Decarbonising with H2 & Electricity

ΣΥΝΔΕΣΜΟΣ ΥΔΡΟΓΟΝΟΥ ΚΥΠΡΟΥ
CYPRUS HYDROGEN ASSOCIATION

Cranfield University

Sustainability = Environment + Economy

Observations
Current Energy Use
Some Replacement Scenarios
Some Concepts - Scale
Socioeconomic benefits

Prof. Pericles Pilidis - presenting a team effort
Cranfield University - Thermal Power & Propulsion

GAS TURBINES - CORE CRANFIELDACTIVITY – ENVIRONMENTAL FOCUS

Two Sites
4000 + PG s
Leading research
& CPD university

H_2 and Gas Turbines At Cranfield

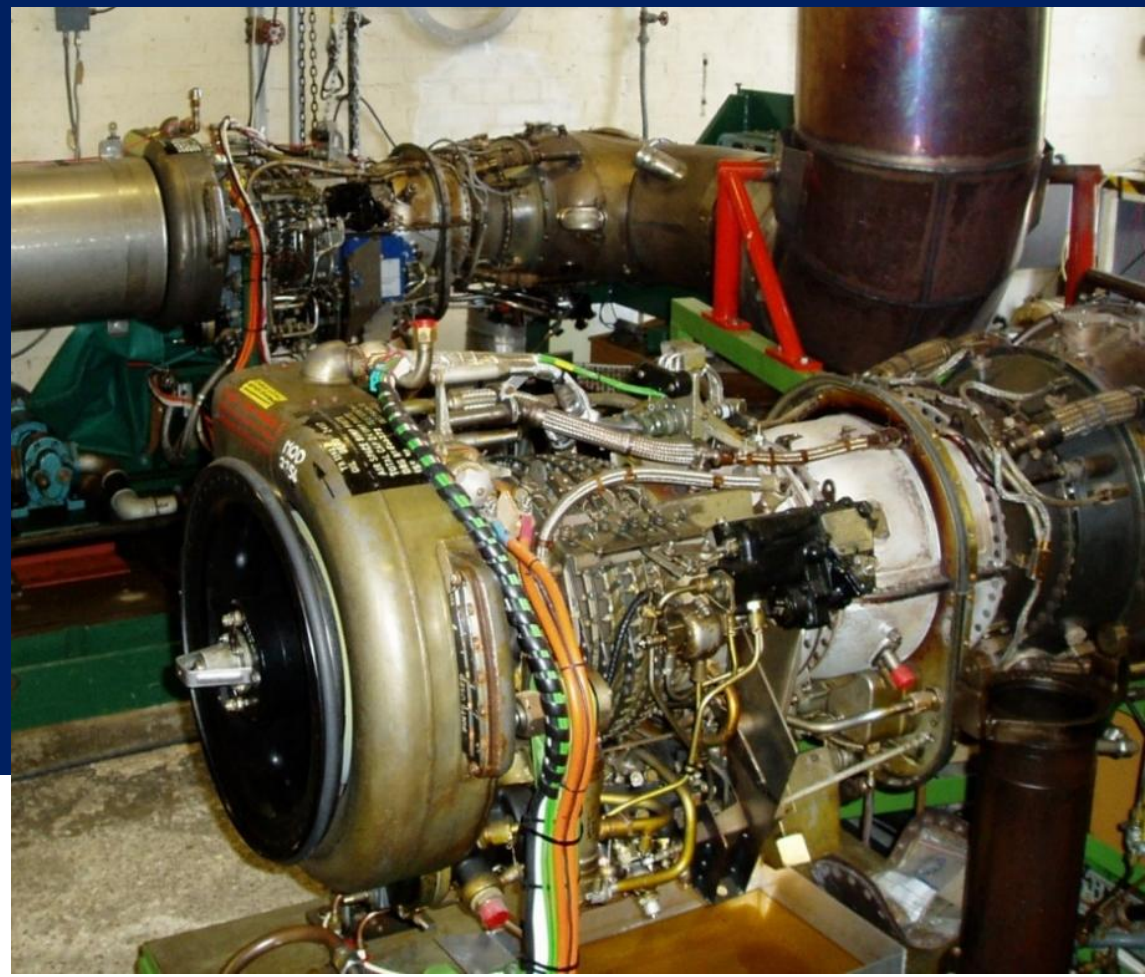
1994 – Hydrogen for GTs

2000 Cryoplane

2010 – NASA Project

Now: ENABLEH2, HyPER Airbus/ATI + 3 x Fly Zero + EU

+ + + Cranfield Own Projects



1946 - Cranfield College of Aeronautics
One of the 4 units was Aircraft Propulsion

