









Imperial College London













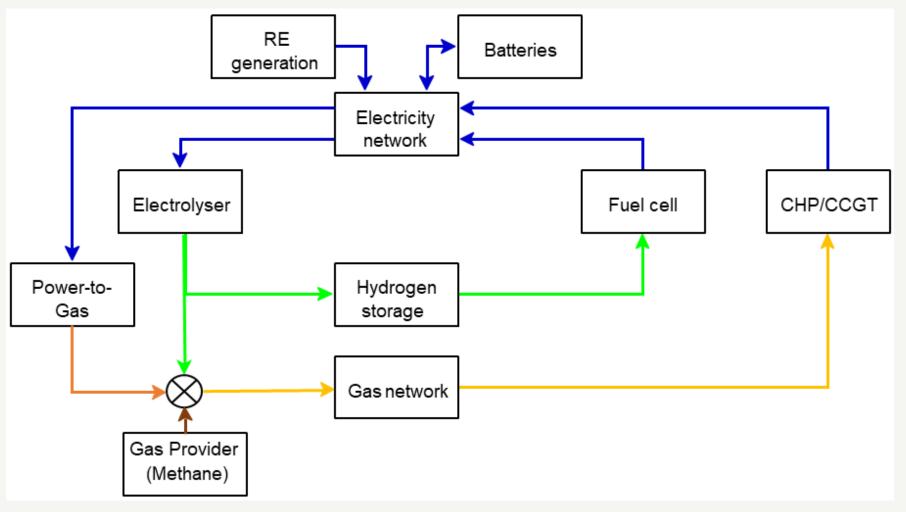






# Study Case of Hydrogen Blending

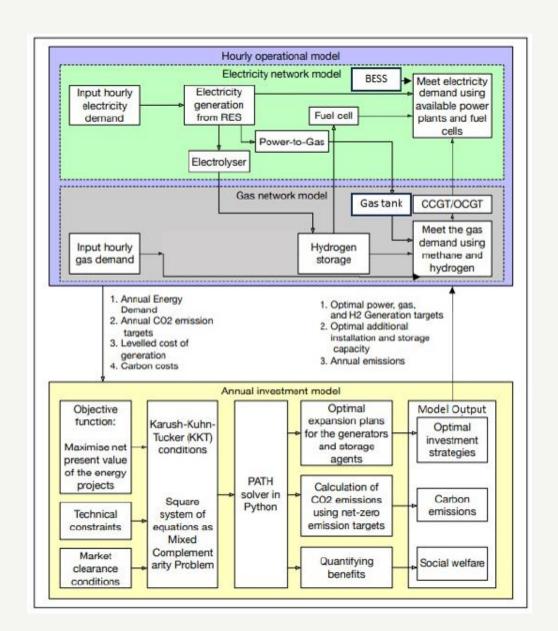




Integrated Multi-Energy System



Schematic Diagram of Game-Theoretic Model





#### Inputs

#### Specification of Gas Network

- Gas Network topology
- Source pressure
- Gas demand
- Source mixture molar friction
- Molar mass, dynamic viscosity and compressibility of gas individual components
- Thermal properties of air
- Atmospheric pressure

#### Specification of Electricity Network

- Electric Network topology
- Scheduled power of PV and PQ buses
- Electric demand

### Specification of coupling components

- Power
- Efficiency

#### **Gas and Power Flow Analysis**

#### Forming the set of equations

- Gas Flow Equations
- Nodal flow balance equations in the gas network
- Equations of power consumption for compressors
- Electrical power balance equations
- Equations of balance of gas and electric power flow at the coupling components

### The set of equations was solved by using two Python packages:

- **1-Pandapower** for power network
- **2-Pandapipes** for gas network

#### Output

#### Gas Network

- Nodal pressures
- Gas flow through branches
- Gas flows through compressors
- Gas consumptions of compressors
- Power consumption of compressors
- Flow from sources

