SIF CoolDown Alpha

Final project report

11th April 2025

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Executive summary

Bringing energy to your door

CoolDown explores the impact of cooling demand growth and flexibility on distribution networks

SC growth is a black box for distribution networks

Air conditioning (AC) already accounts for 10%[1] of UK electricity demand today. 65% of office space and 30% of retail space has AC[1].

Household SC is nascent today, but over a third of English homes are at risk of overheating in the future. 5-32%[1] of UK homes are forecasted to adopt AC by 2035. As the UK warms, cooling load from both sources will increase significantly.

The potential impact of this growth in cooling load, especially domestic SC load, on Distribution Network Operators (DNOs) is poorly understood.

It is also unclear how much network flexibility SC can provide in practice, and what is needed to unlock it.

If unmanaged, cooling growth could significantly alter network planning, accelerating reinforcement needs. This will increase consumer energy bills and hinder progress towards net zero.

Objectives of CoolDown Alpha

1. Develop high resolution cooling uptake and demand projections to improve DNOs' understanding of its impact.
2. Develop novel cooling DR programmes to incentivise and unlock SC flexibility, optimising value for networks, Flexibility Service Providers (FSPs) and GB energy consumers.
3. Trial and refine the cooling DR programmes designed to maximise adoption in BaU.

CoolDown Discovery phase achievements

1. Modelled cooling load growth in two substations and established bounds for SC uptake across offices, retail and domestic spaces.
2. Extrapolated results across wider pool of ENWL substations to develop an initial view of SC DR potential to defer network reinforcement.
3. Did an initial CBA modelling the financial benefits from SC DR.
4. Identified current international SC DR landscape and best practices and synthesised for relevant in the UK.
5. Developed a longlist of potential commercial models for network SC DR in the UK and identified any barriers to deployment. Shortlisted five models for further exploration in Alpha.

[1] A tenth of UK electricity used for air conditioning - CIBSE Journal
[2] Domestic Air Conditioning in 2050 | UKERC | The UK Energy Research Centre

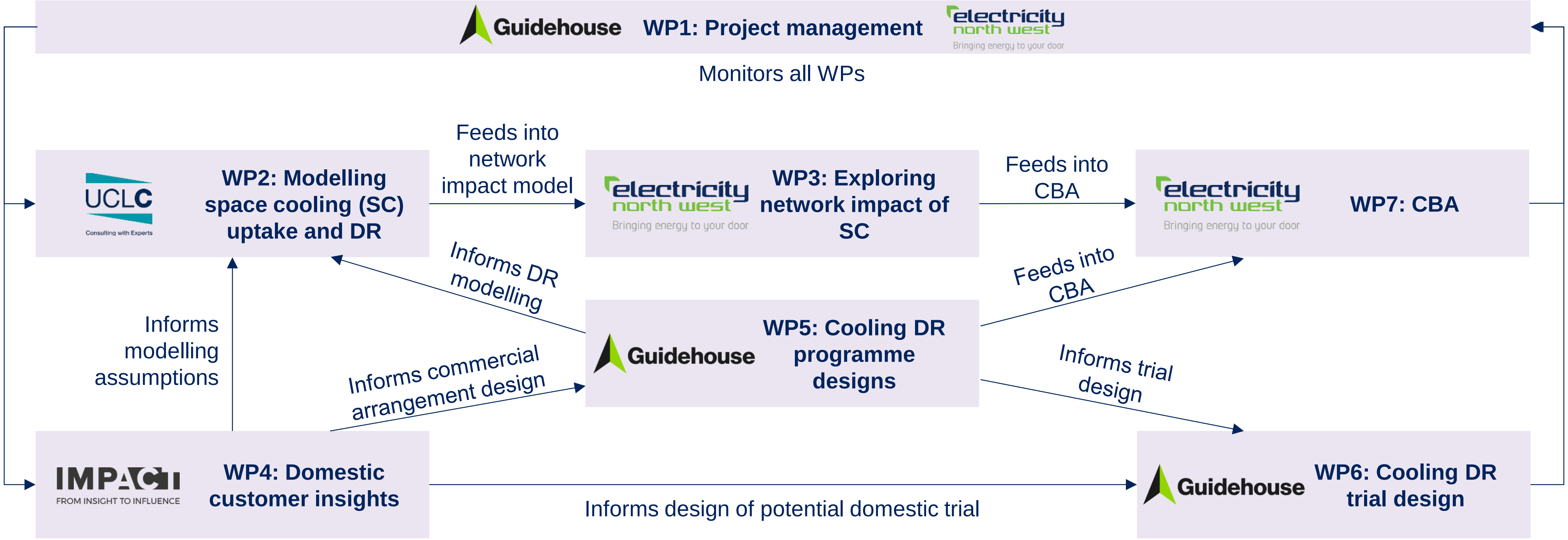
Alpha explored the network impact of SC uptake in depth and designed DR programmes to mitigate against this

