CIRED
ROME, ITALY
12-15 JUNE 2023

Business Models for Virtual Power Plants & their Impact on Economic Operation

Gary, Howorth
Univ of Strathclyde, UK

Ivana, Kockar
Univ of Strathclyde, UK

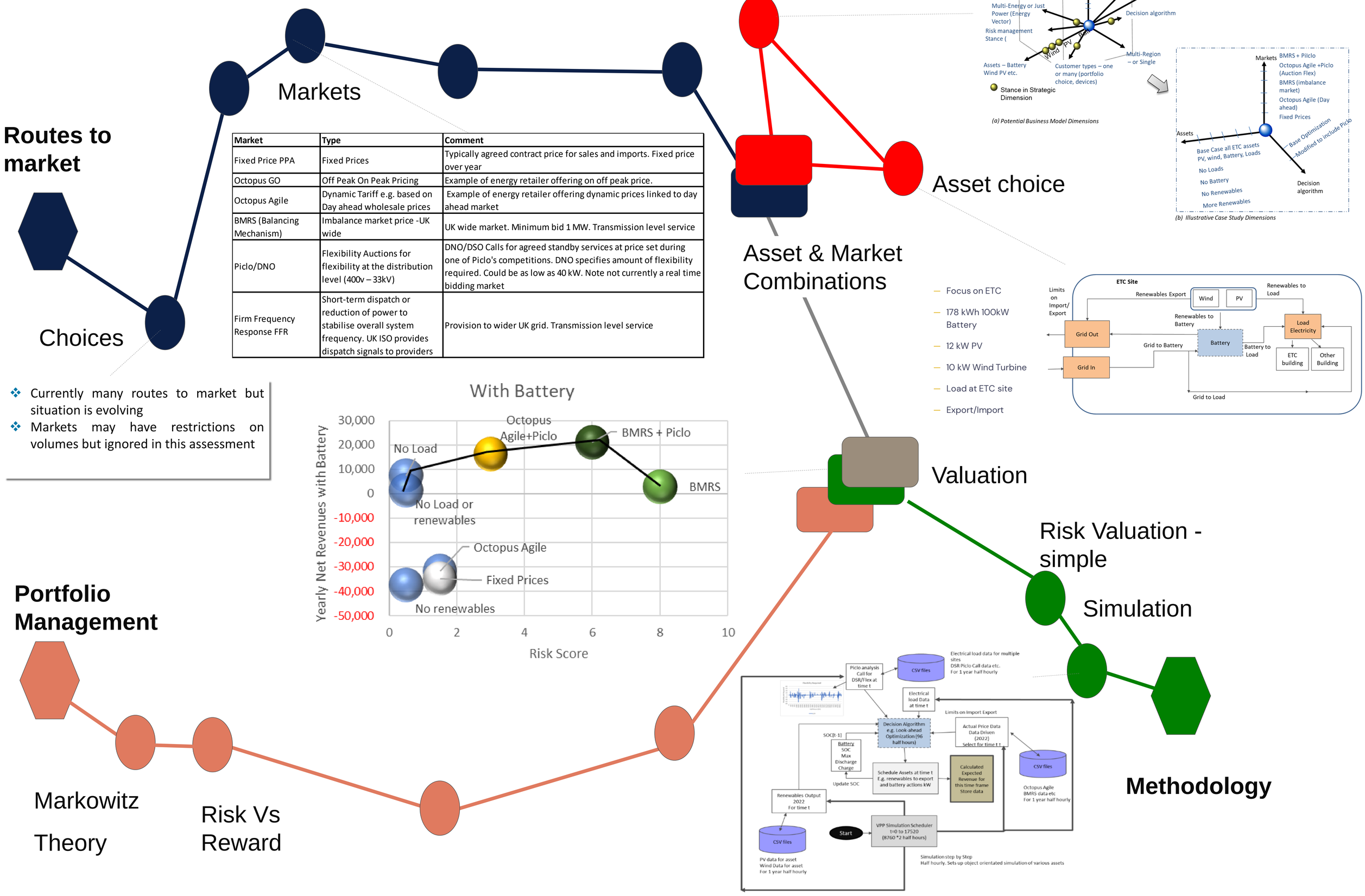
Paul, Touhy
Univ of Strathclyde, UK

Graeme, Flett
Univ of Strathclyde, UK

John, Bingham
Energy Technology Centre Ltd, UK

Introduction

- ERA Learn/EU Horizon 2022 Project (SIES 2022).
- "Learning by Doing" project.
- 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 developing Business Model framework and using demonstrator plant to estimate the value of different business models.