#### **Electricity Network**

- Bus voltages
- Power flow through branches
- Power of slack bus

#### **Coupling components**

Output quantities

Schematic Diagram of OPGF

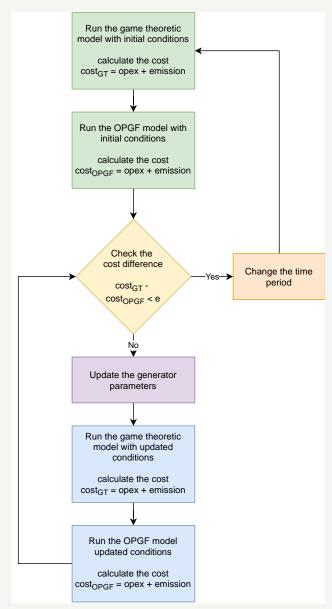


#### **Combining GT model with OPGF model**

Iterative updates: GT model output → OPGF output → GT model

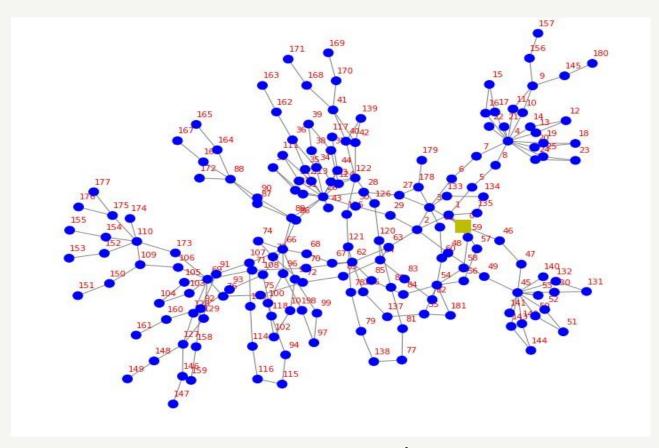
Flow chart of algorithm to perform the short-term

operation and long term investment simulation





Case study utilizes data from the North of Tyne region.

