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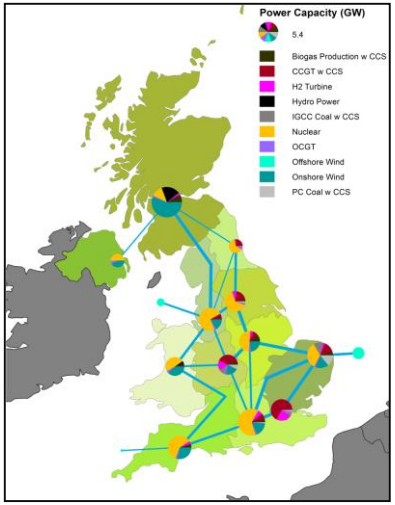
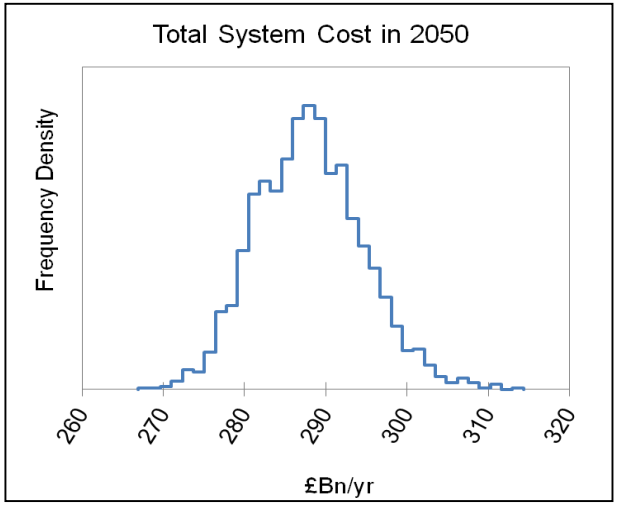
ESME – Sensitivity Studies For Nuclear

Scott Milne – Energy Technologies Institute

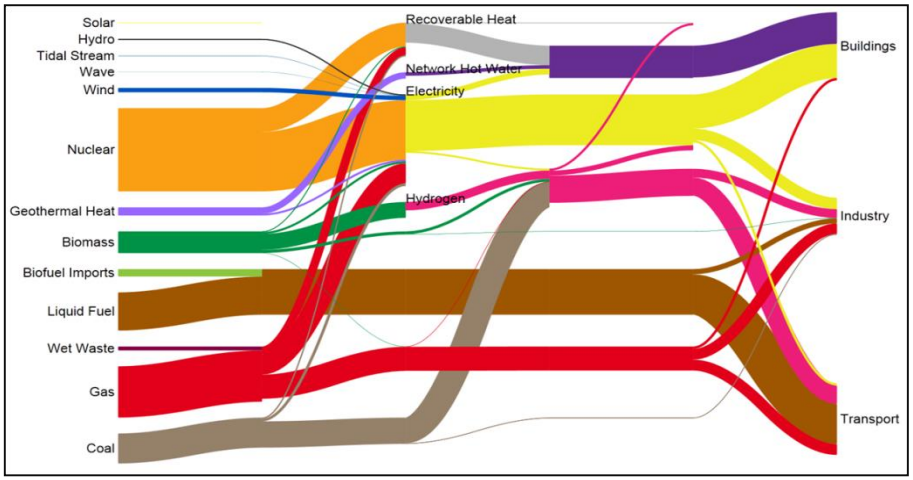
6th October 2015

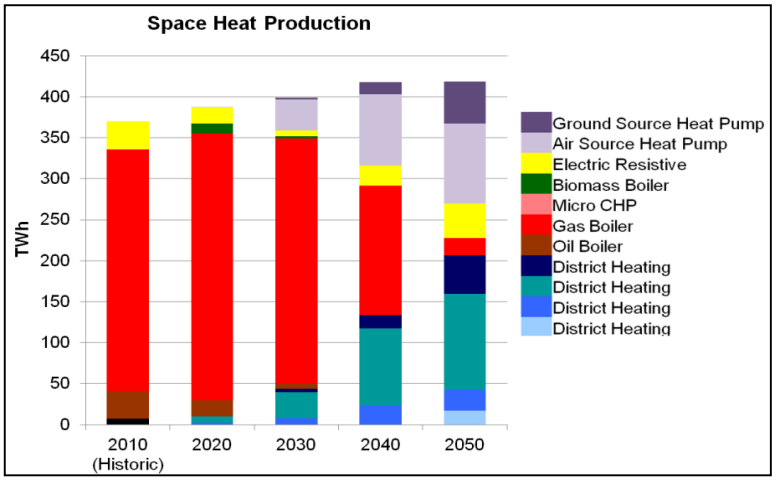
Typical ESME Outputs





Energy
System
Modelling
Environment





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- Impact on the cost of energy system transition transition
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ESME As An Economic Model