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

CIRED
ROME, ITALY
12-15 JUNE 2023

Business Models for Virtual Power Plants & their Impact on Economic Operation

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

SMART INTEGRATED ENERGY SYSTEMS

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

Project Overview

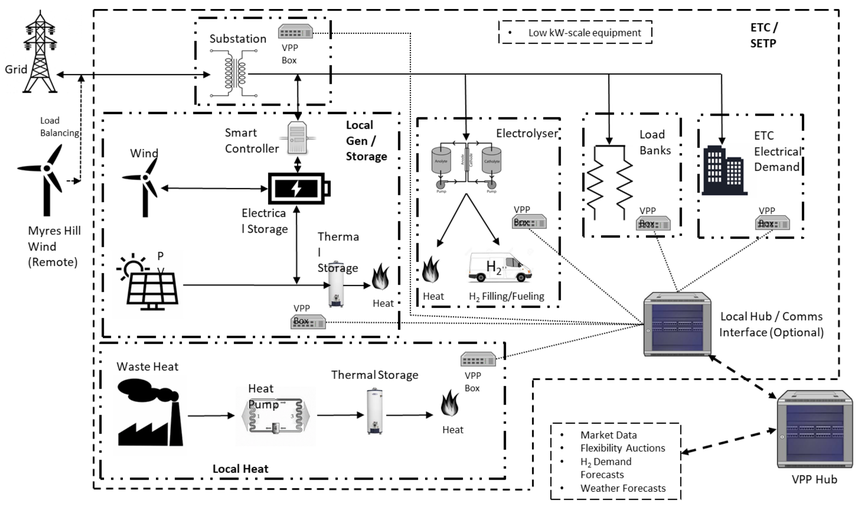
Aim

- 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

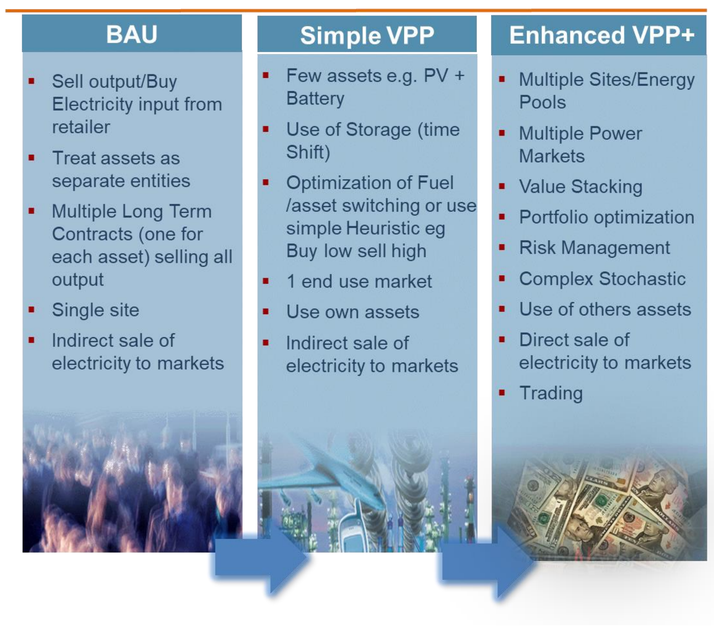
Overview

- 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)

SPEN Power Heat Map (Congested Area)