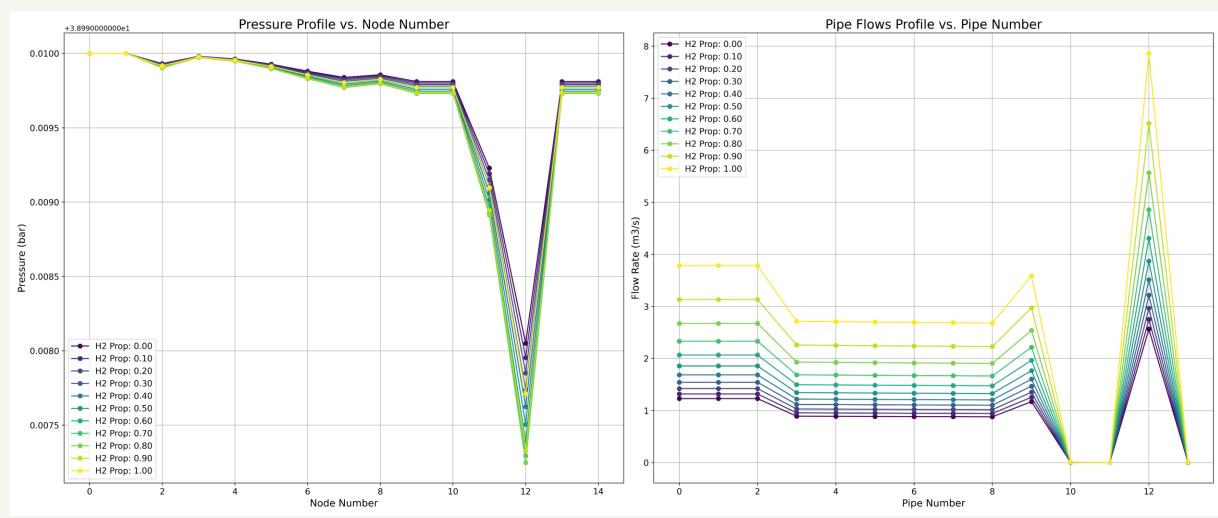


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**Power Network** 

Gas Network



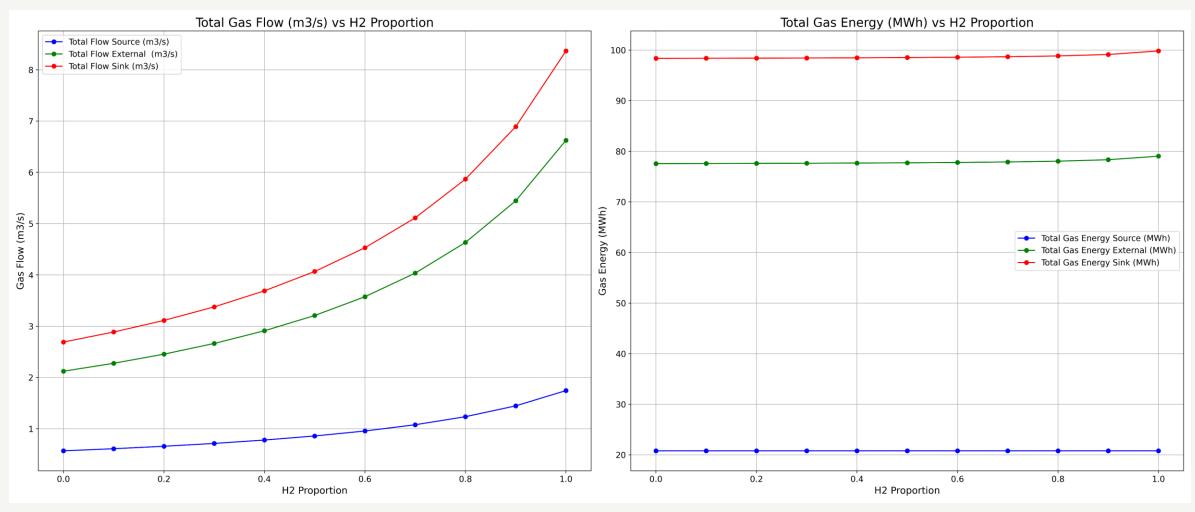




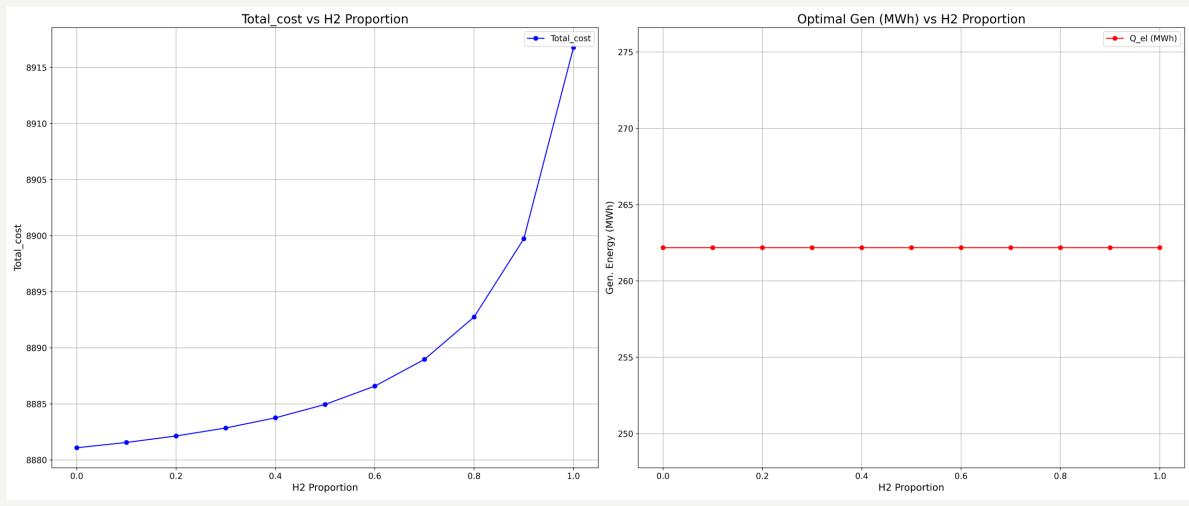
Results OPGF

H2_prop	Total Cost	Total Gas Energy Sinks	Total Gas Energy Sources	Total Gas Energy Externals	Total Flow Rate Sinks	Total Flow Rate Sources	Total Flow Rate Externals
	(£)	(MWh)	(MWh)	(MWh)	(m3/s)	(m3/s)	(m3/s)
0	8881.084	98.365	20.797	77.568	2.690	0.569	2.122
0.1	8881.559	98.385	20.797	77.588	2.886	0.610	2.276
0.2	8882.135	98.409	20.797	77.611	3.112	0.658	2.454
0.3	8882.849	98.438	20.798	77.640	3.376	0.713	2.663
0.4	8883.756	98.475	20.798	77.678	3.689	0.779	2.910
0.5	8884.948	98.524	20.798	77.726	4.066	0.858	3.208
0.6	8886.583	98.591	20.798	77.793	4.529	0.956	3.574
0.7	8888.963	98.689	20.798	77.891	5.112	1.077	4.035
0.8	8892.752	98.845	20.799	78.046	5.868	1.235	4.633
0.9	8899.721	99.132	20.799	78.332	6.890	1.446	5.444
1	8916.779	99.833	20.800	79.033	8.367	1.743	6.624

