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#### Introduction **Business Models** ❖ ERA Learn/EU Horizon 2022 Project (SIES 2022). SMART INTEGRATED ENERGY SYSTEMS Frameworks "Learning by Doing" project. Enhanced VPP+ Design – using multiple vector energy pools. There are a multitude of Energy Pools (Flexibility, Thermal, DSR, electrolyser, EV's, Wind, PV). different business model approaches. \* ETC Demo site @ East Kilbride, Scotland. Congested DSO Area. **Business Models: Dimensions** \* Focus of Paper – on developing Business Model framework and using BM demonstrator plant to estimate the value of different business models. Framework Multi-Energy or Ju Assets - Battery (Auction Flex) Markets Stance in Strategic Octopus Agile (Day <sup>(</sup>a) Potential Business Model Dimensions Routes to Market Type Base Case all ETC assets Typically agreed contract price for sales and imports. Fixed price market Fixed Prices Fixed Price PPA Asset choice Example of energy retailer offering on off peak price. Off Peak On Peak Pricing Octopus GO Example of energy retailer offering dynamic prices linked to day Dynamic Tariff e.g. based on Octopus Agile Day ahead wholesale prices ahead market BMRS (Balancing Imbalance market price -UK UK wide market. Minimum bid 1 MW. Transmission level service Mechanism) DNO/DSO Calls for agreed standby services at price set during Asset & Market Flexibility Auctions for one of Piclo's competitions. DNO specifies amount of flexibility Piclo/DNO flexibility at the distribution required. Could be as low as 40 kW. Note not currently a real time Combinations level (400v – 33kV) bidding market Short-term dispatch or reduction of power to Firm Frequency Renewables to Battery stabilise overall system Provision to wider UK grid. Transmission level service Response FFR Choices Electricity Grid Out frequency. UK ISO provides — 12 kW PV Grid to Battery dispatch signals to providers building 10 kW Wind Turbine With Battery Load at ETC site Currently many routes to market but Grid to Load situation is evolving Export/Import 30,000 Octopus Markets may have restrictions on BMRS + Piclo Agile+Piclo volumes but ignored in this assessment 20,000 No Load 10,000 Valuation **BMRS** No Load or -10,000 renewables Risk Valuation --20,000 Octopus Agile simple -30,000 Fixed Prices **Portfolio** 40,000 Simulation No renewables -50,000 Management Risk Score Piclo analysis DSR/Flex at load Data at time t Limits on Import Export Decision Algorithm Actual Price Data e.g. Look-ahead Battery SOC Discharge CSV files Charge Schedule Assets at time Expected Methodology Revenue for and battery actions kW Octopus Agile Markowitz BMRS data etc Renewables Output For 1 year half hourl 2022 Risk Vs For time t Theory Reward Half hourly. Sets up object orientated simulation of various assets Wind Data for asset For 1 year half hourly

### Conclusions

- An enterprise choice of business model is risk preference dependent (i. e. Risk vs Reward dependent).
- Under the strategic dimension approach there are still many other different combinations of assets, contracts, algorithms, locations and markets etc. that need to be considered. Future work will generate risk values and consider the effect of risk management on the outcomes. In addition, the stochastic nature of many of the inputs need to be included
- Most importantly, the data generated from such simulations will help us develop heuristic rules about which business model (combinations of strategic dimensions) will be best under which circumstances

















