Enhanced Virtual Power Plant Design and Implementation Lessons

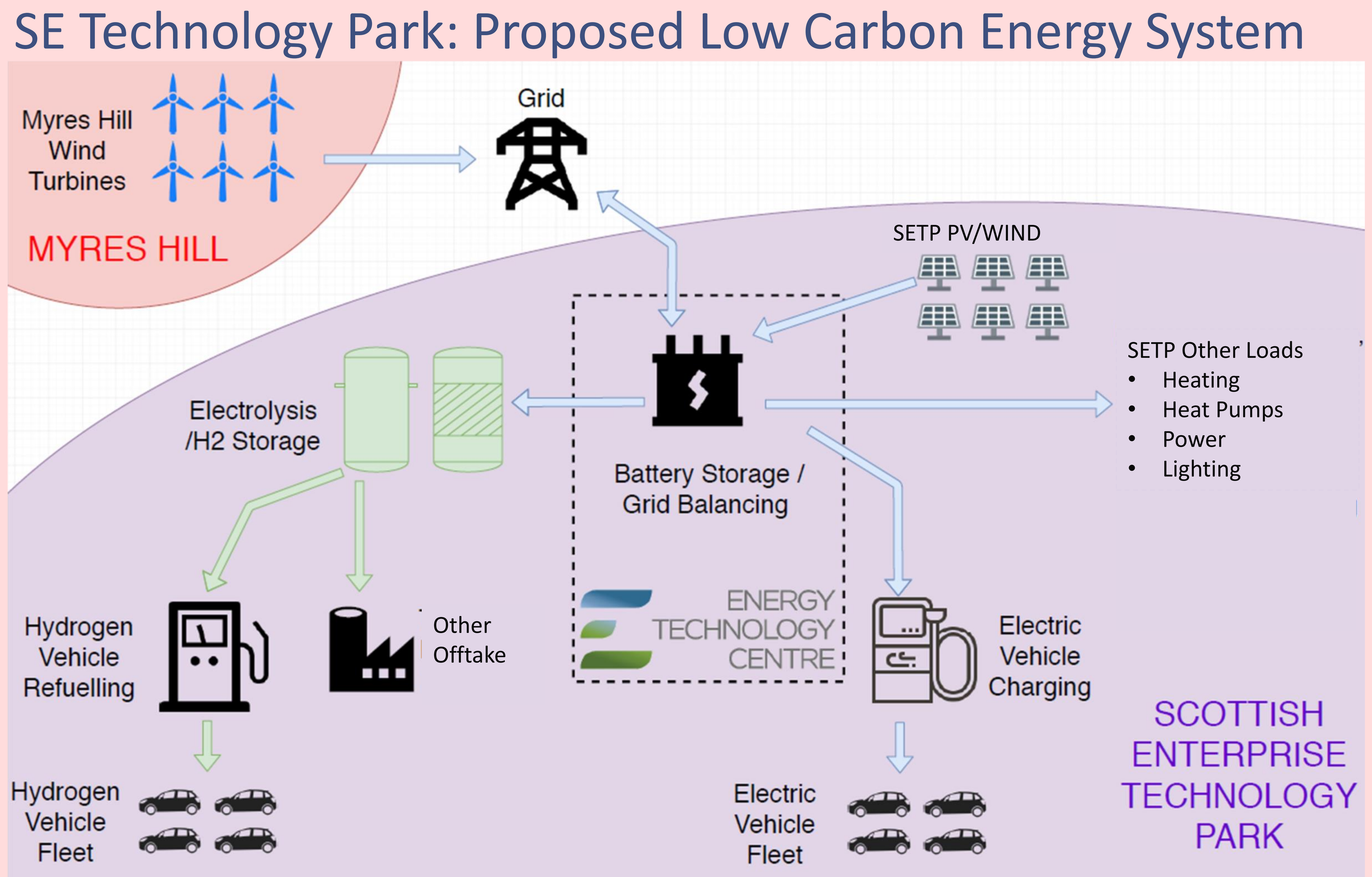
Gary, Howorth — Univ of Strathclyde, UK
Ivana, Kockar — Univ of Strathclyde, UK
Paul, Touhy — Univ of Strathclyde, UK
Graeme, Flett — Univ of Strathclyde, UK
John, Bingham — Energy Technology Centre Ltd, UK

Introduction

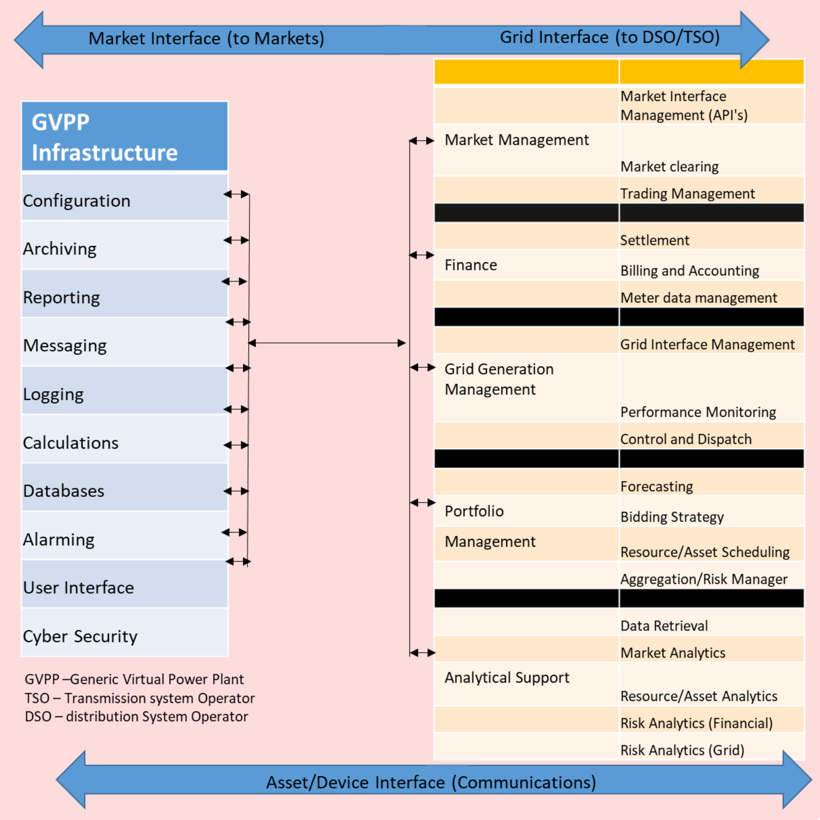
SMART INTEGRATED ENERGY SYSTEMS

- ERA Learn/EU Horizon 2022 Project (SIES 2022)
- "Learning by Doing"
- Enhanced VPP+ Design – using multiple vector energy pools
- Energy Pools (Flexibility, Thermal, DSR, electrolyser, EV's, Wind, PV)
- ETC Demo site @ East Kilbride, Scotland
- Congested DSO Area
- Focus of Paper – on overall architecture (Hardware and Software) of Demonstrator plant, highlighting challenges and lessons learned

