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ATTEYA, A.I. and ALI, D.

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Modelling Real-World Renewable Hydrogen Energy Systems for Enabling Scotland Zero-Carbon Ambition

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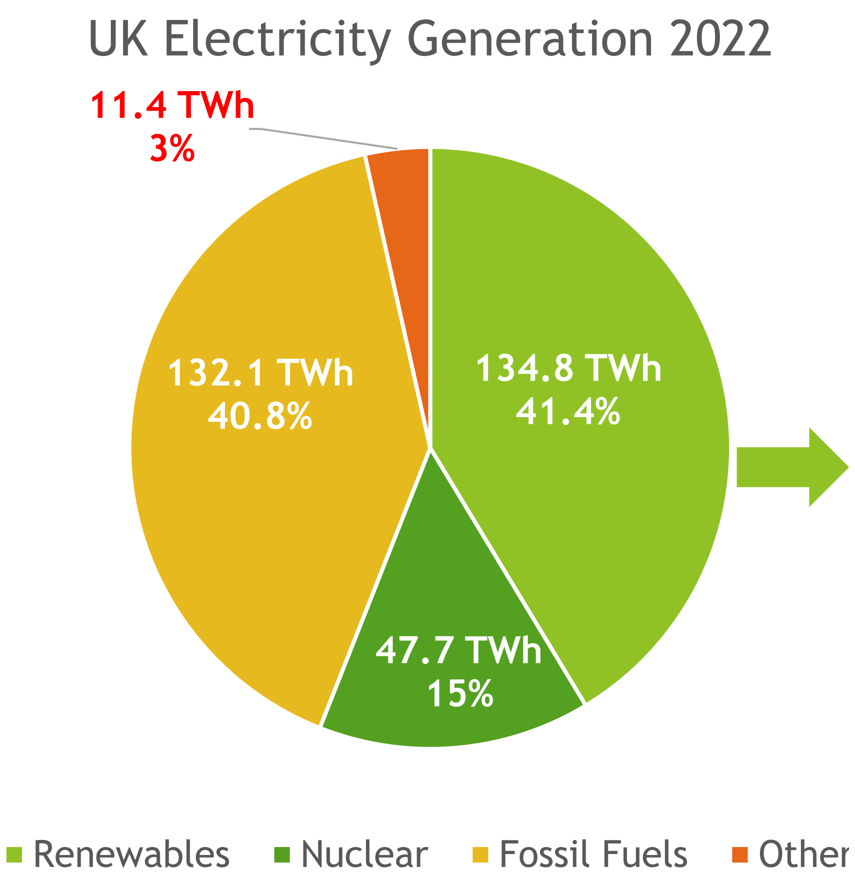
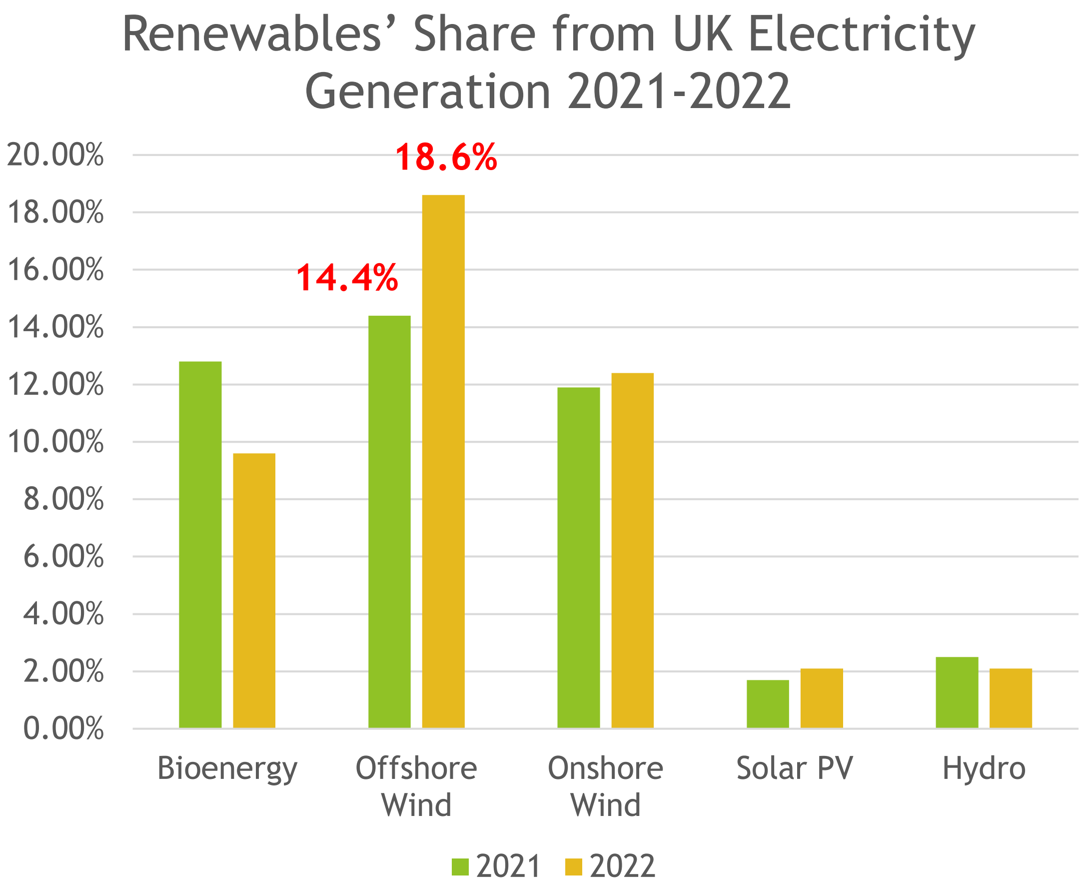
UK Energy Outlook 2022

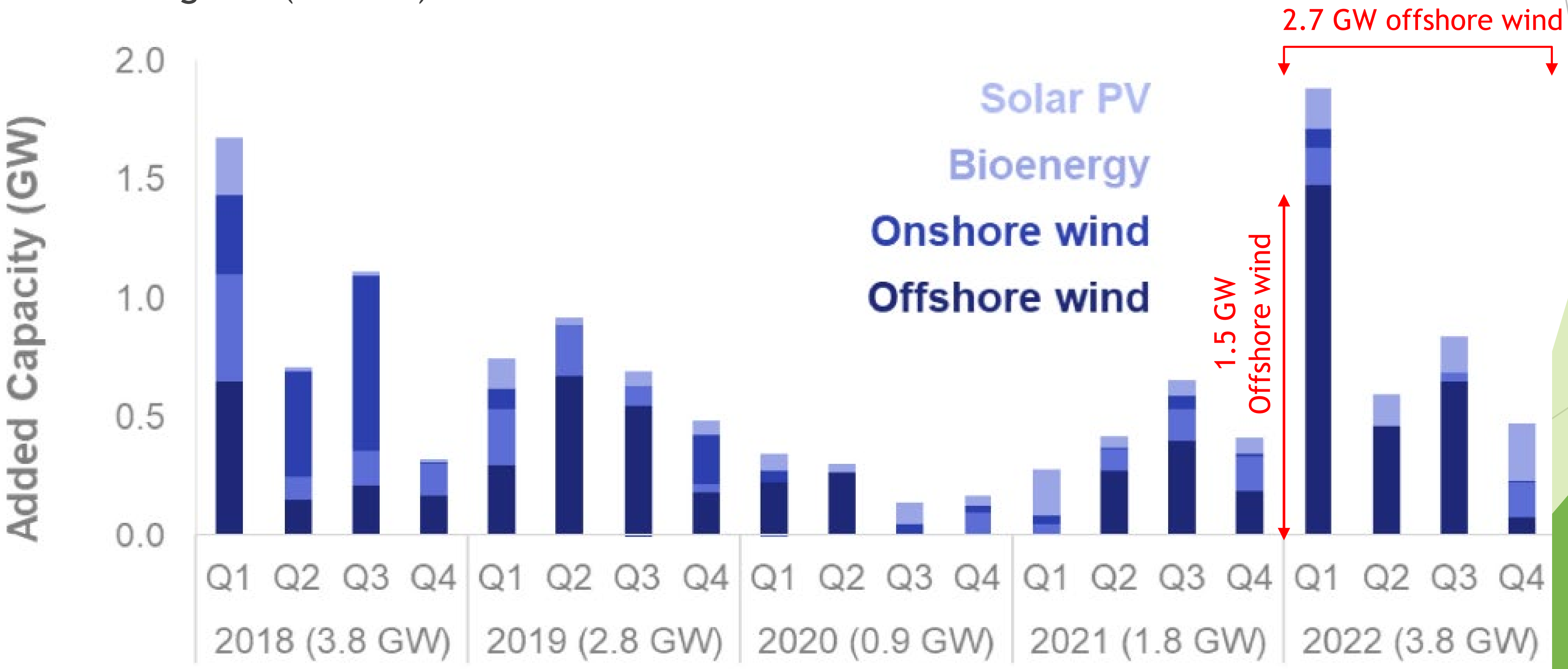
- Energy trends in UK electricity generation were dominated by an increased record of offshore wind energy in 2022 compared to 2021.





