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Splitting Water

A Cost-Benefits Analysis

08/12/2020

About the Speaker

Simon Porter

- Studied Automotive Engineering at Loughborough University

- Spent 10 Years in Aerospace;
  - Maintenance Programme Management
  - Cost Reduction Engineering
  - Process Development (ERP Introduction)

- 18-Months with tpgroup as a Cost Consultant

About *tpgroup*

tpgroup provide consulting, digital solutions and bespoke engineering services and solutions across the full lifecycle of mission and safety critical programmes in Defence, Space and Energy.

Consulting

Feasibility Analysis

Enterprise Transformation

Digital Service Delivery

Programme Delivery & Support

Digital Solutions

Autonomy

Asset Optimisation

Digital Engineering

Safety Critical Software

Bespoke Engineering

Renewable Energy

Life Support Systems

Rugged Electronics

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Introduction: Why?

Government Target;

Net Carbon Zero by 2050

- Climate Change is an issue that is growing in public awareness
- In 2019 the UK was the first nation to commit to being 100% Net Carbon Zero by 2050
- There is a significant amount of work required to achieve the target
- Developing the 'Hydrogen Economy' is one option, but what does that mean?

Introduction: What is the Hydrogen Economy?

What is Hydrogen?

- Hydrogen is the most common element in the universe
- On Earth it can be found associated with oxygen as H_2O – Water
- Using an electrolyser to perform electrolysis,
  - Pure water can be split into hydrogen and oxygen atoms.

- Hydrogen is a fuel
  - Combustion of hydrogen in air produces heat,
  - The main by-product of this combustion is water,
  - Thus it is carbon zero at end use.

- The ‘Hydrogen Economy’ is the cover-all term for production, storage, transportation and usage of hydrogen.

Introduction: What is the Hydrogen Economy?

What is an electrolyser?

- This is an electrolyser cell stack
- Any number of cells can be stacked between 1 and 150.
- Any number of stacks can be daisy-chained to produce more hydrogen

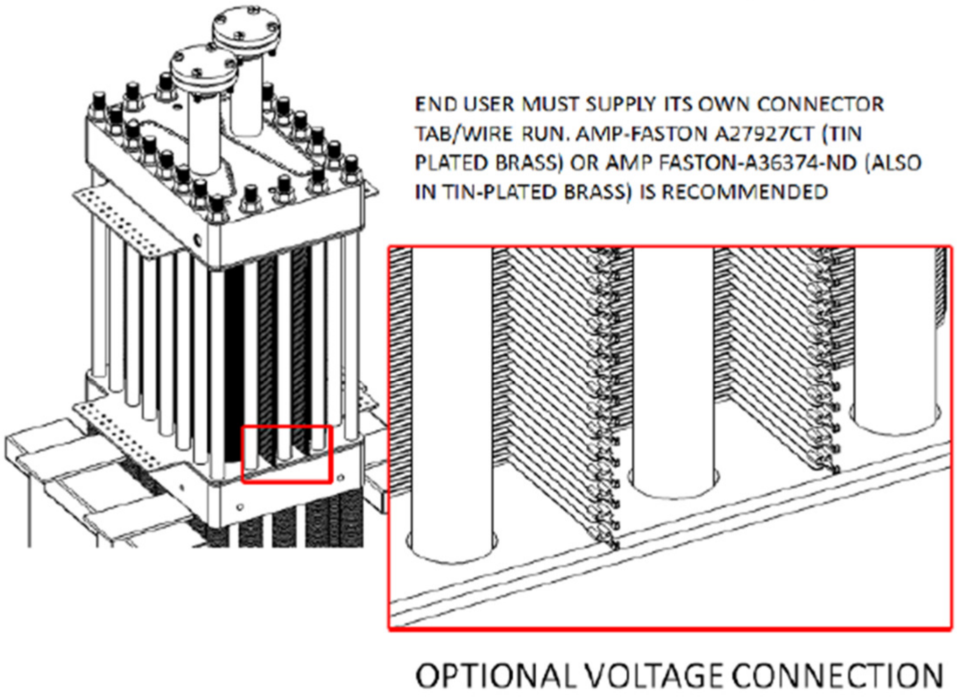

Figure 8. Stack Electrical Connections

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Situation: Study Background

Hydrogen application in this study

- Situation;
  - Hospitals often have an undersized Combined Heat and Power (CHP) plant
  - Existing CHP's can usually be converted to run on a percentage of hydrogen
  - New CHP's can run on 100% hydrogen
  - Hospitals also use oxygen for patients
  - Hospitals have a large Carbon Footprint

- Question;
  - How much does a CHP powered by hydrogen supplied by an on-site electrolyser cost,
  - What are the associated benefits to the hospital and society??