SE Technology Park: Proposed Low Carbon Energy System



Generic VPP Design

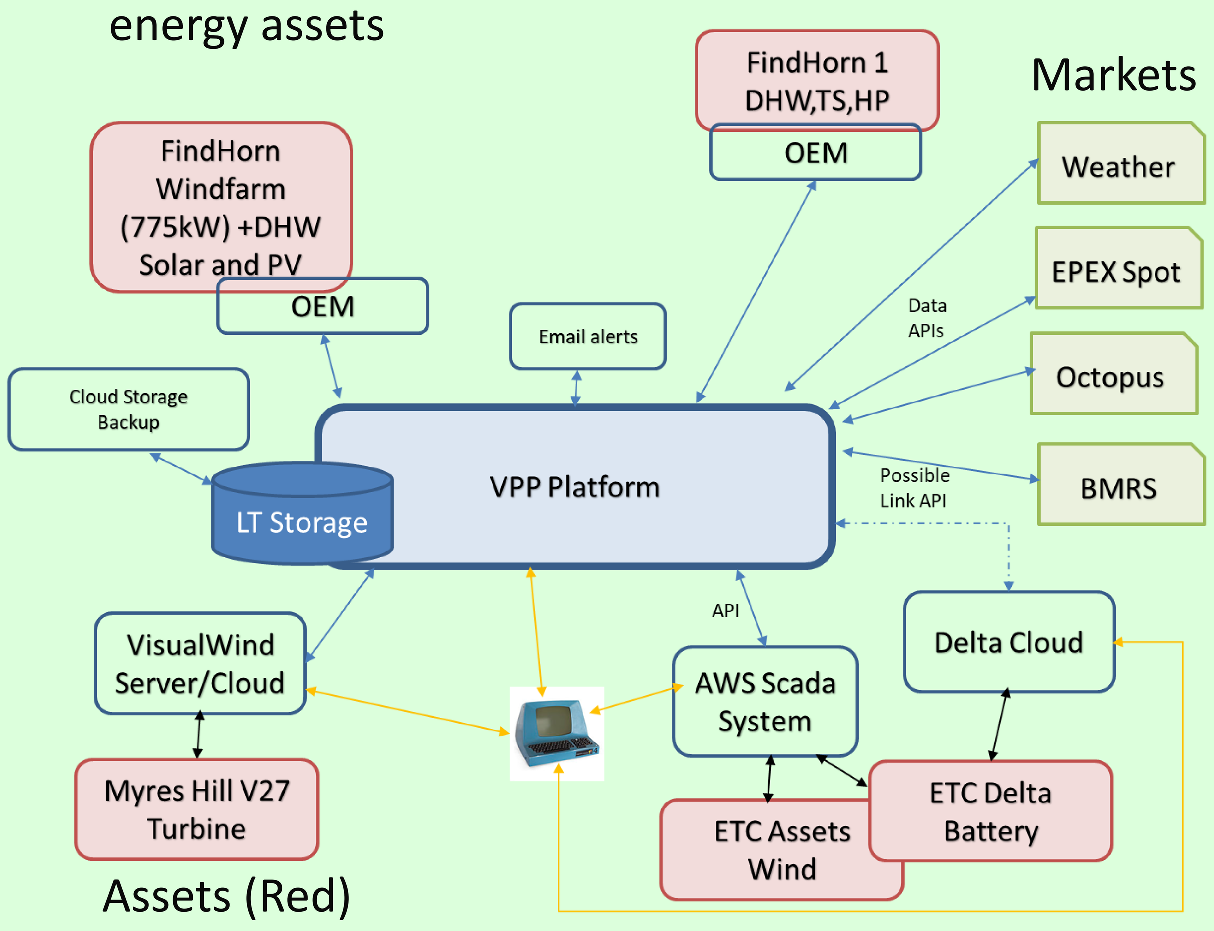


Hardware Design

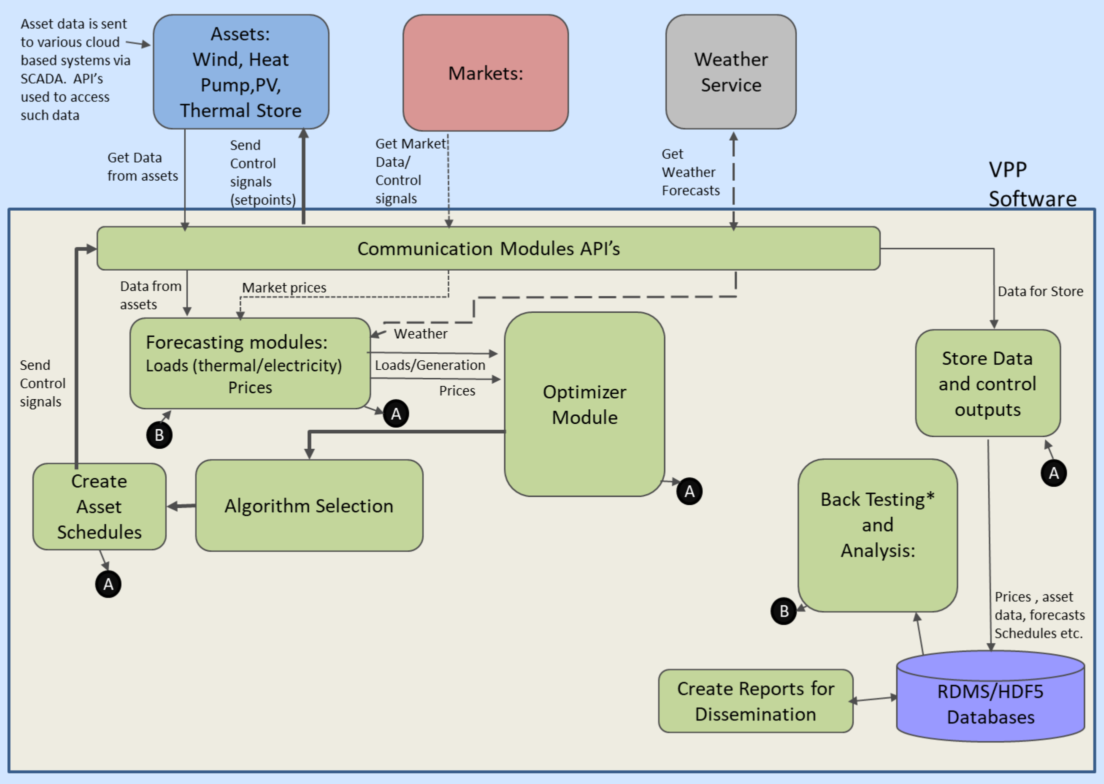
Software Design

Asset and Data Communication: High Level Design

- Energy Management Control System" (EMCS) provides control and data logging interface between the VPP application and the various energy assets