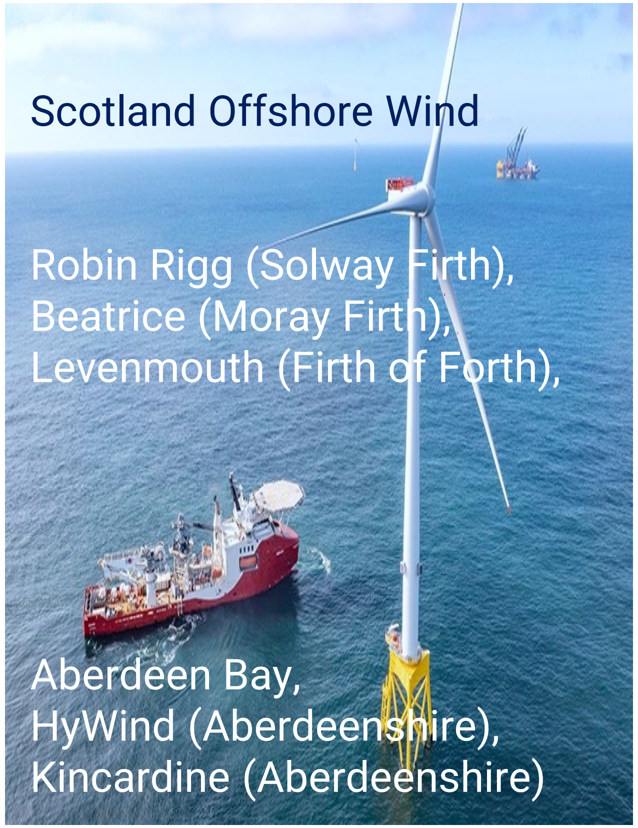
UK Energy Outlook 2022

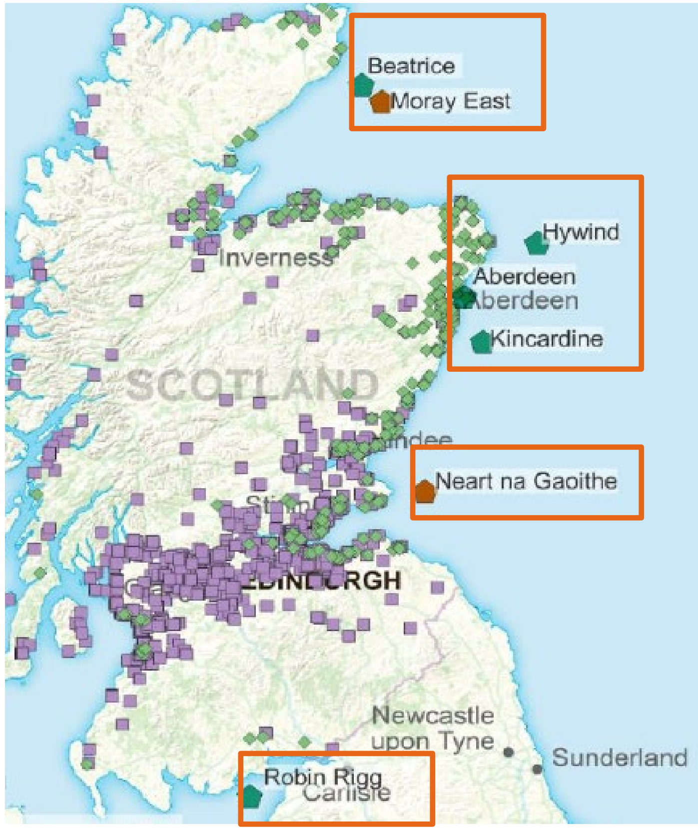
- In the first quarter of 2022, 1.5 GW was installed in offshore wind alone.
- In total 2.7 GW in offshore wind was installed in 2022 including key sites at Moray East (1.0 GW) and Seagreen (0.3 GW) in Scotland, as well as Hornsea Two in England (1.4 GW).



Scotland's Renewable Potential

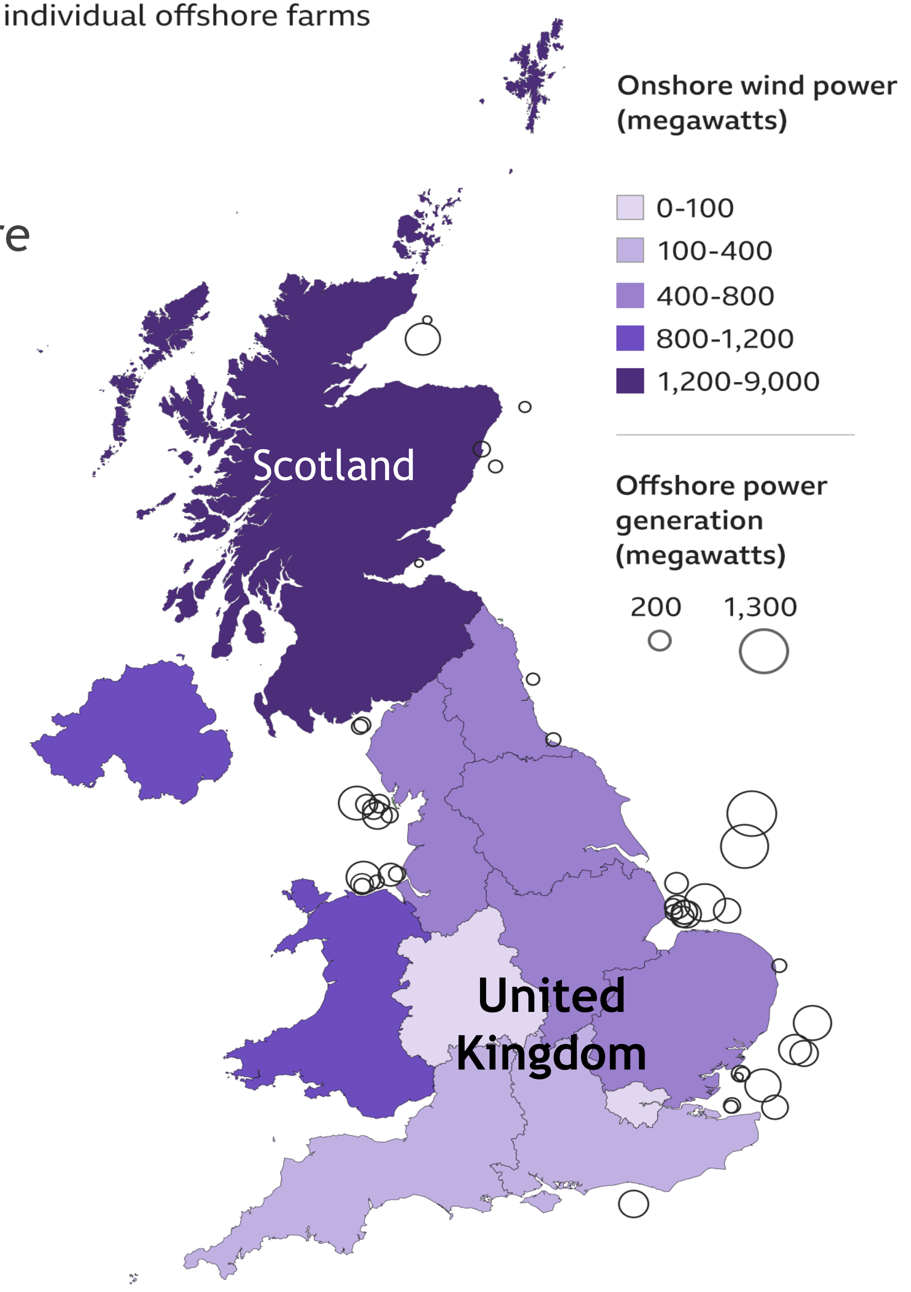
- Onshore Wind: Currently Scotland has over 20 operational onshore windfarms with a total installed capacity of 7.3 GW.
- Offshore Wind: Scotland has six operational offshore windfarms with total installed capacity of around 9.6 GW.





Where does the UK generate its wind power?

