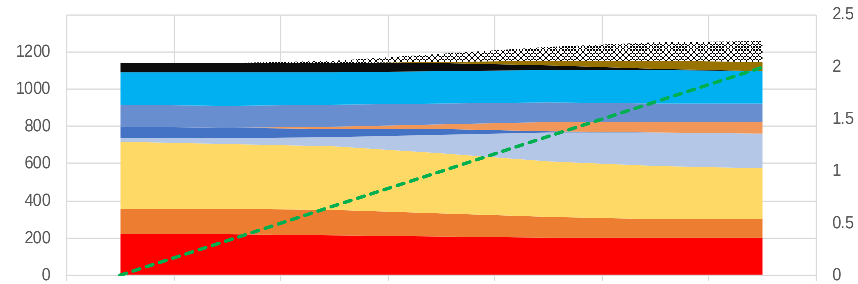
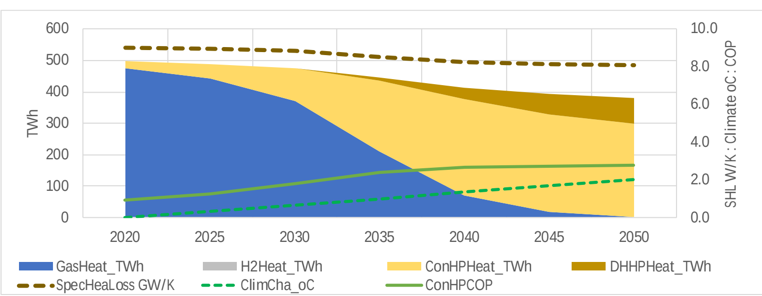

Other
Gas

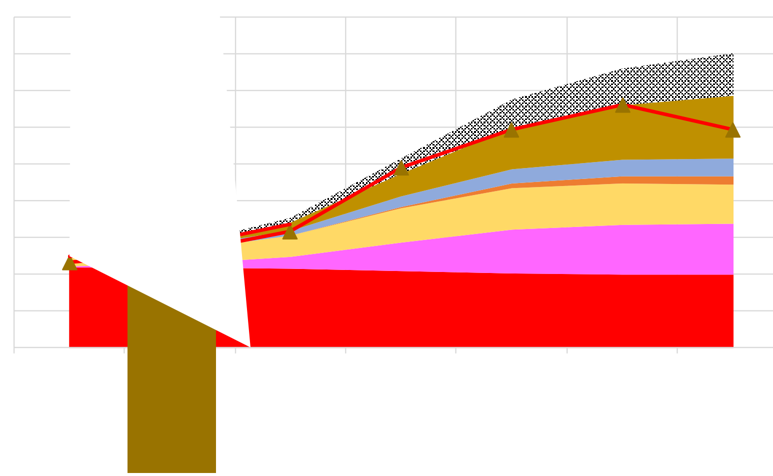
decreases
demand increases



shift to electric HPs and DH

EVs, hydrogen, ammonia for ships,
DACS negative emissions



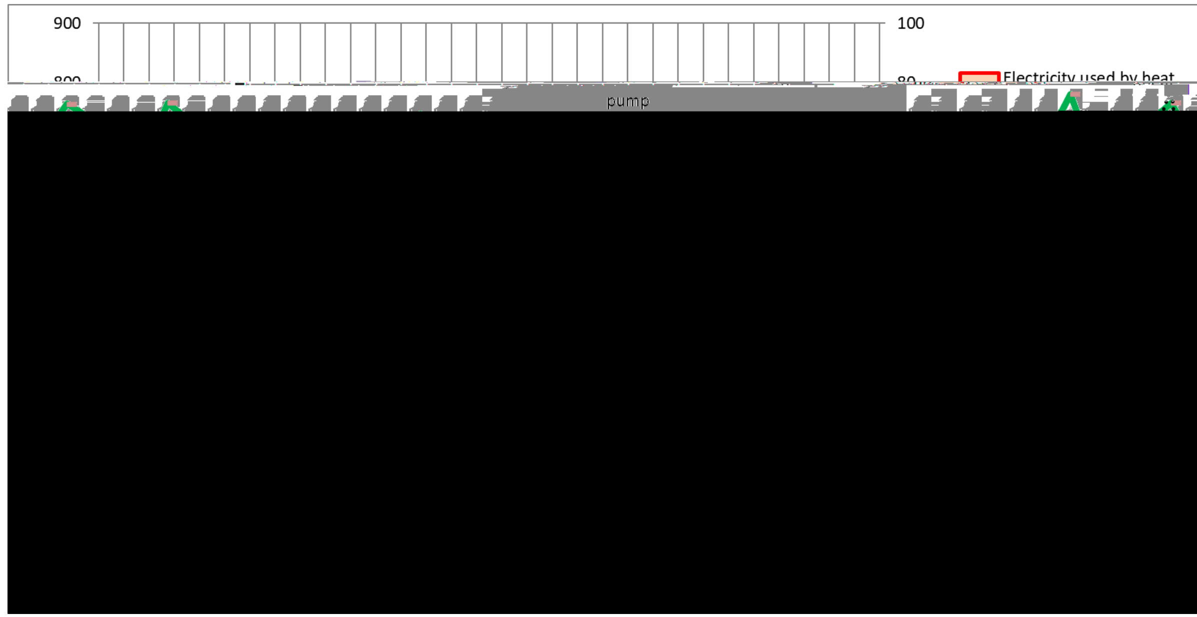


increases from
about 300 to 800 TWh.