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

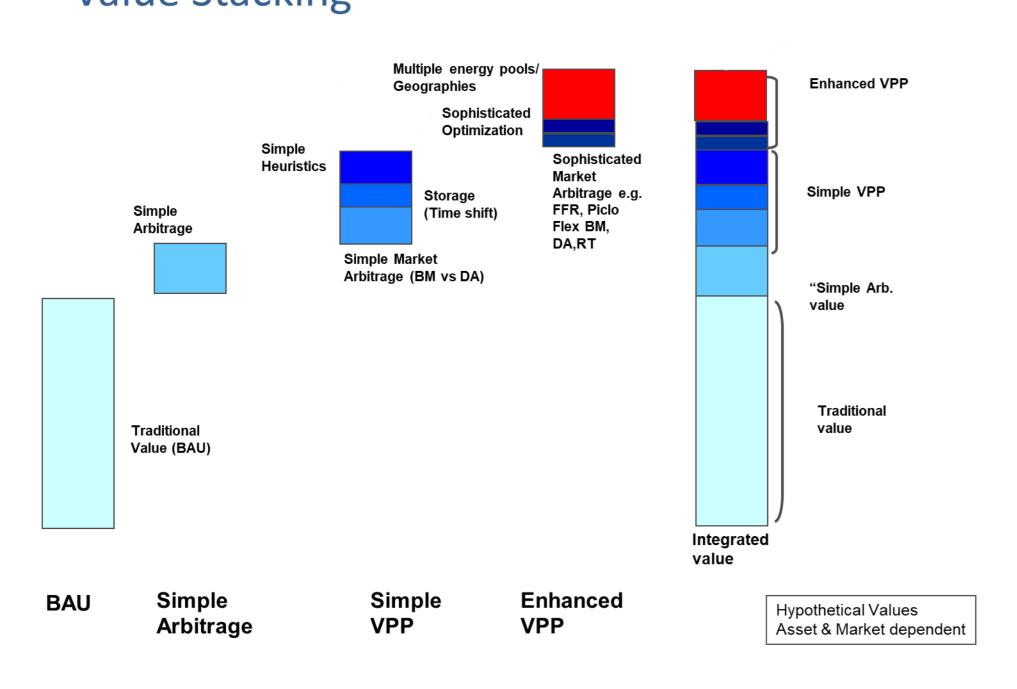
## Aim

- 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

### Overview

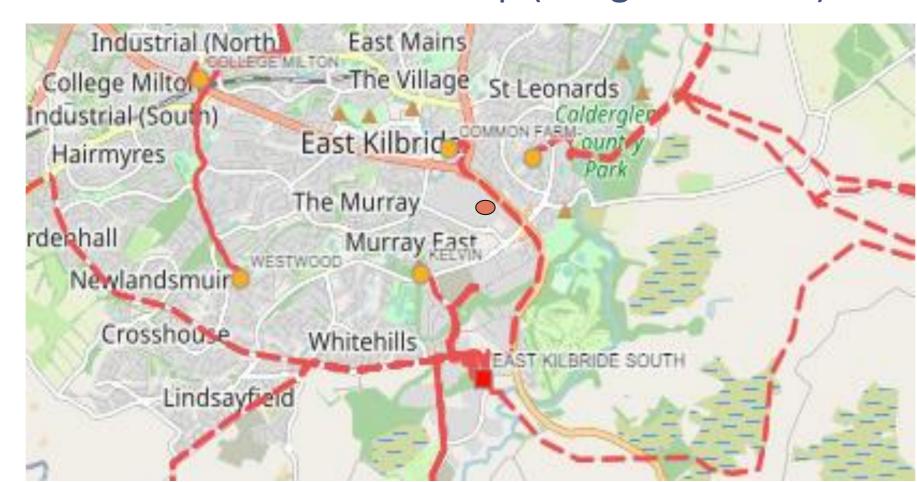
- Number of Proposed Energy Pools (ETC [Myres hill & SETP], Community Energy ,
   Strath Energy Centre , PNDC) Heat DSR,
   HY2GO etc.]
- VPP ++ (connecting different types of assets including DSR), to maximize profits and provide support to an already congested grid;
- Algorithms to be developed for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

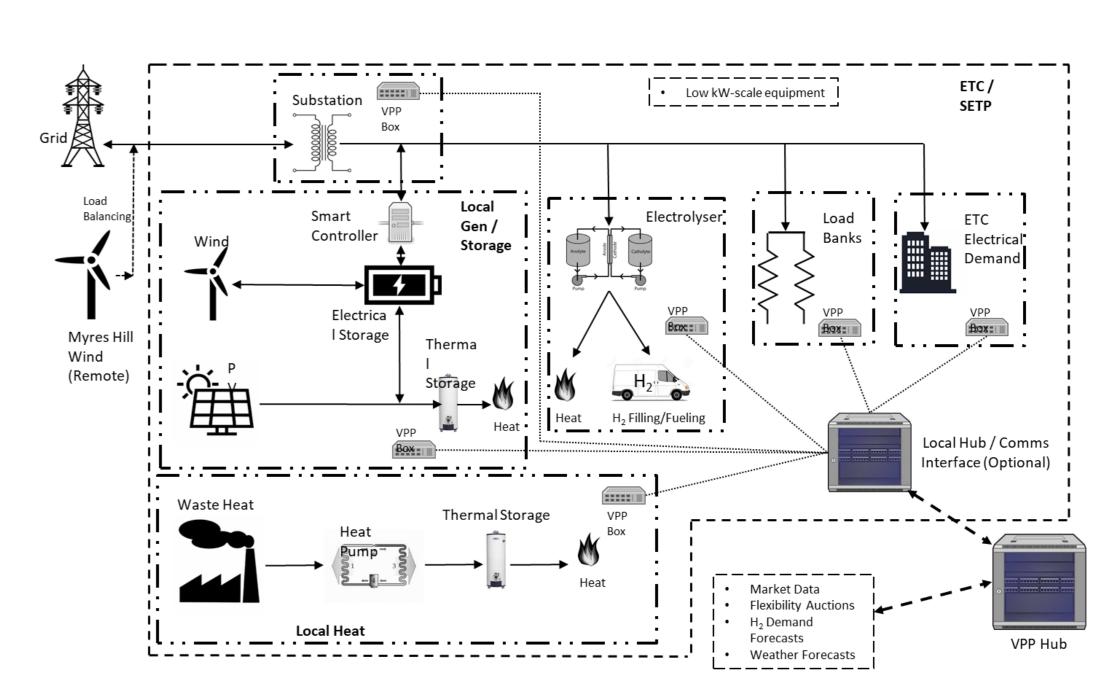
## Value Stacking



## Project Overview

#### SPEN Power Heat Map (Congested Area)





## **Business Model Spectrum**

BAU	Simple VPP	Enhanced VPP+		
<ul> <li>Sell output/Buy         Electricity input from         retailer</li> <li>Treat assets as         separate entities</li> <li>Multiple Long Term         Contracts (one for         each asset) selling all         output</li> <li>Single site</li> <li>Indirect sale of         electricity to markets</li> </ul>	<ul> <li>Few assets e.g. PV + Battery</li> <li>Use of Storage (time Shift)</li> <li>Optimization of Fuel /asset switching or use simple Heuristic eg Buy low sell high</li> <li>1 end use market</li> <li>Use own assets</li> <li>Indirect sale of electricity to markets</li> </ul>	<ul> <li>Multiple Sites/Energy Pools</li> <li>Multiple Power Markets</li> <li>Value Stacking</li> <li>Portfolio optimization</li> <li>Risk Management</li> <li>Complex Stochastic</li> <li>Use of others assets</li> <li>Direct sale of electricity to markets</li> </ul>		
		• Trading		

