	80	1493852	master	Replayed #79	2d 22h 39m 8s	2 minutes ago
✓	79	1493852	master	Update readme.md	23m 31s	8 days ago
✓	78	a0dffba	master	sql changes	8m 2s	a month ago
✓	77	f054e4a	master	TFT database changes	8m 49s	a month ago
✓	76	cb0b234	master	Updated jenkinsfile to activate venv	15m 1s	a month ago
✗	75	55e9a02	master	Major revisions to testcase files	11s	a month ago
✓	74	69e09c9	master	updated Jenkinsfile params	17m 25s	a month ago
✓	73	f3300e9	master	updated Jenkinsfile params	27s	a month ago
✗	72	b9d019a	master	updated Jenkinsfile params	5s	a month ago
✗	71	c6302b7	master	updated Jenkinsfile params	5s	a month ago
✗	70	33168b4	master	updated Jenkinsfile params	5s	a month ago
✗	69	4a58695	master	updated Jenkinsfile params	5s	a month ago



MLOps for FCR-N market forecasting

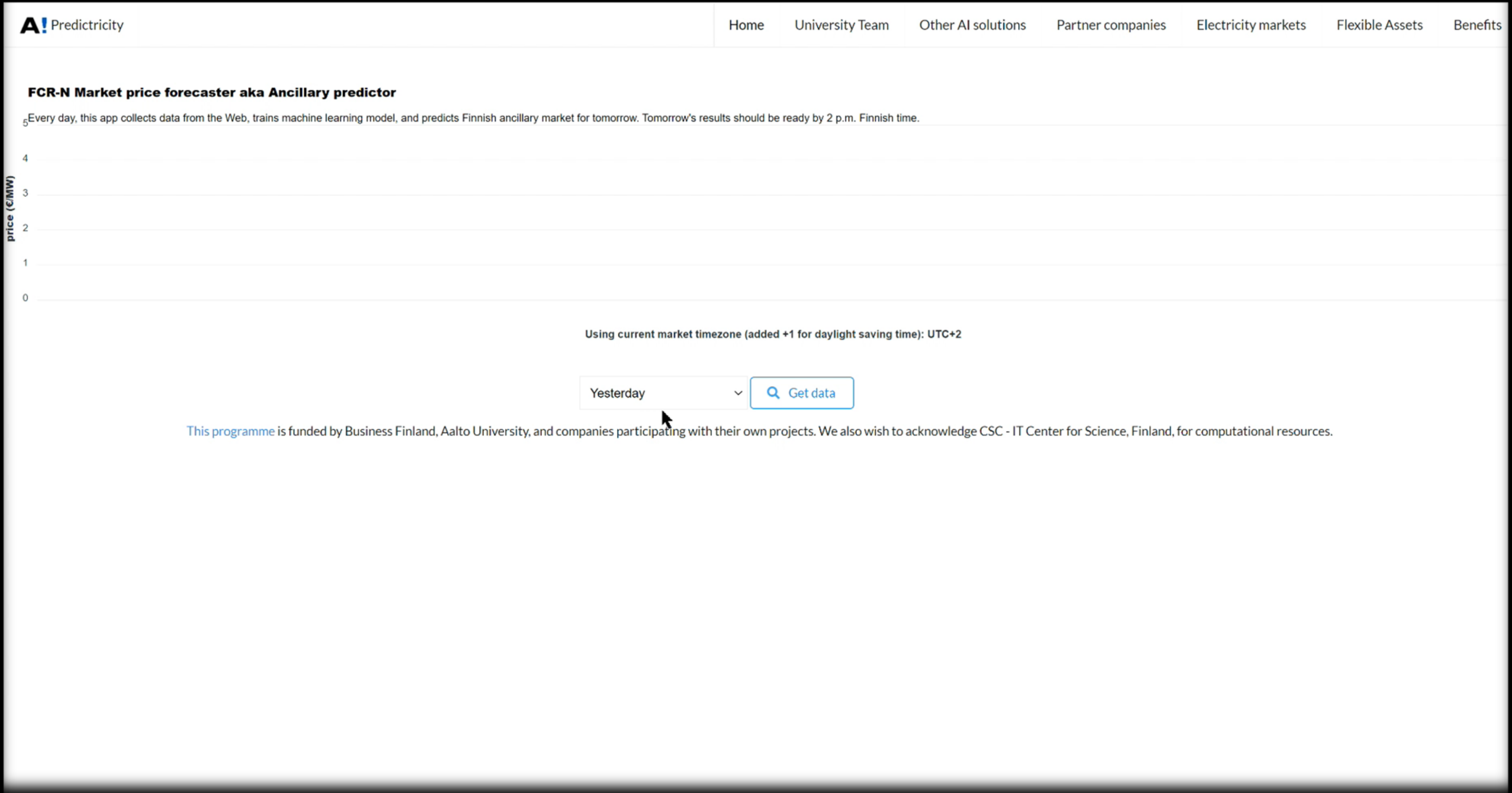
Build model, Deploy

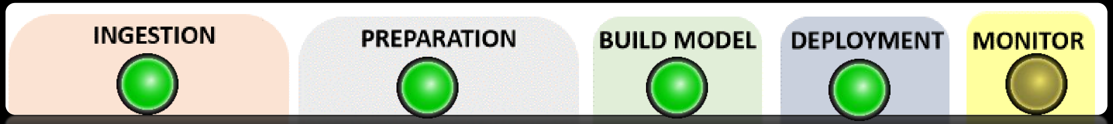




MLOps for FCR-N market forecasting

Monitor





Thank you