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Approach

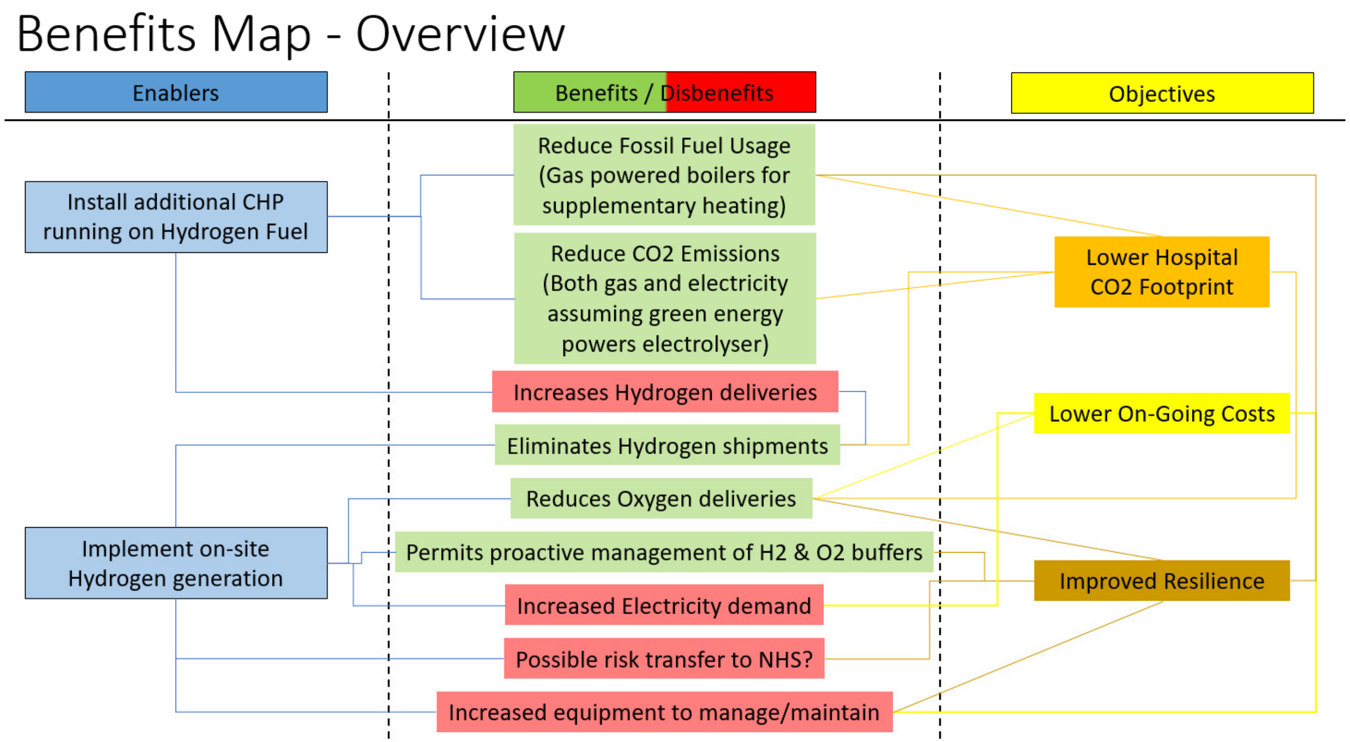
Options analysis

- Do Nothing – No Carbon Footprint Reduction
- Do Minimum – Install an LNG powered CHP to meet additional demands
- Option 1 – Install a hydrogen CHP with supplied hydrogen
- Option 2 – Install a hydrogen CHP with on-site electrolyser

Approach

Benefits mapping

- Option 1 – Hydrogen Delivered
- Option 2 – On-Site Electrolyser



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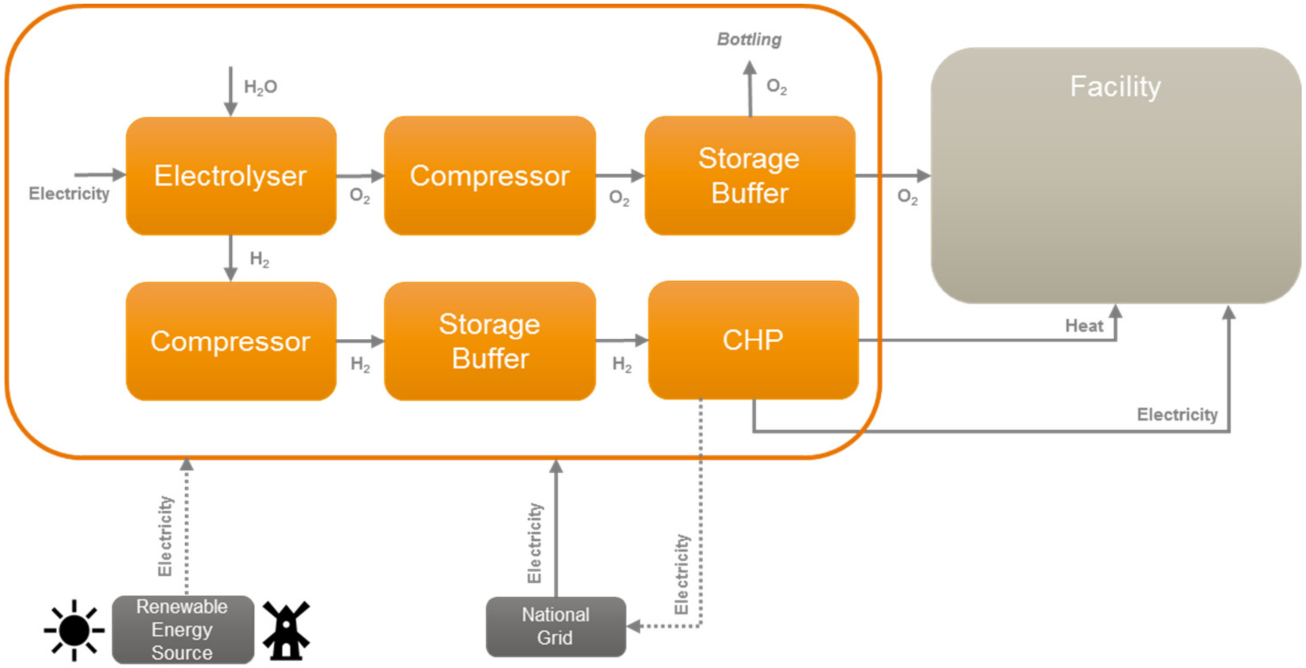
Approach

Proposed solution

- Hydrogen CHP
- On-Site Electrolyser
- Hospital receives;
  - Heat
  - Electrical Power
  - Oxygen



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Approach

What is to be costed?