## Key element of the project was to develop Business models for a VPP.

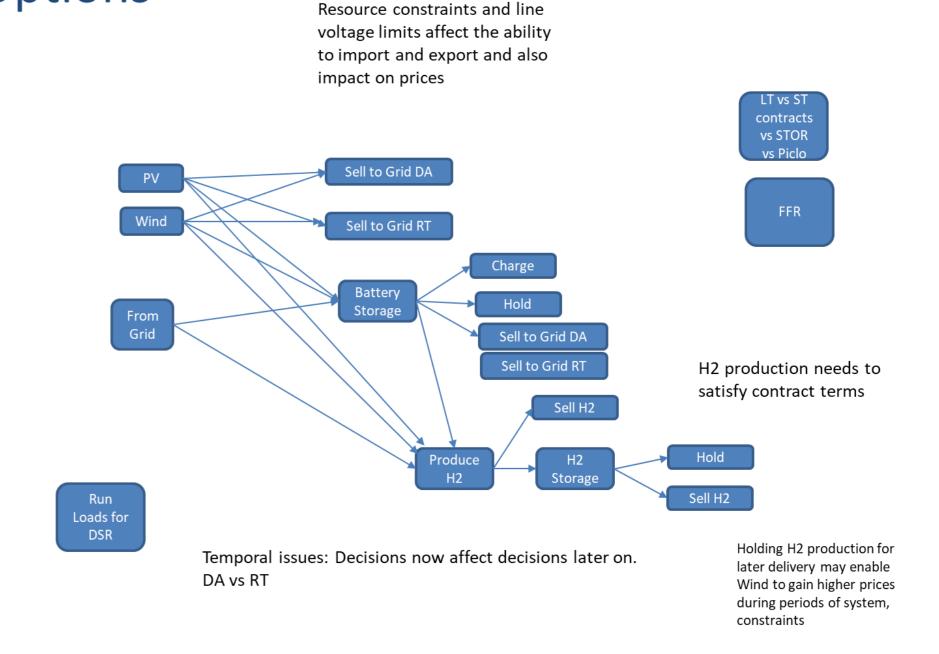
**Business Models** 

- 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

### **Options**



## 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"





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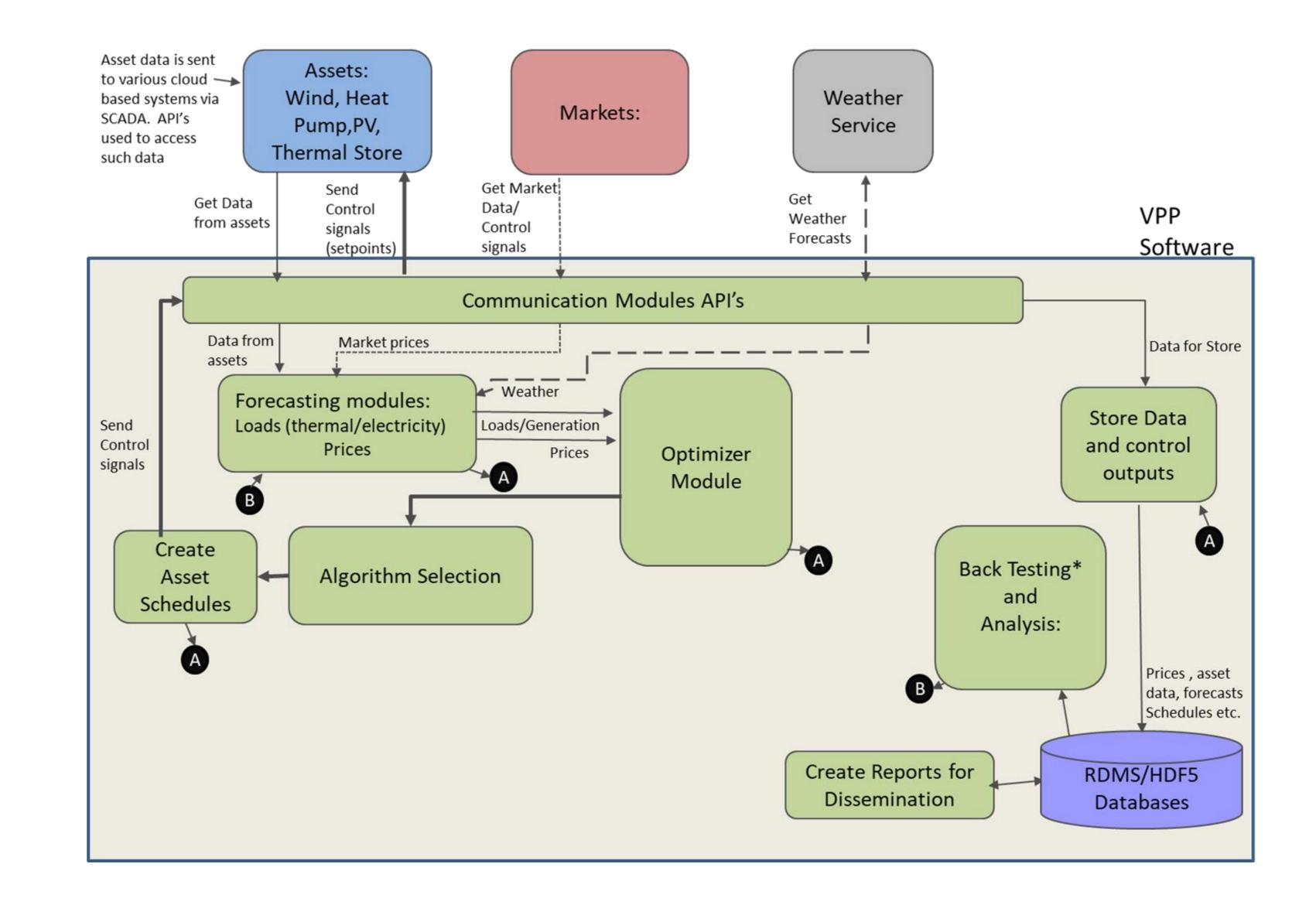