Objectives of Alpha:

1) Explore impact of SC on network capacity via improved uptake and demand projections.
2) Develop novel DR programmes to incentivise and unlock SC flexibility, reducing network reinforcement requirements and optimising value for customers.
3) Trial and refine the cooling DR programmes designed to maximise adoption in BaU.

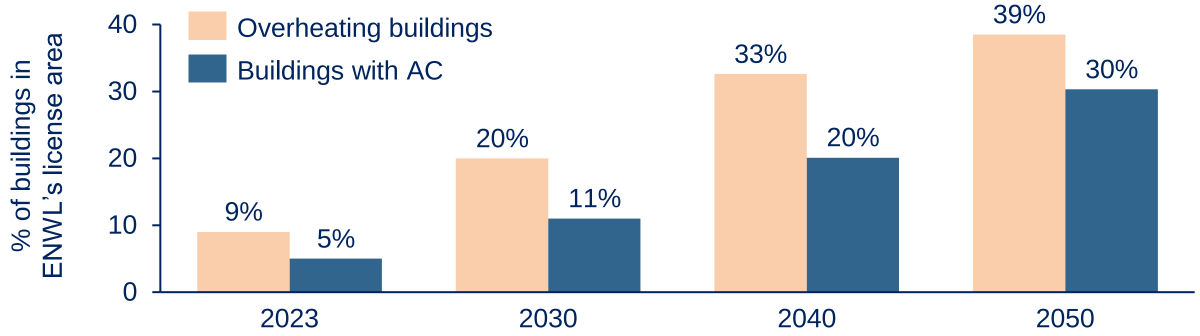
6 project partners

electricity north west – Bringing energy to your door; Guidehouse; UCLC – Consulting with Experts; OAKTREE POWER; IMPACT – FROM INSIGHT TO INFLUENCE; nationalgrid

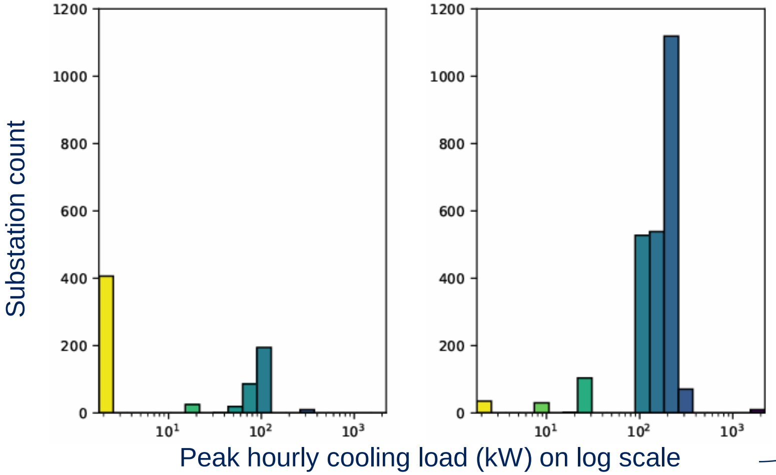


Building overheating due to climate change is predicted to increase cooling uptake across all building types