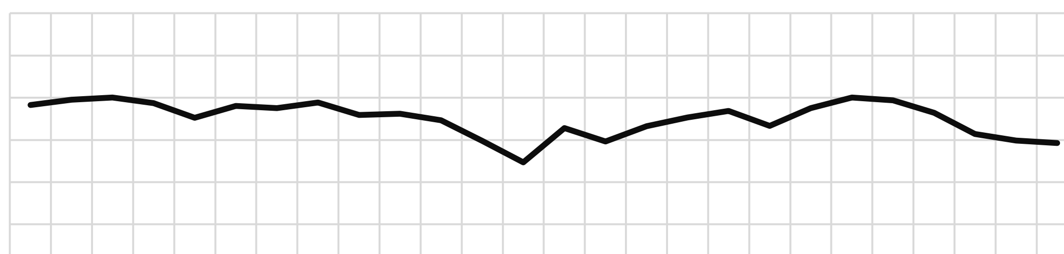
increases from about
60 GW to about 150 GW.

Wind off +/-9%
Wind on +/- 20%
Solar +/- 11%

Offshore wind capacity factors projected for 55-65%



~70-83% capacity factor
Dip to <50% in some years



mass produced, costs falling, privately financed, no insurance subsidy

Capacity MW	30	8	12	3300
Construction Yrs	4	4	5	12
Operate Yrs	30	25	30	50
Decommission Yrs	1	1	1	100
CapFac	11%	34%	57%	85%
Generation kWh/kW	964	2978	4993	7446
Const Capital £/kW	350	1020	1430	6500
Decom £/kW	50	150	300	2500
O&M £/kW/a	2.5%	2.5%	2.2%	2.0%
O&M £/MWh	1.0	6.0	3.0	2.0
Fuel p/kWh				0.5
Tech. specific rate	6.5%	6.5%	7.5%	8.9%

Nuclear Decommissioning Authority (NDA):

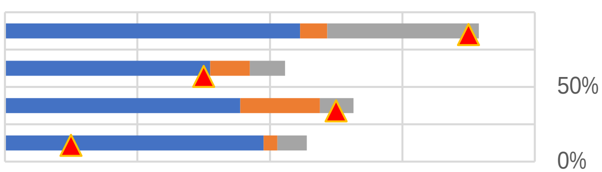
[Nuclear Provision: the cost of cleaning up Britain’s historic nuclear sites - GOV.UK (www.gov.uk)]

About 1

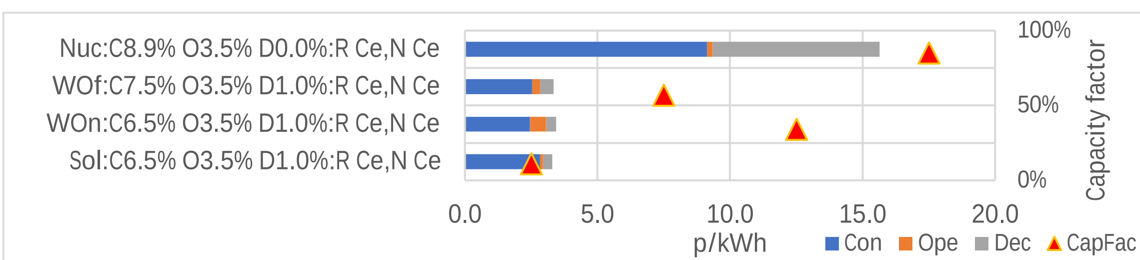
£bn from operator

Fukushima cost 100-200 £bn

Indifferent discount rates: nuclear decommissioning rate 0%/a



Technology specific discount rates 0%/a nuclear decommissioning rate




of year 1 Jan 2010 met
Scenario DH20
Demands
D_Air con
H2 electro
AirConEle
DH HP Ele
Cons HP Ele
StEle_In
StEle_Out

Meteorology

Demands

Generation

Stores, renewables, flexible

Surplus/deficit, H2 electrolysis and DAC

Heat pump COPs

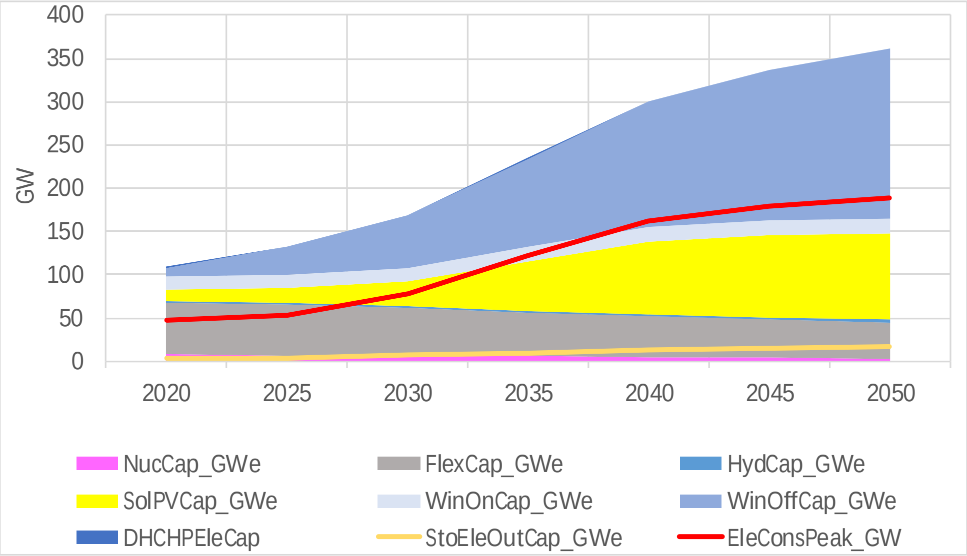
:

84% from wind, mainly offshore
10% solar
2% nuclear
4% other

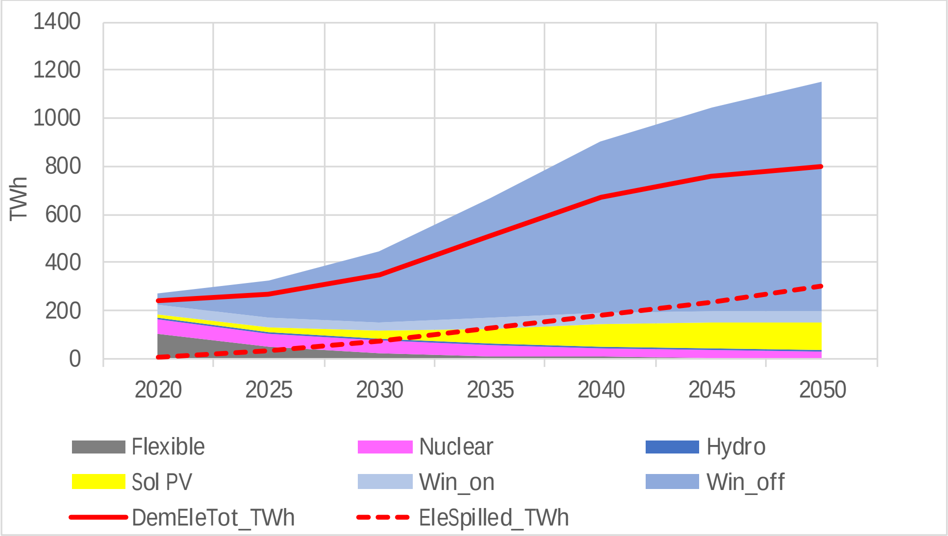
About 50 GW of gas/bio flexible generator used with capacity factor of ~1%

~300 GW of new generation capacity – what policies and markets will deliver this?

GENERATION CAPACITIES



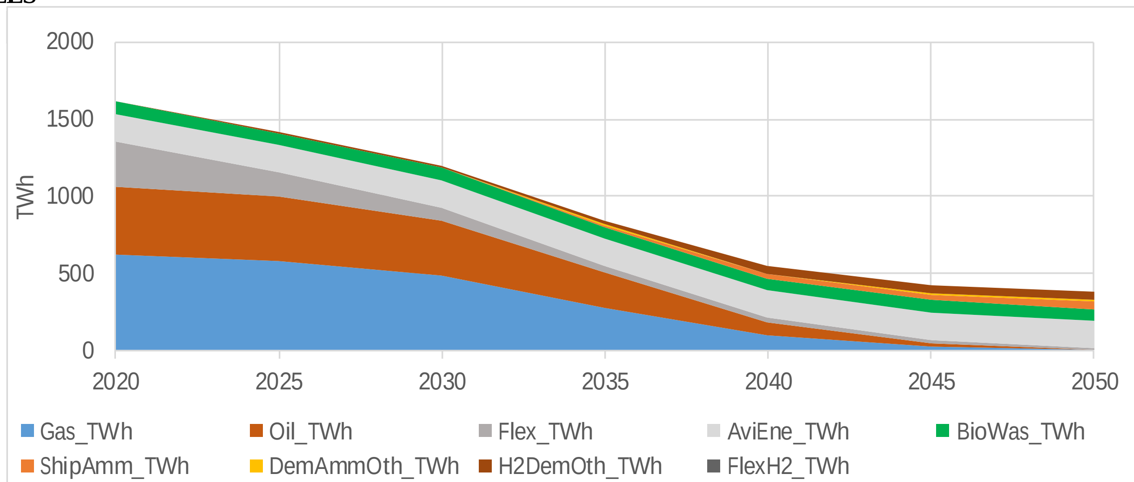
GENERATION



Chemical fuel consumption reduced to:

- Waste biomass
- Hydrogen
- Ammonia ships
- Gas peaking generation

FUELS



CO2 emission largely eliminated apart from:

CO2e EMISSION

- A little flexible gas generation

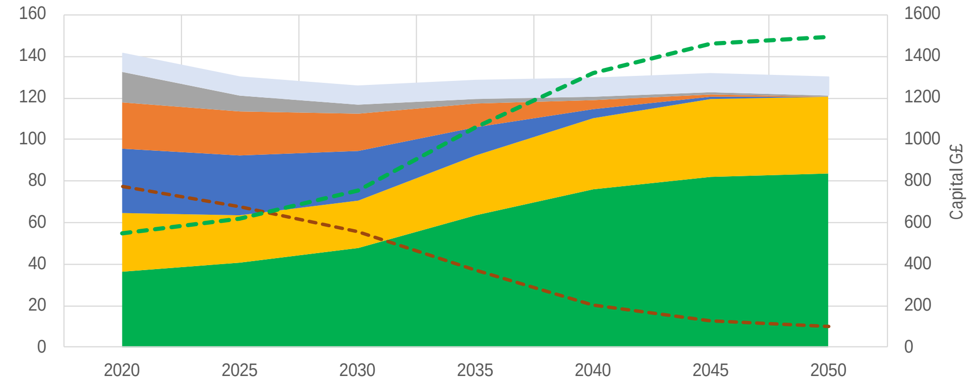
CO2e emission balanced by negative emission with unproven DACS (Direct Air Capture and Sequestration) similar to current, assuming ~2022 fuel prices.