- Is there more than one solution configuration?
- What CHP’s are applicable?
  - How do they operate?
  - How much do they cost to procure?
  - What are the running costs?
  - How much hydrogen is required?
- How big will the electrolyser need to be?
  - How much to procure and run at the required level?
  - How much oxygen will the electrolyser produce?
- Can the current carbon footprint be established?
- Can the benefits to the hospital and wider community be quantified?
- What other variables need to be considered?

Approach

Option 2 – Configurations

- Configurations due to the following variables;
  - 2 x CHP Choices
  - 2 x Electrolyser sizing methods
  - CAPEX/OPEX Choice
  - Opportunities for 'Overproduction' and sale
  - Storage / Buffer size

Config. Reference	CHP	Electrolyser		
		Sizing		
No.	Size	CHP Draw	Preference	Overproduction
1	Medium	Max	CAPEX	None
2	Large	Max	CAPEX	None
3	Medium	Av.	CAPEX	None
4	Large	Av.	CAPEX	None
5	Medium	Max	OPEX	None
6	Large	Max	OPEX	None
7	Medium	Av.	OPEX	None
8	Large	Av.	OPEX	None
9	Medium	Max	CAPEX	Hours
10	Large	Max	CAPEX	Hours
11	Medium	Av.	CAPEX	Hours
12	Large	Av.	CAPEX	Hours
13	Medium	Max	OPEX	Hours
14	Large	Max	OPEX	Hours
15	Medium	Av.	OPEX	Hours
16	Large	Av.	OPEX	Hours
17	Medium	Max	OPEX	Max
18	Large	Max	OPEX	Max
19	Medium	Av.	OPEX	Max
20	Large	Av.	OPEX	Max

Approach

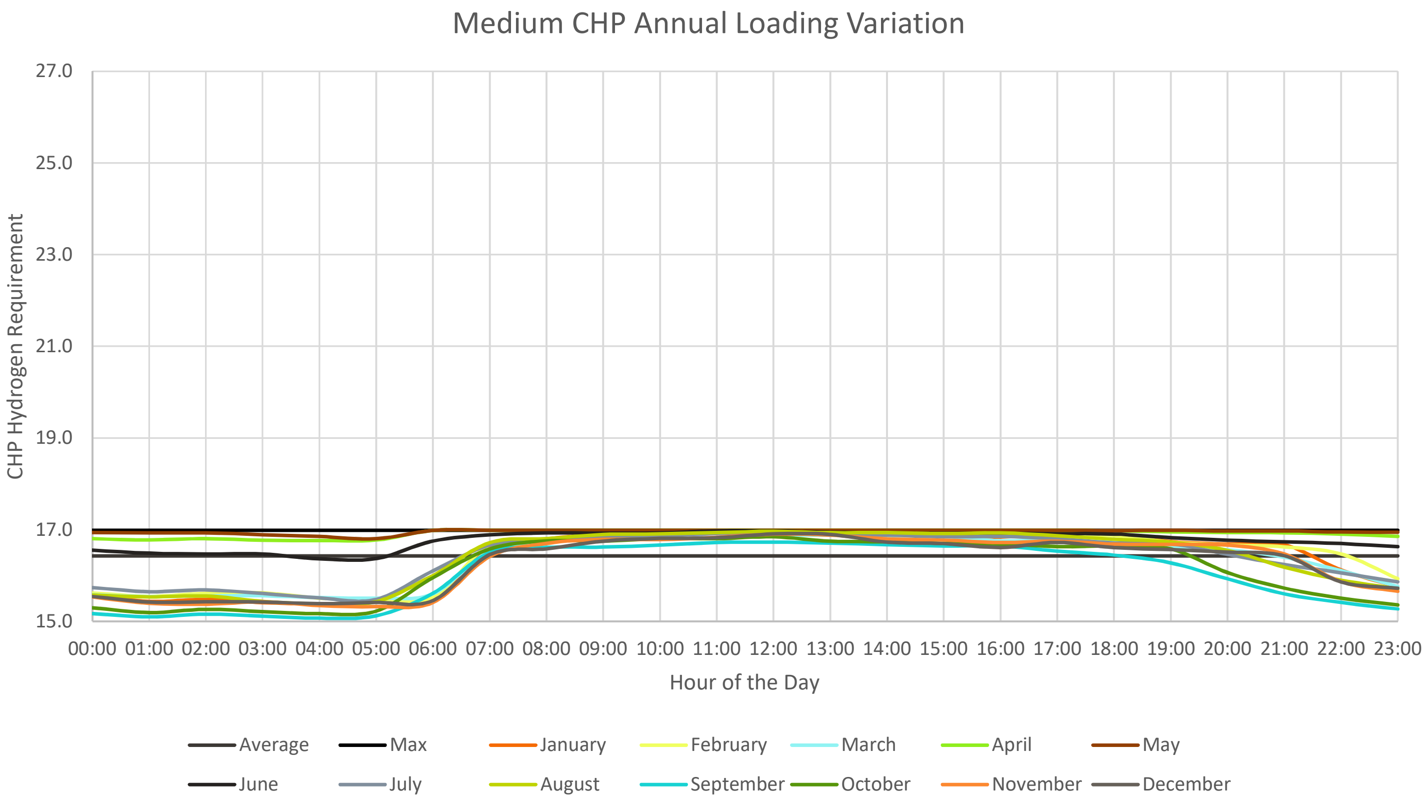
Costing Inputs

- Quotes for both CHP choices
- Quotes for hydrogen storage
- Historic data used for running costs (e.g. £/kWhr)
- Carbon savings based on several datasets for saving areas
- In-house calculator created for Electrolyser sizing – Feed-In model
- In-house cost model used to analyse and compare 20 configurations within Option 2
- 10-Year estimating period, results posted as outturn