Minimises total system cost to 2050

- by summing NPV of future annualised costs - 3.5% discount rate
- Capex annualised over economic life of the technology - 8% investment rate

Opportunity Cost

- Cost of system with *technology x* versus cost of system with option removed
- *Technology x* can feature prominently with low opportunity cost
  - implies affordable substitutability

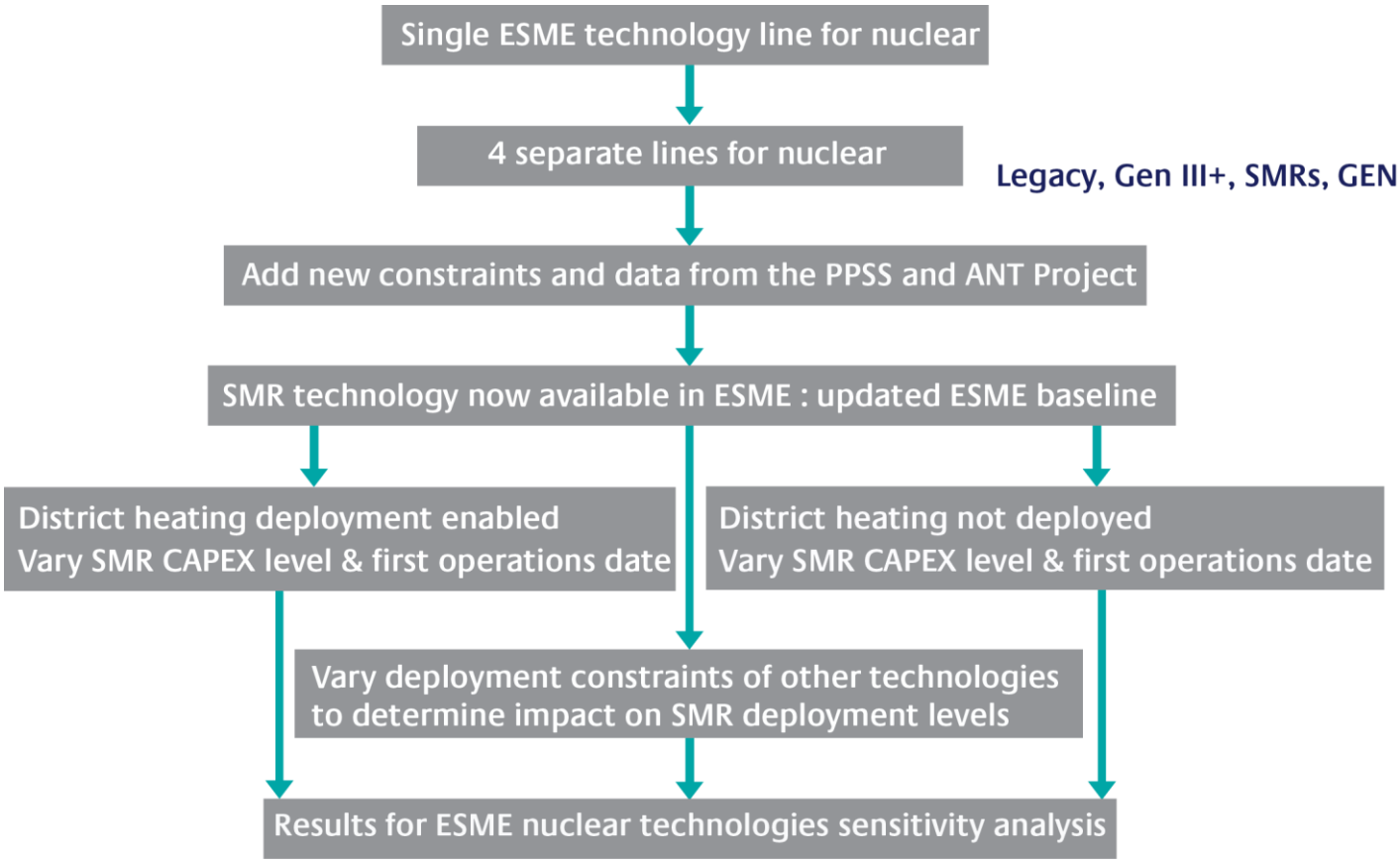
Abatement Cost

- Energy system costs would be incurred even if no carbon targets
- Abatement cost is additional cost for low-carbon solution to given set of demands

Note for ESME Model outputs

- Scenario model outputs are neither forecasts nor credible delivery plans
- Transition requires policies, markets, interventions, incentives, supply chain capacity & investor confidence; more details contact George.Day@eti.co.uk