Current potential output in megawatts by region and by individual offshore farms



Source: BEIS (2022)

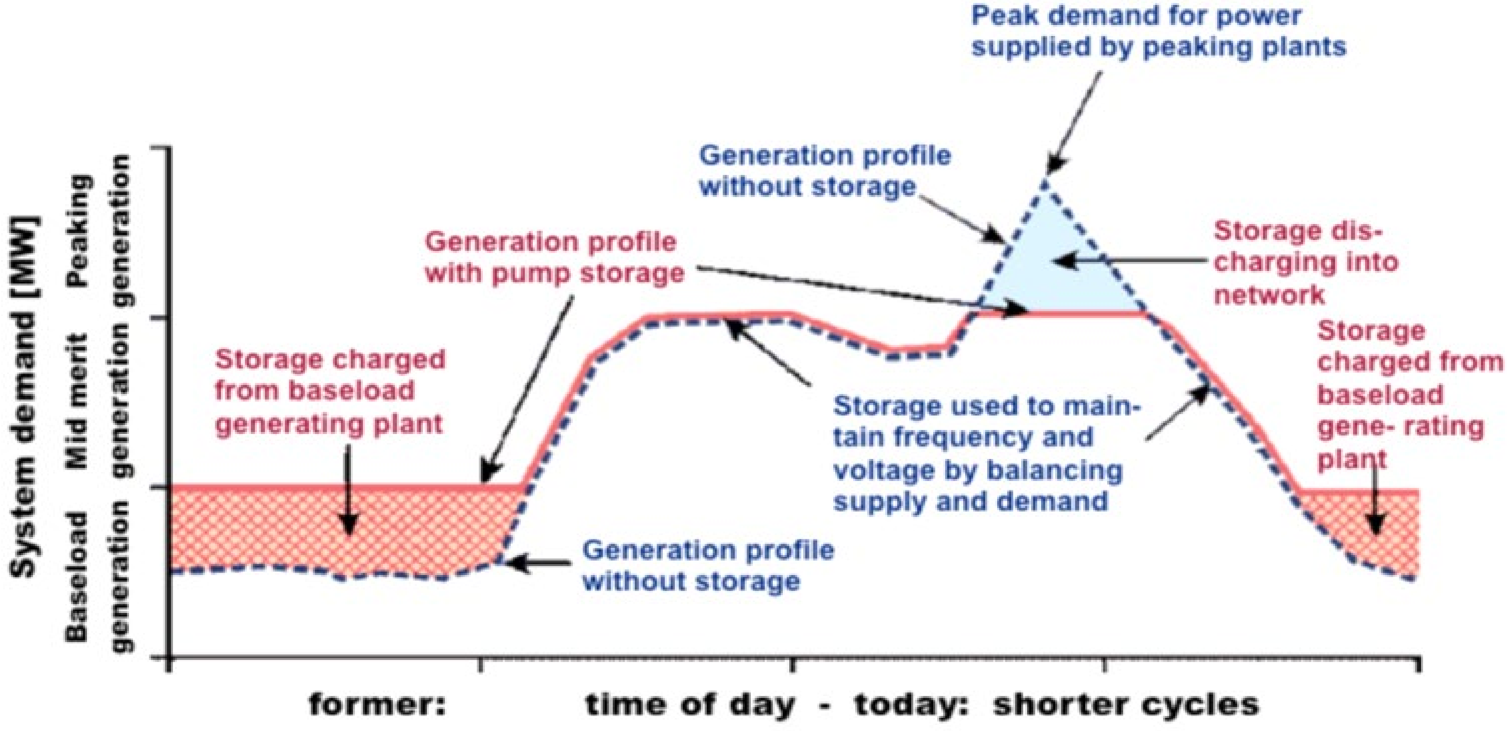
BBC

Can we Fully Exploit All Renewable Potential in Scotland??

Weather or not we can exploit full renewable potential in Scotland depends on a number of factors: weather conditions, capacity factors and the usage of adequate energy storage systems to absorb the excess of renewable energy.

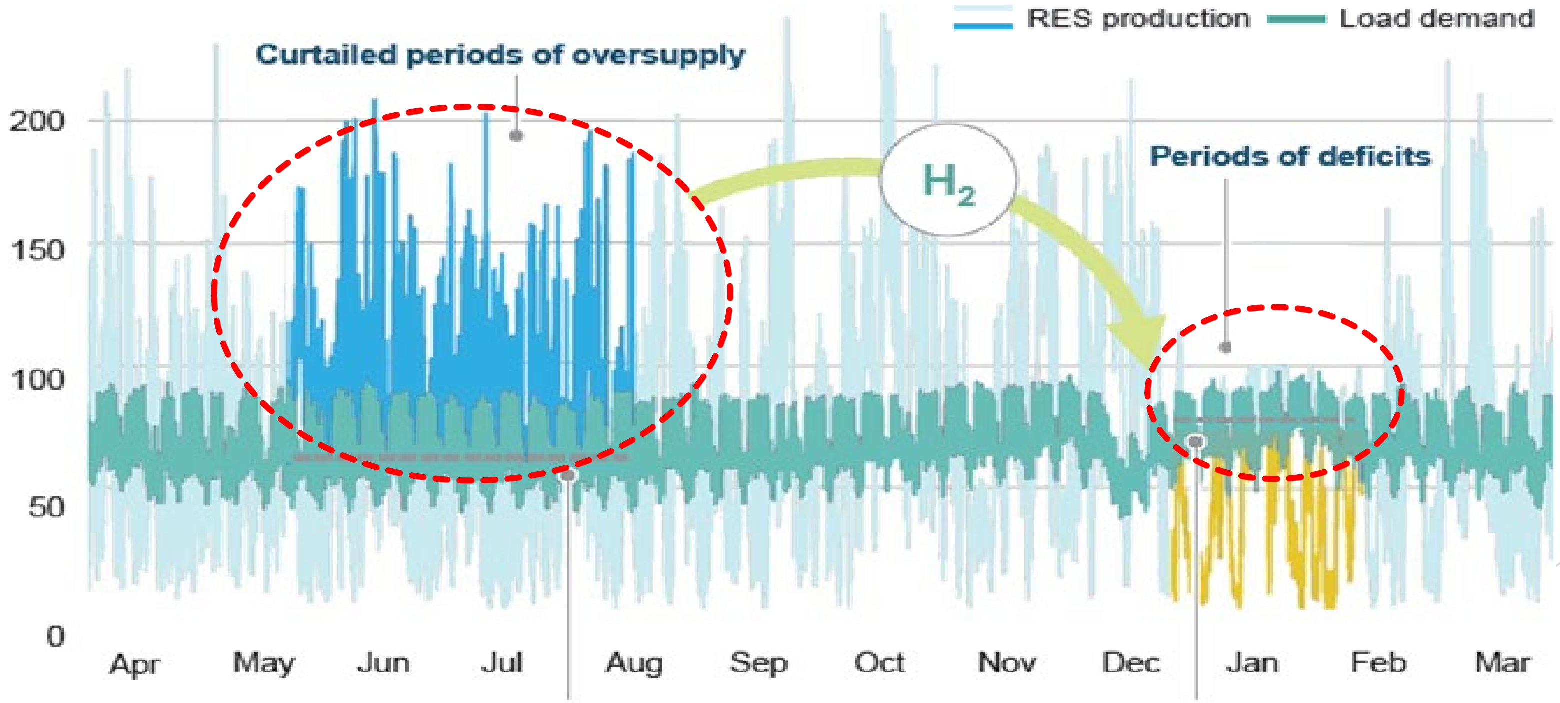
The need for Energy Storage Systems

- Renewable energy systems are subject to significant variability due to their intermittent nature.
- Integrating energy storage systems is then crucial to balance between generation and consumption and unlock the full renewable potential.