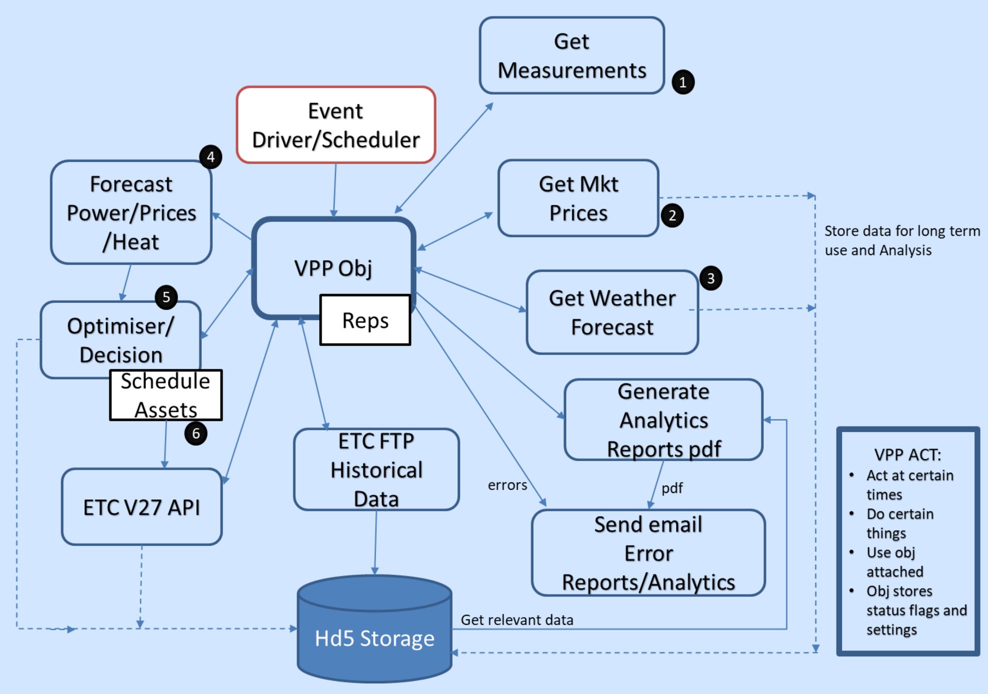


Software Architecture



- Software architecture based on existing framework developed for simulating aggregators (PyEmLab [1]). Rapid Prototype /Agile development approach has been used.

VPP Operation



- Platform allows for multiple decision models to be used e.g. ensemble approach or change in decision approach.
- RESTful API communication between services.

Challenges/Lessons Learned

Hardware

- Many different asset manufactures – non standard interfaces. Many legacy assets at ETC.
- Integration into VPP platform has been time consuming
- Defining measurement and communication protocols has been problematic
- Chip Shortages for PLC. Lead times for equipment.

Software

- Existing VPP software solution, but much of the functionality missing vs an "ideal" VPP.
- Forecasting important to the commercial success of the unit.
- Difficult to forecast Flexibility market prices accurately.
- Considerable effort in error capture & communication retry routines expended.
- Care to be taken with spurious data (Pre-processing).
- Current solution times for decision making software relatively fast – but using deterministic approaches.

References
G. Howorth, "Extending the AgentSpring/EMLab Tool to Evaluate Additional Agent Behaviour such as Electric Vehicles and Demand Side Response," ed. ETP Annual Conference 2019 - Energy Technology Partnership Dundee UK: ETP, 2019.

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SMART INTEGRATED ENERGY SYSTEMS

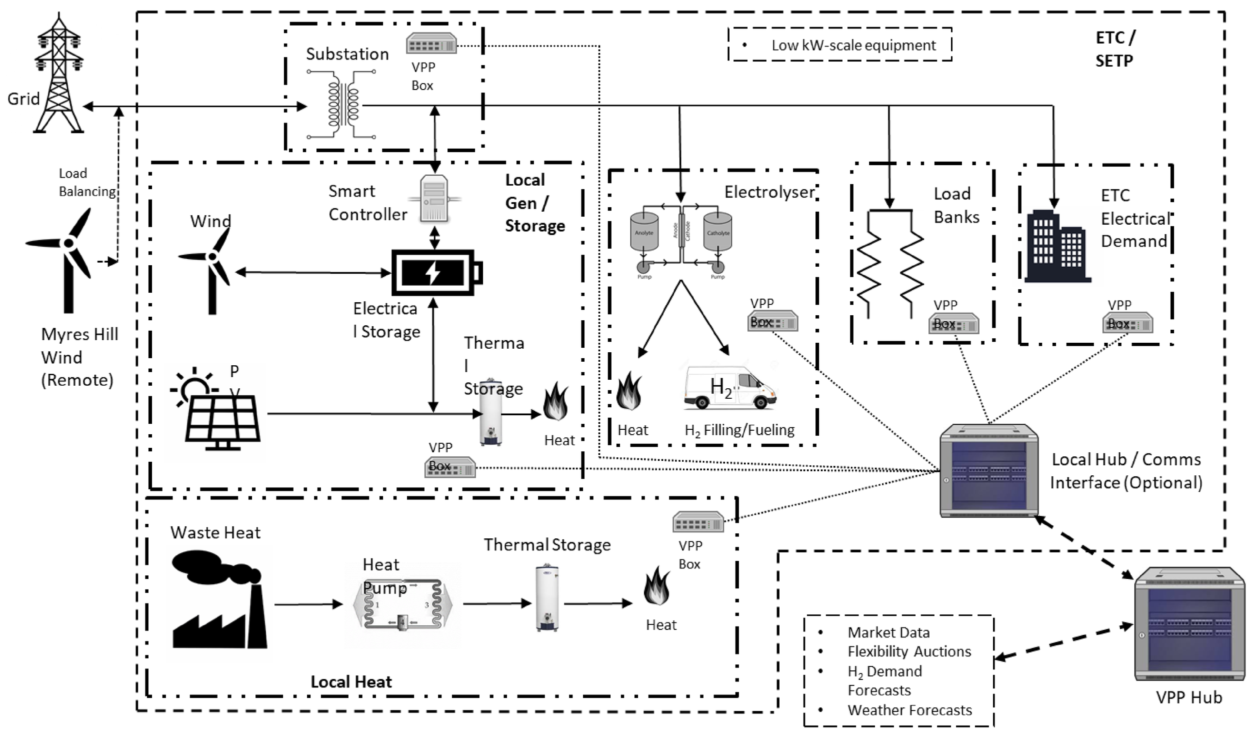
SIES [Smart Integrated Energy Systems: Enhanced Virtual Power Plant VPP+ Energy Pool Integration for Local and Regional Resistance]

Project Overview

Aim

- ERA-Net's SIES 2022 project focuses on the technological and business related barriers and opportunities of how VPPs can function in flexibility markets.
- The SIES 2022 project aims to develop a digital energy utility management service (VPP) capable of managing local and regional energy systems and markets using a number of energy pools – use cases. E.g. ETC, FindHorn .
- "Learning by doing" Project

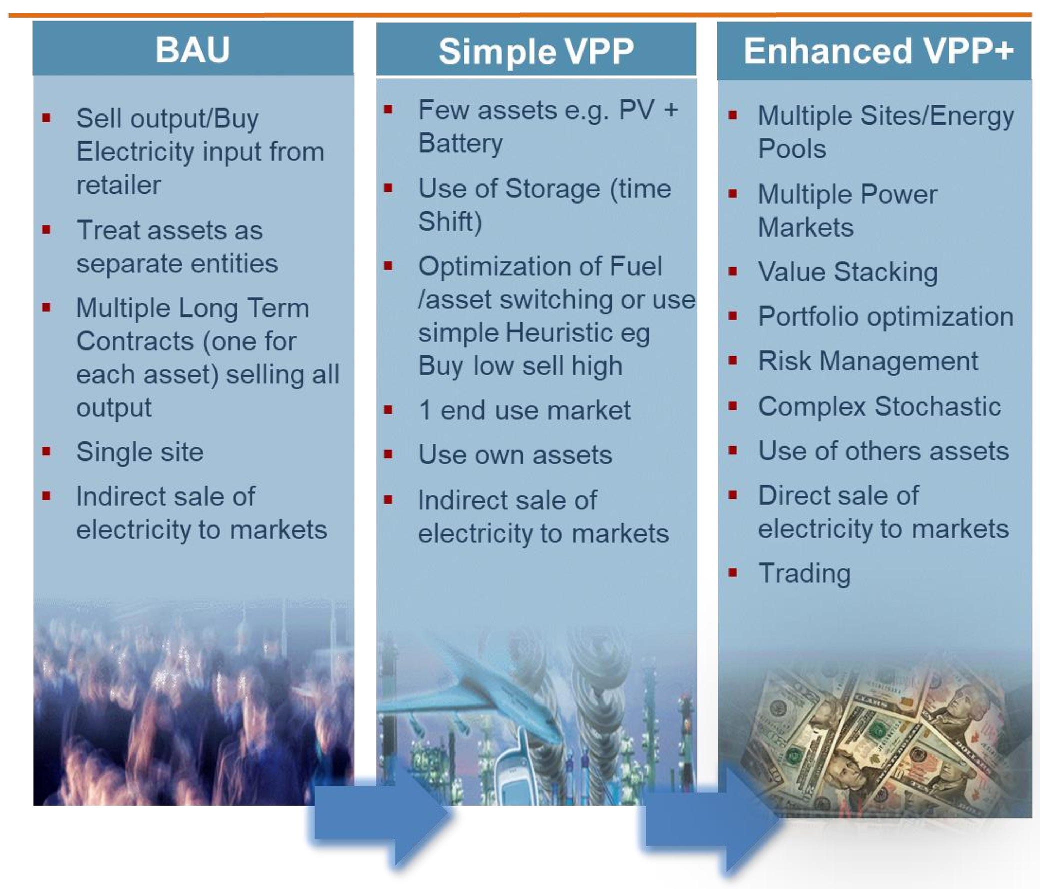
SPEN Power Heat Map (Congested Area)