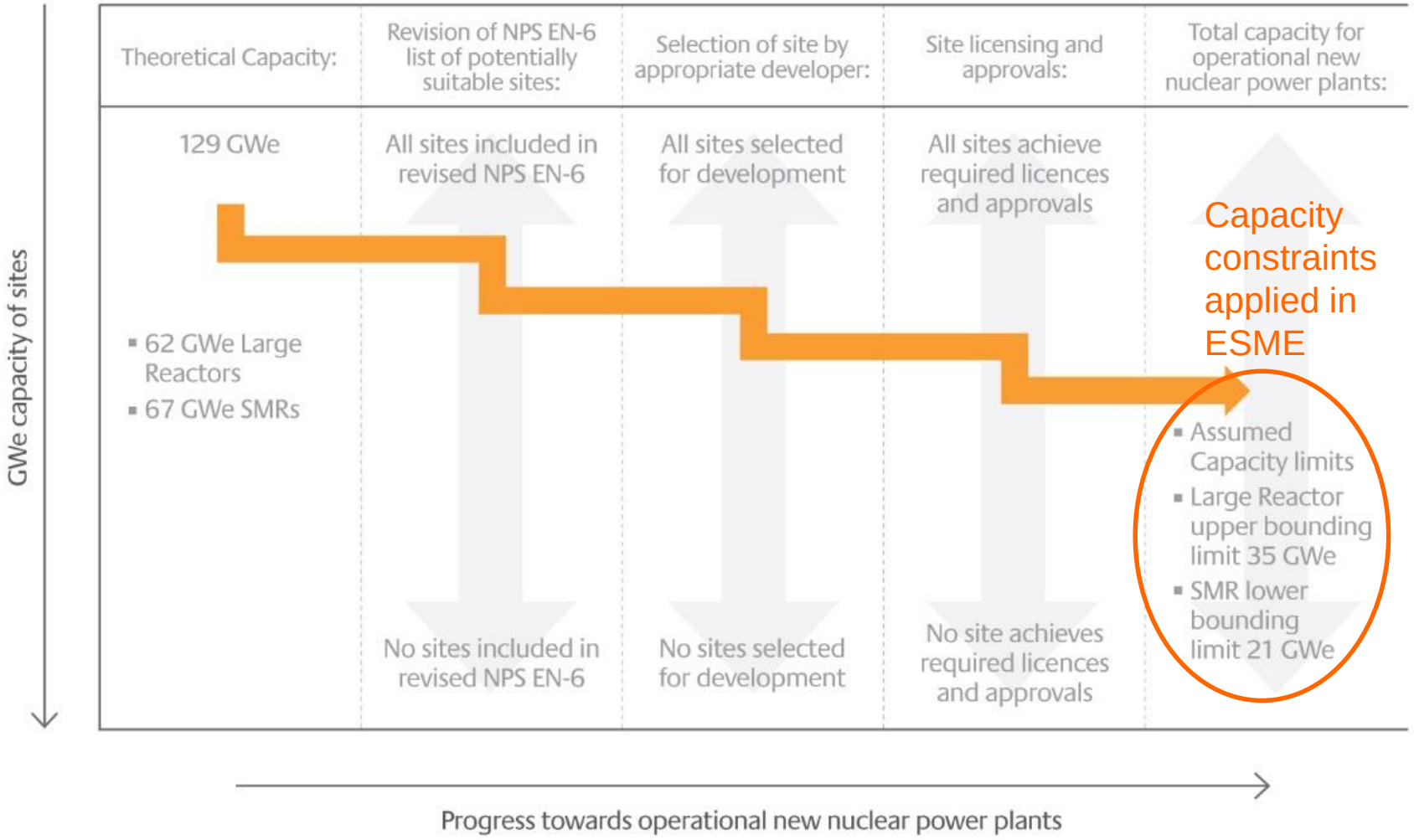
Sensitivity Studies - Approach



Revised baseline is optimised selection from 4 SMR variants:

- Baseload electricity
- Electricity extraflex
- Baseload CHP
- CHP extraflex

Data From The PPSS Project

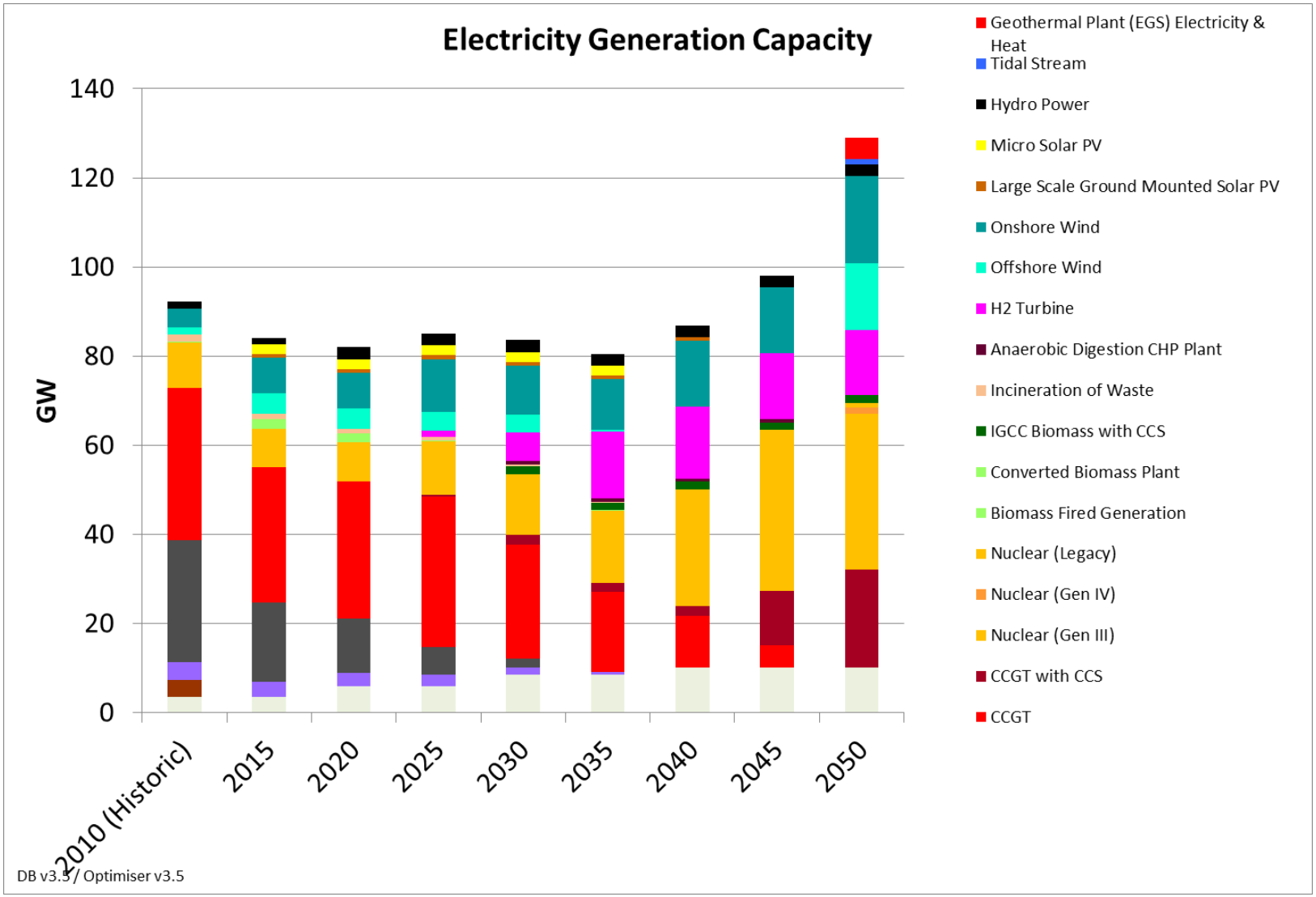