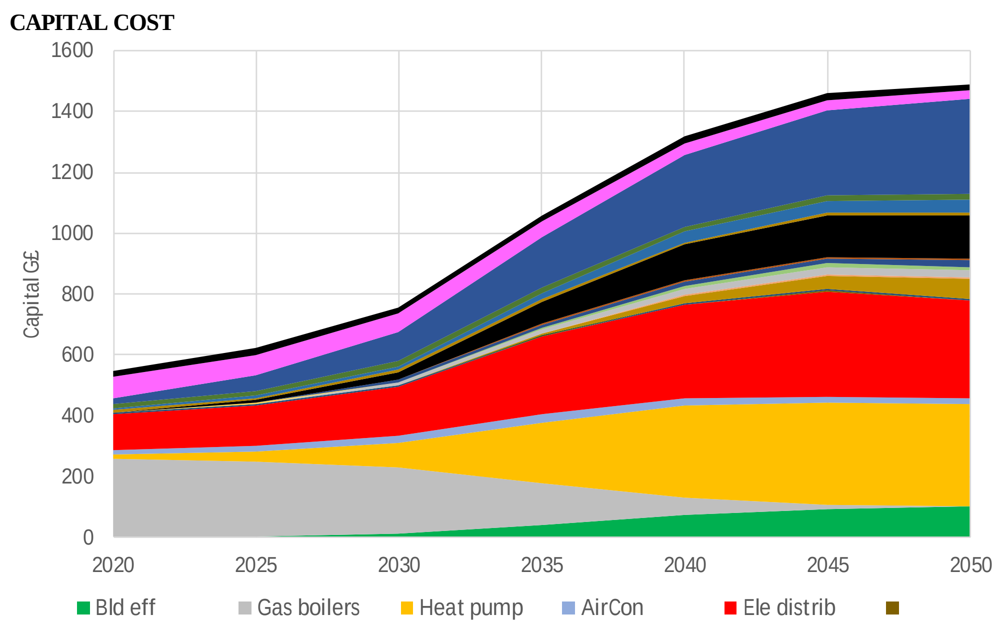
are dominated by capital and fixed O&M, so little volatility and high security

Capital investment about 2% of annual GDP

The are:

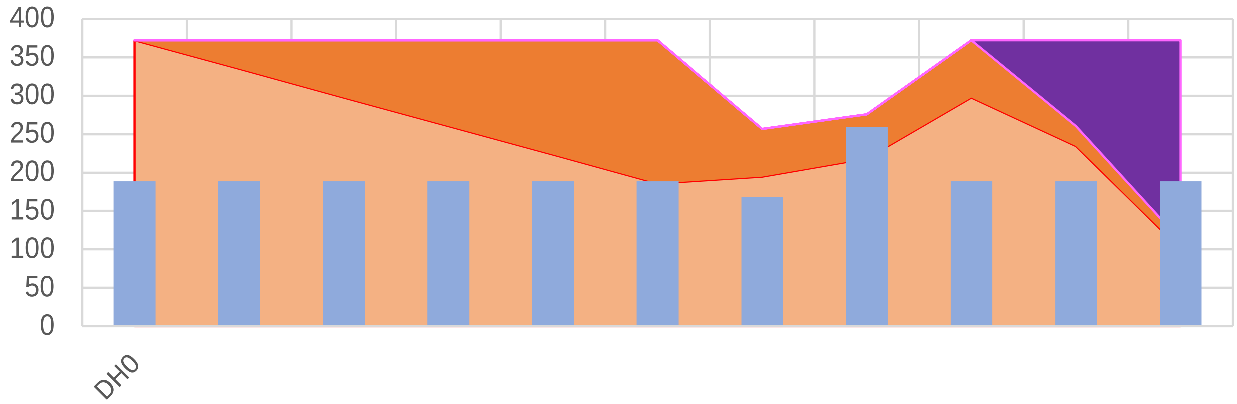
- Heat pumps
- Electricity network
- Offshore wind
- Direct air carbon capture and storage





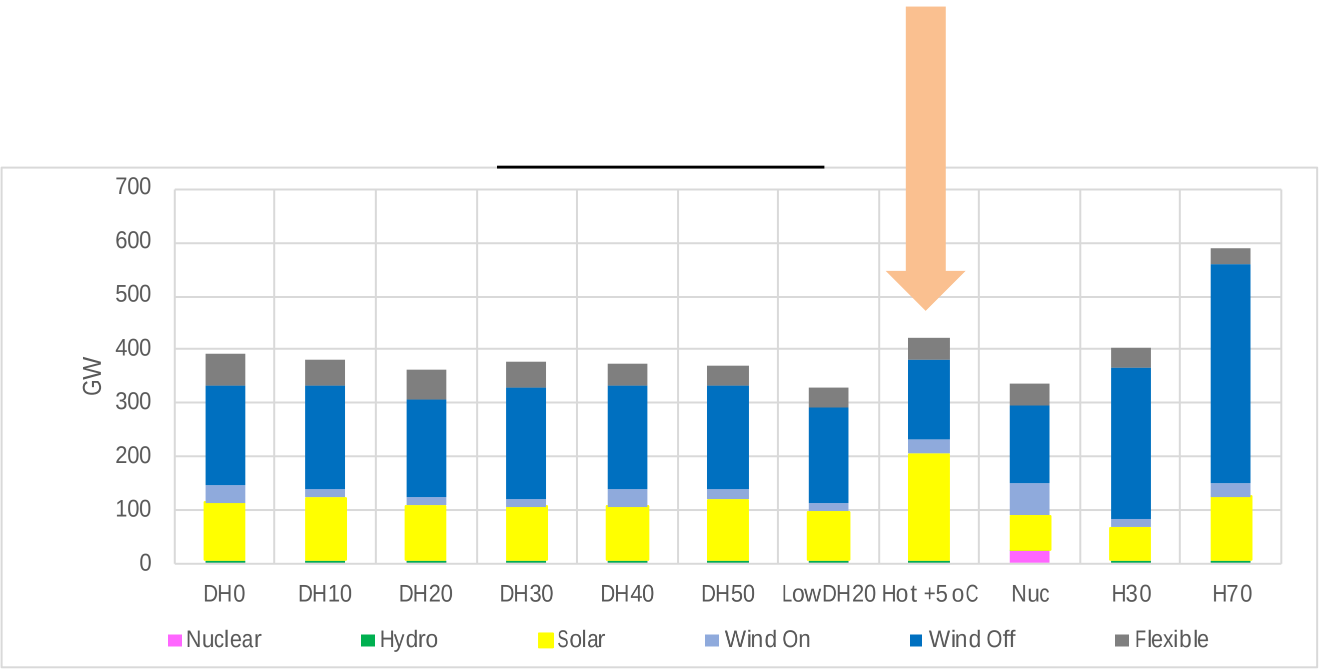
given the lives of buildings and infrastructure