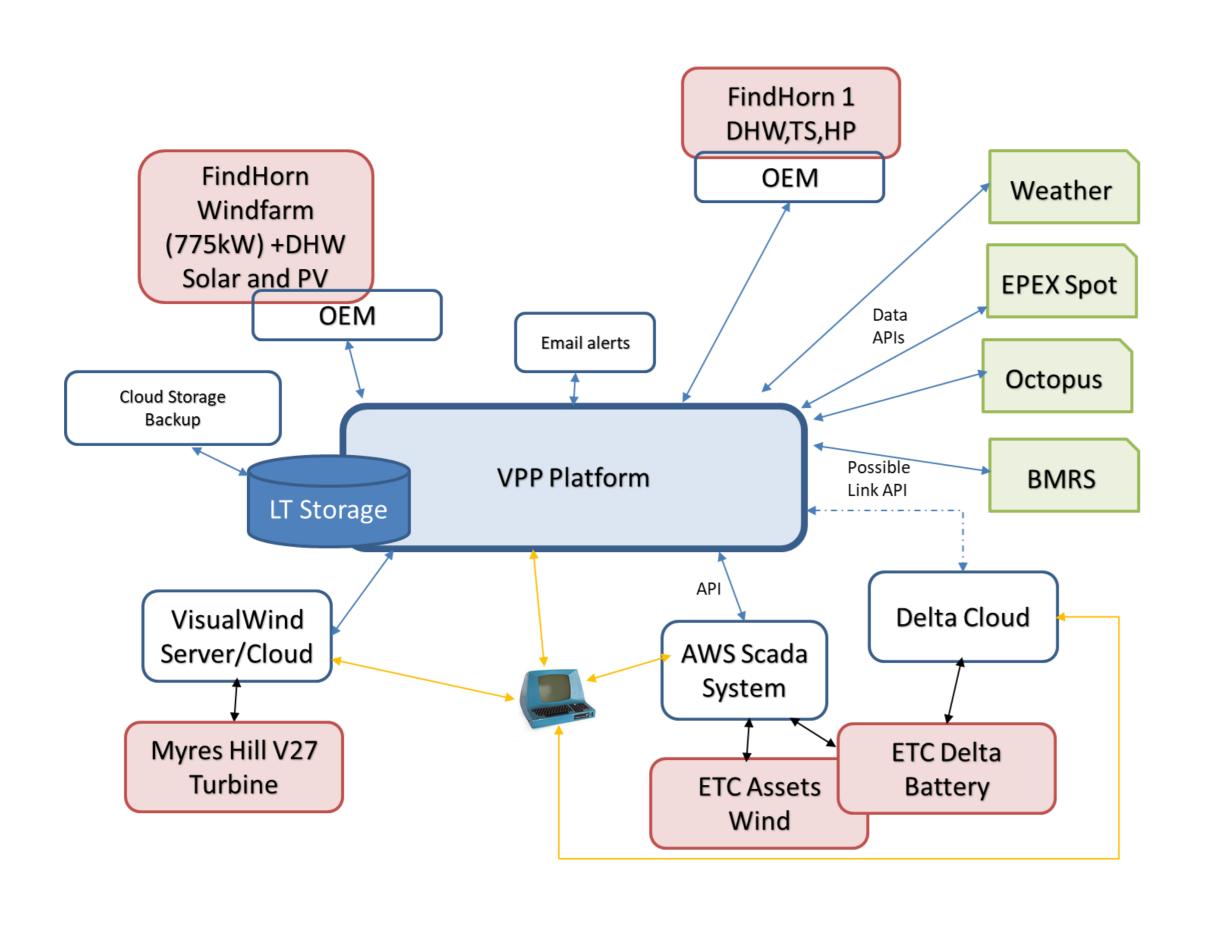
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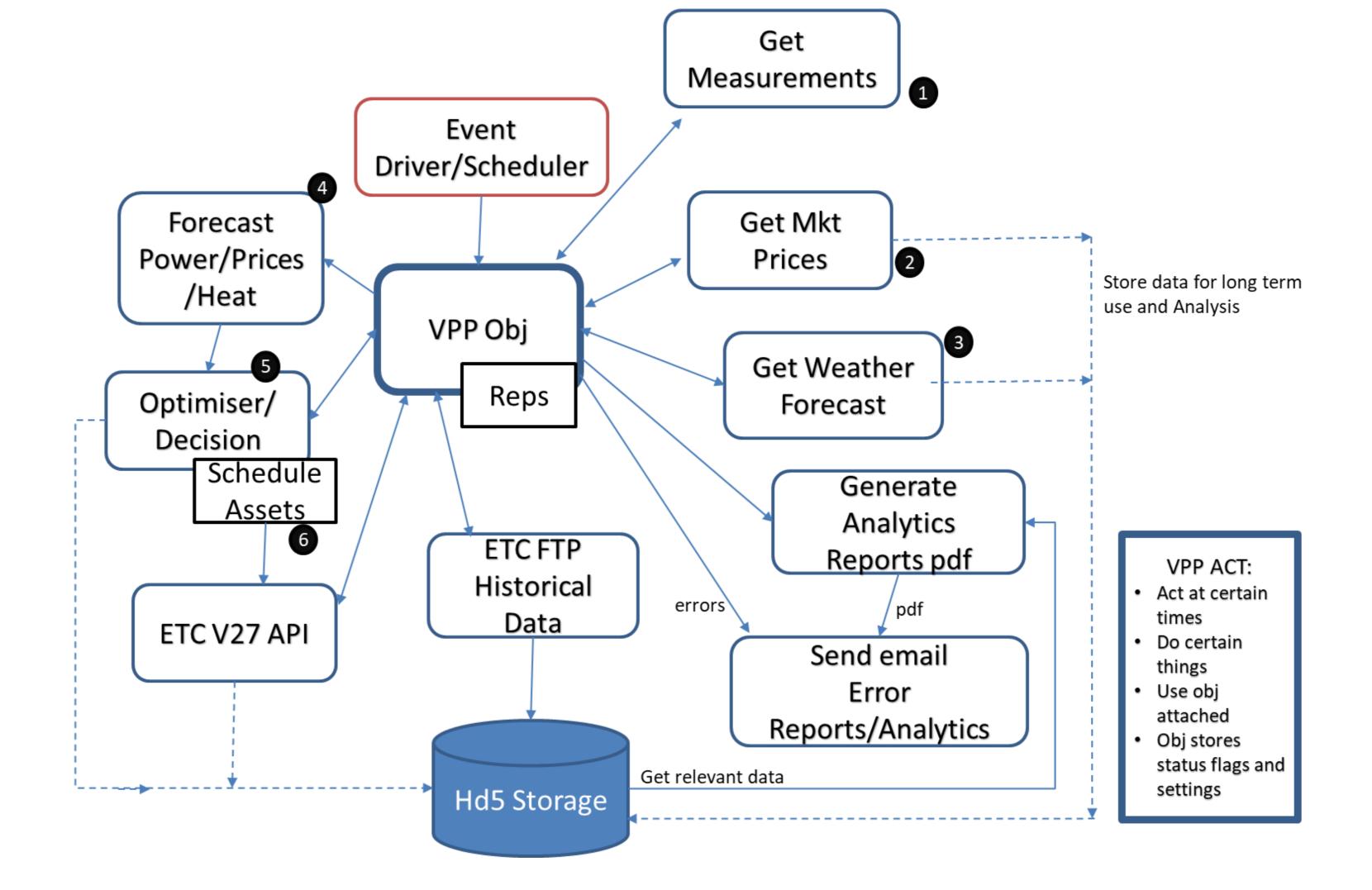
## Overview of Software Used in Assessments