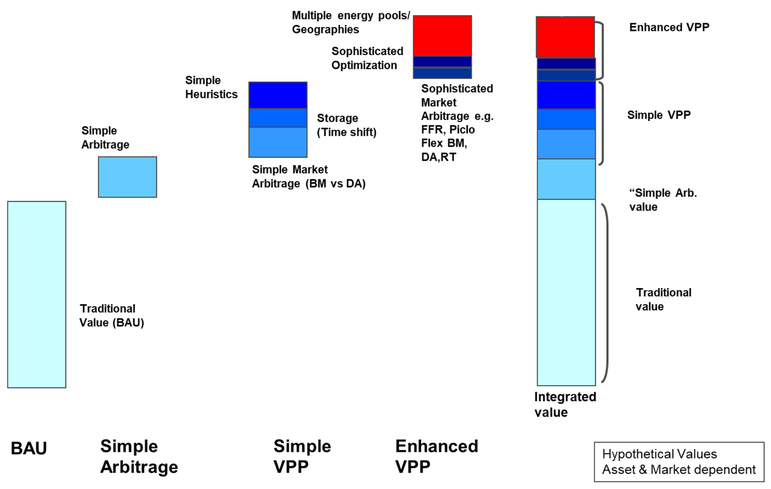
Business Model Spectrum



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

Value Stacking



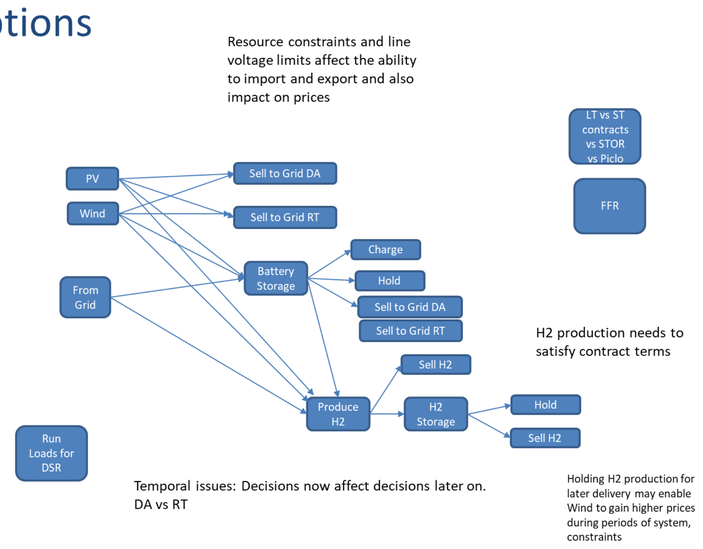
Markets, Value Stacking

- 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"