Approach

CHP Choices

- Two different CHP's
- Two ways to assess hydrogen requirements
- Linked to cost of storage



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Approach

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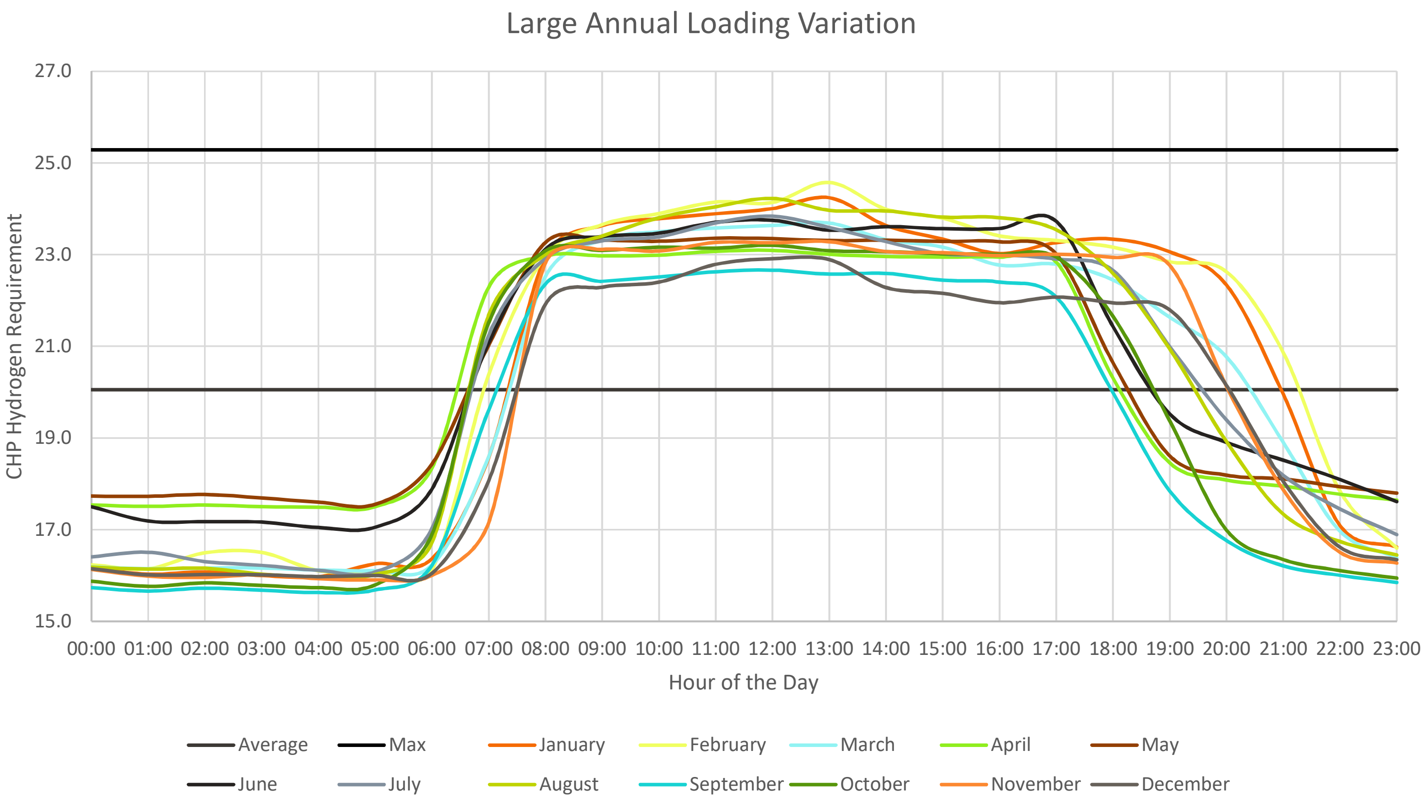

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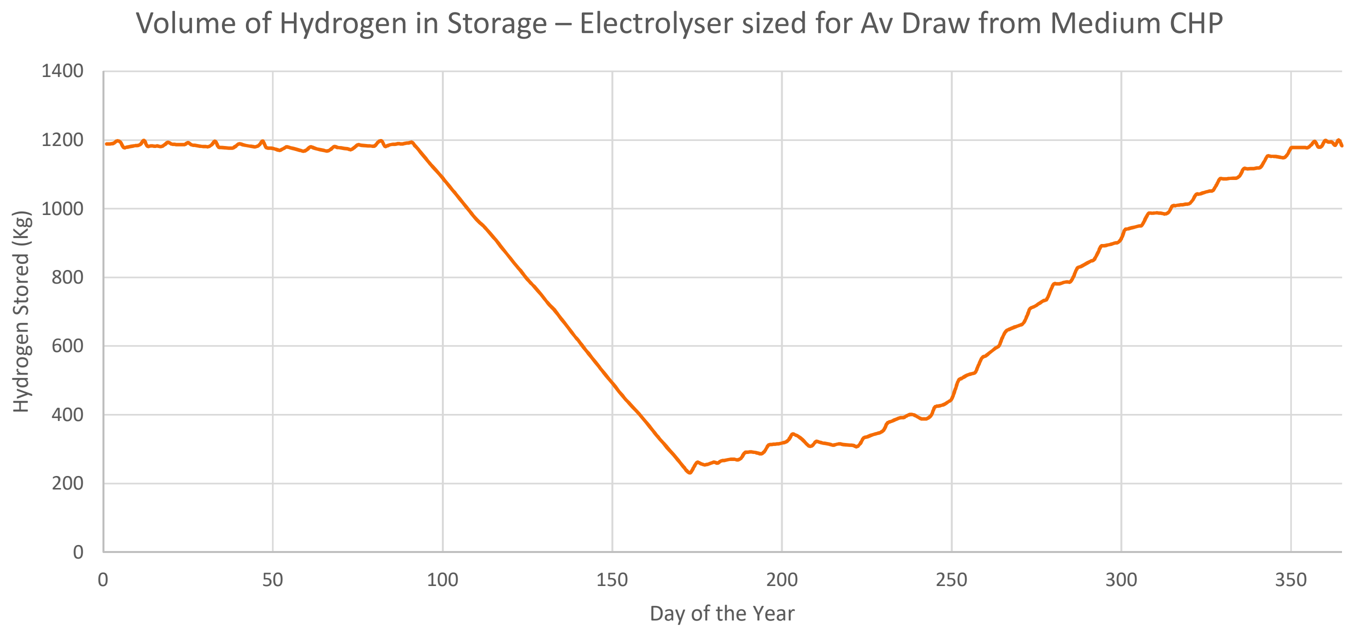
Approach