Overview

- Number of Proposed Energy Pools (ETC [Myres hill & SETP], Community Energy , Strath Energy Centre , PNDC) – Heat DSR, HY2GO etc.]
- VPP ++ (connecting different types of assets including DSR), to maximize profits and provide support to an already congested grid;
- Algorithms to be developed for operation
- VPP Software under development
- Smart Transformer (ANM)

Business Model Spectrum



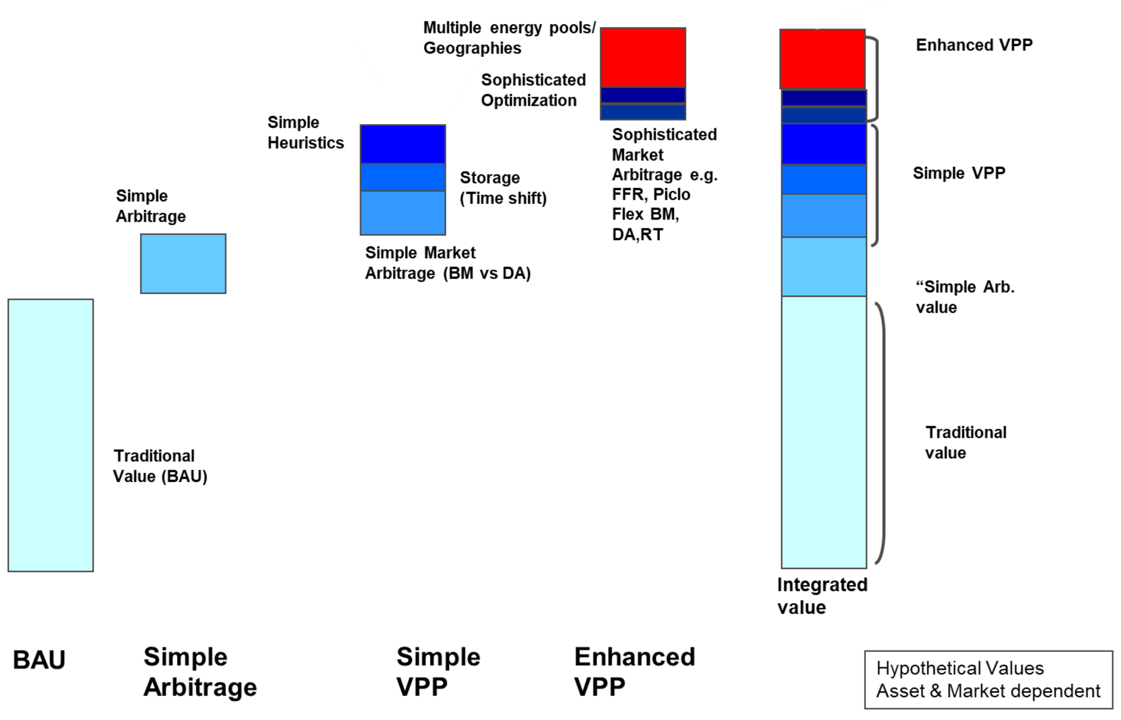
Business Models

- Key element of the project was to develop Business models for a VPP.
- By collating data, analyzing it and simulating different use cases – it has been possible to value these business models.
- Work is underway to develop heuristics that will identify which models work best and under what conditions

Decision Options

- At each time step – a decision has to be made about resources.
- Growing Complexity with more assets
- Plus assets are stochastic

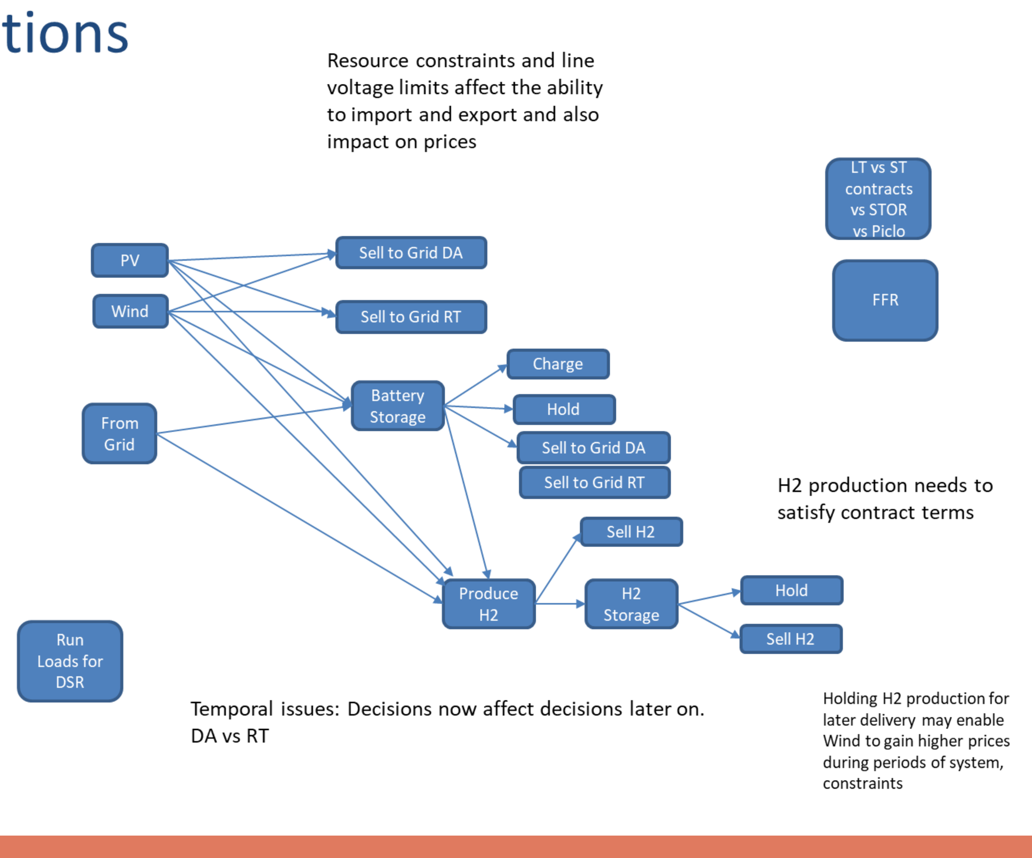
Value Stacking



Markets, Value Stacking

- Although assessments shown herein assume a sale of flexibility services to one market, t is expected that VPP providers would sell to one more than one market.
- Some of these markets could be sold concurrently.
- This results in revenue streams that can be "stacked"