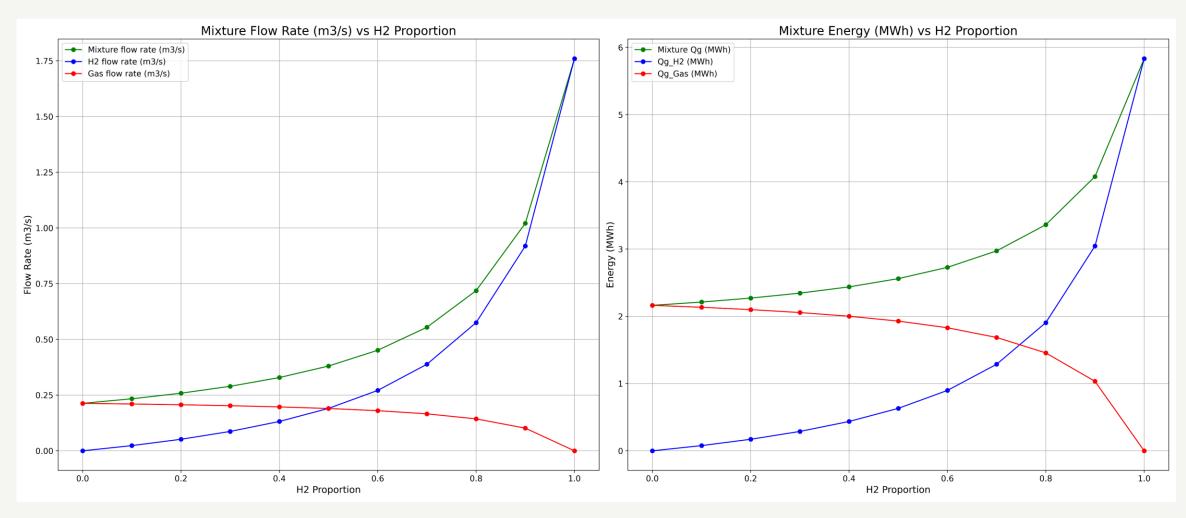




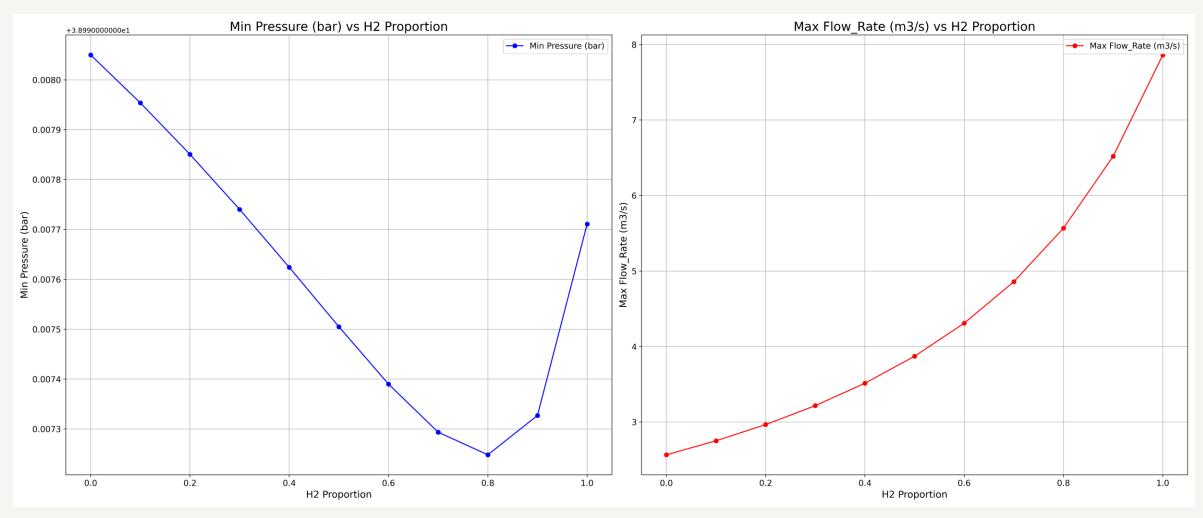












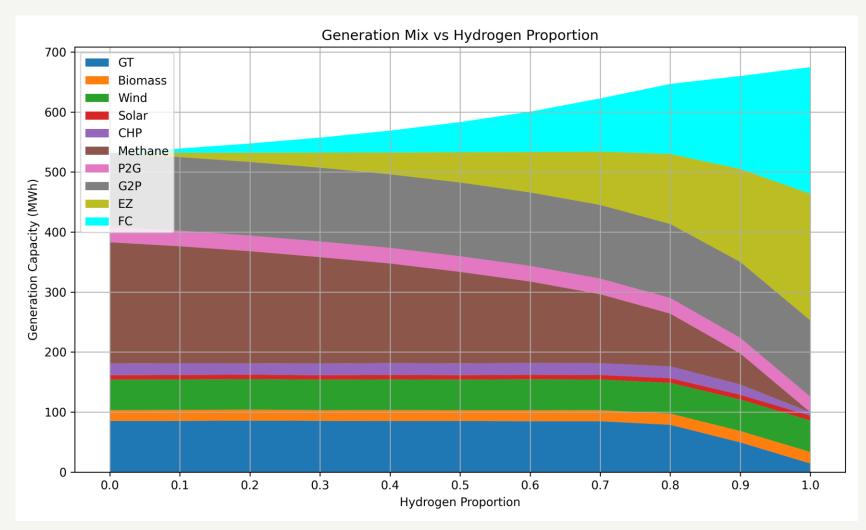


H2	Cost	Cost_	Cost	NPV	Total	Total	Emissions	Emissions
Proportion	GT	OPGF	Difference	INPV	Supply	Demand	GT	OPGF
0	75366.44	120621.69	-45255.26	57623.59	557.96	557.96	318.76	965.21
0.1	73690.35	118156.95	-44466.60	59818.51	558.38	558.38	308.17	931.48
0.2	71750.16	115990.18	-44240.02	62360.21	558.88	558.88	296.27	901.71
0.3	69546.65	112388.24	-42841.59	65256.56	559.51	559.51	282.65	850.54
0.4	66886.52	108210.15	-41323.63	68791.39	560.31	560.31	265.66	792.96
0.5	63705.12	103817.32	-40112.20	72991.18	561.35	561.35	246.07	731.25
0.6	59801.56	97921.71	-38120.15	78246.06	562.79	562.79	221.32	649.45
0.7	54923.81	90998.50	-36074.70	84798.73	564.88	564.88	190.89	552.43
0.8	48403.73	82064.51	-33660.78	92795.86	568.20	568.20	149.84	427.13
0.9	39334.12	68683.05	-29348.93	101445.73	574.32	574.32	92.54	240.05
1	28758.90	53208.43	-24449.53	114073.17	589.29	589.29	23.35	23.20