Decision Options

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

Options



CIRED
ROME, ITALY
12-15 JUNE 2023

Business Models for Virtual Power Plants & their Impact on Economic Operation

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

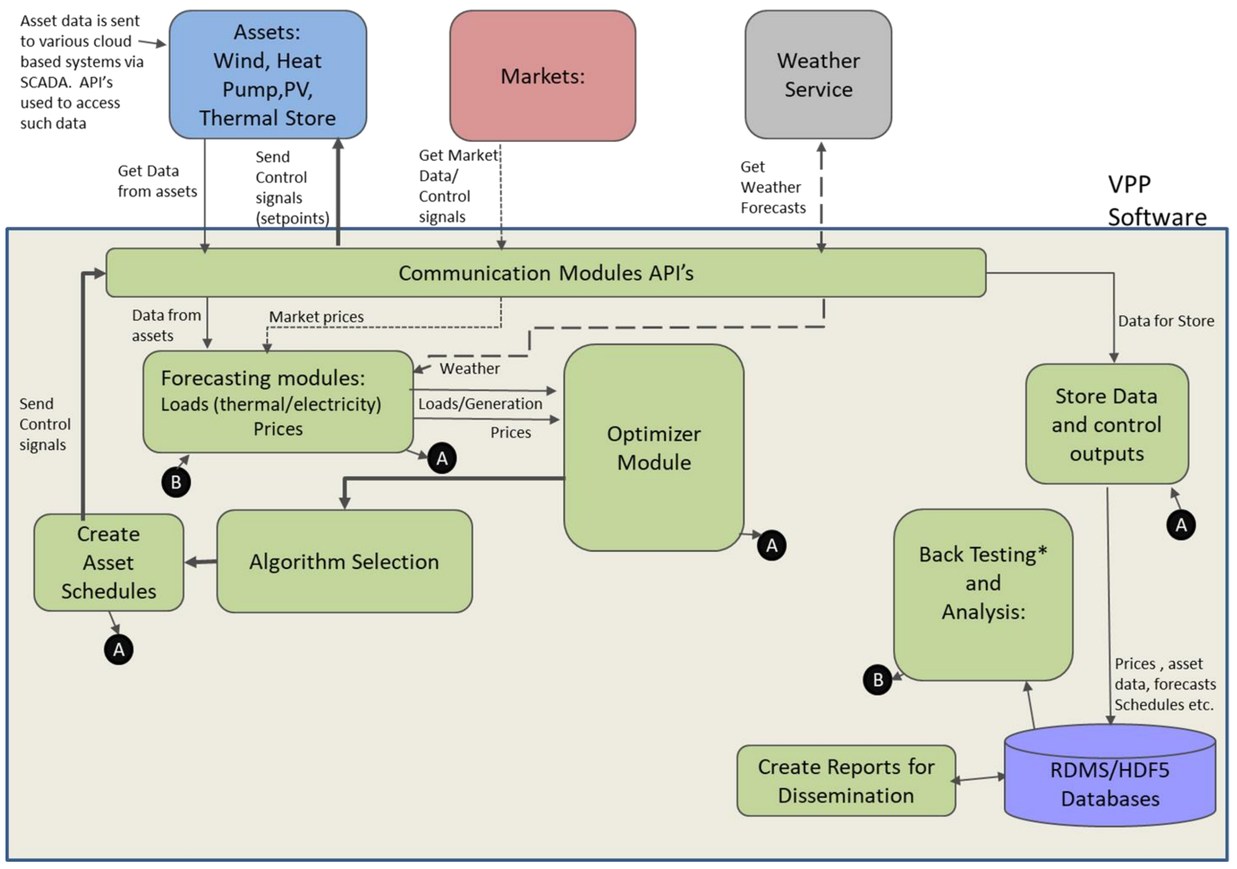
SMART INTEGRATED ENERGY SYSTEMS

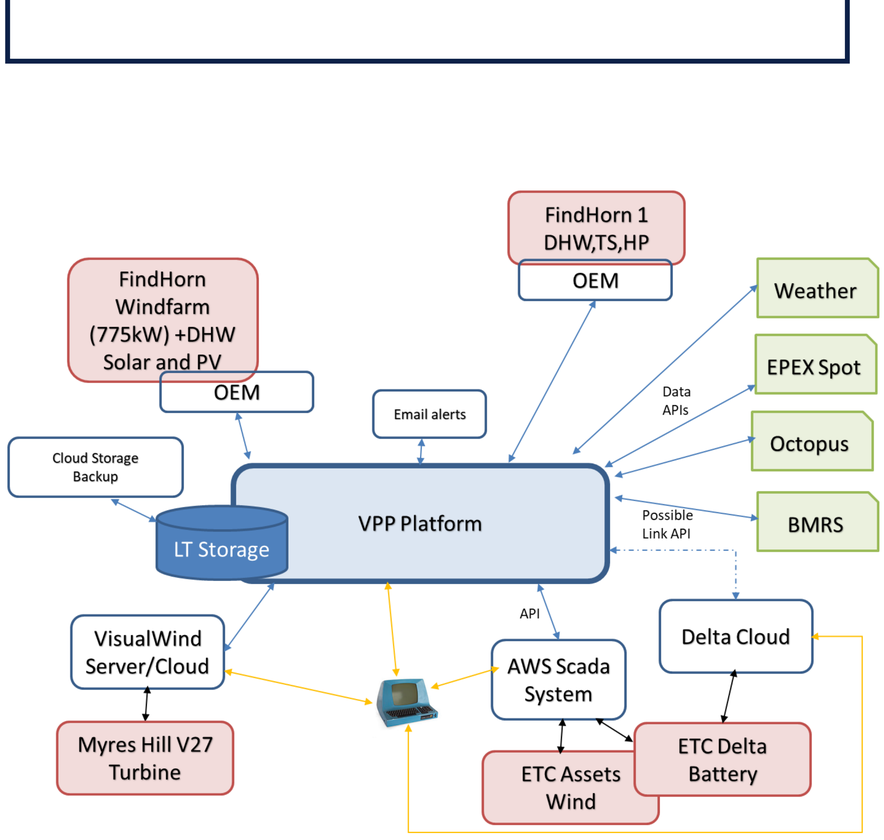
SIES [Smart Integrated Energy Systems: Enhanced Virtual Power Plant VPP+ Energy Pool Integration for Local and Regional Resistance]