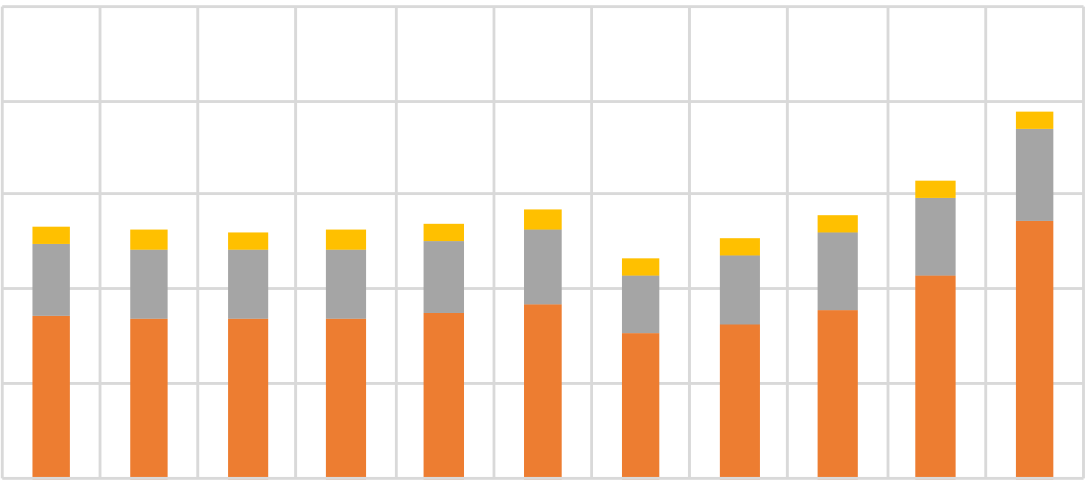
With climate change:



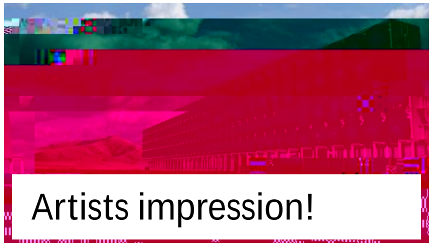
in buildings or district heat and cooling provide resilience

The more cooling, the more solar PV and less wind is optimal





Direct Air Capture and Carbon Storage



demand will reduce, will increase
and with consumer and DHC heat pumps the lowest cost

Economy largely electrified; electricity demand triples

Renewables give supply and price security

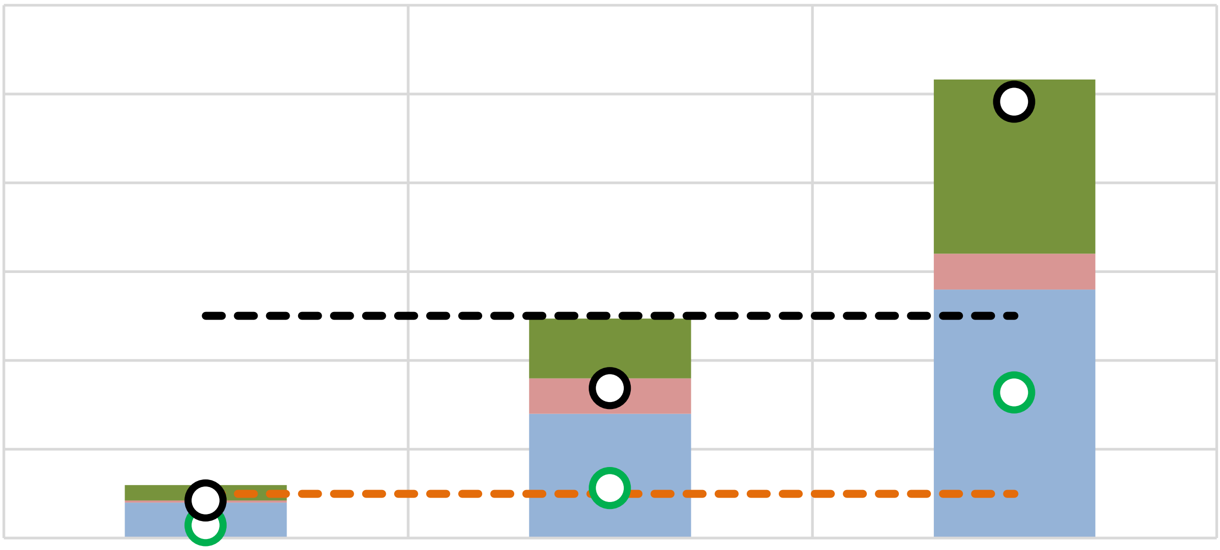
Nuclear is more expensive and less reliable than renewables

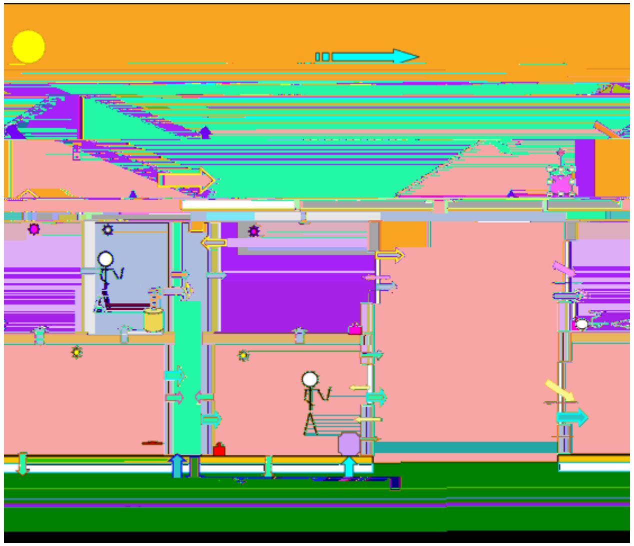
Net zero systems have a similar total cost to the current system