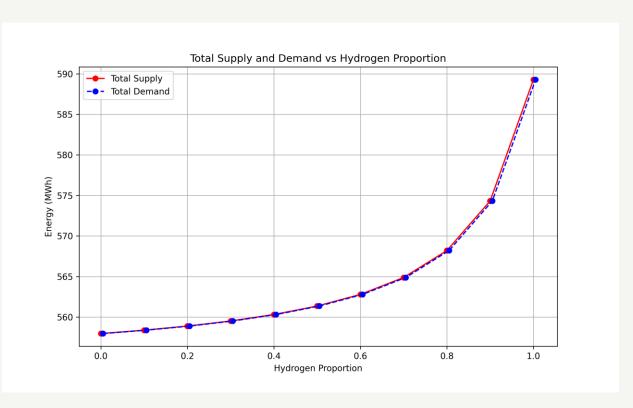


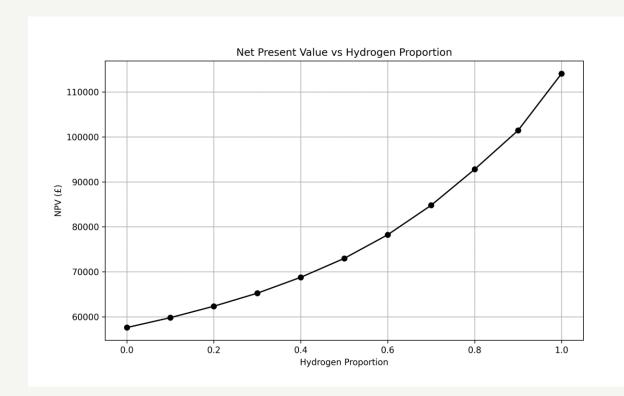
Player	Generation Capacity (MWh) vs. H2-Prop										
Туре	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
СНР	19.70	19.57	18.94	19.71	19.64	19.72	19.65	19.70	19.77	17.16	5.76
EZ	0.00	7.12	15.36	25.00	36.44	50.26	67.26	88.72	116.69	154.92	211.06
FC	0.00	7.12	15.36	25.00	36.44	50.26	67.26	88.72	116.69	154.92	211.06
G2P	122.93	122.59	122.73	123.12	122.53	123.01	122.47	122.82	123.32	126.55	127.05
GT	85.30	85.28	85.83	85.40	85.06	85.18	84.82	84.79	78.81	49.50	14.31
P2G	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
Biomass	18.06	18.34	18.31	17.95	18.43	18.14	18.50	18.40	18.65	18.97	19.11
Meth	201.88	194.84	186.71	177.20	165.94	152.39	135.78	114.92	87.94	51.64	0.00
Solar	7.42	7.63	7.58	7.34	7.62	7.46	7.63	7.59	7.77	7.90	8.00
Wind	50.68	50.71	50.77	50.69	50.99	50.80	51.29	51.08	51.23	52.51	52.54



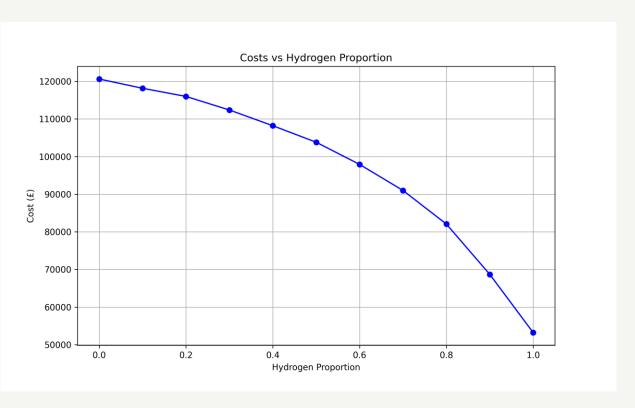


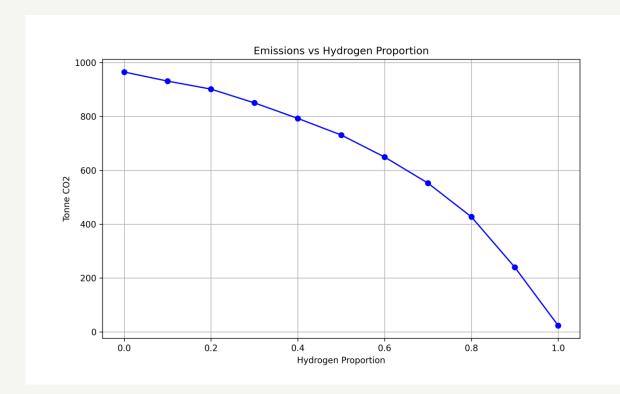














## Thank you for your attention