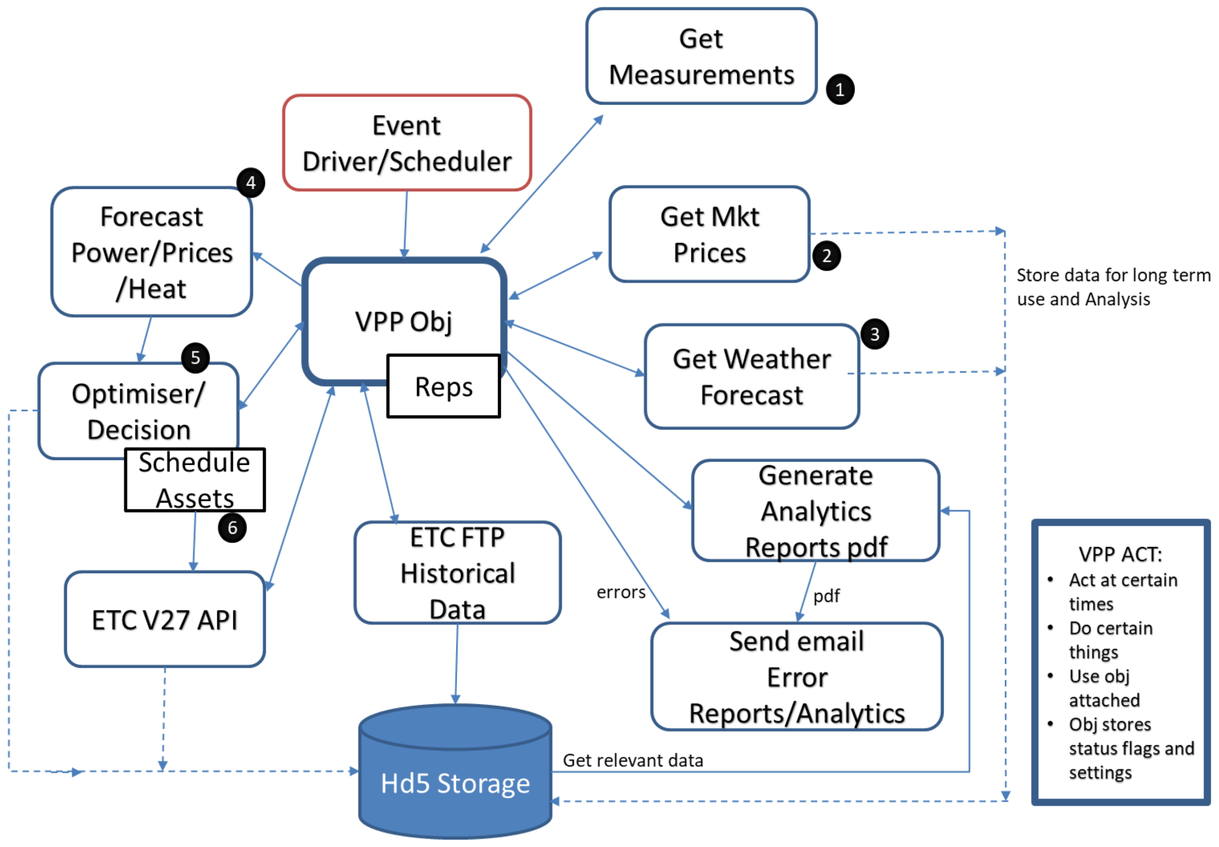
Overview of Software Used in Assessments

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.