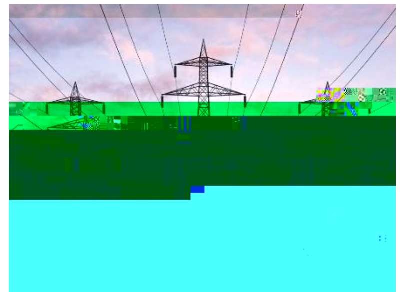
Renewable systems economically and technically secure

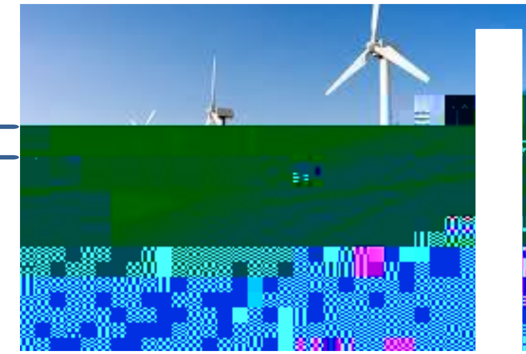
How to fuel aviation and balance high altitude warming?
How to provide negative emissions?
How to install heat pumps and district heating fast?
What is the potential role for interconnector trading?

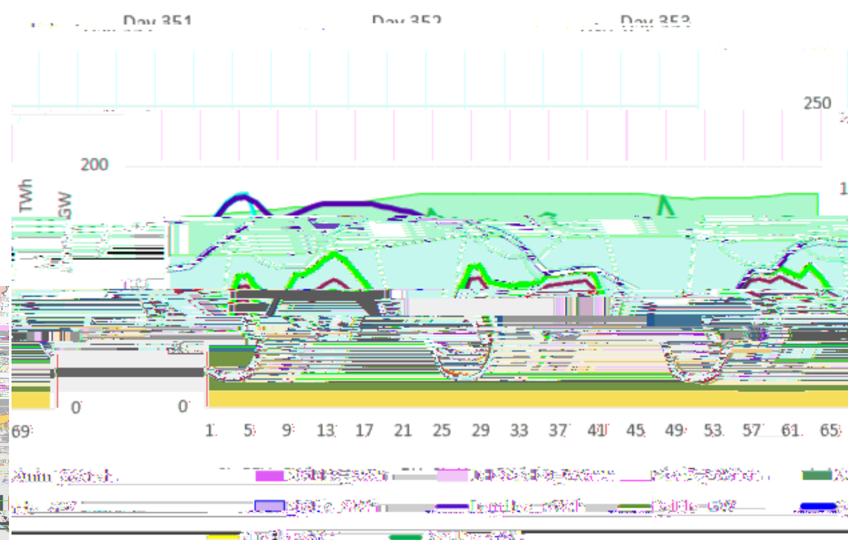
Cost of flying doubled or tripled ~300 £/tCO2 or electrokerosene
Return flight to Spain = average African emission
Return flight to USA = average UK person emission

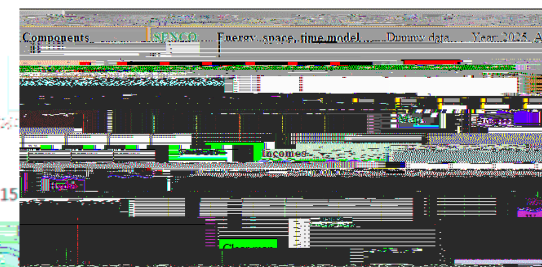








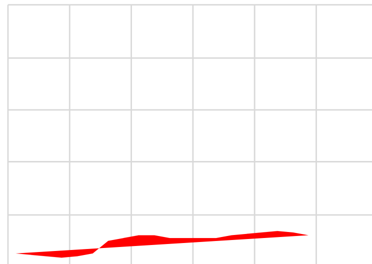

Day 351
Day 352
Day 353
250
200
15
TWh
GW
0
0
69
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65