### Overview

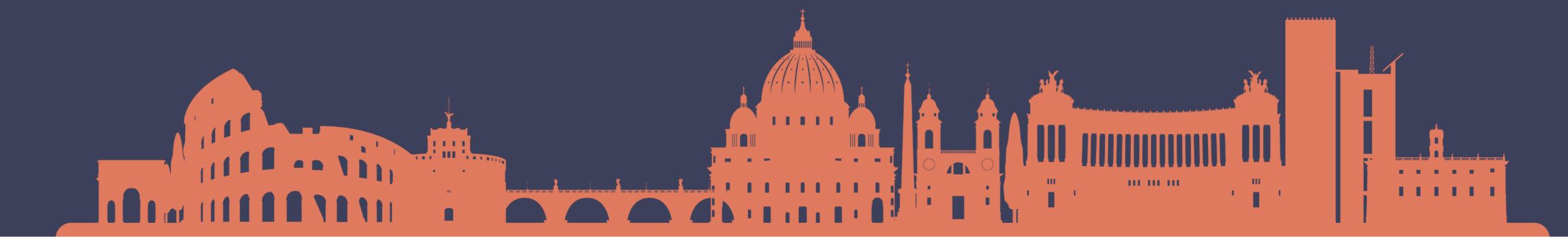
- Business model values generated in this
   work use a VPP platform to simulate different
   combinations of assets using data collected
   from actual VPP operation at the ETC
   demonstrator plant.
- Platform modified to simulate time steps rather than operate in real time.
- An overview of this platform is shown here
- The VPP platform uses a model predictive control optimizer to schedule assets so that it maximizes net revenue (exports vs imports)
- Revenues for the year are calculated and used to generate plots shown other pages.











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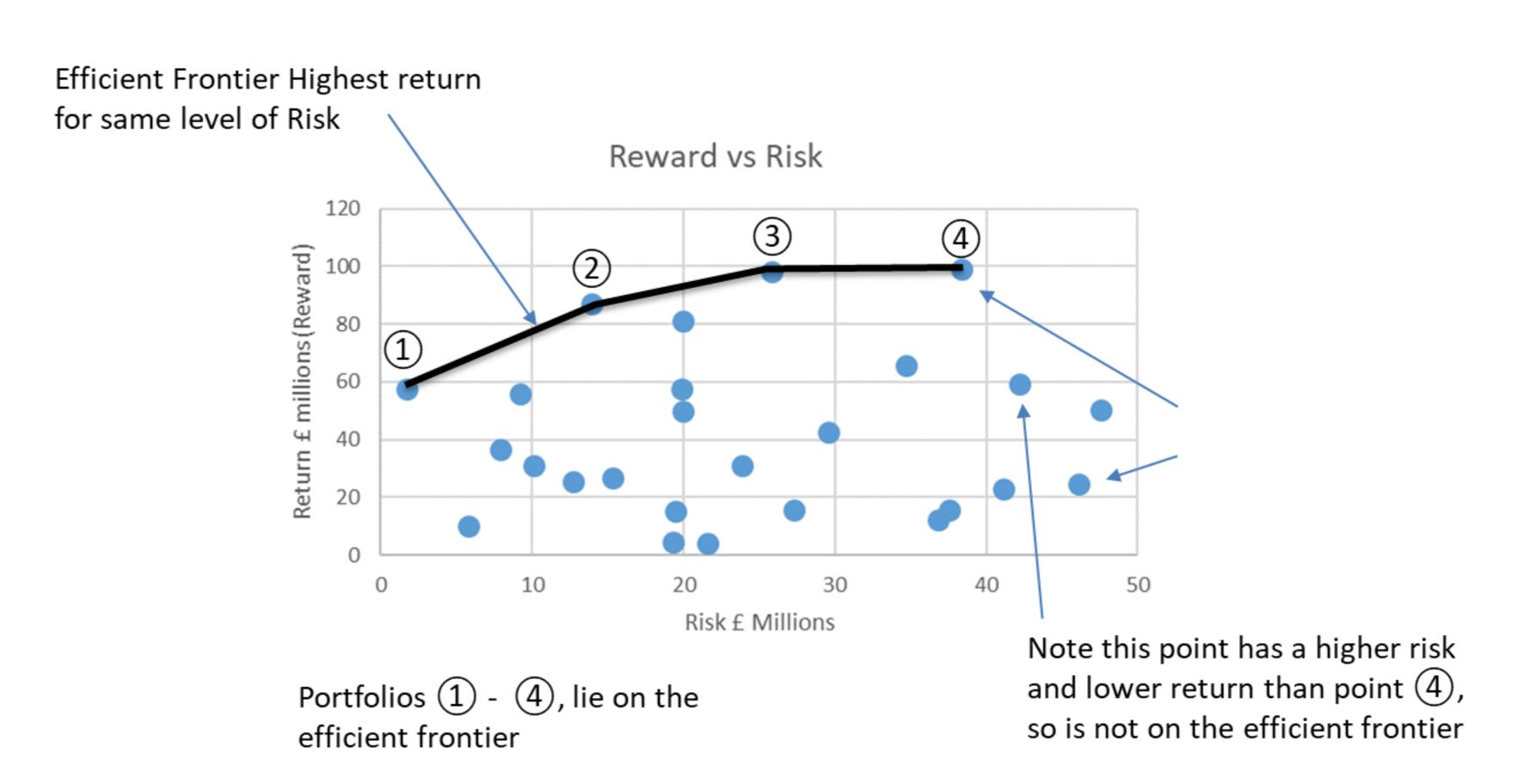
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## Results: Additional Detail