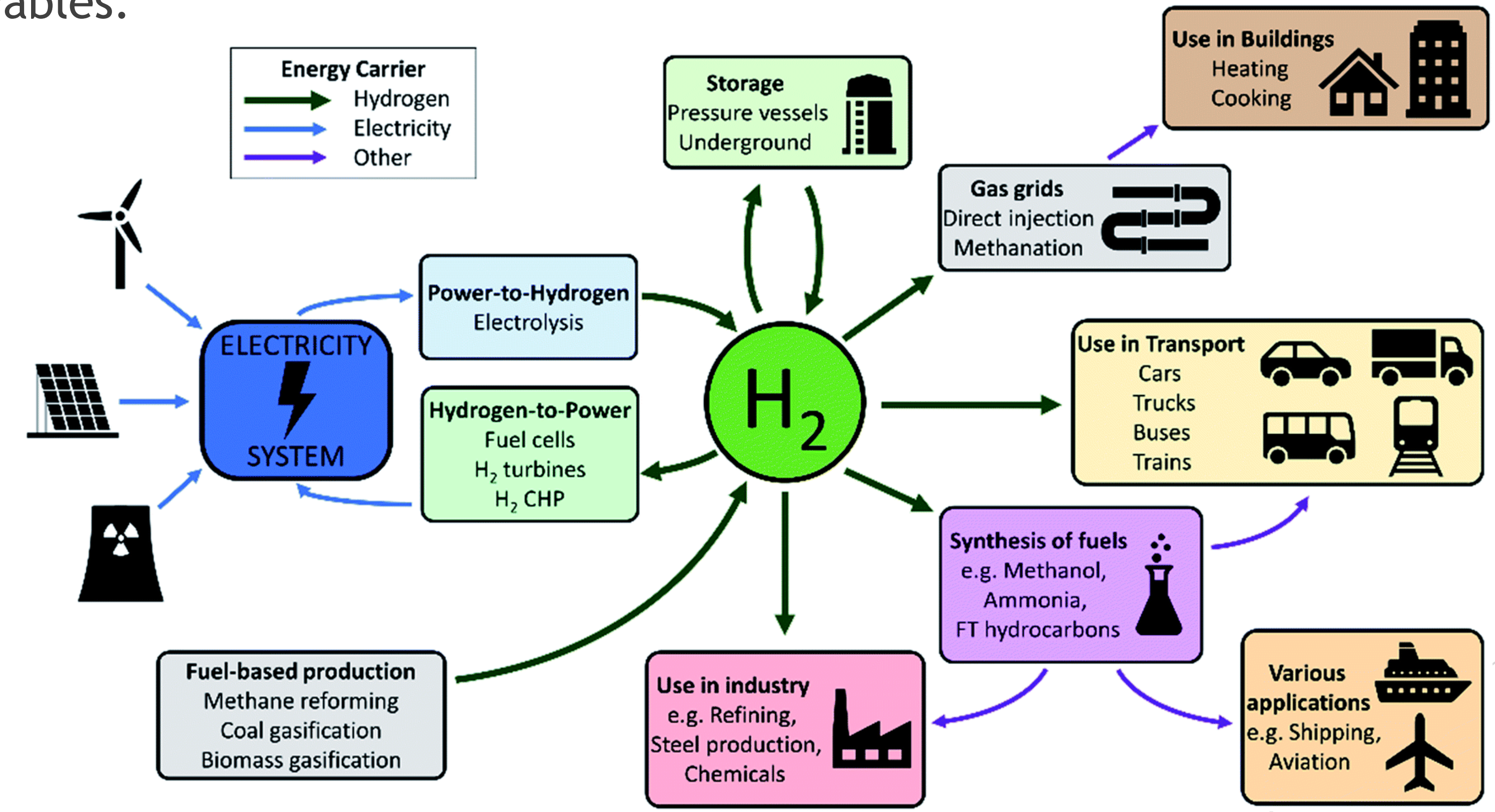
Green Hydrogen Energy Storage Systems

- H2 is a free-carbon energy carrier that can be used to store the surplus of renewable power generation, thus allowing the large-scale integration of renewables and realizing Scotland's decarbonization goals.
- The Scottish government has recognized the potential of H2 energy and set out a target of generating 5GW of low-carbon and renewable hydrogen by 2030.

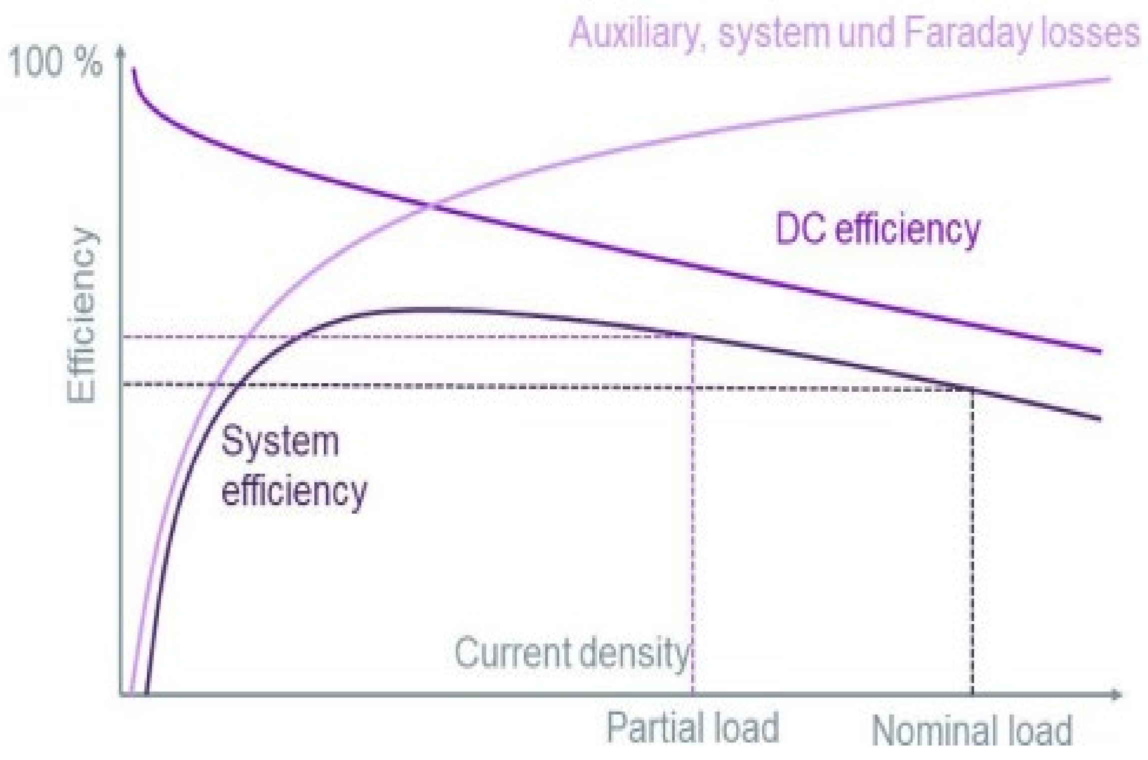


Why Hydrogen?

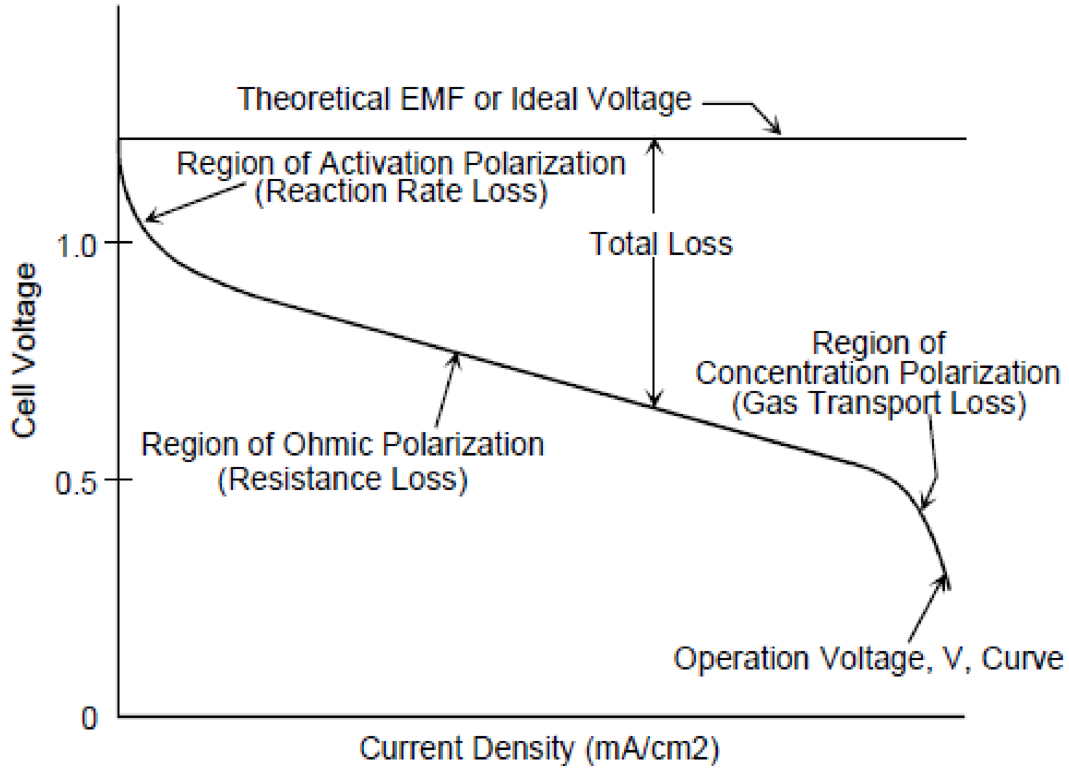
- H2 is versatile and offers greater flexibility in decarbonizing the energy supply chain by providing multiple energy stream revenues: electricity, heat and fuel.
- H2 is distinguished from other storage alternatives by its large-scale storage capacity and long-term storage capability, being ideally suitable for seasonal storage of renewables.