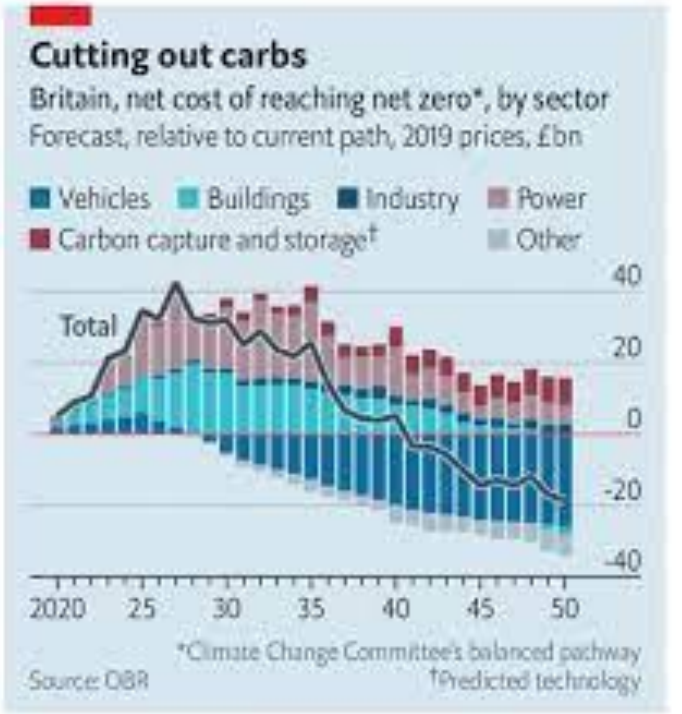
1969 - Cranfield Institute of Technology (University)

1993 - Cranfield University (change of name)

Some Observations

Sustainability = Environment + Economy

OBR - £1.3tr (gross) to green the UK – 2% of GDP in 30yrs



Why Hydrogen?

H_2:

No CO2 (if green)
No CO, UHCs, aromatics, soot, SOx
Much lower potential NOx than Hydro**c**arbons – 90%?
Cirrus avoidance

Transition cost, certification & legislation!

Holistic Use & Capacity on a National Basis

			Energy TJ
Coal - electr			78300
Coal - Ind			78300
Other			51300
Total Coal			207900
			0
Petrol			578100
Diesel - Cars			699200
Diesel-GoodsV			469200
JetFuel			565800
Other (Marine 12%, Rail 4%)			777000
Total Liq Fuels			3089300
			0
			0
Gas-electr			972000
Gas-Domestic			1094400
Gas-Other			1087200
Total Gas			3153600
			0
	Capacity GW		0
Wind-land	13.99		115920
Wind-sea	9.89		114840
Hydro	1.61		21600
Solar PV	13.22		45720
BioEnergy	7.84		131760
Total Renewables	46.55		429840
Coal Electricity	6.82		24840
Gas Electricity	34.58		477000
Nuclear Electricity	9.26		202320
Other electricity	0.00		31320
Total Electricity Gen Capacity	97.21		1165320
Av gen Capacity	36.95		0
Total Primary E			7114280

Demand:
Heat + Electricity + Transport

Decarbonise avoiding socio-economic damage same demand scenario

2019 Energy Demand & Supply

Source = DUKES (UK govt) + researcher's estimates

Decarbonising the UK – H2 & Electricity

Hydrogen: **35-40 % of electricity supply (use seawater electrolysis)**

25 kt/day **Aviation 40- 50% of H2 supply, Liquify at airports**

Benefits of thermal plant and better heat use in colder countries (like UK)

Cost ~ 2% of GDP-

Scenario	Electricity Supply	Installed Capacity
2019 Baseline	1	1
S1 - Emphasis on Renewable	4.4	4.0
S2 - Emphasis on Nuclear	3.6	1.8
S3 - Emphasis on Nuclear and RES	3.6	2.2
S4 - Emphasis on Gas Turbines and RES	3.6	2.2
S5 - Similar to 4 low heat	4.1	2.4
S6 - Emphasis on Gas Turbines	3.6	1.8