Options



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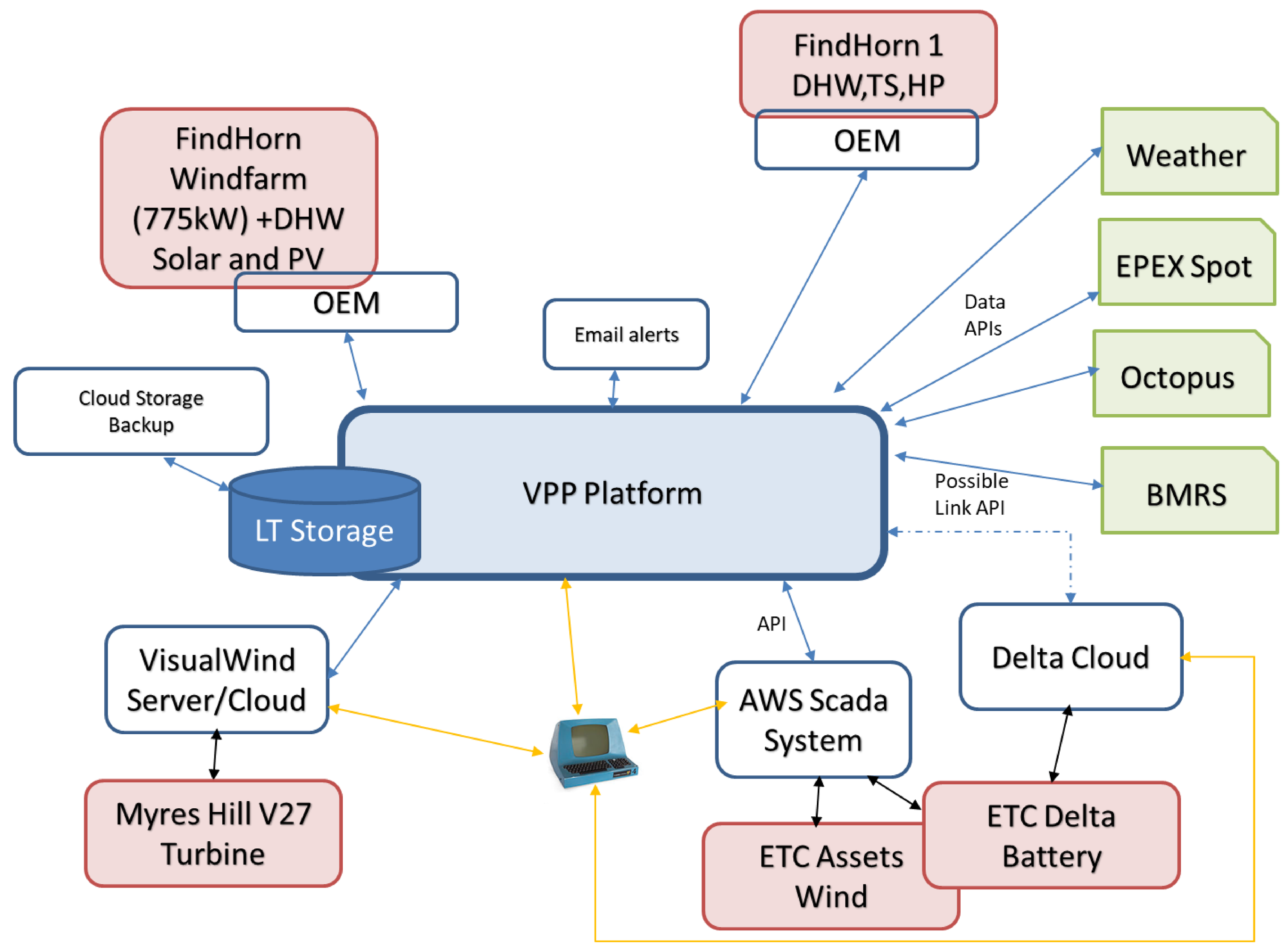
VPP Hardware Overview

VPP Asset Network

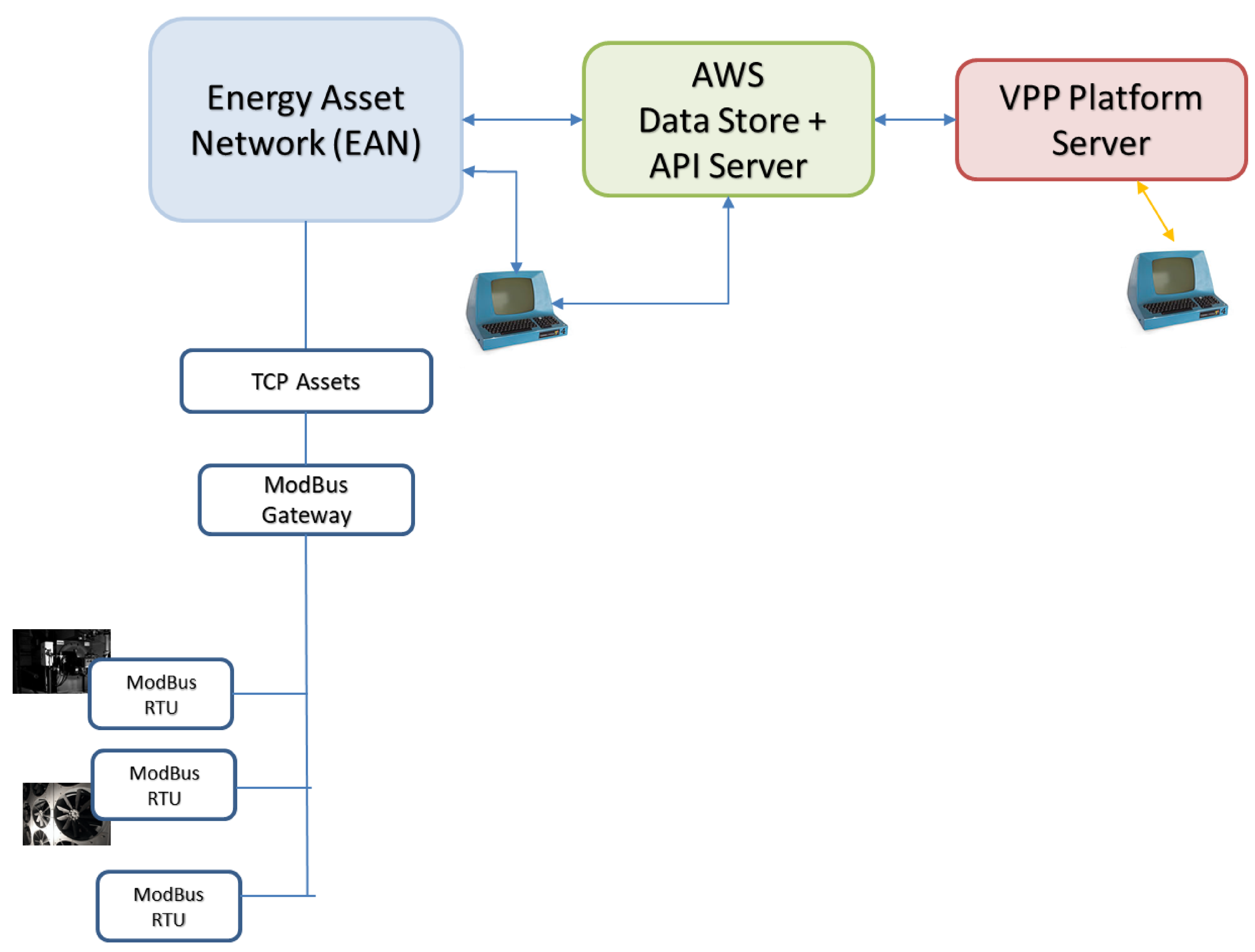
- Two key components –
  - VPP platform hosted on server on or off site. Currently offsite.
  - Energy Management Control System (EMCS) at comprises of an Energy Asset Server, local asset network (Modbus RS485) and AWS
- EMCS is used to provide a control and data logging interface between the Virtual Power Plant (VPP) application and the various energy assets and meters installed at the energy pools.
- ECMS gathers operational data from assets at the various energy pools
- ECMS interfaces with AWS database & provides logging of instantaneous data from assets.
- Assets are connected to Modbus network.
- AWS used to host a cloud server which forms the central hub for EMCS data and interaction with separate VPP application.
- Local assets: VLAN over LAN (Energy Asset Network [EAN]). EAN uses Modbus Gateway and RTU's (TCP - RS485) and essentially forms a Modbus network.
- Modbus gateways are used to interface to the various existing Modbus RTU (RS485) devices to Modbus TCP, and to interface with the EMCS server.