Performance of Renewable Hydrogen Energy Storage Systems



Electrolysis Efficiency with increased load operation



Actual Fuel Cell Voltage/Current Characteristics

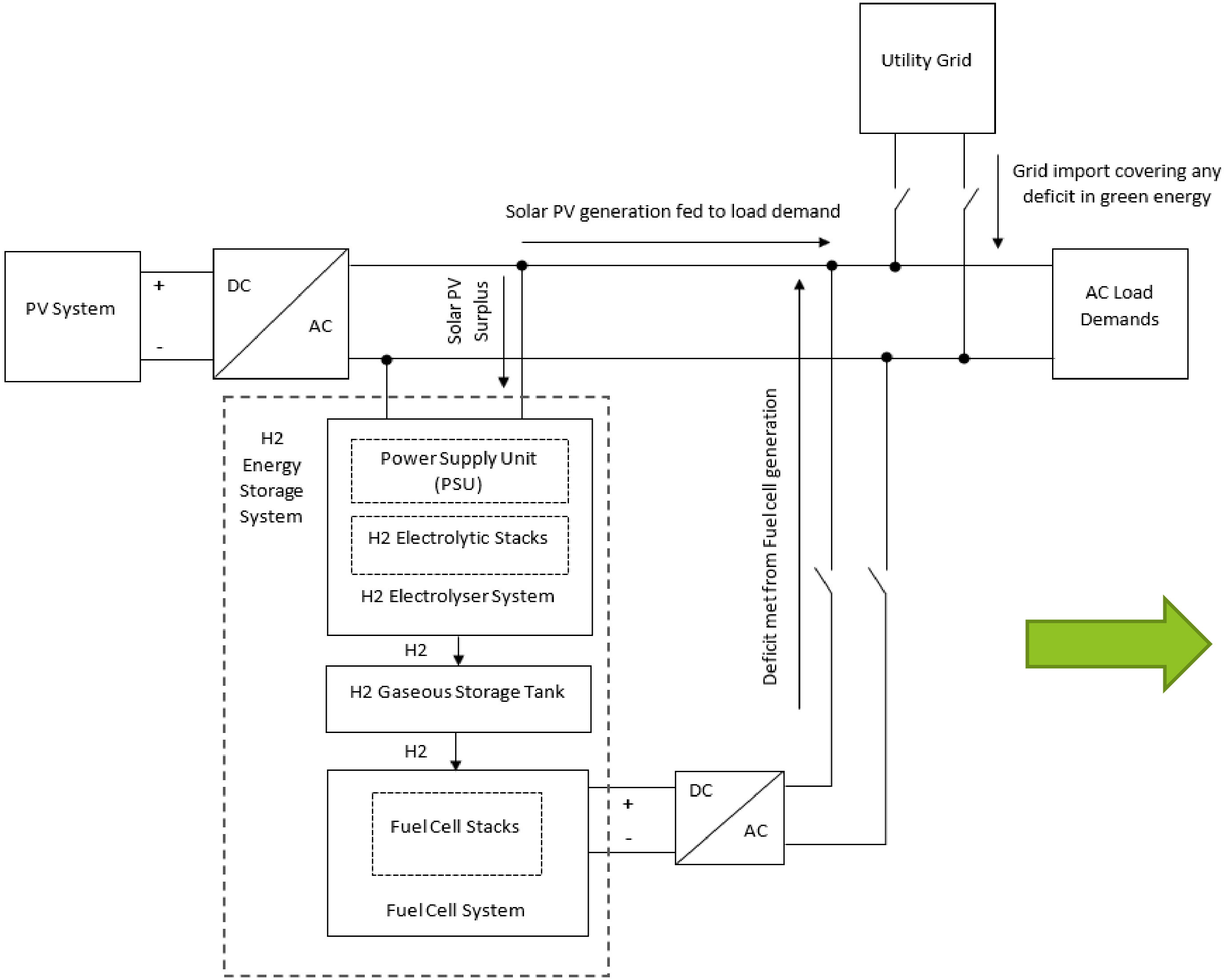
Commercially-available Tools for Modelling Renewable Hydrogen Energy Storage Systems

HOMER simulates and optimizes the operation of Hybrid Renewable Energy Systems

HYDROGEMS as part from TRANSYS performs detailed modelling of Hydrogen Energy Storage systems

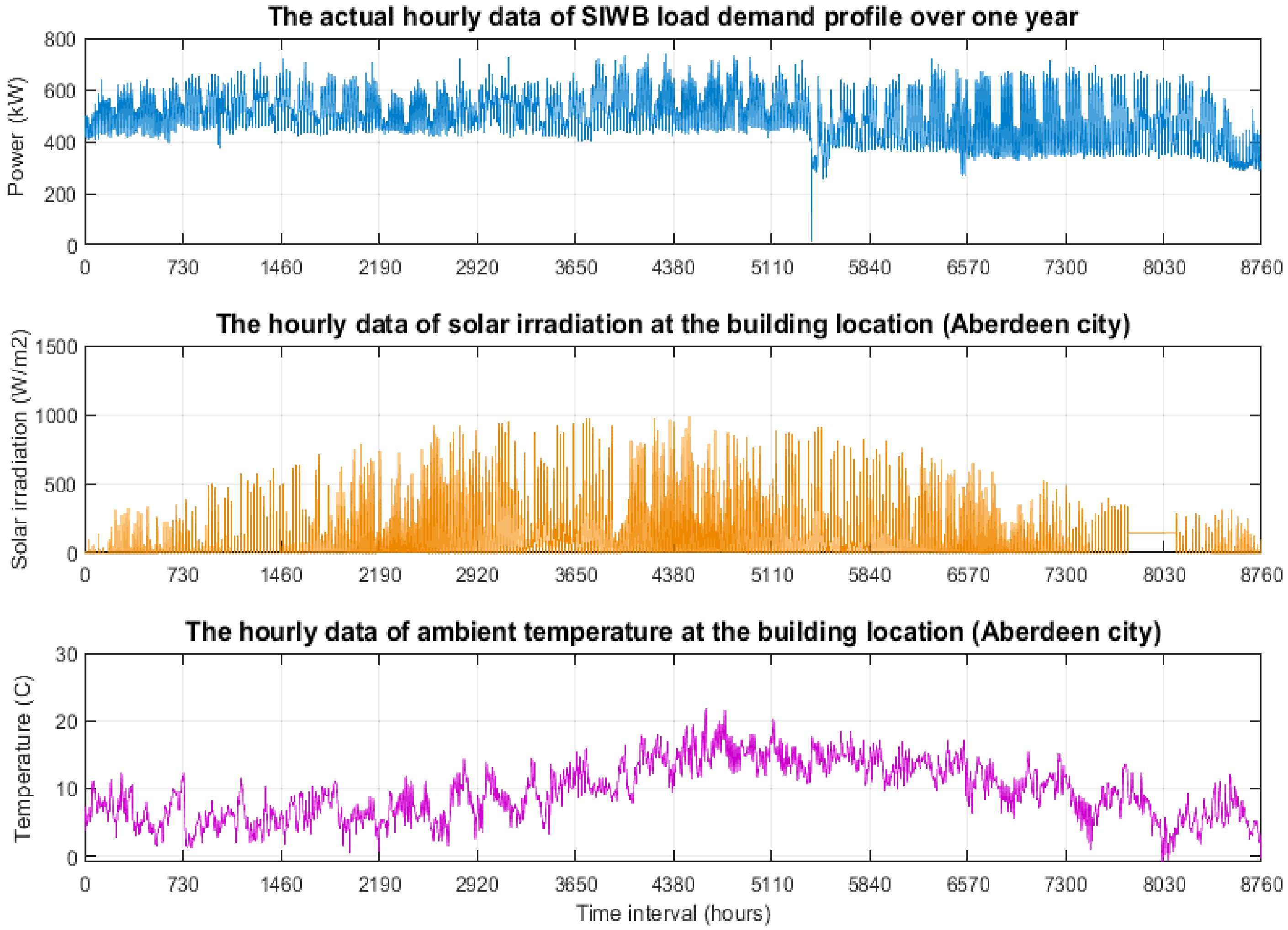
ANSYS simulates and optimizes the internal working of electrolysis and fuel cells

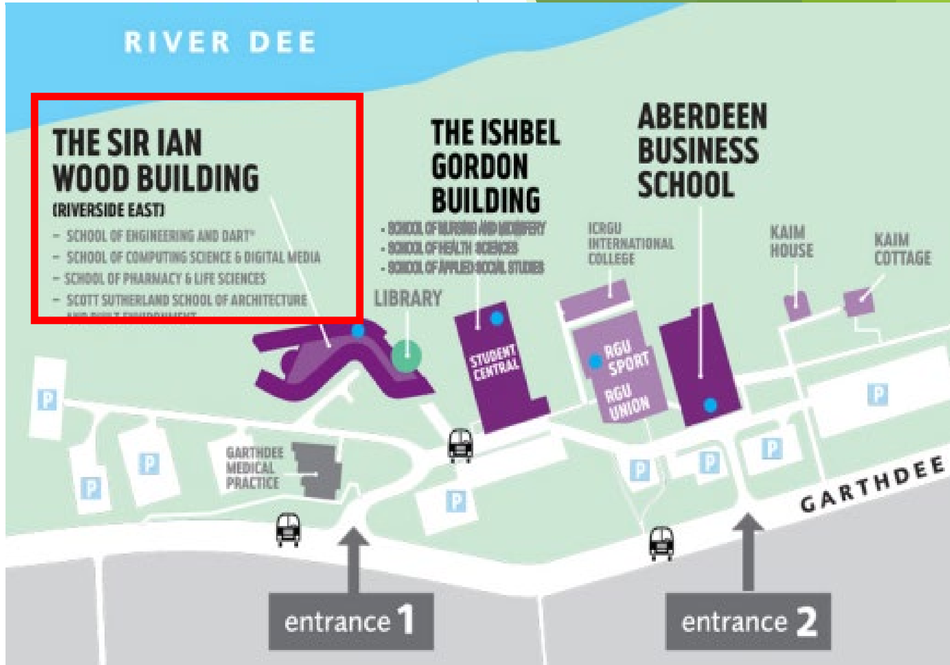
Developing a Precise Dynamic Model for Sizing and Simulating Hybrid Solar Hydrogen Energy Storage (HSHES) Systems