CIRED
ROME, ITALY
12-15 JUNE 2023

Business Models for Virtual Power Plants & their Impact on Economic Operation

Gary, Howworth
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

SMART INTEGRATED ENERGY SYSTEMS

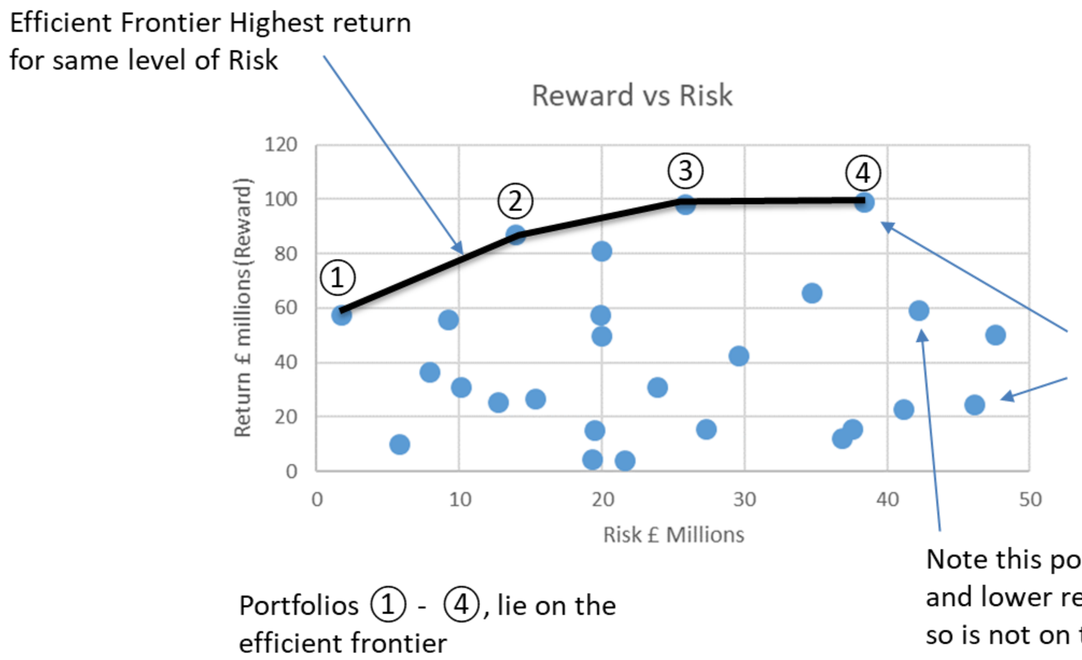
SIES [Smart Integrated Energy Systems: Enhanced Virtual Power Plant VPP+ Energy Pool Integration for Local and Regional Resistance]

Results: Additional Detail

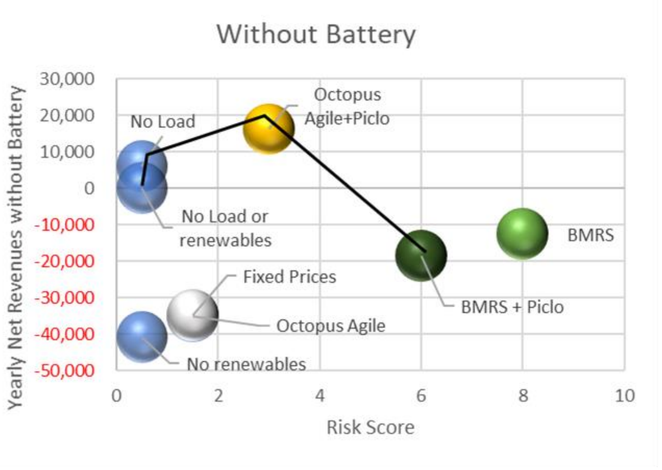
Business Model Valuation

- 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.