Components
Energy, space, time model
Year 2025

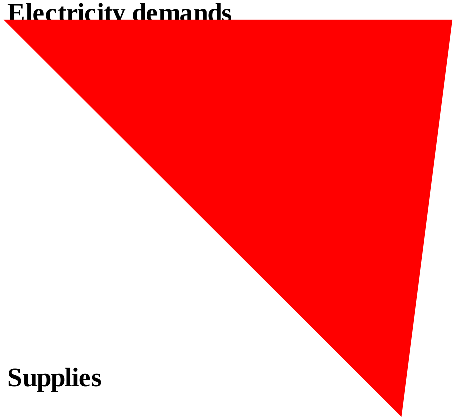
Day of year	51	February

Day of year

Demands

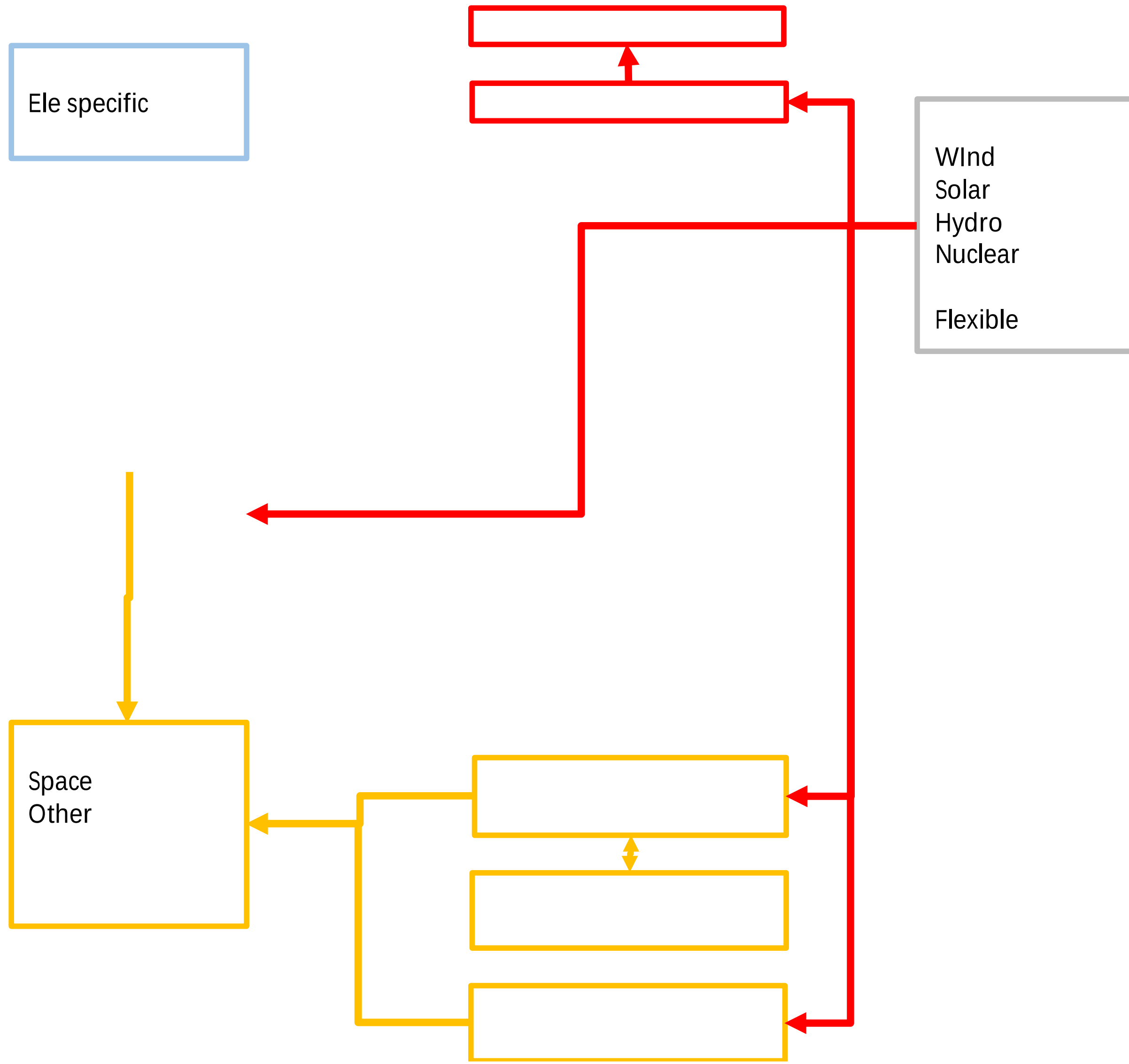


Electricity demands



Supplies

This system does not include interconnectors which will reduce costs, storage and spillage



X

Demands	Weather independent	(Use pattern) x (average demand)
	Weather dependent	(Use pattern) x (Tint_oC - Tamb_oC) (Specific heat loss) - (IncGain)
	Elec: general	(Use pattern) x (average demand)
	Elec: BEVs	(vehicle use pattern) x (average demand) x (weather sensitivity)
	Hydrogen demand	Variable demand for heat + average demand for industry/NH3
	Ammonia demand	Average demand
Generation	Hydro	follows general use pattern
	Sol PV	hourly varying resources
	Win_on	hourly varying resources
	Win_off	hourly varying resources
	Nuclear	base load
	Flexible	dispatched if shortage
BEV	Charge	if battery nearly empty
Heat supply	**Consumer HP**	(Heat demand) (HP heat share)
	Elec use - cons HP	Consumer HP / COP(Tdemand, Tamb)
	District heating	(Heat demand) (DH heat share)
		1 Heat from store
		2 Heat from heat pumps to demand if store empty
		3 Heat and elec from CHP if more heat nee((l)2(e)-123dETBT/F3 1225

UK climate projection for late 21st century

“A greater chance of warmer, wetter winters and hotter, drier summers long with an

.” (high emission scenario: summer +0.9-5.4°C summer, winter +0.7-4.2°C)

:

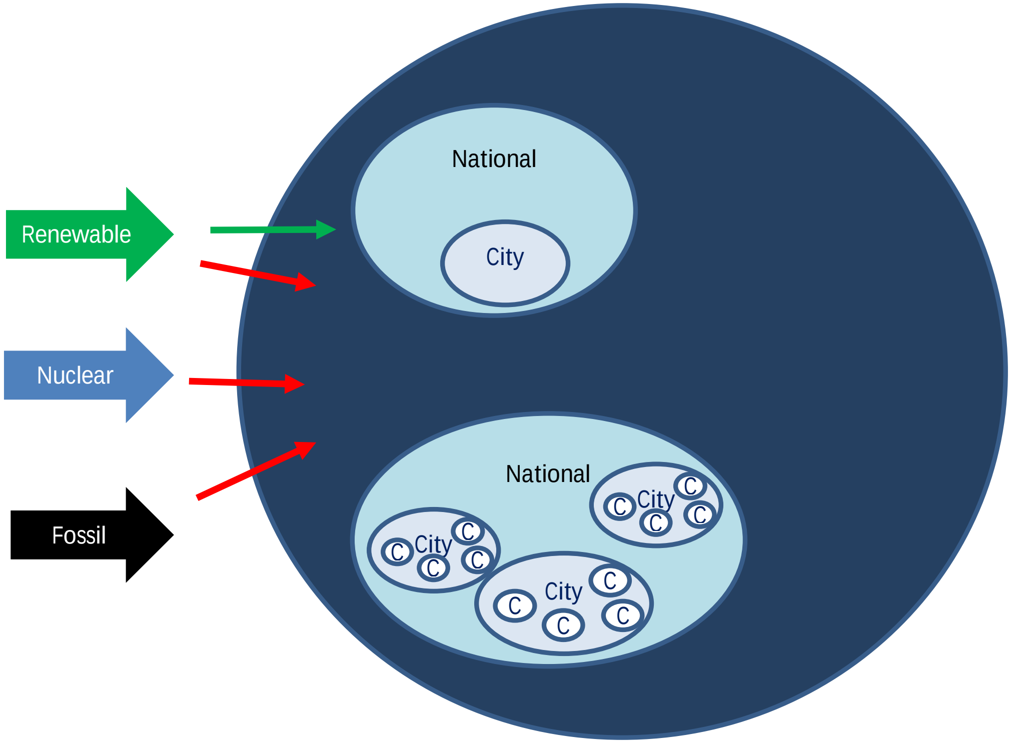
Designing low emission energy systems for a changed climate