- PV System Model
- Electrolyser Model
- Hydrogen Storage and Fuel Cell Model

Case Study: The Sir Ian Wood Building (SIWB) – Robert Gordon University (RGU)





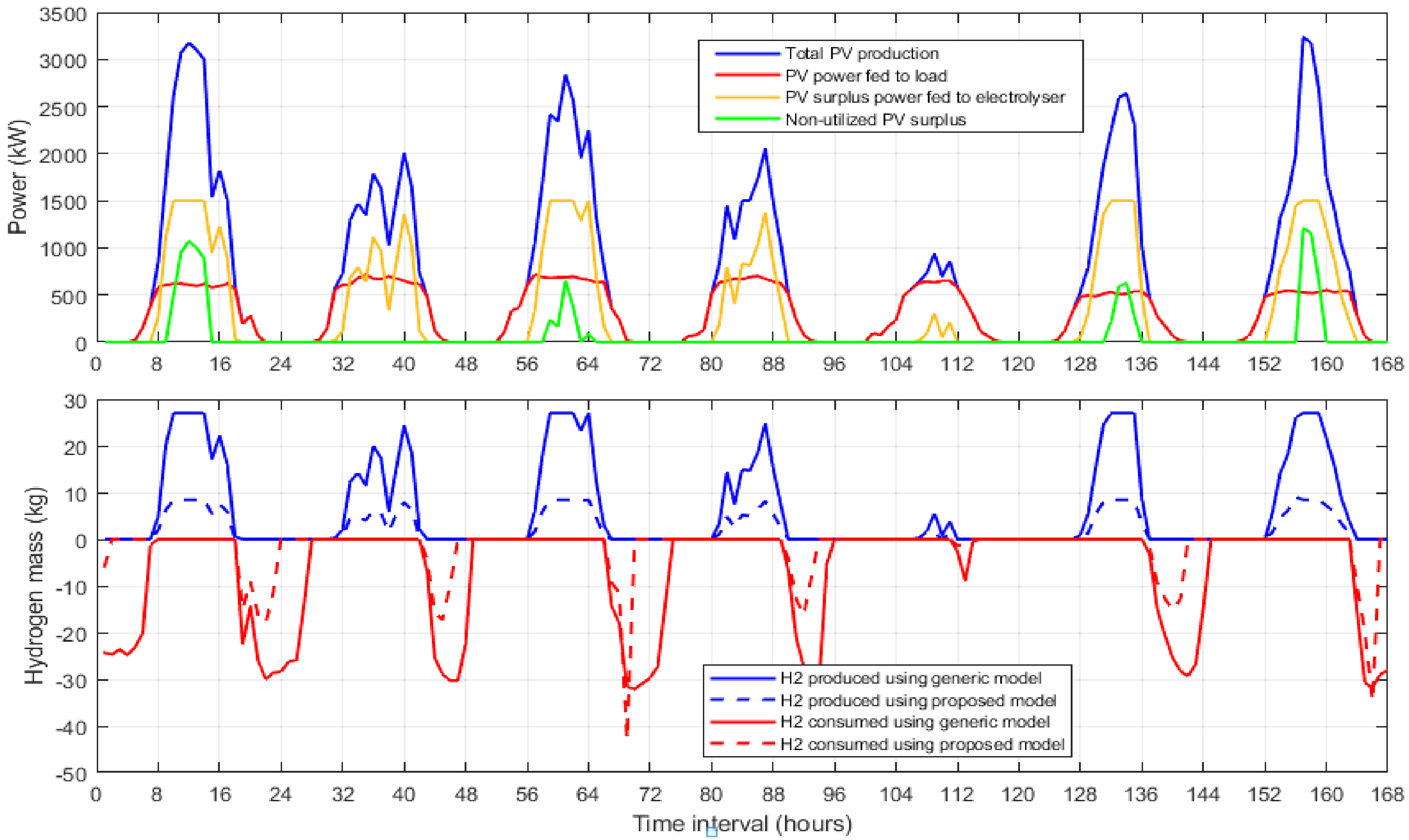
Parameter	Rating
Average Demand	497.2 kW
Peak Demand	738 kW
Total Annual Demand	4.36 GW

Results of the Developed Model

- Sizing Results of the proposed HSHES System for SIWB

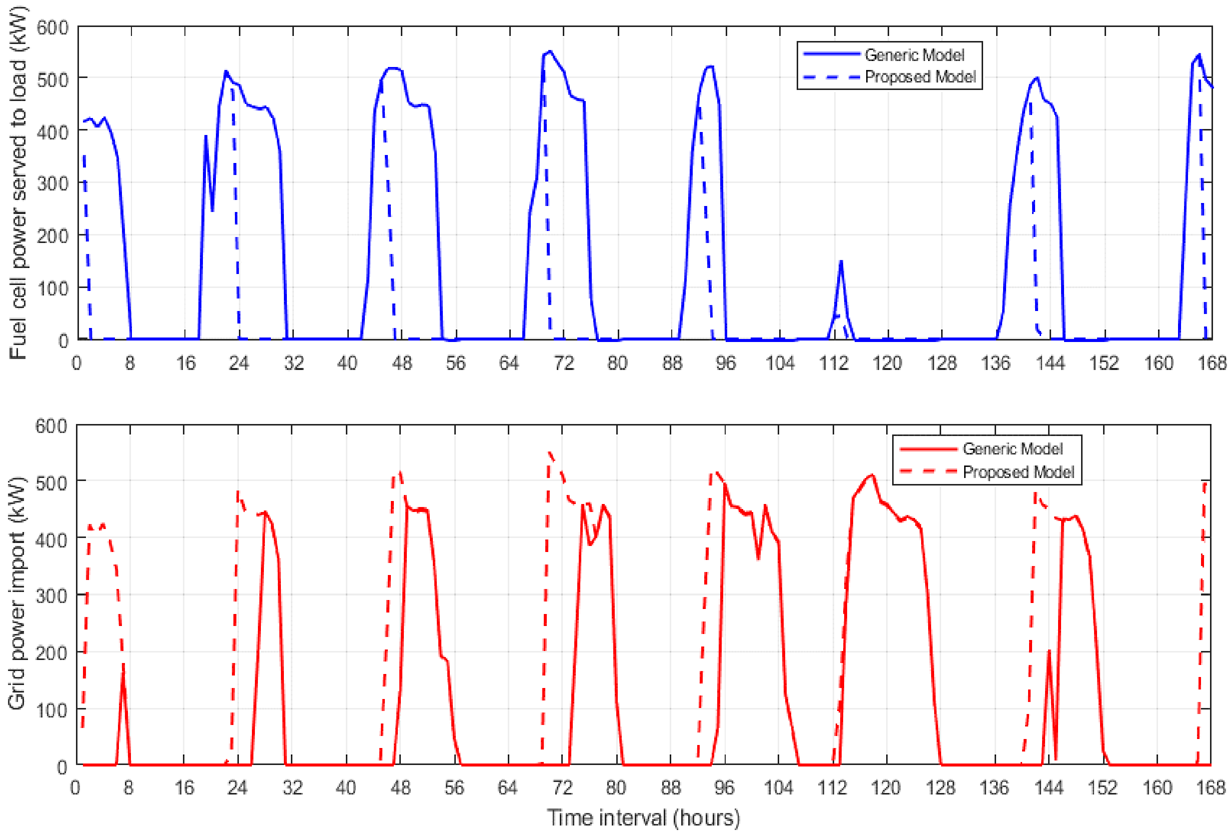
Component	Sized Capacity
PV System	4.15 MW
Electrolyser	1.5 MW
Pressurized H2 Storage Tank	106 kg
H2 gas Cylinder Volume	7.21 m3
H2 Target Pressure	175 bar
Fuel Cell	600 kW

- Simulation Results of the hourly PV production, H2 production and H2 consumption by the sized HSHES System over one summer week