Storage Impact

- Medium Max = £102,200
- Medium Ave = £365,000

- Large Max = £146,000 (higher than Medium because you need a bigger buffer)
- Large Ave = £642,400



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Approach

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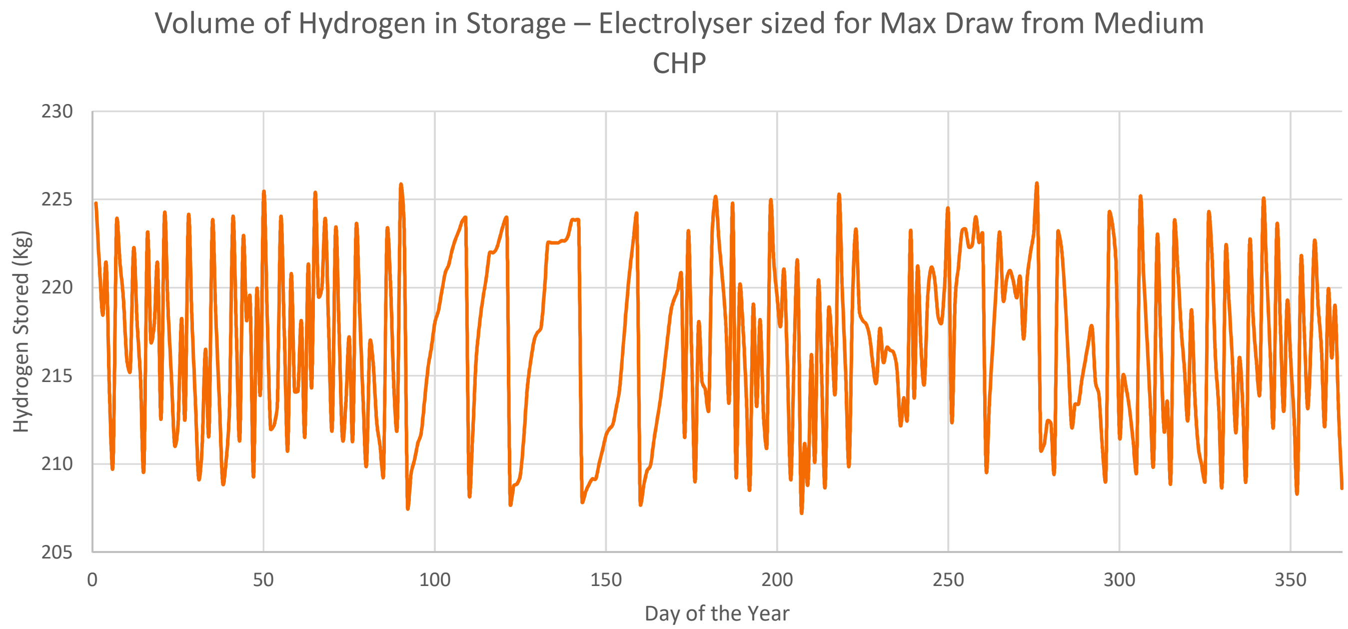

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Approach

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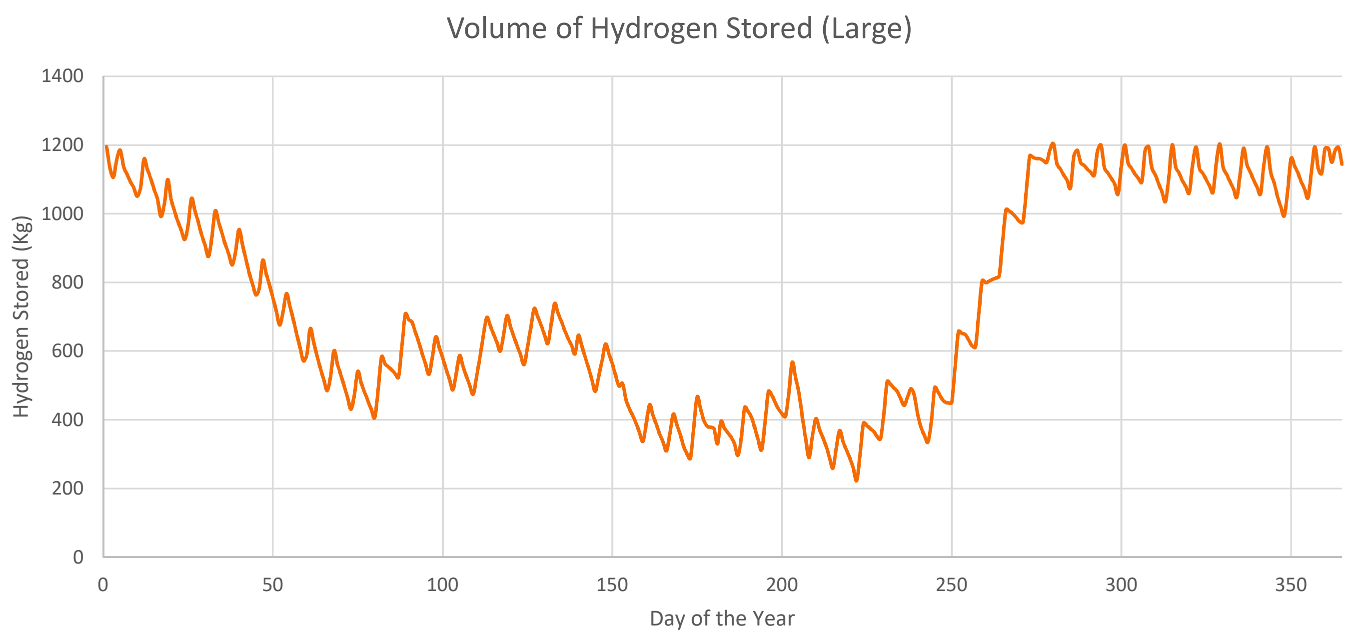