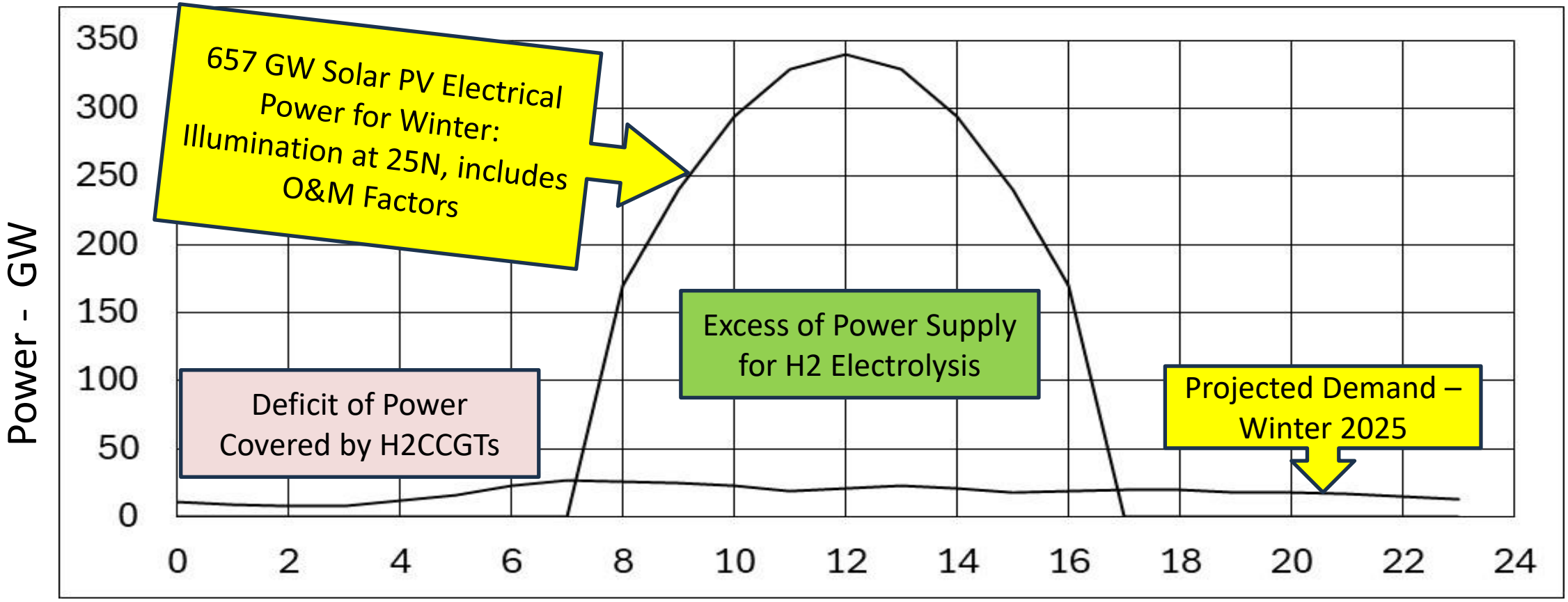
Decarbonising an Oil Exporting Country

Solar Case Study: H2 for National Demand + Night Electricity Generation + Energy Exports

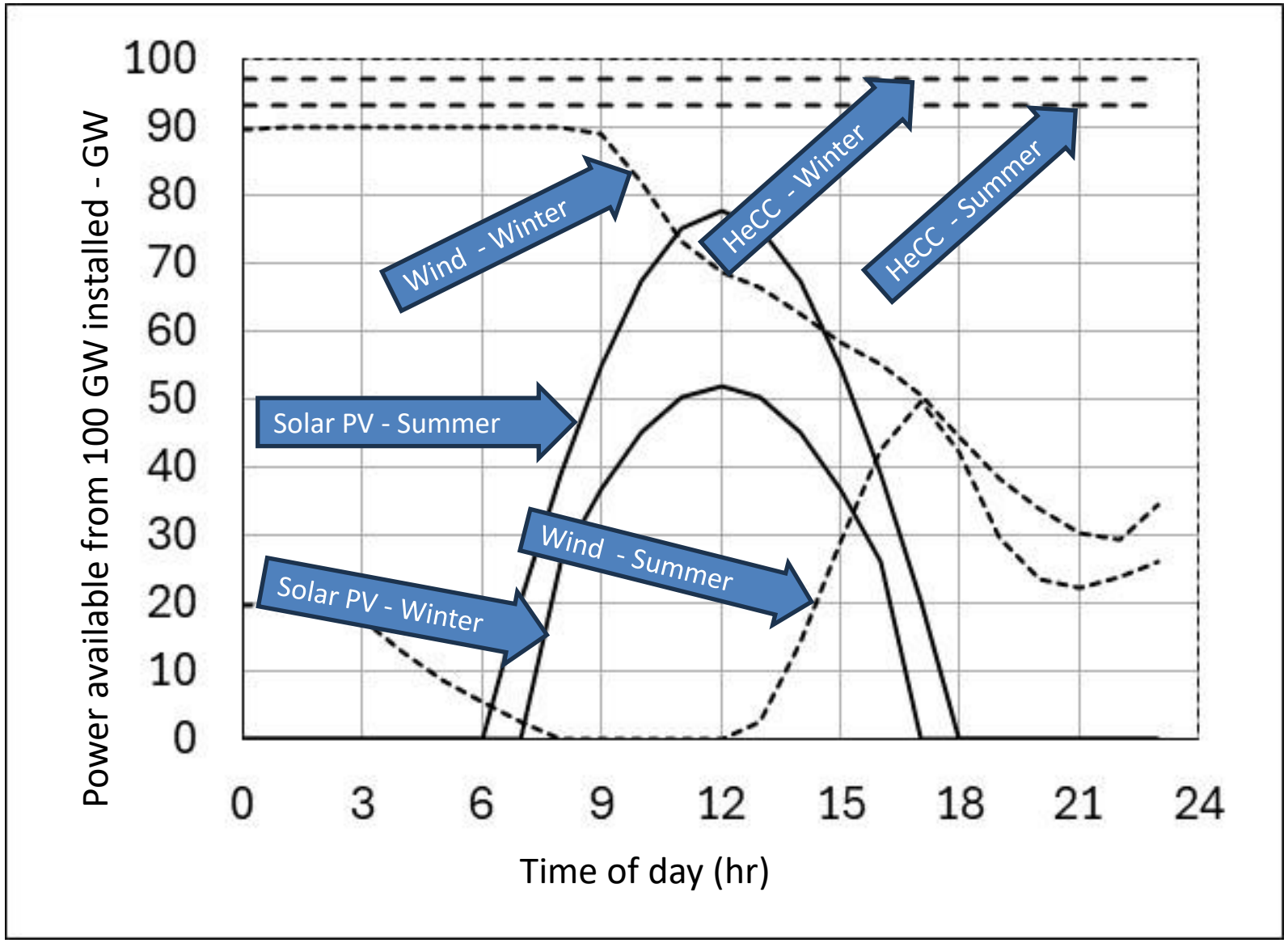
Project Economic Growth to 2050 – Conventional

Satisfy all 2050 Requirements with H2 and Electricity, including night electricity with H2CCGTS