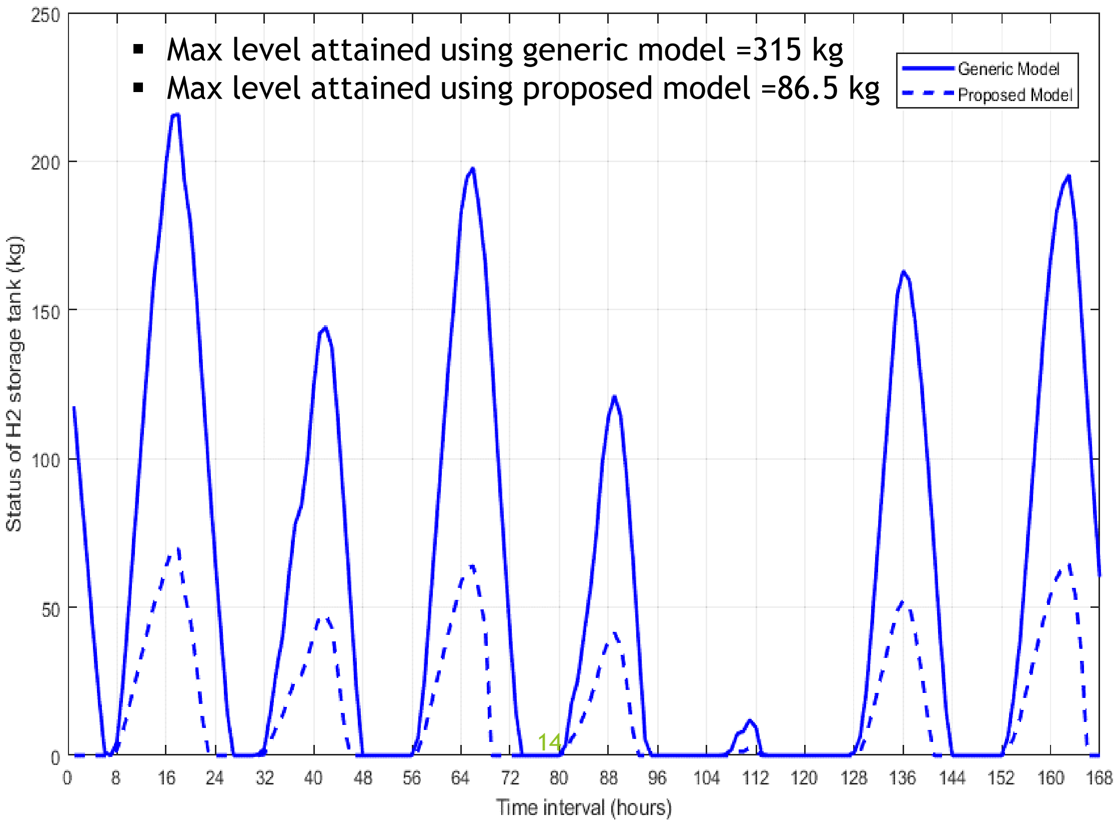


Results of the Developed Model

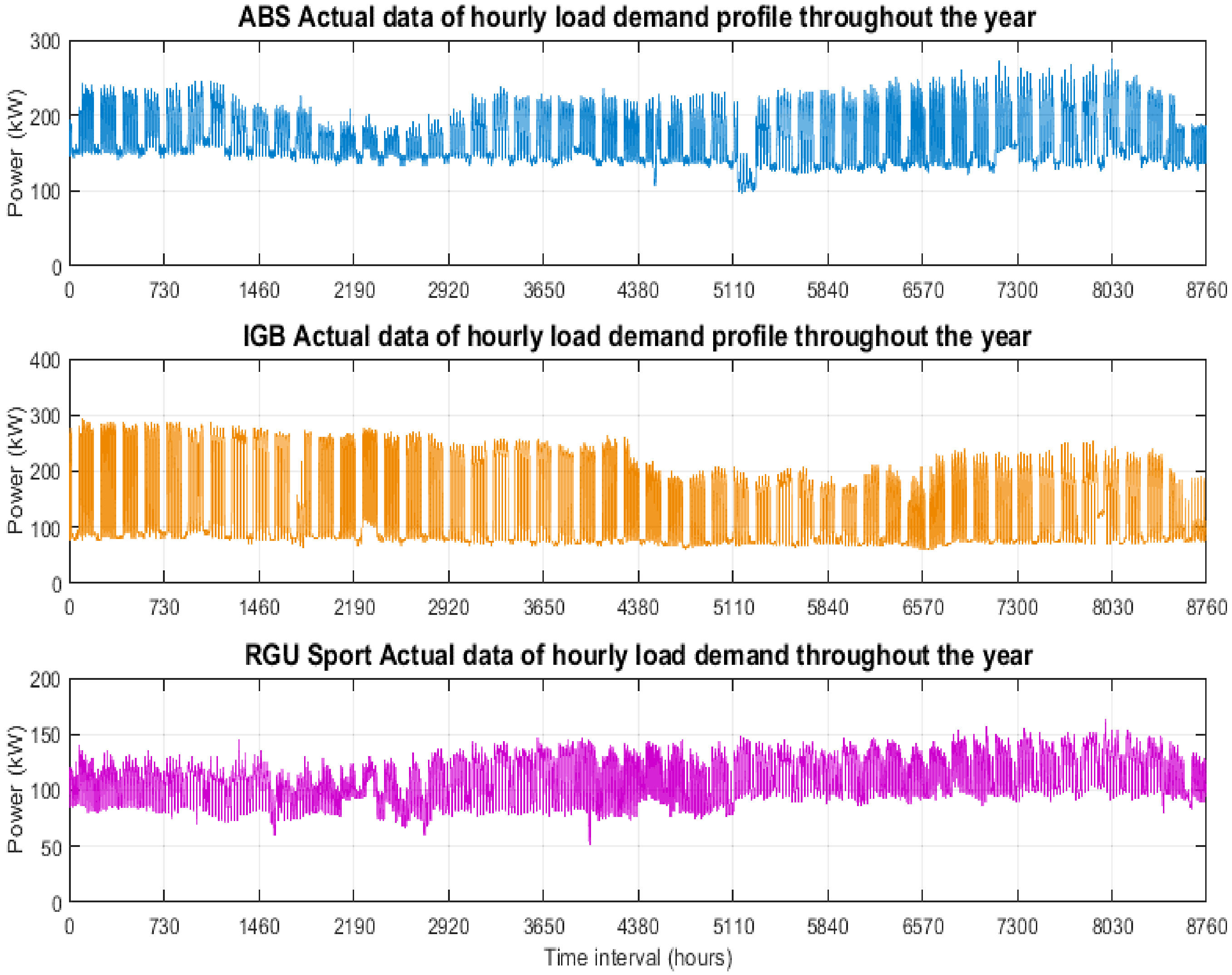
Simulation Results of the hourly power served to the load from the fuel cell and utility grid by the sized HSHES system over one summer week



Simulation Results of the hourly status of Pressurized Hydrogen Storage Tank level over one summer week