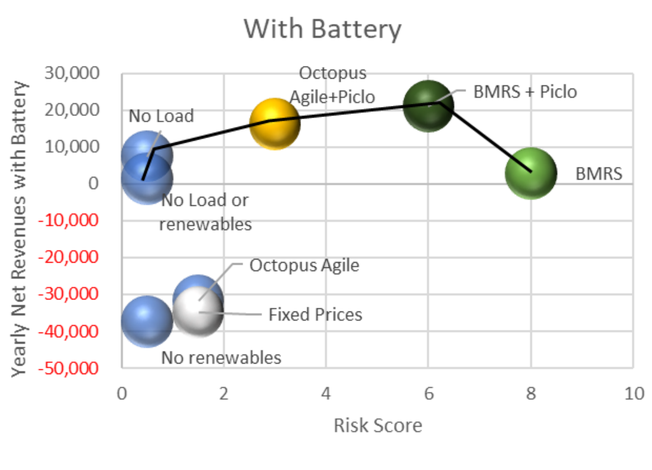
Portfolio Management: Reward vs Risk



Business Model Assessments: Reward vs Risk

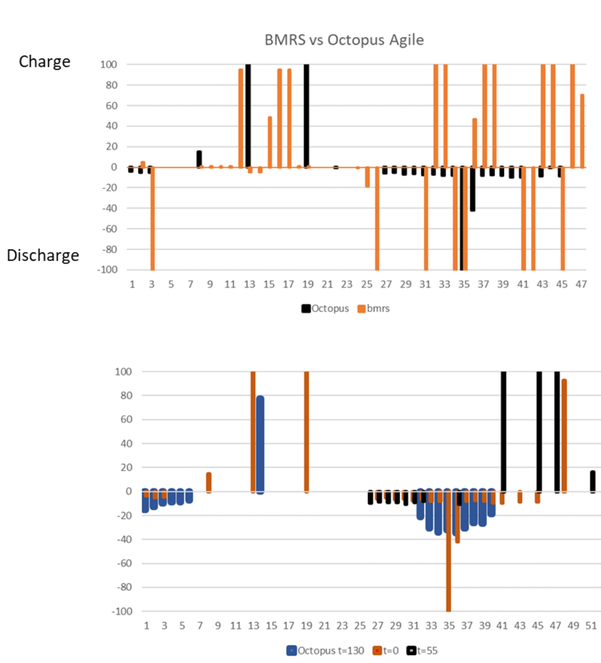


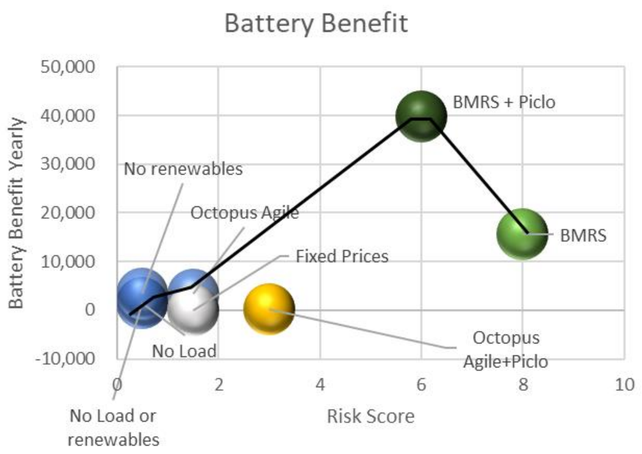
(a) Yearly Net Revenues (Without Battery)



(b) Yearly Net Revenues (With Battery)

Battery Dispatch Example: Same Asset but different Markets





(c) Battery Benefit

Assets Asumption						
Load	**Renewables**	**Market**	**Net Revs without Battery**	**Net Revs with Battery**	**Battery Benefit**	**Risk Score**
Load (ETC +other 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

(d) Tabular summary

CIRED
ROME, ITALY
12-15 JUNE 2023

Business Models for Virtual Power Plants & their Impact on Economic Operation

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

SMART INTEGRATED ENERGY SYSTEMS

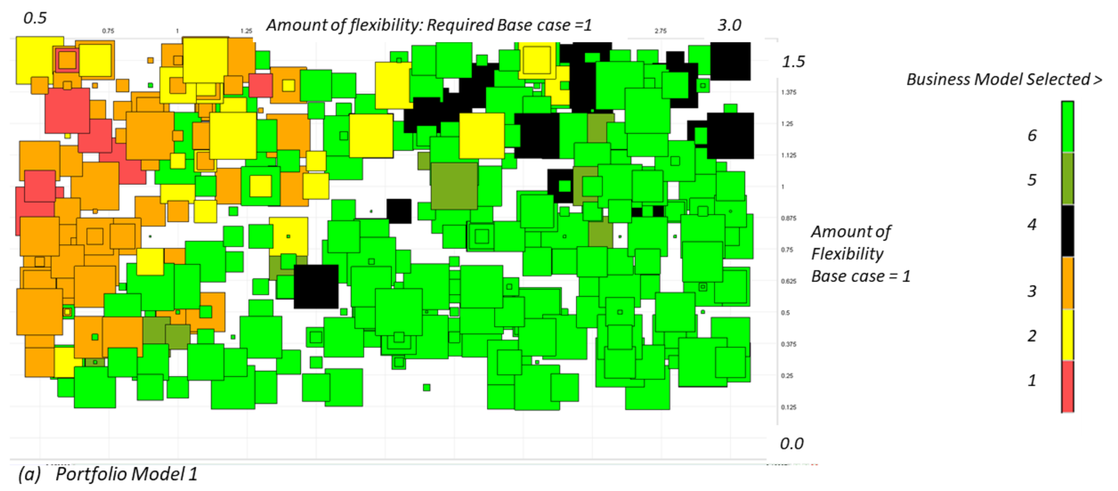
SIES [Smart Integrated Energy Systems: Enhanced Virtual Power Plant VPP+ Energy Pool Integration for Local and Regional Resistance]