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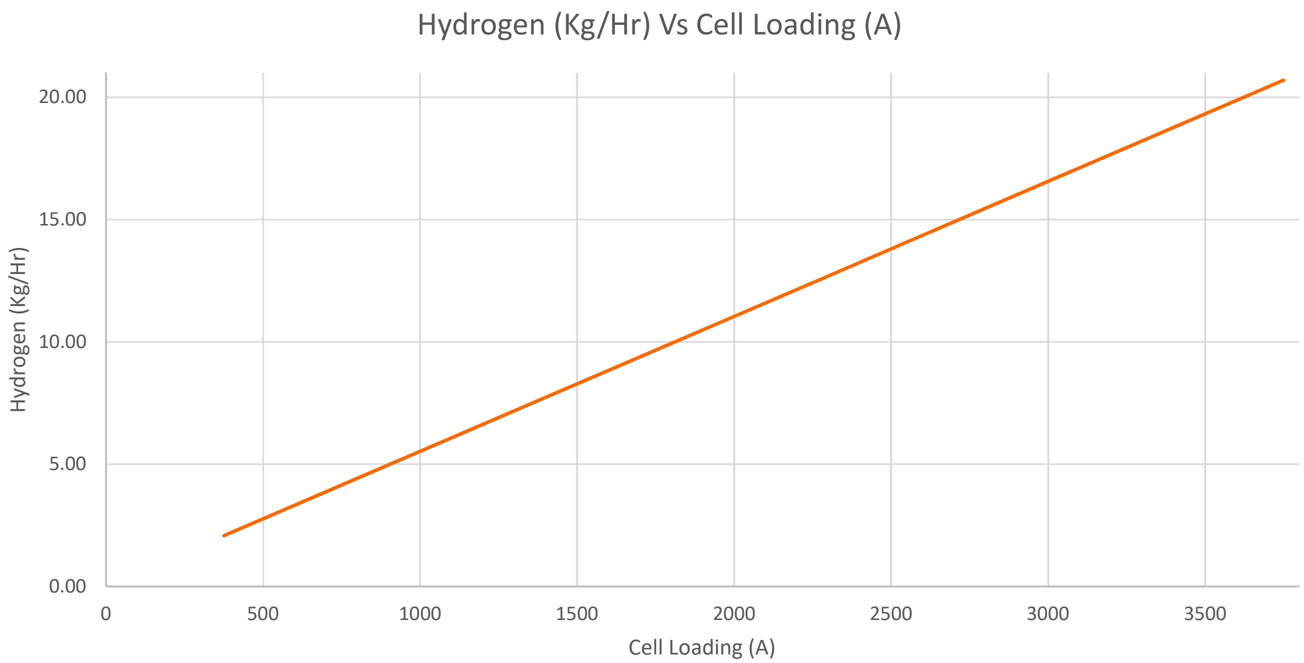
Approach

CAPEX or OPEX focus?

- How does loading affect output & efficiency?
- How does sizing of the electrolyser stack change the CAPEX / OPEX balance?



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Approach

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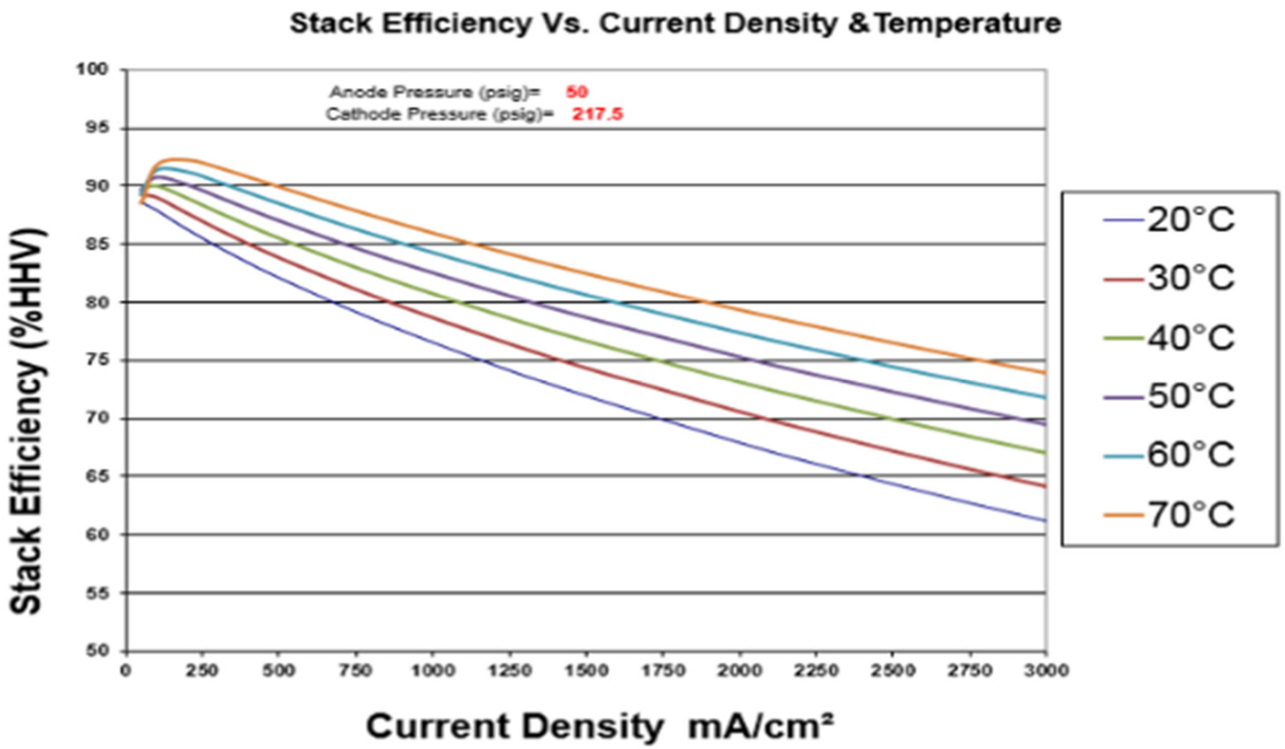