Data From ANT Project

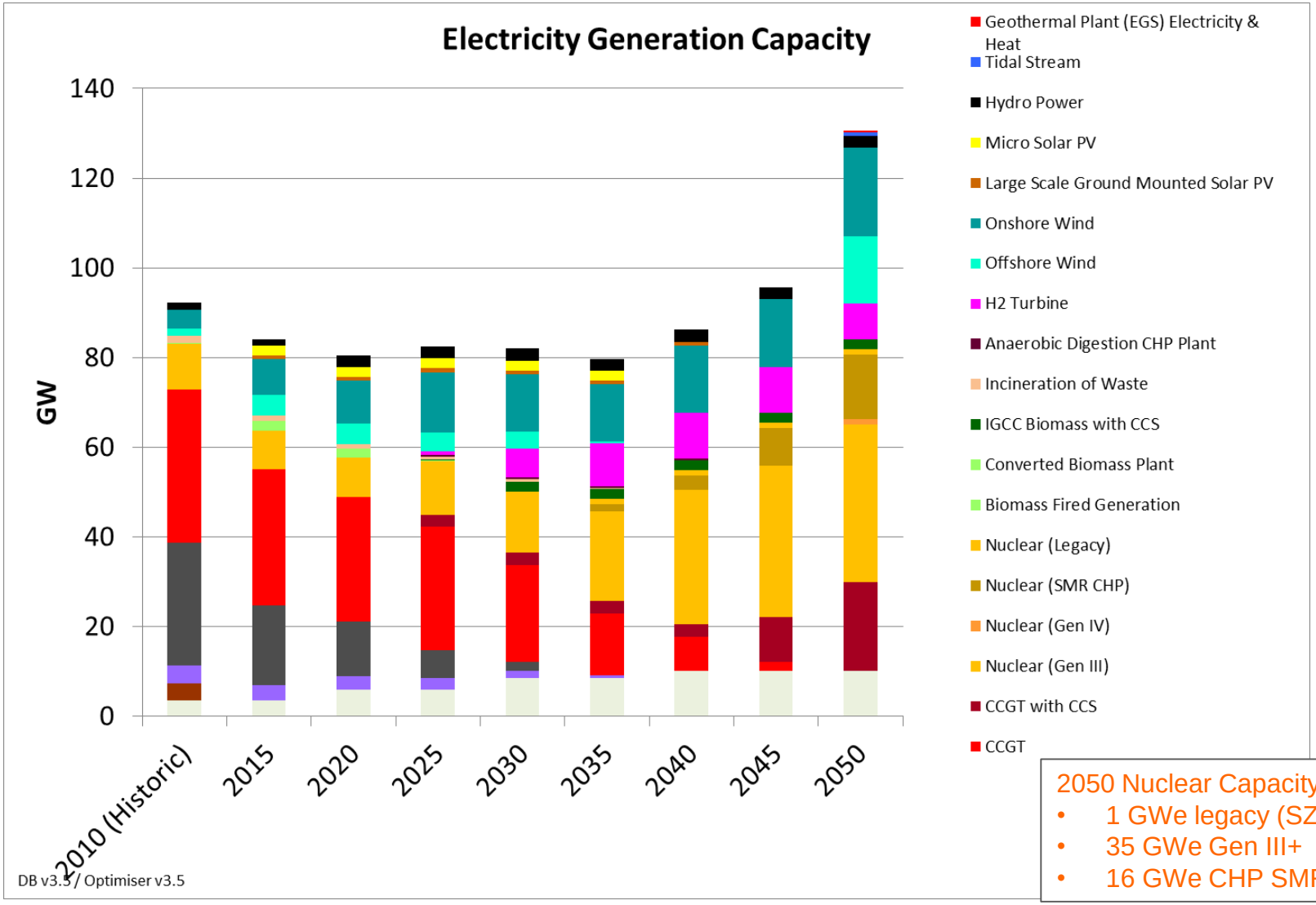
Additional ANT Project data used to create ESME data file for SMRs:

- **CAPEX:** £4000/kWe (LOW), £4500/kW (MID), £5250/kWe (HIGH)
  - **Uplift for CHP:** £200/kWe
- **OPEX:** £105/kWe (by 2050)
- **First Operations Date:** 2025, 2030, 2035
- **Construction Period:** 3yrs
- **Build Out Rate**: (from first operations) 400MWe/yr for 10 years, then 1.2 GWe/yr
- **Regional site capacity**: 21 GWe total distributed across the following regions:
  - East, East Midlands, London, North East, North West, South East, South West, Wales, West Midlands, Yorkshire & Humber
- **Power downrate during CHP heat take off**: 20%
- **Economic life:** 50yrs
- **Technical life:** 50yrs

Updated ESME Baseline – Capacity with 35 GWe Large Gen III+ and without SMRs

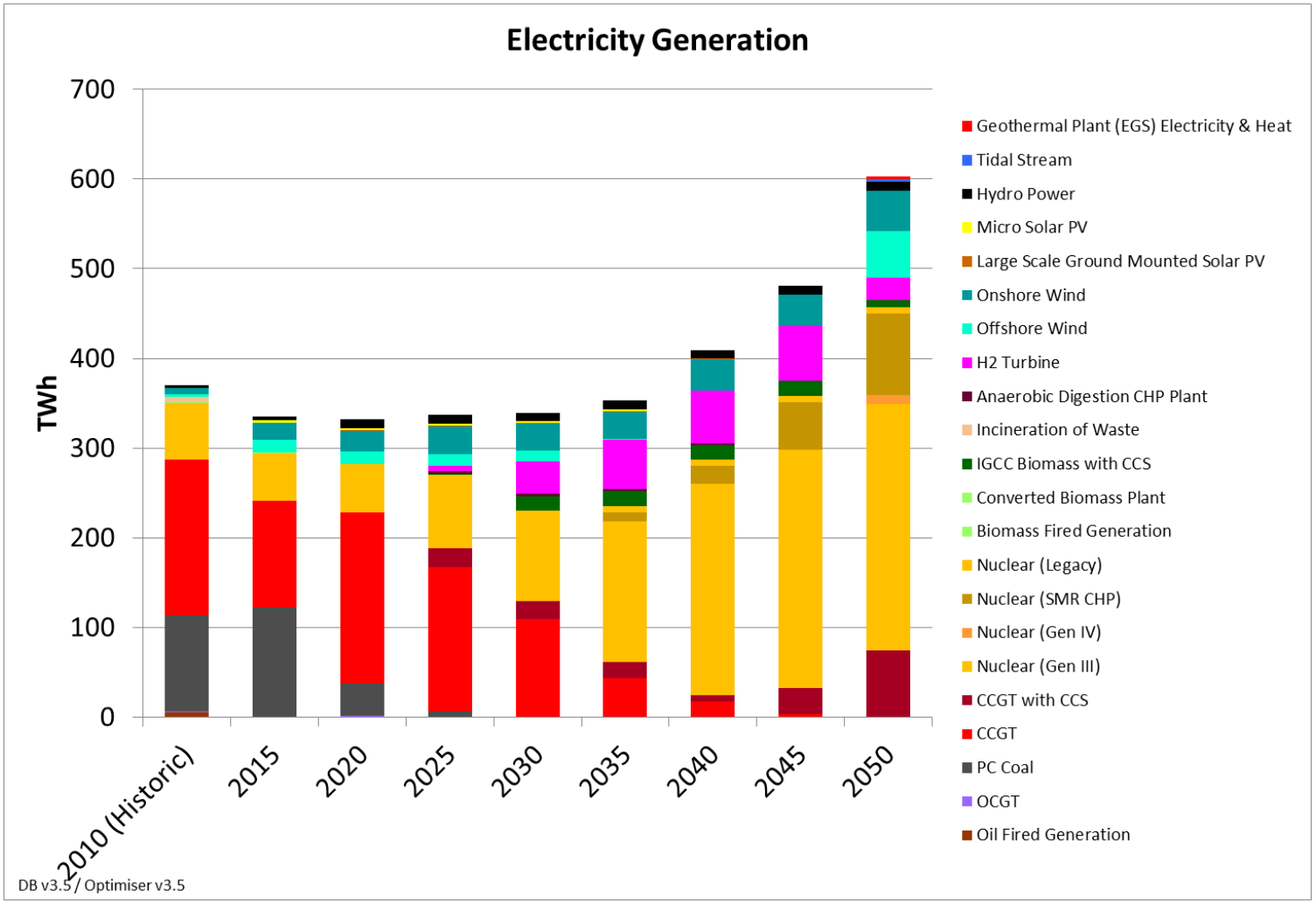


Updated ESME Baseline – Capacity with 35 GWe Large Gen III+ with SMRs available



2050 Nuclear Capacity
- 1 GWe legacy (SZB)
- 35 GWe Gen III+
- 16 GWe CHP SMRs

Updated ESME Baseline – Generation with 35 GWe Large Gen III+ with SMRs available



ESME Analysis – CHP SMRs Attractive When District Heating Is Deployed

	ESME Sensitivity Studies - SMR 2050 Deployed Capacity (GWe)					
	WITHOUT District Heating option			WITH District Heating Option		
First Ops	2025	2030	2035	2025	2030	2035
High Capex	8 *	8 *	8 *	15	14	10
Mid Capex	14	14	9	19	16	10
Low Capex	20	16	10	20	16	10

CAPEX	2025	2030	2035	2025	2030	2035
High	5250	5250	5250	5450	5450	5450
Mid	4500	4500	4500	4700	4700	4700
Low	4000	4000	4000	4200	4200	4200

* Electricity only SMR at £5250/KW CAPEX not operating until after 2040; delayed build out

- Plant utilisation not necessarily at the limit of Annual Capacity Factor
- For comparison with ANT economic analysis:
  - CHP Target Capex (ANT) is £6,400/KW @ 40% ACF For Heat @ £65/MWhr
- When District Heating is not deployed, 2050 generation capacity rises from 125 to 175 GWe

SMR LCOE and Annual Capacity Factor

2050 SMR Levelised Cost Of Electricity £/MWh (note 1) and Annual Capacity Factor Electricity (%)						
	WITHOUT District Heating			WITH District Heating		
CAPEX	2025	2030	2035	2025	2030	2035
High	£94/MWh 85%	£94/MWh 85%	£94/MWh 85%	£115/MWh 84%	£113/MWh 85%	£115/MWh 85%
Mid	£85/MWh 85%	£85/MWh 85%	£85/MWh 85%	£111/MWh 79%	£104/MWh 84%	£104/MWh 85%
Low	£79/MWh 85%	£79/MWh 85%	£79/MWh 85%	£105/MWh 77% (note 3)	£97/MWh 84%	£97/MWh 85% (note 2)

Note 1: Price excludes heat credit from sale of low carbon heat (ANT base case £65/MWth)