Building to city to national to international

Heat, cool, power, electricity…
Domestic, services, industry, transport

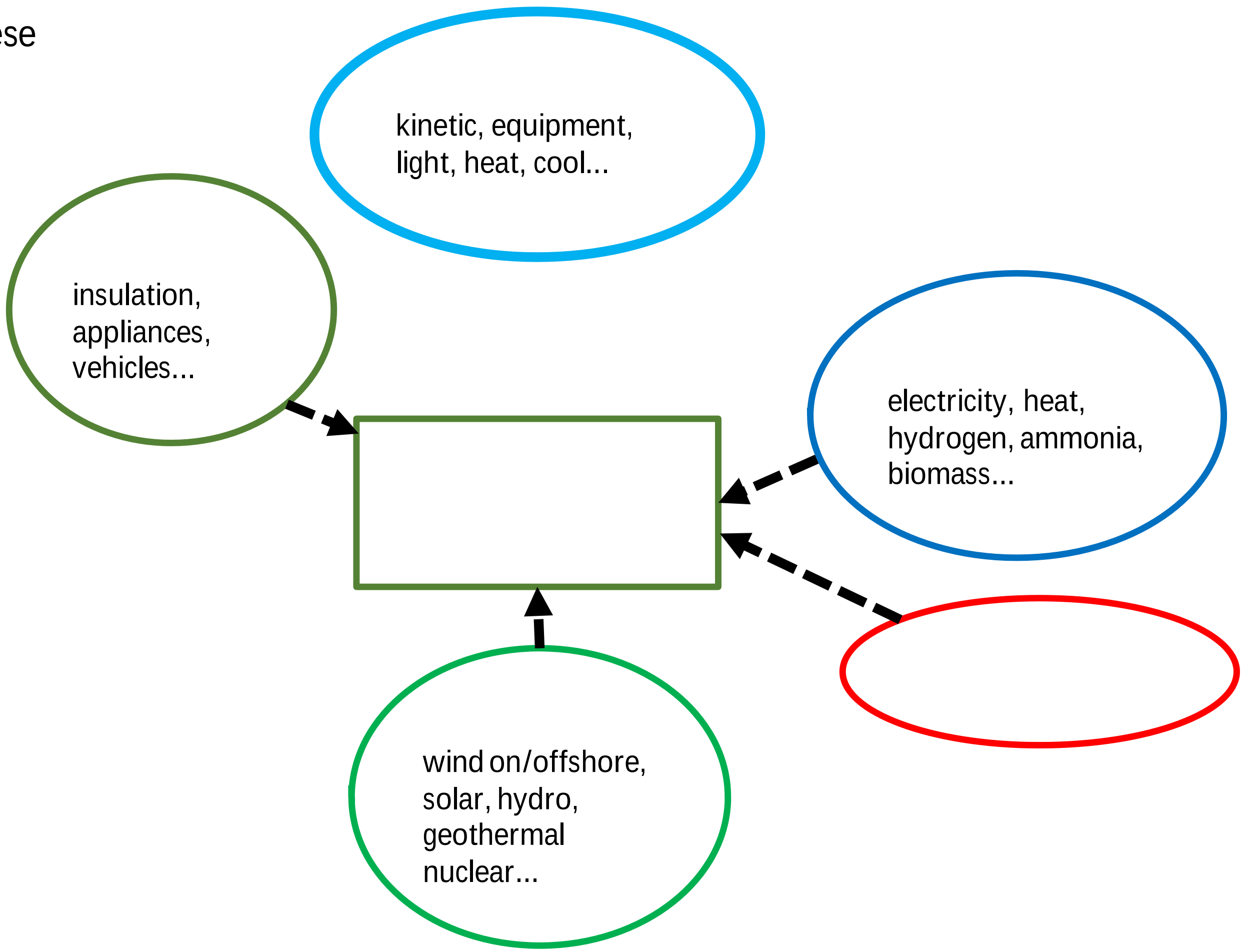
Renewable
Nuclear
Fossil

Primary chemical: fossil, biomass
Secondary chemical (H2, NH3…)
Electricity
Heat



, we design with these components:

- Efficiency
- Intermediate conversion
- Primary supply mix
- Storage mix
- Interconnectors to average demands/supplies



1. Consumer heat pumps (HP), district heating (DH) and hydrogen heating (H2)

2. Aviation fuelling assumed to be mainly fossil

3. All other non heat/cool demands met with electricity, e-hydrogen or e-ammonia

4. Primary energy: renewable electricity, waste biomass, nuclear

5. Direct Air Capture Sequestration (DACS) negative emissions to balance aviation CO2 and high altitude global warming

Systems with different combinations of options:

Optimised for 2050
Transition 2020-2050 emulated with logistic functions
Simulated 2020-2050 at 5 year intervals

KEY

Barrett, M, Gallo Cassarino, T, (2021), Heating with steam methane reformed hydrogen, Research Paper, https://www.creds.ac.uk/publications/heating-with-steam-methane-reformed-hydrogen-a-survey-of-the-emissions-security-and-cost-implications-of-heating-with-hydrogen-produced-from-natural-gas/

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