## **Business Model Valuation**

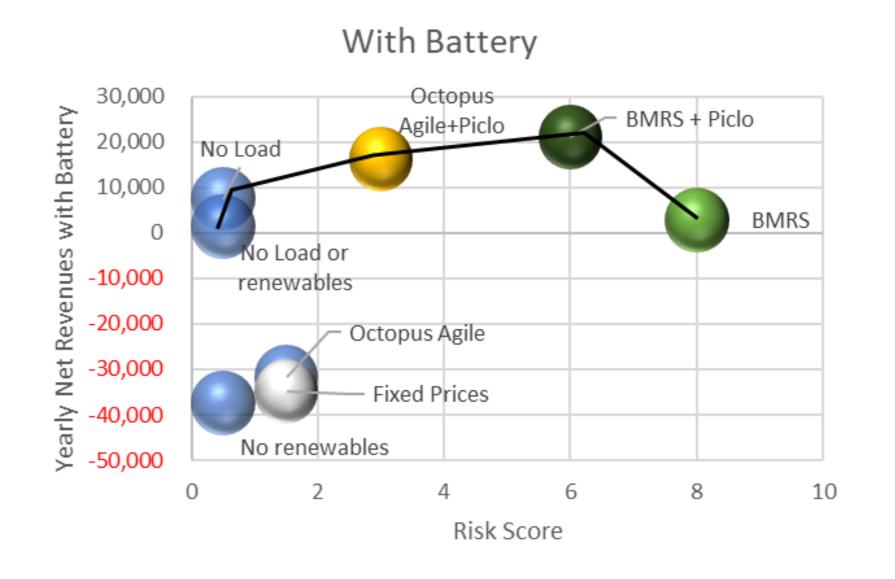
- Which business model?
- Depends on risk reward preferences.
- ETC demonstrator used as an illustrative case study.
- Calculated the net revenues to the project half-hour by half-hour over a period of a year through simulation.
- The results are shown in figure. Graphs are for the renewables output at the actual rates at ETC. Spheres of the same colour have the same routes to market.
- Battery dispatch patterns vary throughout the year and also depend on the market selected (see below). This impacts on valuation values.

## Portfolio Management: Reward vs Risk



### Business Model Assessments: Reward vs Risk





(a) Yearly Net Revenues (Without Battery)

Battery Benefit 50,000 BMRS + Piclo 40,000 30,000 No renewables 20,000 Octopus Ag BMRS Fixed Prices 10,000 Octopus -10,000 Agile+Piclo 10 Risk Score No Load or renewables Battery Benefit

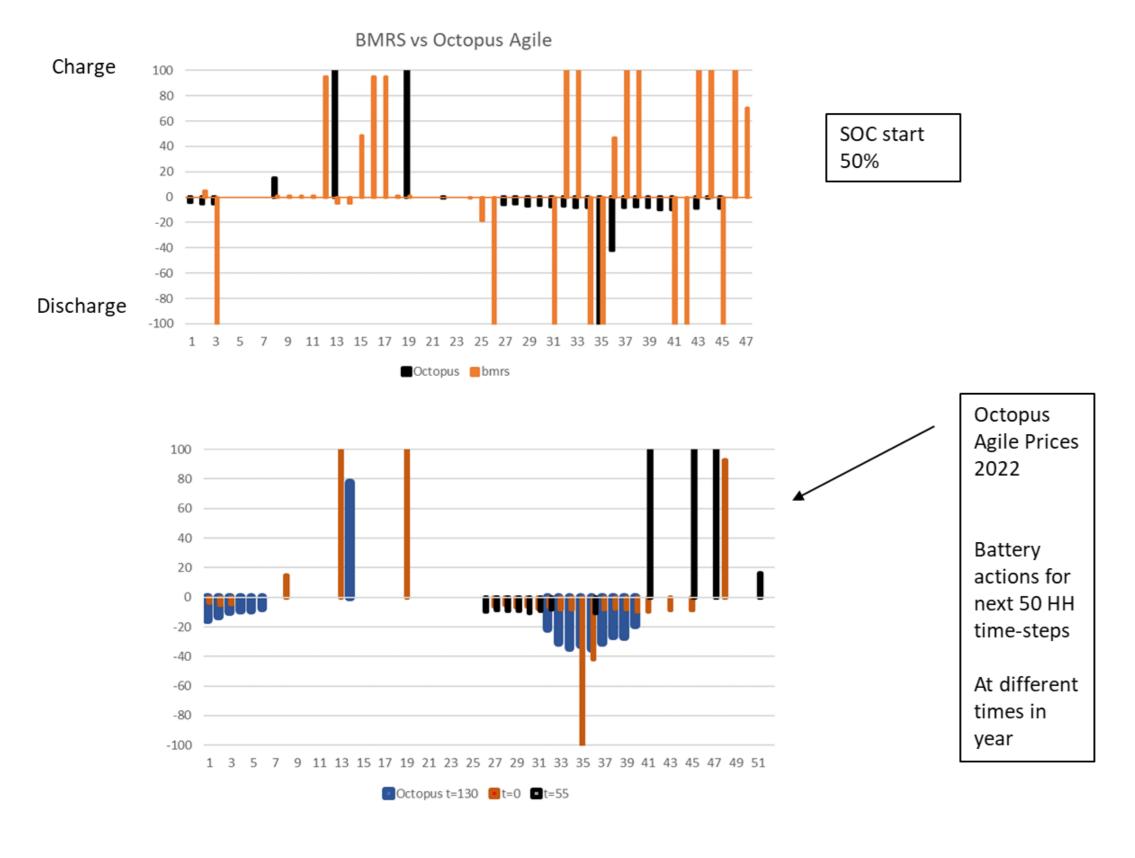
(b) Yearly Net Revenues (With Battery)