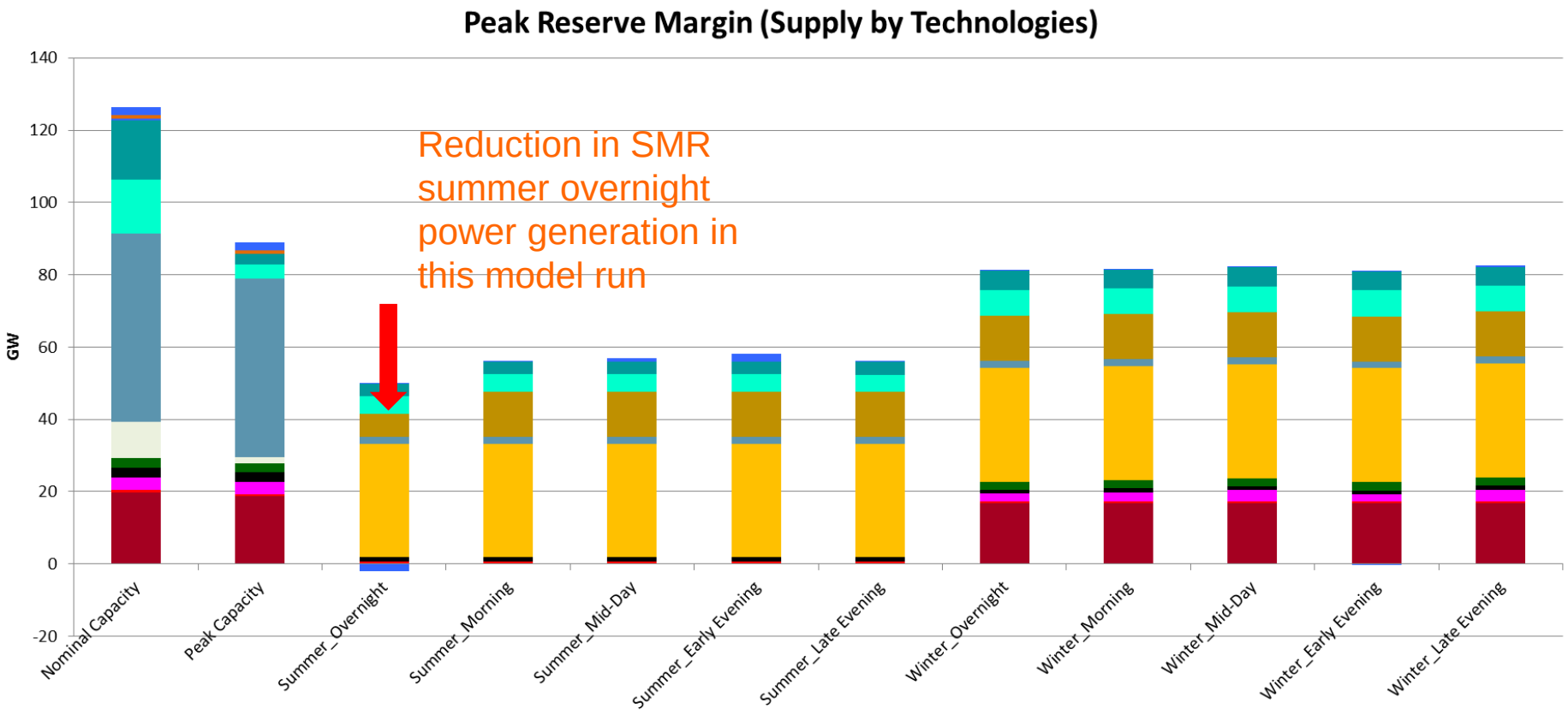
Note 2: SMR operates for maximum time permitted by annual capacity factor limit of 85%.
SMR does not generate maximum electricity all the time
Majority of time is CHP operation but with significant period of electricity only

Note 3: See following chart regarding the "lost" generation hours which increases LCOE