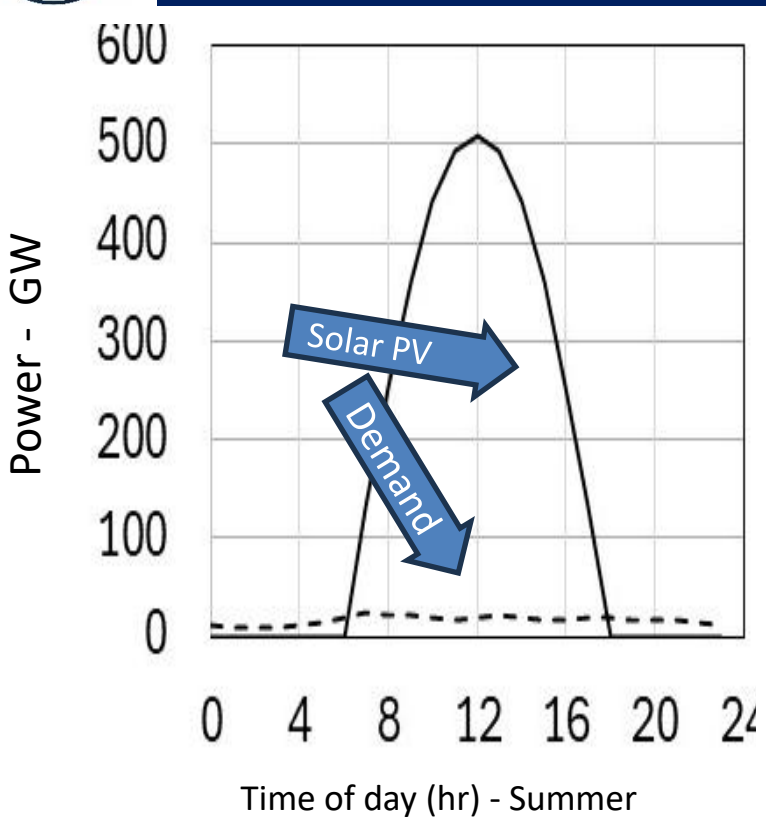
Seasonal demand and supply.