Future Work: Initial Results

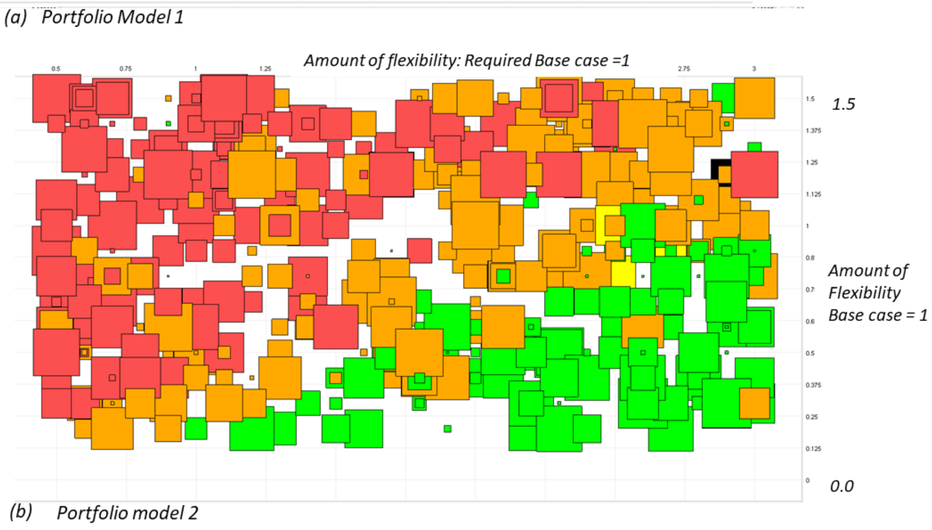
Overview

- 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:
  - Flexibility requirements (grid location).
  - Amount and type of flexibility available.
  - 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



(a) Portfolio Model 1



(b) Portfolio model 2

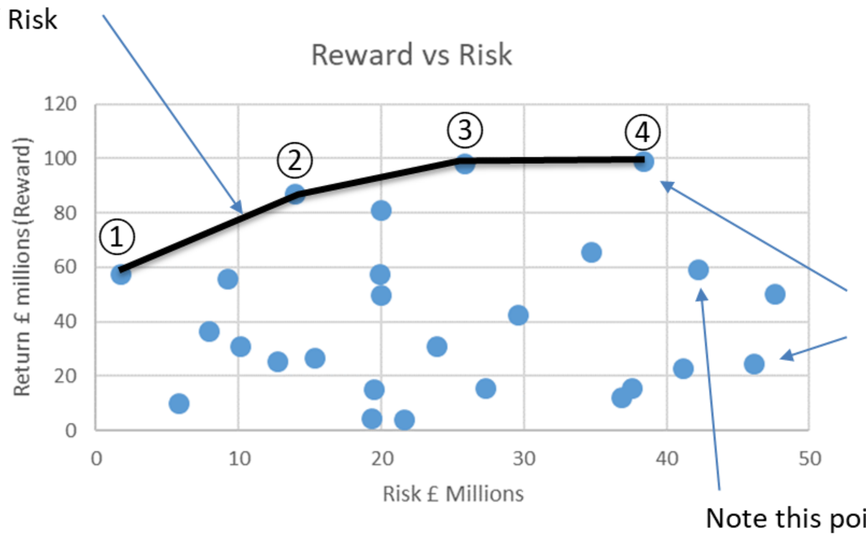
Note :
Six Business /models. Last three include risk managment

Size of Tile –Conventional Generation available for flex

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

Efficient Frontier Highest return for same level of Risk



Portfolios ① - ④, lie on the efficient frontier

Note this point has a higher risk and lower return than point ④, so is not on the efficient frontier

References

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