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Approach

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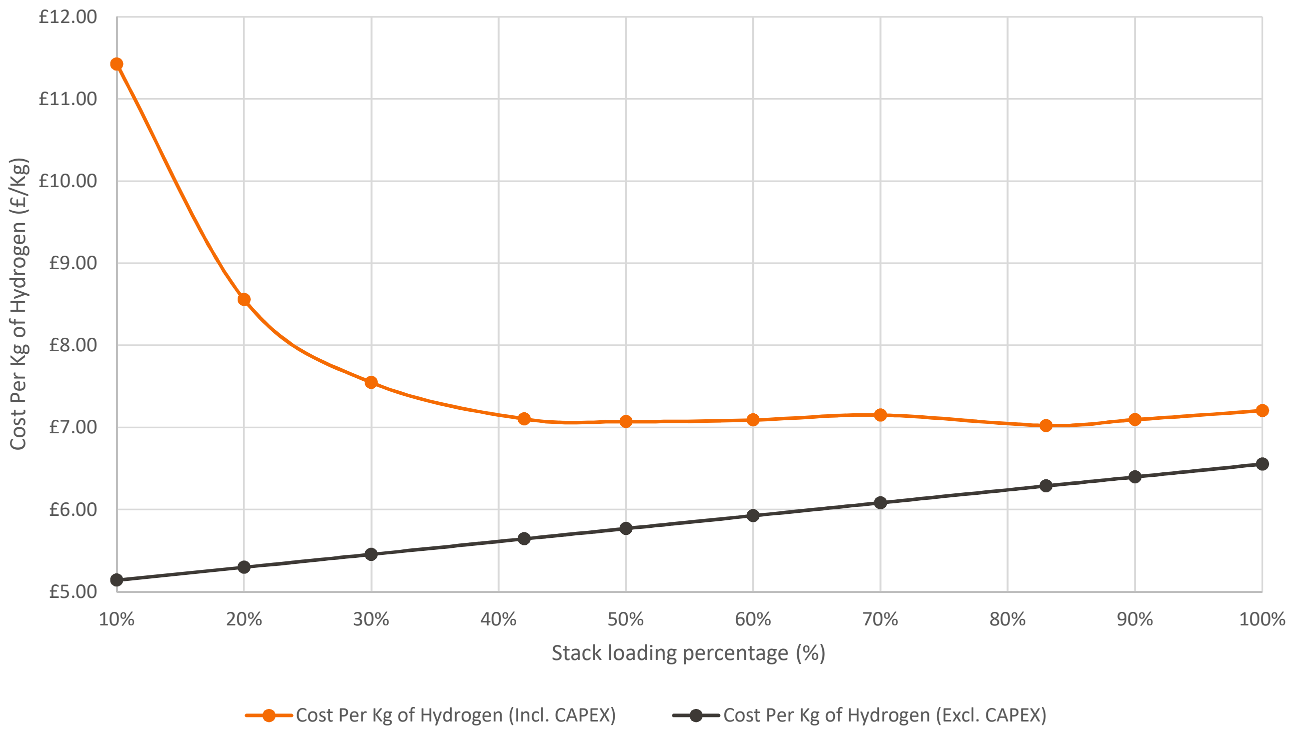

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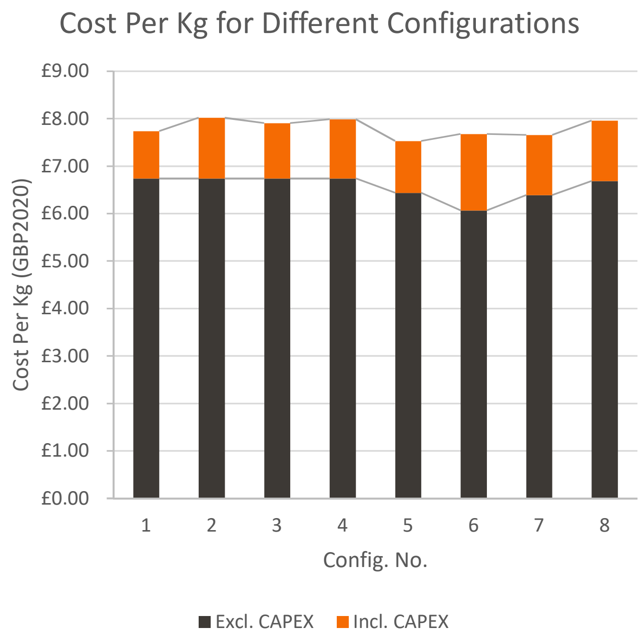
Results