VPP Operation



Energy Management Control System (EMCS)

- EAN located at local site i.e. Energy Technology Centre (ETC)
- Module structure shown below



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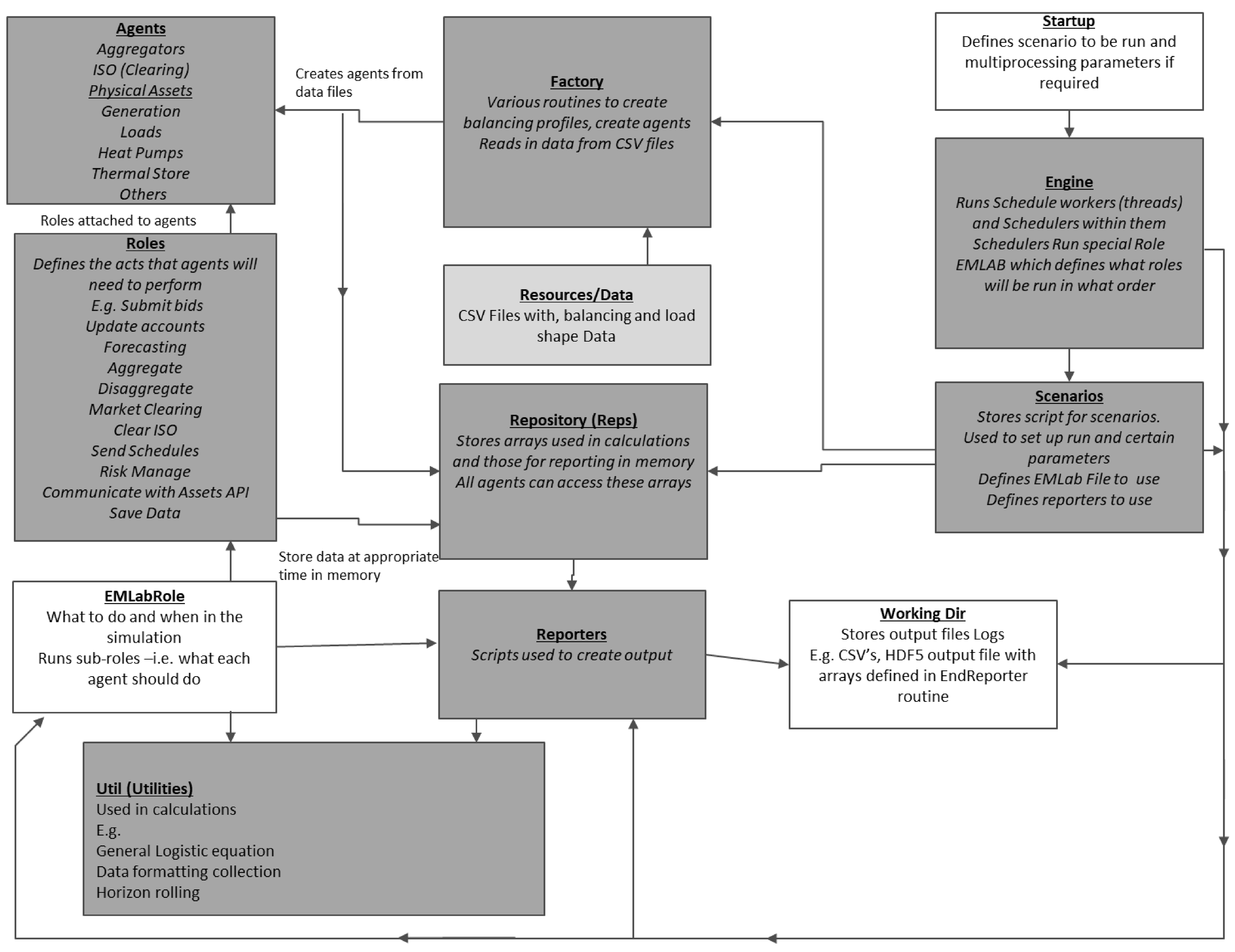
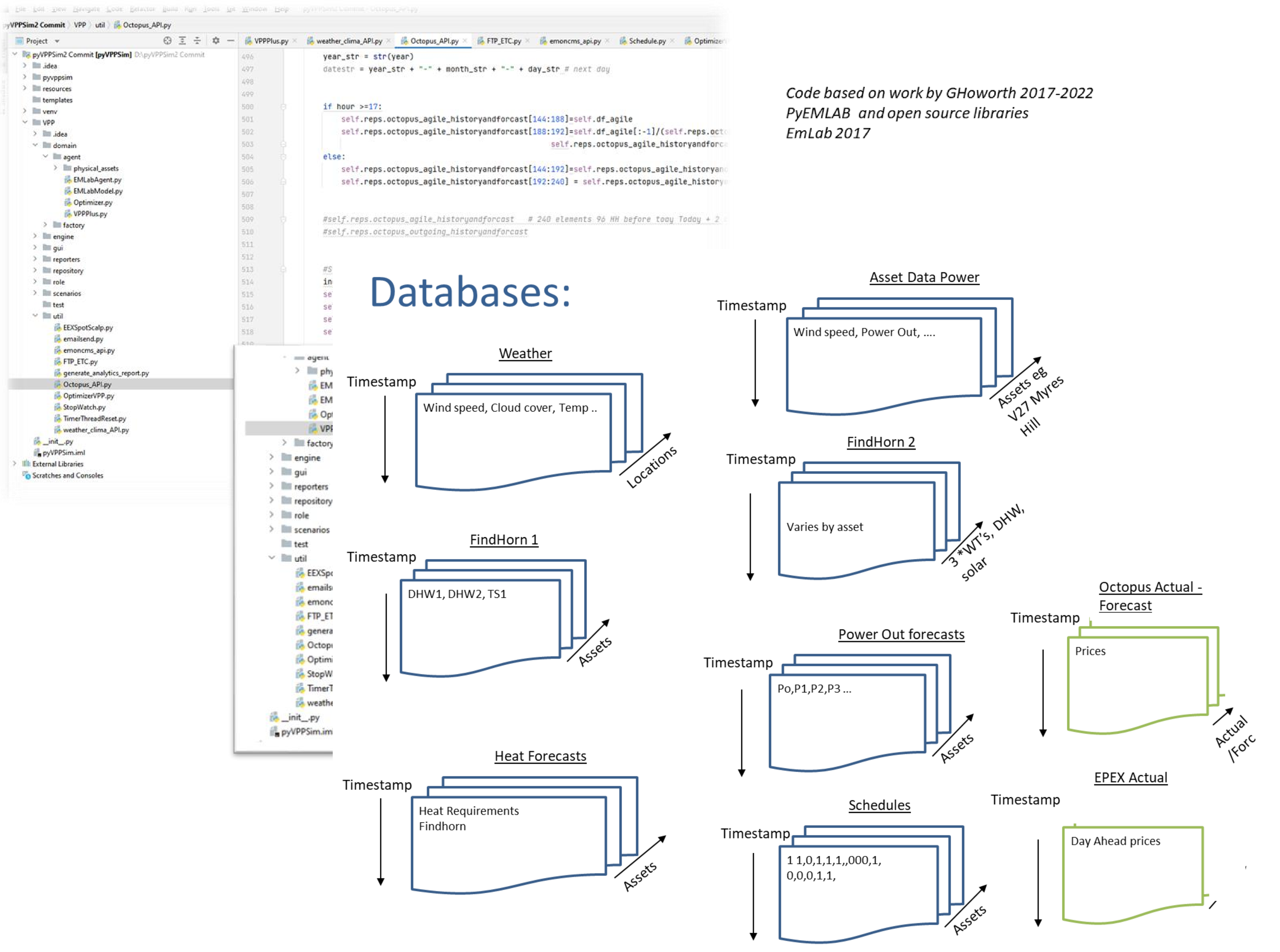
VPP Software Design