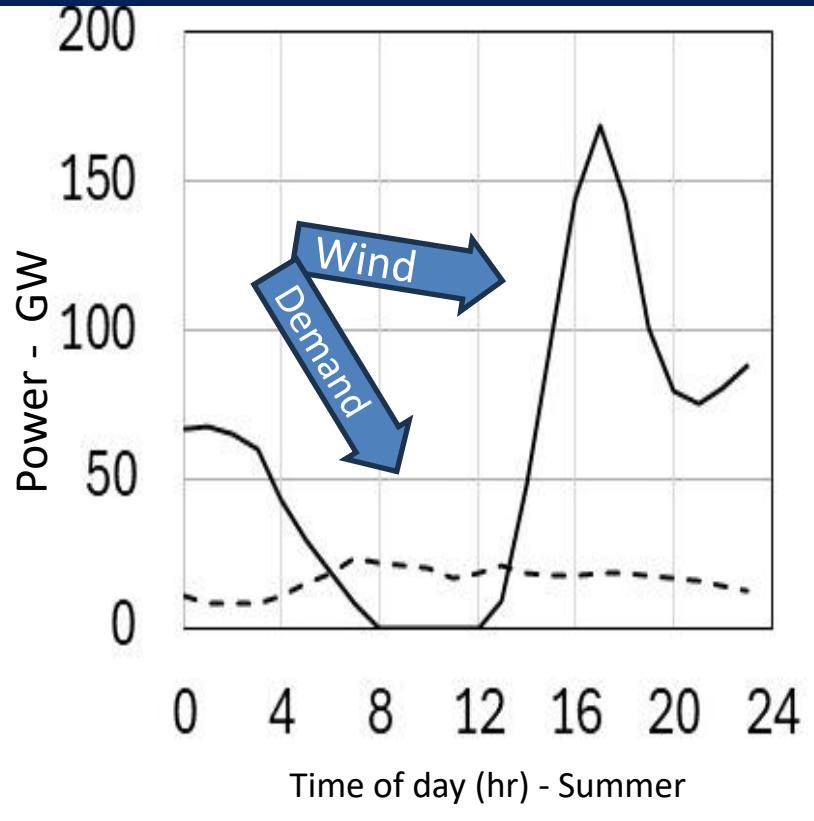


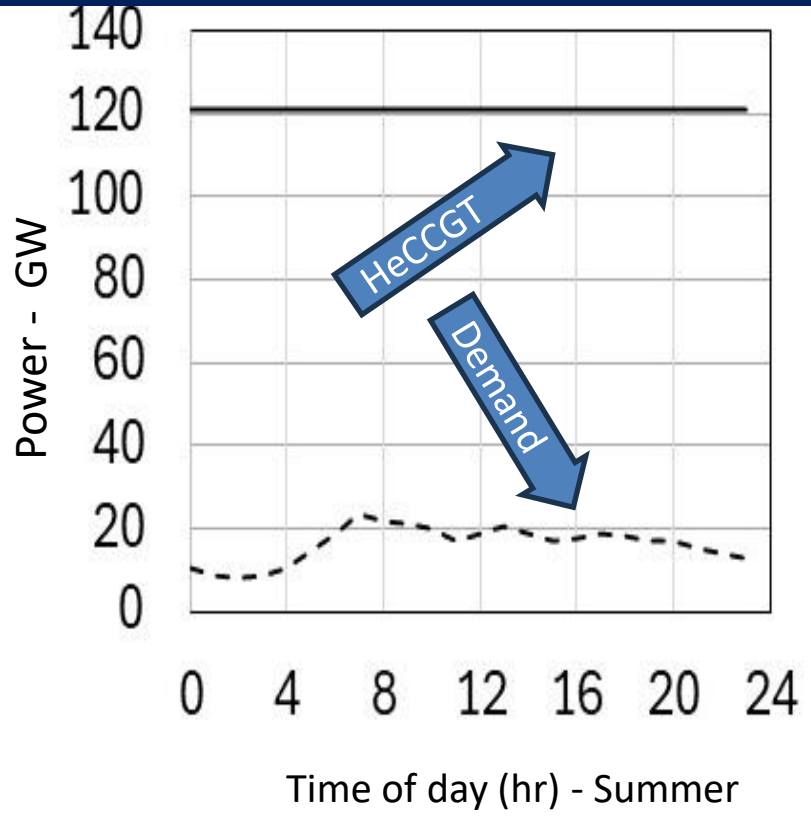
Utilisation of Power Plants



Decarbonisation – Summer Case Studies: Solar, Wind, HeCCGT

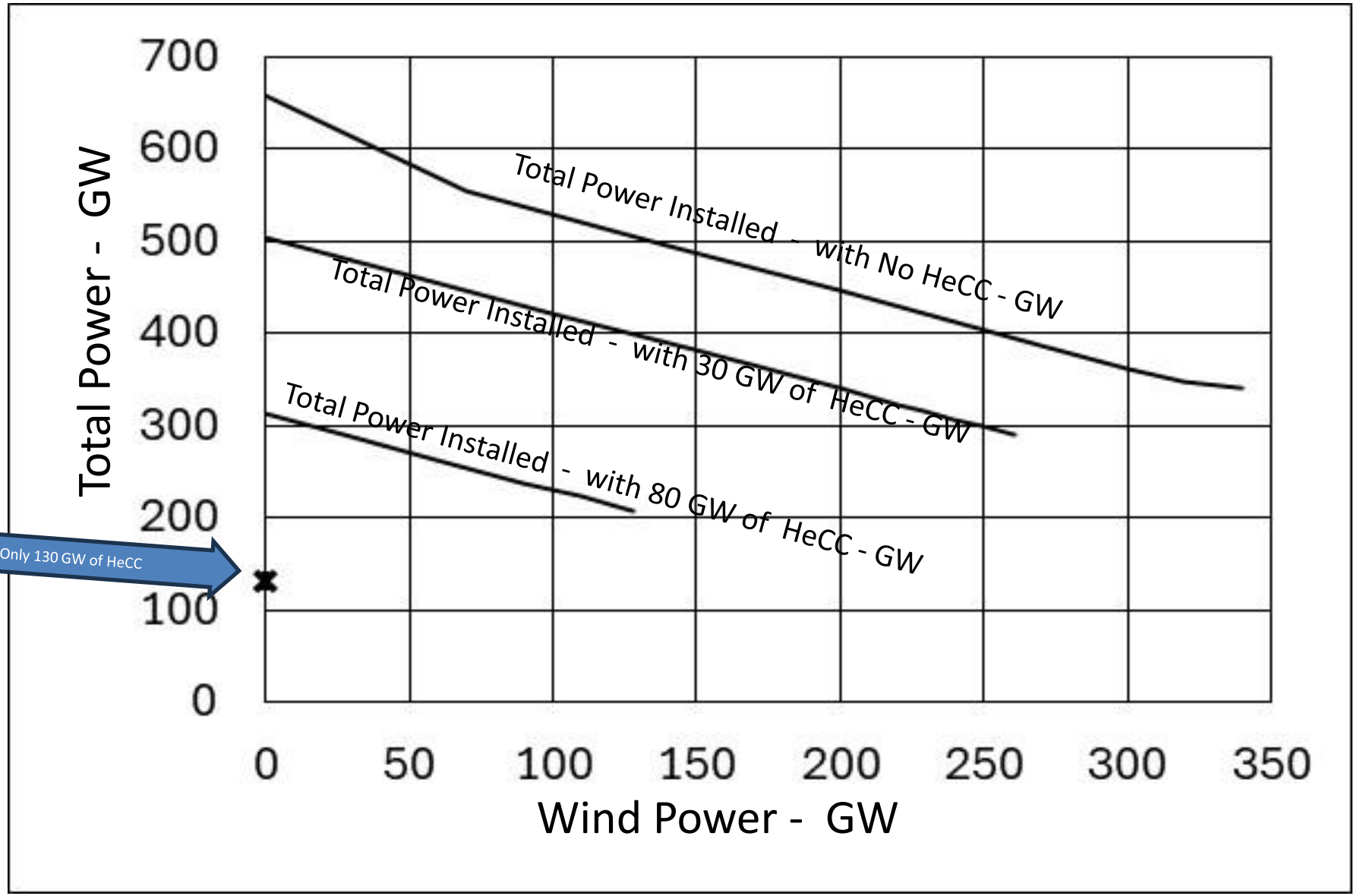




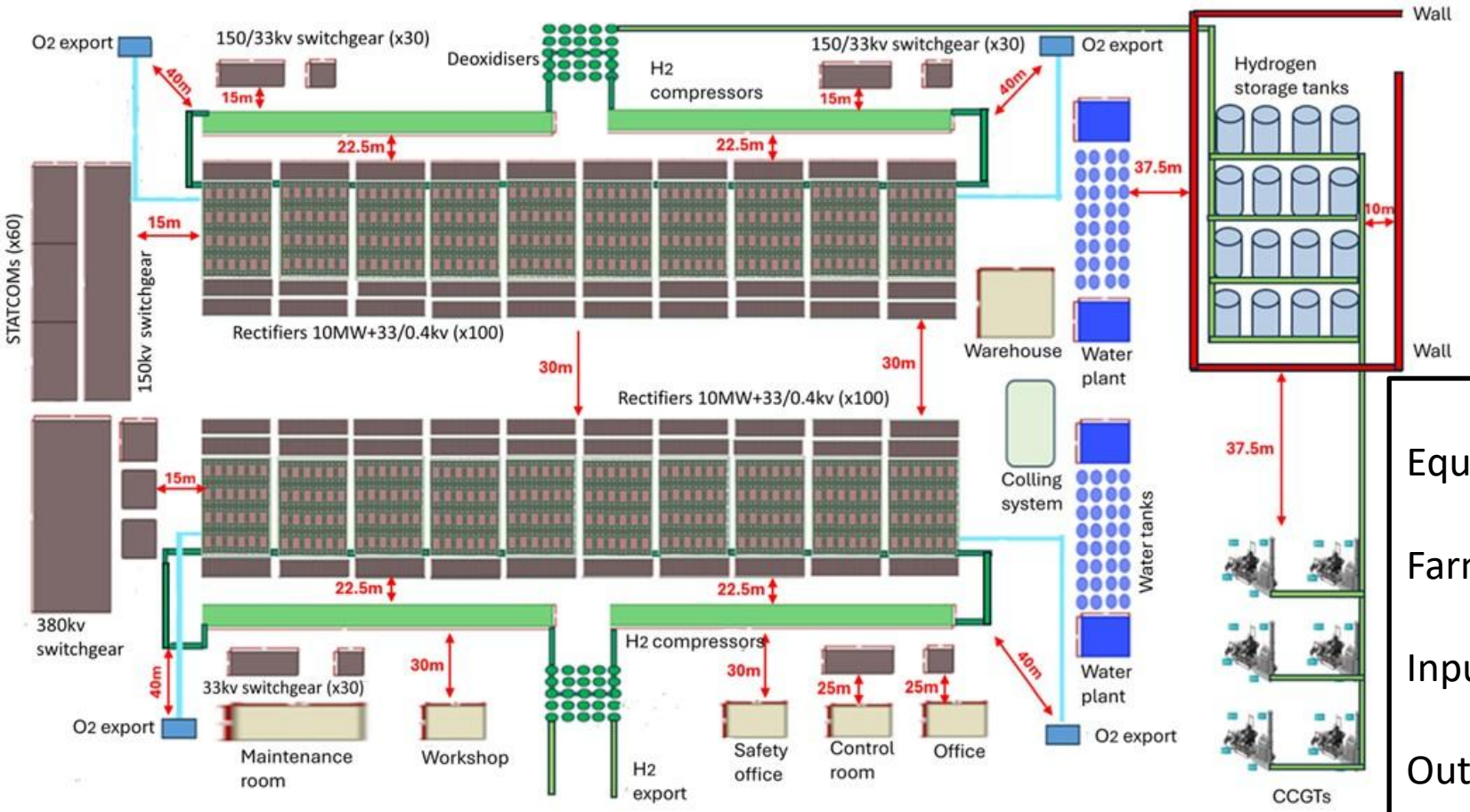


Generation Power Installed GW			Always for export case = 2100 PJ of H2 or 17.5MT of H2						
Solar	Wind	HeCC	Total	Solar Area km2	Wind Area km2	He CC units	Electrolyser GW	H2 Storage tonnes	H2CCGT units
657	0	0	657	11972	0	0	491	43500	54
0	340	0	340	0	37325	0	298	24000	44
0	0	130	130	0	0	130	120	1080	0