Outputs

- Scenario 1: No Over-Production
- Config. 1-4: 100% Load
- Config. 5-8: Optimised



Config.	CHP	Draw	Load
1	Medium	Max	Stack runs at 100% Load
2	Large		
3	Medium	Average	
4	Large		
5	Medium	Max	Stack size Maximised
6	Large		
7	Medium	Average	
8	Large		

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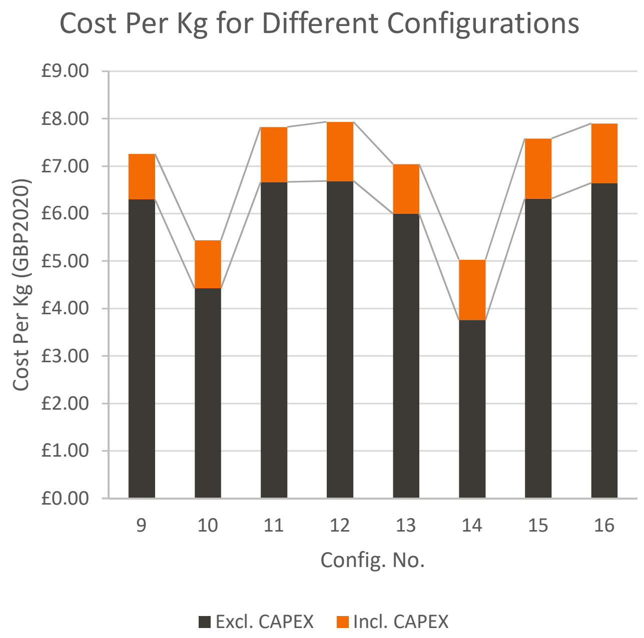
Results

Outputs

- Scenario 2: Extra Hours for Over-Production
- Option 9-12: 100% Load
- Option 13-16: Optimised



Config.	CHP	Draw	Load
9	Medium	Max	Stack runs at 100% Load
10	Large		
11	Medium	Average	
12	Large		
13	Medium	Max	Stack size Maximised
14	Large		
15	Medium	Average	
16	Large		

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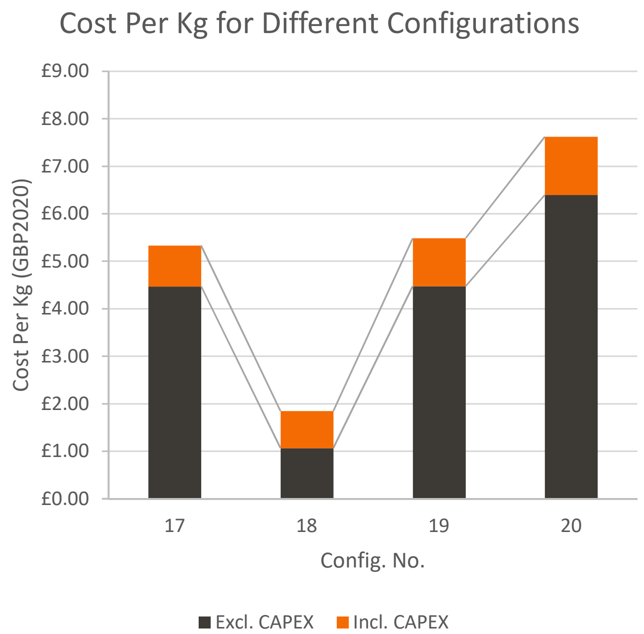
Results

Outputs

- Scenario 3: Maximum Production
- All Options Optimised



Config.	CHP	Draw	Load
17	Medium	Max	Stack size Maximised
18	Large		
19	Medium	Average	
20	Large		

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Results

Costs Summary

- CAPEX / OPEX balance decisions on a case-by-case basis
  - Consider opportunities for sale of excess hydrogen – create hydrogen hubs?
  - Short-term CAPEX focus results in higher OPEX in the long term
  - Maximising stack size creates opportunities for future development

- 'Best' option in this scenario:
  - Configuration 5 – Electrolyser sized for maximum draw of smaller CHP with a single full-sized stack
  - Smaller storage required
  - Minimal risk – business case is not based on sales of excess hydrogen
  - Lowest overall cost, lowest cost per Kg assuming no sales

- NOTE: Option 1 – Hydrogen Delivery cost was identified at £20/kg

Results

Benefits Summary

- Reduced Carbon Footprint
  - Reduced usage of LNG for heating
  - Reduced oxygen deliveries
  - Avoidance of Carbon levies
  - Green electricity is ESSENTIAL!

- Increased resilience
  - Additional oxygen supply
  - Directly controlled oxygen availability
  - On-site hydrogen buffer & CHP provides reserve of power and heat

- Lower on-going costs
  - Not realised due to the current cost of electricity!

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Conclusions

Recommendations

- Bigger is better – up to a point…!
  - Efficiency improves, but be mindful of the CAPEX/OPEX balance
- There is no one-size-fits-all answer
  - Electrolyser sizing requires understanding of many variables
- Currently, going green costs money
- As the hydrogen economy develops, costs are anticipated to improve
  - Improved availability of well-priced renewable energy
  - Opportunities for hydrogen hub development

Further Work

Further Investigations

- Renewable energy
  - On-Site generation – solar, wind, geothermal power
- Refined system design & operation
  - Innovative control algorithm to optimise output
- CHP heat storage
  - Overcome possible timing issues with supply of heat
- Hydrogen hub development
  - Improve value proposition of excess capacity

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