PyEMLab Structure

- PyEMLab used as the base structure for VPP platform [1-2]
- Module structure shown below



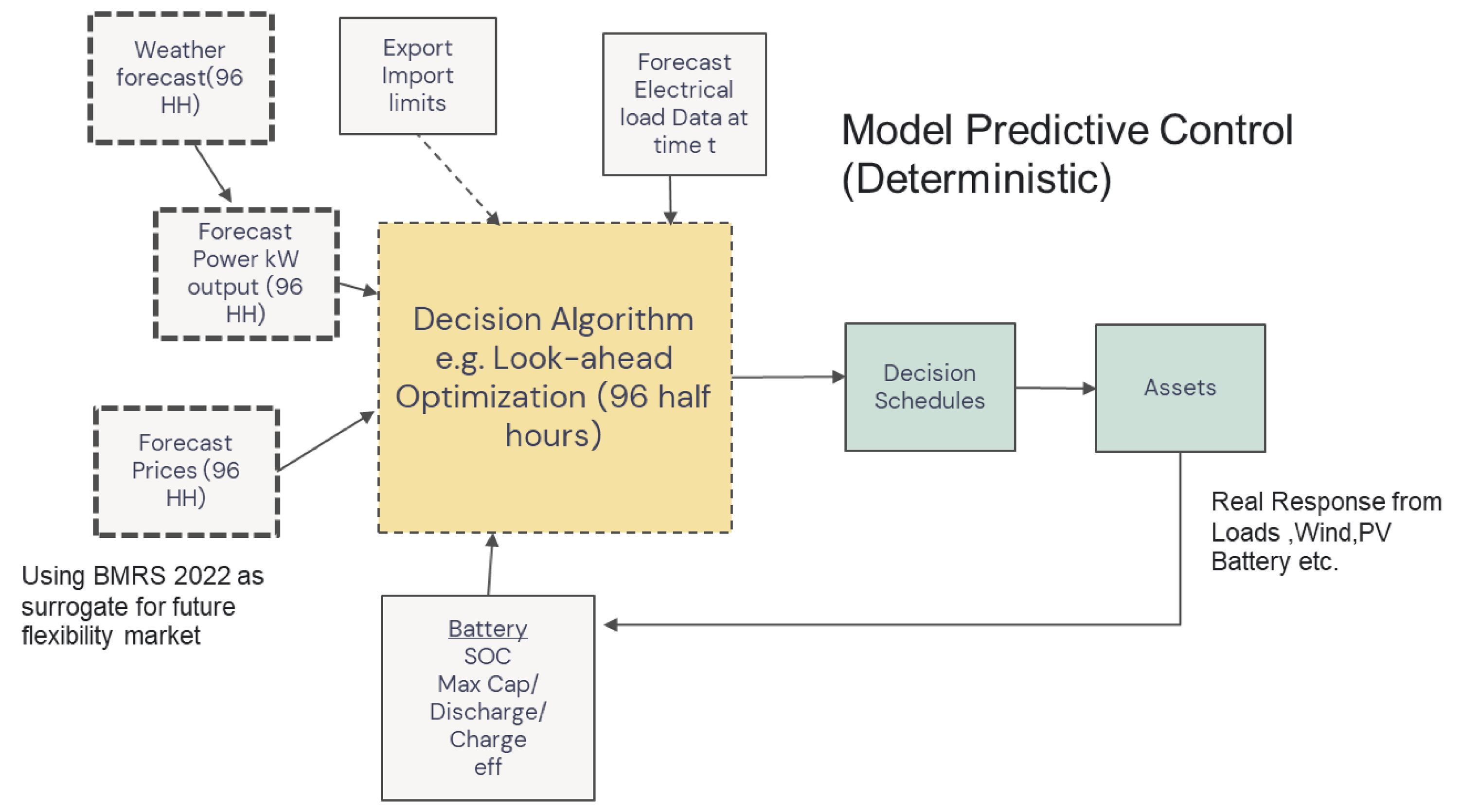
VPP Platform Code-Base



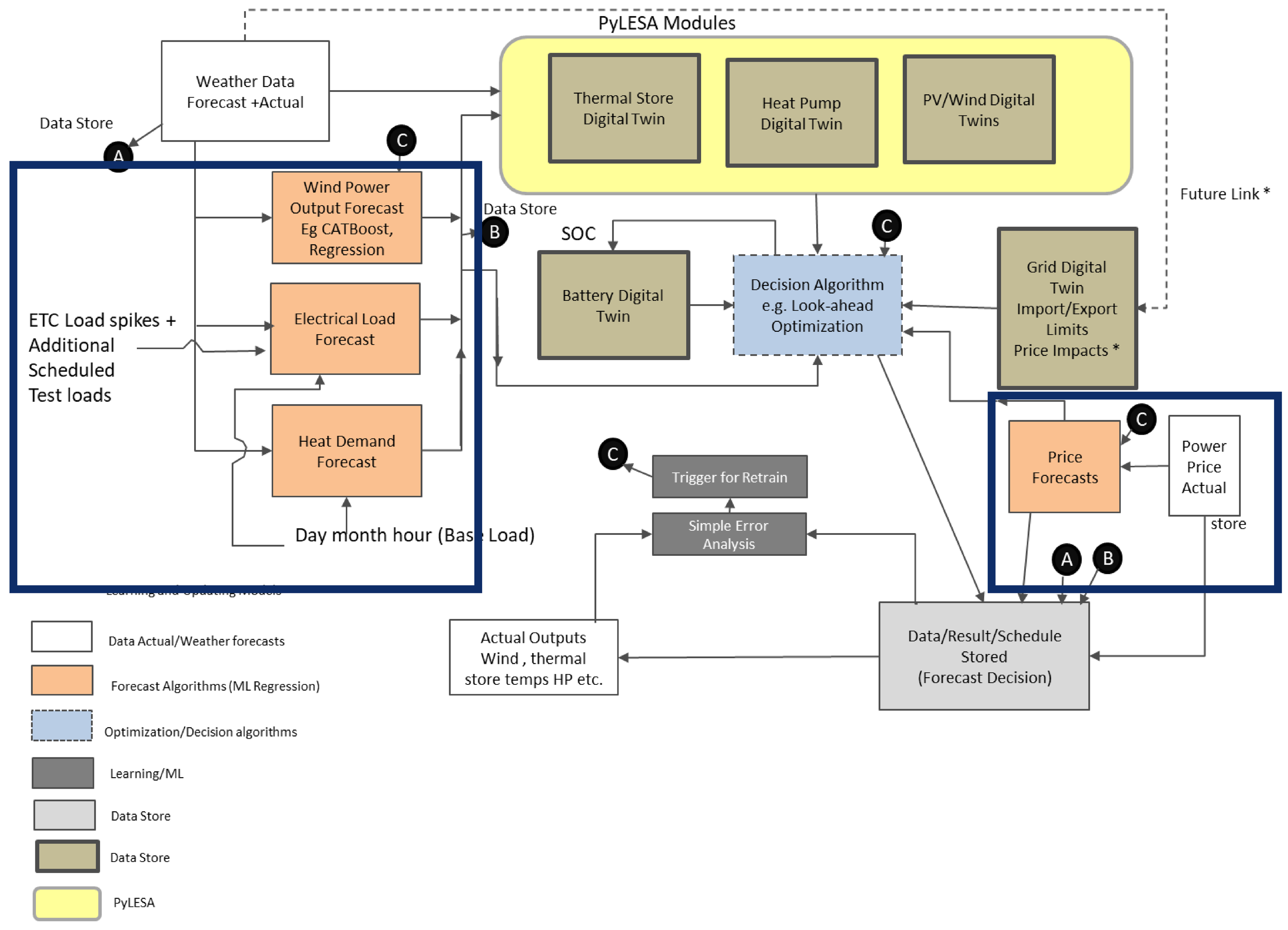
VPP Forecasting

- Forecasting Key part of VPP Functionality
- Data →Learn → Predict →Review
- Prices, Wind Power, Solar, Heat demand, Power demand (Load)
- Weather forecasts used as input
- Using various forecasting techniques including multi linear regression Machine learning eg XGBoost etc.

Forecasting Overview



Forecasting Modules



References

[1] G. Howorth, "Extending the AgentSpring/EMLab Tool to Evaluate Additional Agent Behaviour such as Electric Vehicles and Demand Side Response," ed. ETP Annual Conference 2019 - Energy Technology Partnership Dundee UK: ETP, 2019.