Decarbonisation – Combined HeCC, Solar & Wind



A 20 GW PEM Electrolyser H2 Farm



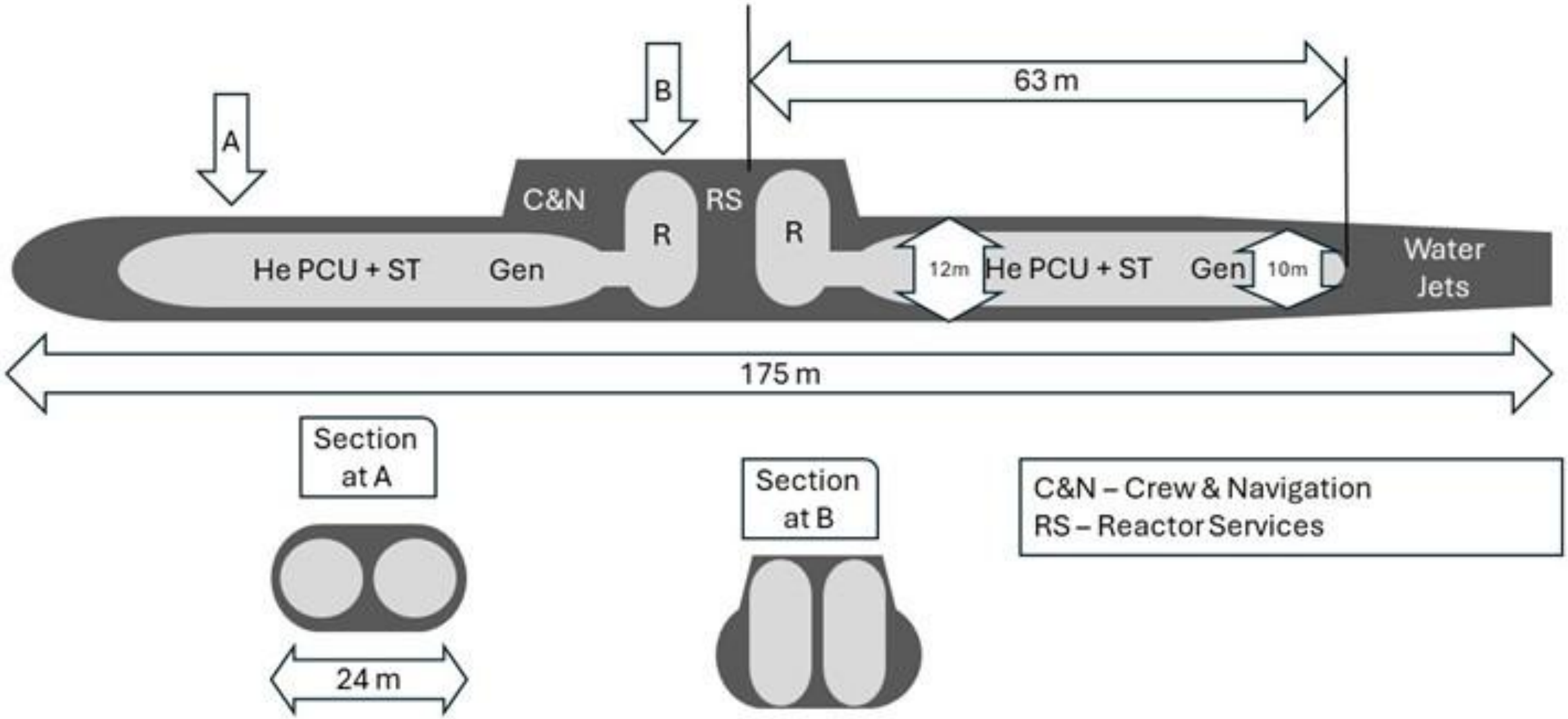
Equipment not to scale

Farm is ~ 4.5 x 2.5 km

Input is electricity

Output is GH_2

A Submersible 1 MW HeCCGT Nuclear Power Station



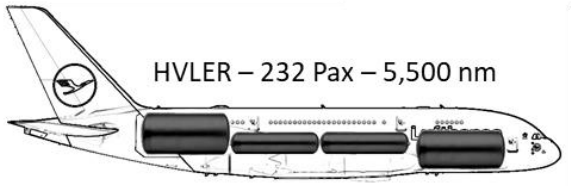
HVLMR From a family of 1st generation H_2 airliners

Design Derivative & Vast Integration Challenge – NOT a retrofit!

Energy ~same

Energy +10%

Energy +20%



	AIRBUS A350-1000	AIRBUS A380-800	HVLSR	HVLMR	HVLLR	HVLER
Mass (tonnes)						
Ramp	317	577	288	274	304	310
Max. take-off	316	575	287	273	303	309
Max. landing	236	394	275	251	275	276
Max. payload	68	83	80	50	45	36
Operational empty	155	276	194	200	229	238
H2 Tank: grav eff. 0.45			20	33	51	59
Engines	2	4	2	2	2	2
Cruise thrust/engine (kN)	87	81	84	81	88	90
Static thrust/engine (kN)	432	374	421	406	441	448
Range (nm)	8700	8000	1800	3300	4800	5600
Pax (2 class)	315	555	720	388	332	232

Huete, J., Nalianda, D., & Pilidis, P. (2022). Impact of tank gravimetric efficiency on propulsion system integration for a first-generation hydrogen civil airliner. *The Aeronautical Journal,* 1-9. doi:10.1017/aer.2022.60

A Mature National Hydrogen Network?

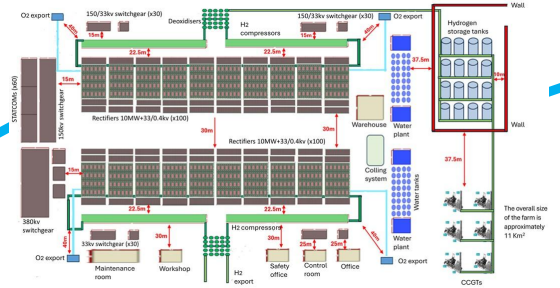
H2 Hub Airport

98+%

H2 Liquefier

<2% to Other LH2 Users

GH2 Pipeline

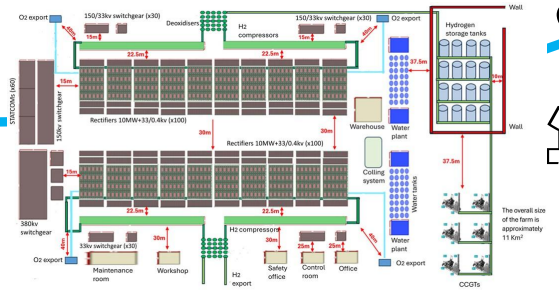


GH2 Pipeline

Large GH2 Users

Small GH2 Users

GH2 Pipeline



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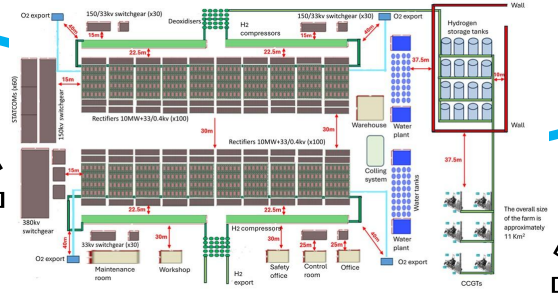