SMR DH Hot Water Contribution In CHP Mode

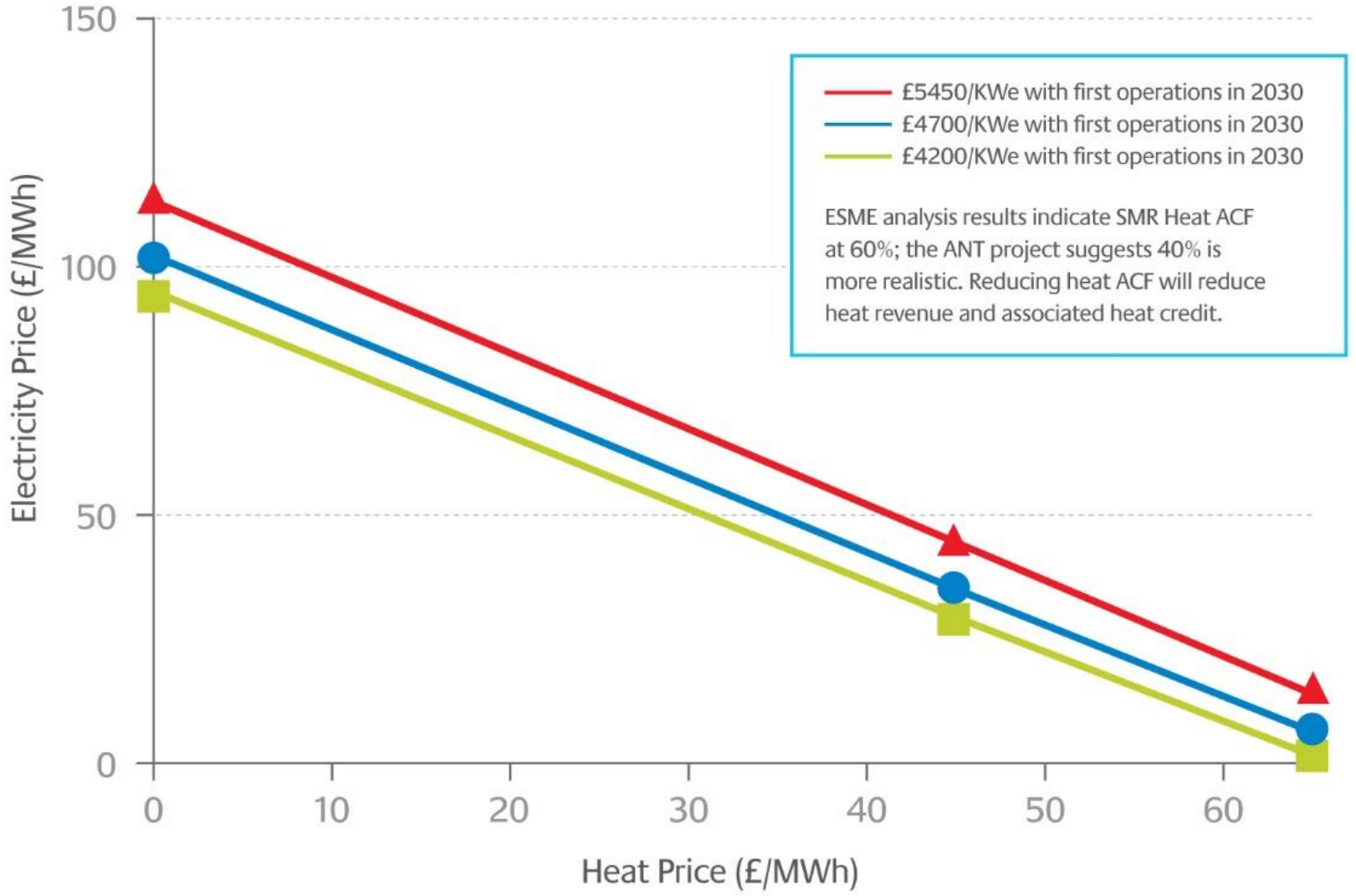
CAPEX	Hot Water Contribution in 2050 from CHP SMRs as a Percentage Of Total DH System Demand					
	WITHOUT District Heating			WITH District Heating		
	2025	2030	2035	2025	2030	2035
High	Nil	Nil	Nil	61%	60%	45%
Mid	Nil	Nil	Nil	73%	66%	45%
Low	Nil	Nil	Nil	74%	66%	45%

Requirement For SMR Flexible Power Delivery



- Flexibility is likely to be important to be able to modulate power to help balance the grid
- The “flexibility” here is diurnal, within a seasonal pattern
- Remember also the impact from intermittent renewables and associated peak generation

The Case For CHP SMRs



Impact On Cost Of System Transition - SMRs

ESME Baseline (with District Heating available but without SMRs deployed)

- Annual abatement cost by 2050 - £58.24 Bn/yr
- Equivalent to 1.55% of GDP

Key messages from table below:

- RHS – reduction in system cost where CHP SMRs energise District Heat networks
- LHS – significantly higher system cost without District Heating

SMR CAPEX Range	Annual Cost Of Abatement in 2050 (£bn/year) and as % of GDP					
First Year of SMR Operations	WITHOUT District Heating			WITH District Heating		
	2025	2030	2035	2025	2030	2035
High	£65.60 Bn	£65.60 Bn	£65.60 Bn	£55.83 Bn	£55.88 Bn	£55.96 Bn
	1.75%	1.75%	1.75%	1.49%	1.49%	1.49%
Mid	£64.71 Bn	£64.72 Bn	£65.03 Bn	£54.22 Bn	£54.63 Bn	£54.56 Bn
	1.72%	1.72%	1.73%	1.44%	1.45%	1.45%
Low	£63.97 Bn	£64.07 Bn	£64.55 Bn	£53.25 Bn	£53.90 Bn	£54.81 Bn
	1.70%	1.71%	1.72%	1.42%	1.43%	1.46%

SMRs - Hedge Technology For Energy Security

Series of runs with the 3 biggest generation technologies limited (indicated in red)

- Large Gen III+ nuclear - 9 GWe
- Gas CCGT with CCS - 8 GWe
- Offshore wind - 3 GWe

Limit on SMR site capacity lifted for these runs, consistent with PPSS potential

2050 Capacity (GWe) across scenarios					
Scenario	Large Nuclear	Gas With CCS	Wind Offshore (+Onshore)	SMRs CHP (+Elec)	Grid Capacity GWe
Baseline	35	18	13 (+17)	16	125
Low Large Nuclear	**9**	20	17 (+20)	29 (+3)	125
Low Gas with CCS	35	**8**	15 (+18)	26	130
Low Offshore Wind	35	16	**3** (+16)	23	118

Conclusion for SMRs -
Hedge role, should any of the biggest generation technologies fail to deliver their full potential

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