Tabular summary

Assets Asumption

Load	Renewables	Market	Net Revs without Battery	Net Revs with Battery	Battery Benefit	Risk Score
buidling)	(PV Wind)x1	Octopus Agile	-35,156	-31,852	3,304	1.5
Load (ETC +other						
buidling)	(PV Wind)x10	Octopus Agile	42,157	42,748	591	1.5
No Load	(PV Wind)x1	Octopus Agile	5,990	7,508	1,518	0.5
No Load	No Renewables	Octopus Agile	0	1,491	1,491	0.5
Load (ETC +other						
buidling)	No Renewables	Octopus Agile	-40,875	-37,508	3,367	0.5
Load (ETC +other						
buidling)	(PV Wind)x1	BMRS	-12,632	2,925	15,558	8
Load (ETC +other						
buidling)	(PV Wind)x10	BMRS	21,779	36,073	14,294	8
Load (ETC +other						
buidling)	(PV Wind)x1	BMRS+Piclo	-18,577	21,130	39,707	6
Load (ETC +other						
buidling)	(PV Wind)x10	BMRS+Piclo	40,031	54,278	14,247	6
Load (ETC +other						
buidling)	(PV Wind)x1	Octopus Agile+Piclo	16,149	16,355	205	3
Load (ETC +other						
buidling)	(PV Wind)x1	Fixed Prices	-34,813	-34,766	47	1.5
Load (ETC +other						
buidling)	(PV Wind)x10	Fixed Prices	28,044	28,091	47	1.5

## Battery Dispatch Example: Same Asset but different Markets





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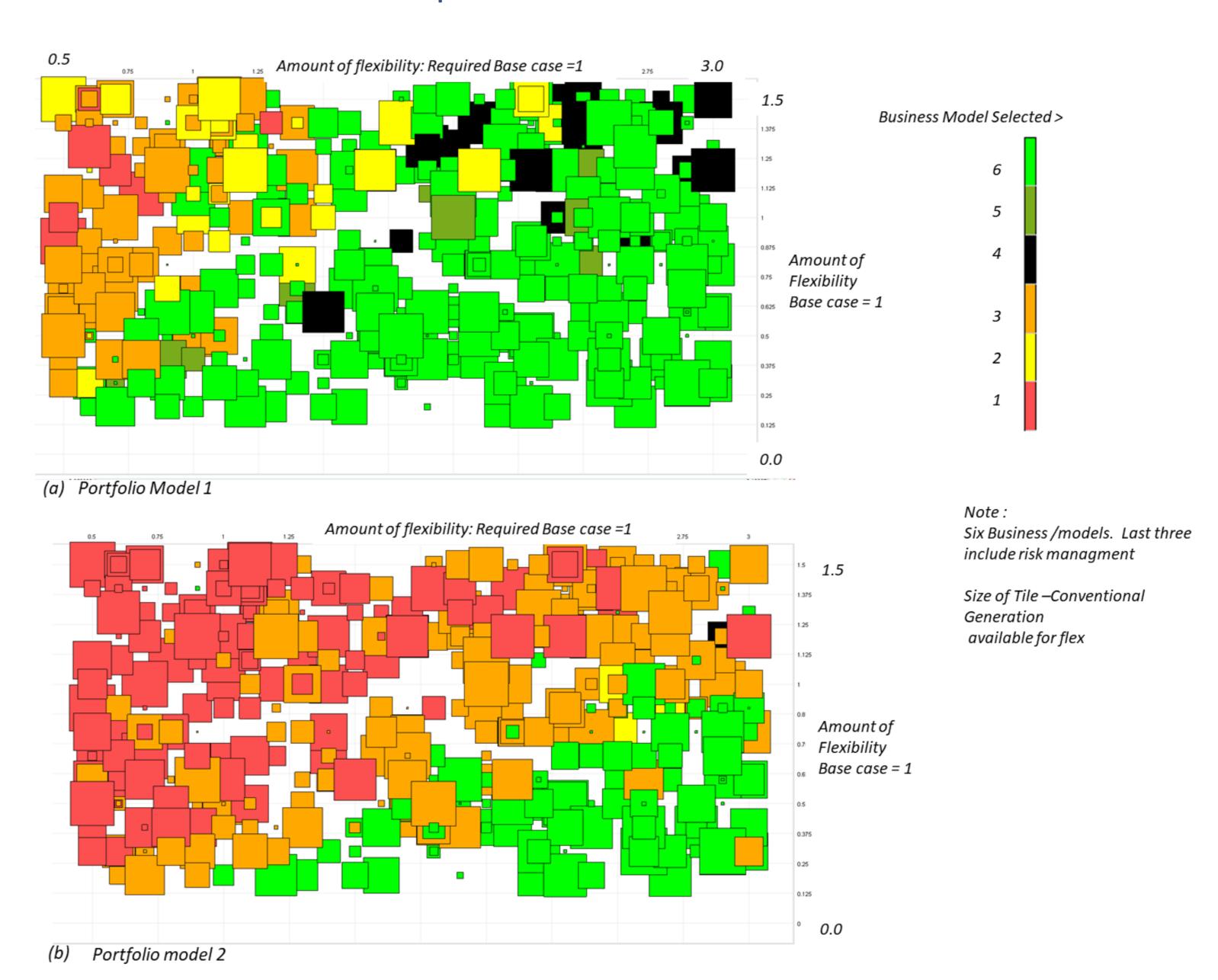
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## Future Work: Initial Results