GH2 Pipeline

Large GH2 Users

Small GH2 Users

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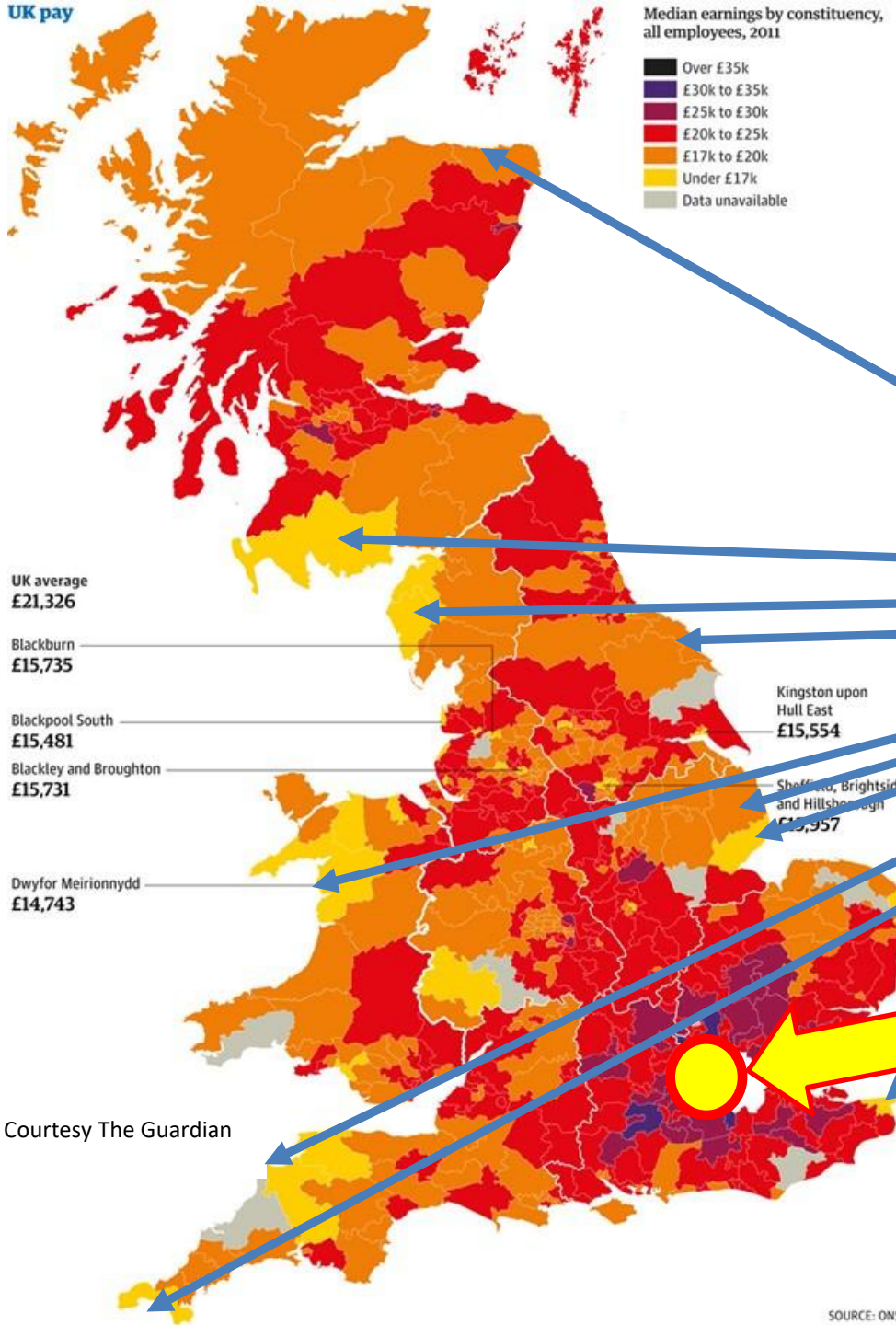
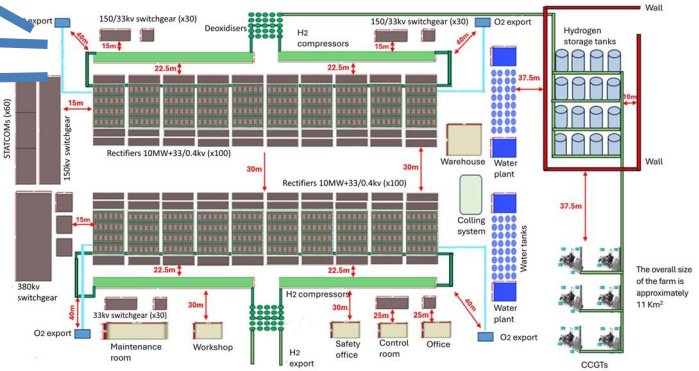
Hydrogen – Social Benefits





Hydrogen Hub Airport

Courtesy The Guardian

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