[2] L. J. De Vries, É. J. L. Chappin, and J. C. Richstein, "EMLab-Generation An experimentation environment for electricity policy analysis," 2013.

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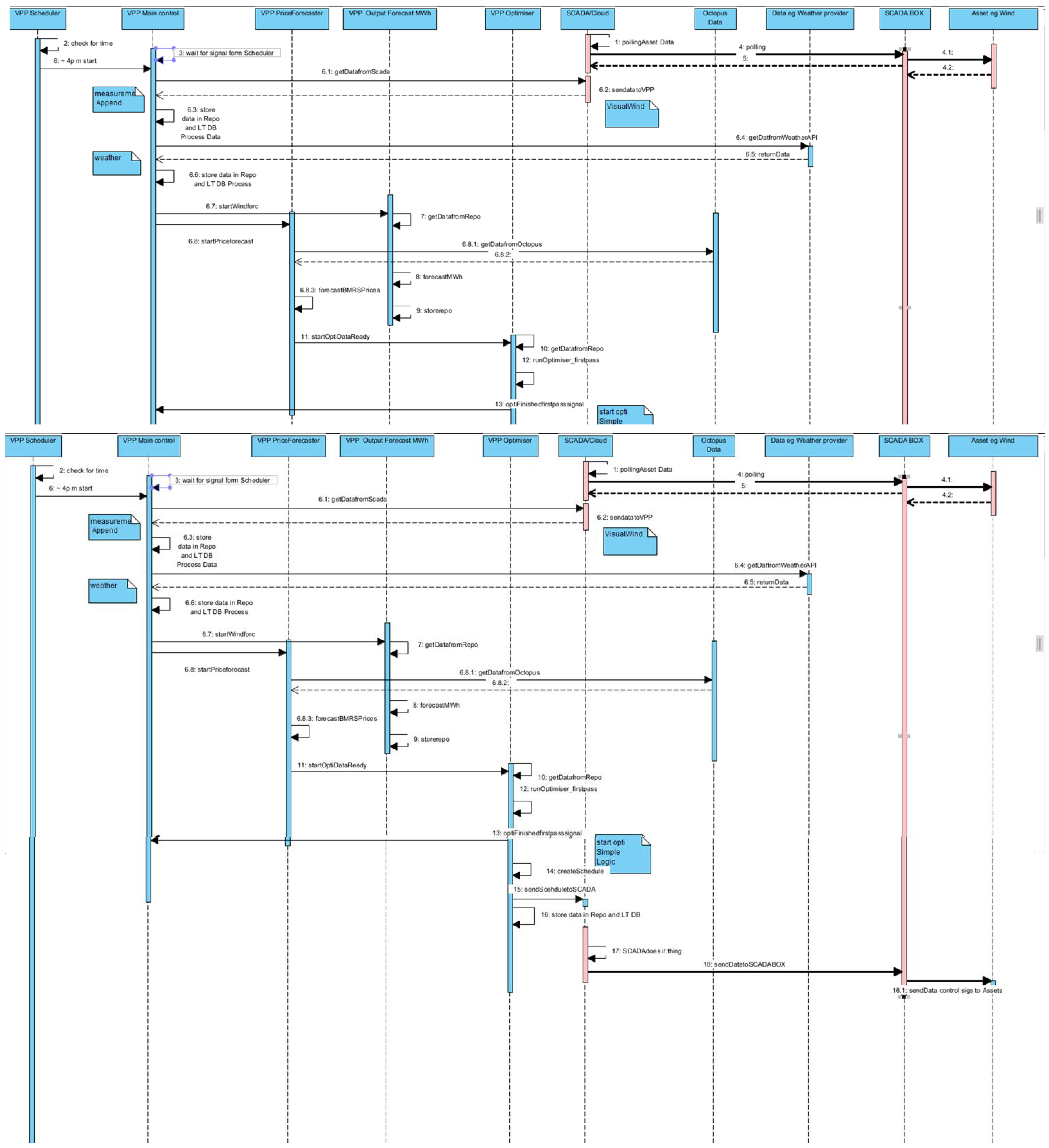
VPP Design Interactions

Simple Use Case



Sequence

- A Sequence Diagram for a simple use case is shown.
- In essence the VPP software:
  - Collects data from markets, assets and other services
  - Uses that data to forecast power output loads (thermal and electrical power) etc.
- Uses forecasts to "optimize" the assets using some algorithm
- Sends signals to the assets for action
- Records data for later analysis

VPP Operation