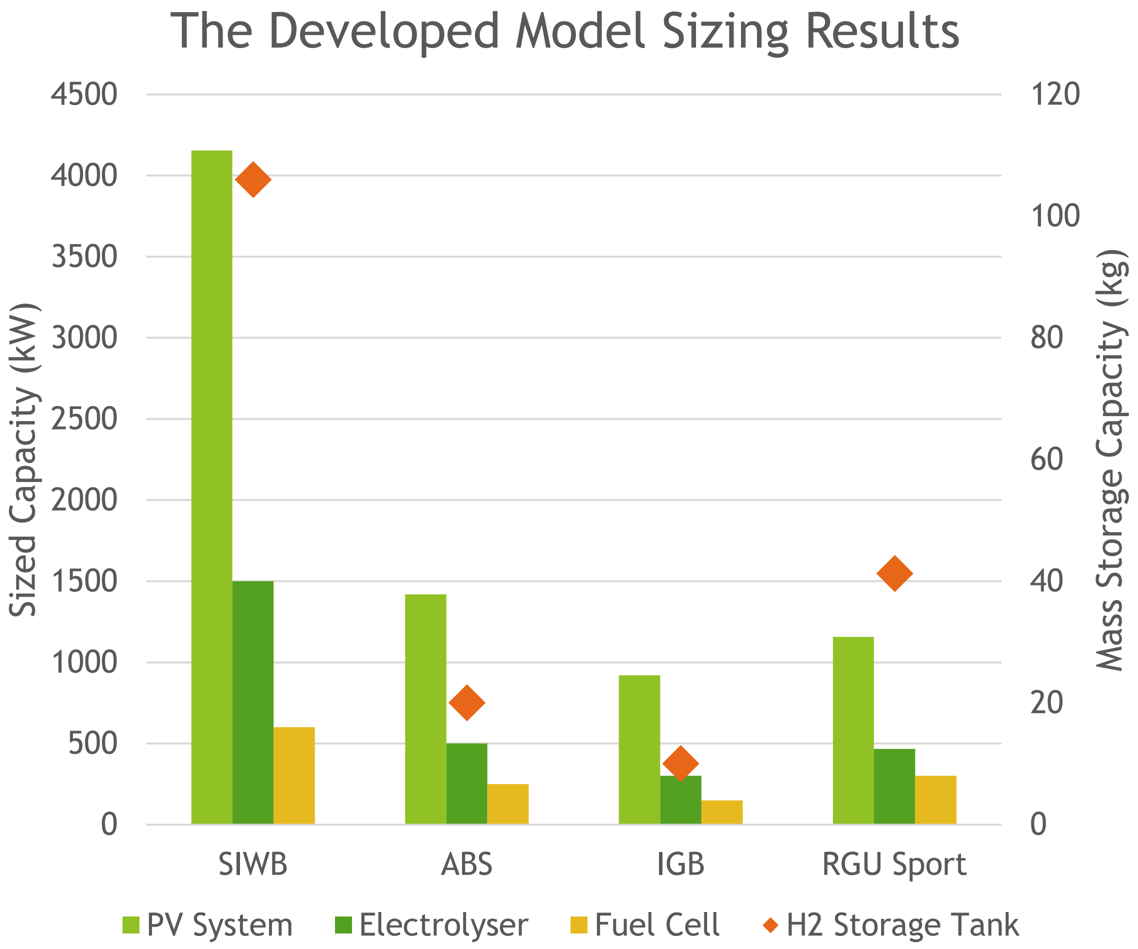


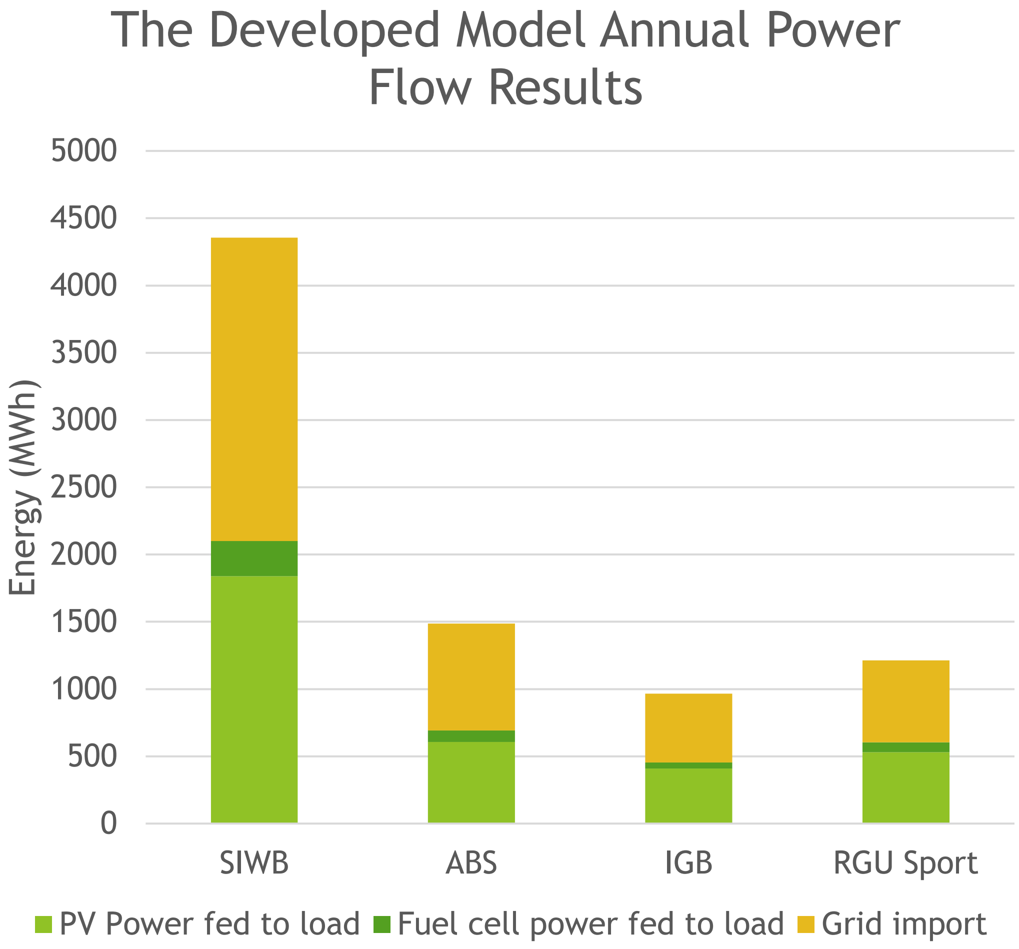
Applying the Developed Model on Other RGU Buildings



Parameter	ABS	IGB	RGU Sport
Average Demand (kW)	170	138.4	110.2
Peak Demand (kW)	273.8	293.2	162.8
Total Annual Demand (GW)	1.487	1.212	0.965

Sizing and Power Flow Results for Other RGU Buildings



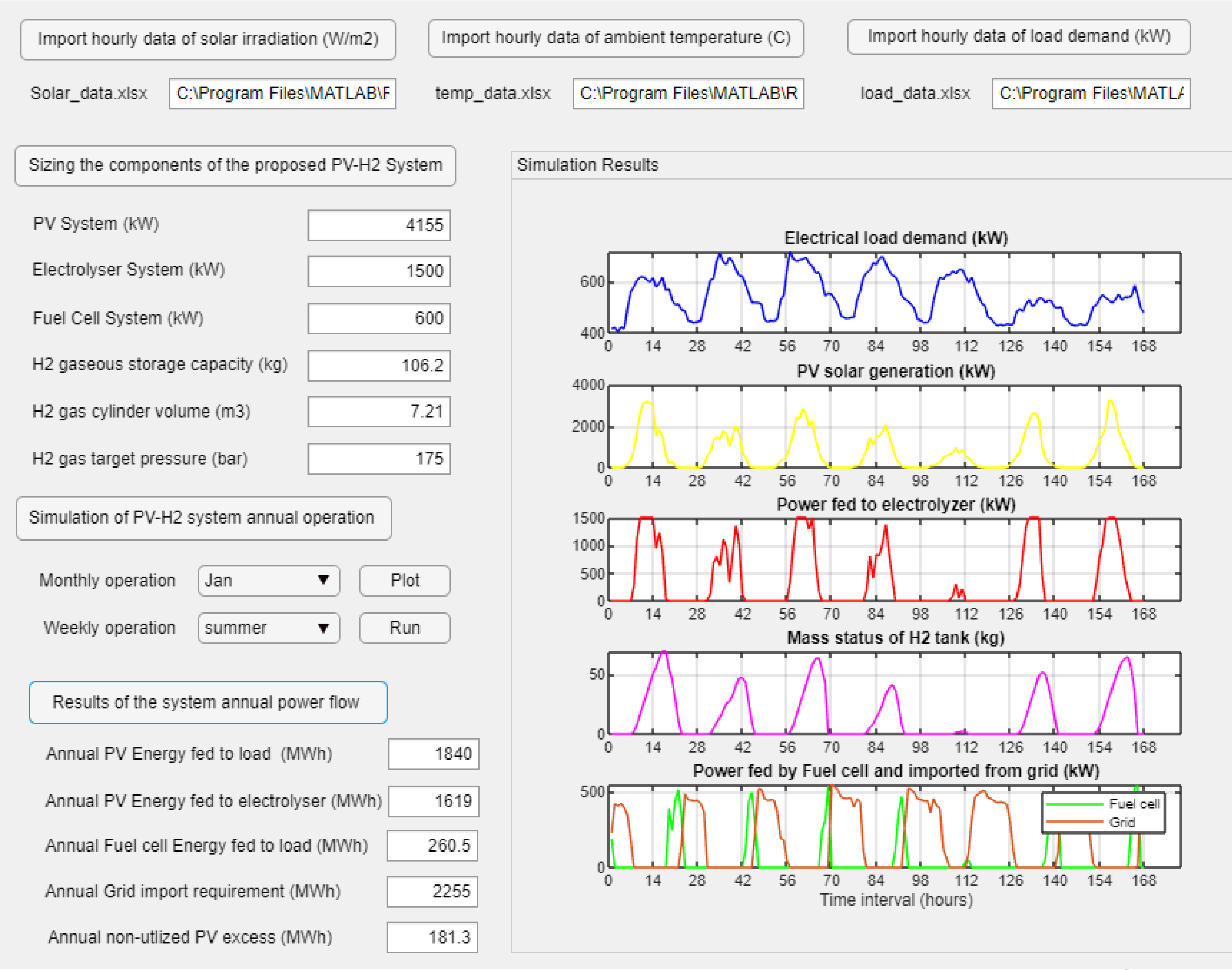


Developing a Graphical User Interface (GUI) Tool for Sizing and Simulating HSHES System for any grid-connected Building

Data input

Sizing Feature

Analysis of the System Annual Power Flow



Simulation Feature

Conclusion

- For unlocking the full renewable potential through implementing hydrogen energy storage solutions, we developed a model for sizing and simulating Real-World dynamic operation of Hybrid Solar Hydrogen Energy Storage (HSHES) Systems within grid-connected buildings.

- The developed model enables sizing the capacity of HSHES system components and modelling the dynamic behavior of electrolysers running back intermittent solar energy production while emulating the electrochemical behavior of fuel cell systems in response to load demand requirements.

- The developed model has been implemented on a group of grid-connected buildings and results have shown around 47-50% of green energy supply has been provided to load demands from the sized HSHES systems.

- A novel Graphical User Interface (GUI) is under development to achieve around 50% carbon reduction for any grid-connected building.

Thank You

Any Questions?