### Overview

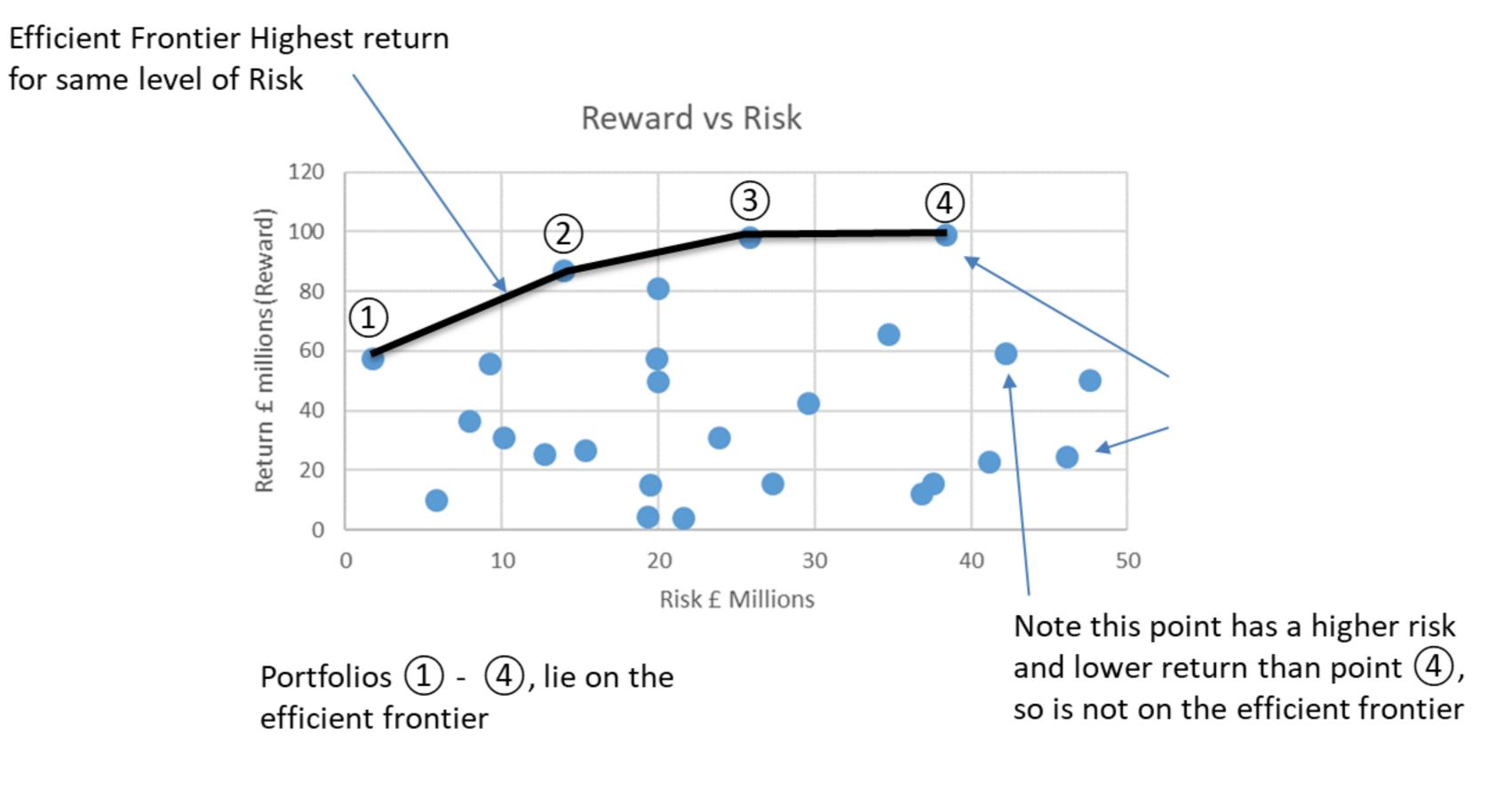
- A VPP business model framework has been proposed that uses a number of strategic dimensions. The selection of elements along the various strategic dimensions constitutes what defines a business model.
- Under the strategic dimension approach of this work, there are still many other different combinations of assets, contracts, algorithms, locations and markets etc. that need to be considered.
- Risk management is an important element of this work.
- Initial work using a larger market with many assets shows that business model preference depend on a number of factors including:
  - o Flexibility requirements (grid location).
  - Amount and type of flexibility available.
  - o The Portfolio selection method.
- In some cases Risk Management is preferred (BM's 4-6) and in others it is not.

### Which Business Model Example



### Portfolio Management

- The figure above uses the concept introduced by Markowitz [1] and is summarized in the figure below.
- Whether an enterprise prefers one business model over another is a matter of personal choice and risk preference. E.g. 3 vs 2 see below
- Utility theory and other techniques can be used to reflect the risk reward numbers as a single value. This single value can then be used to select an appropriate business model



### References

[1] H. Markowitz, "Portfolio Selection: Efficient Diversification of Investments, New York, John Wiely & Sons," ed: Inc, 1959.