Modelled proportion of overheated buildings and buildings with AC installed across 2,438 substations in ENWL's license area



Distribution of maximum peak cooling load across 2,438 ENWL substations in 2023 (left) and 2050 (right)

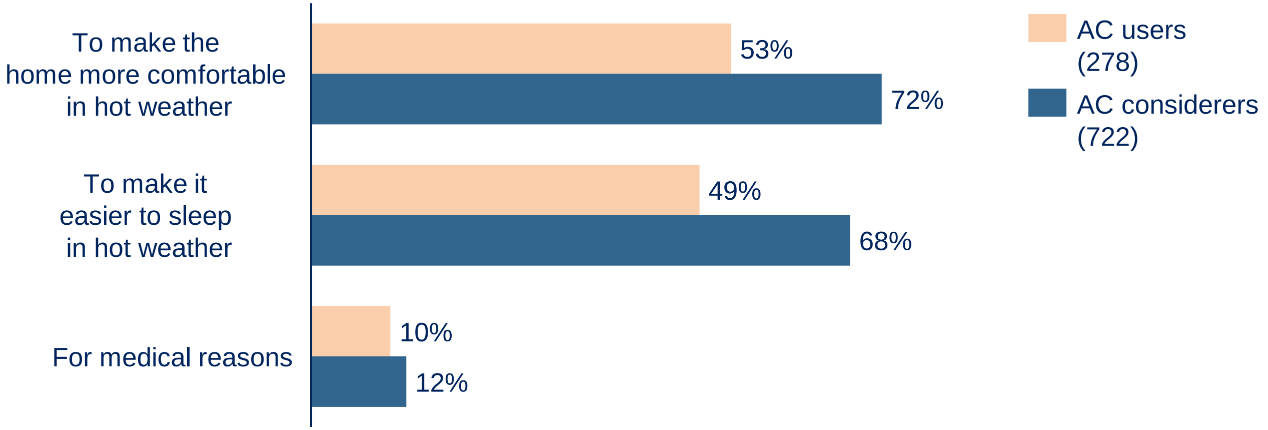


We modelled building overheating and cooling demand growth and found that:

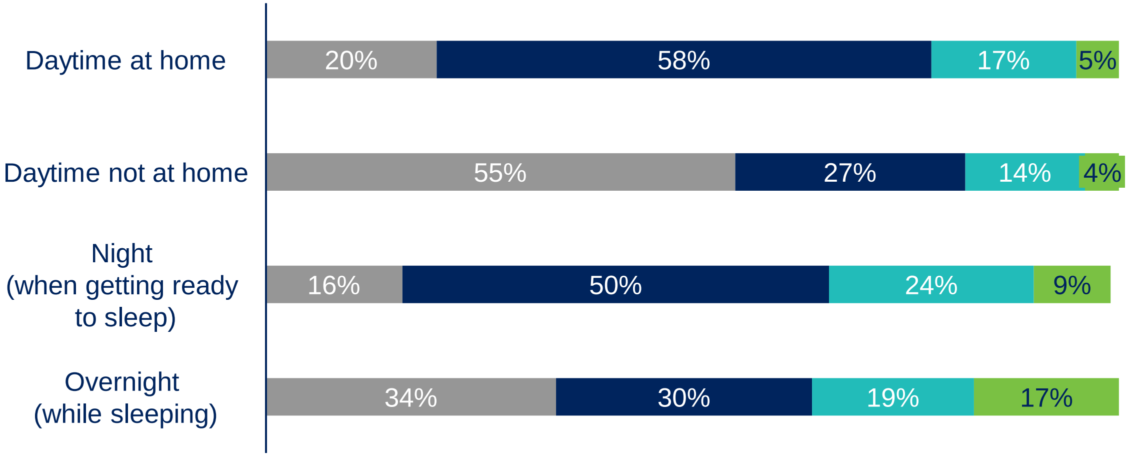
- Climate change is expected to result in increased overheating across all building types.
- In ENWL license areas, 39% of all buildings are predicted to overheat by 2050, up from 9% in 2023.
- The modelling assumes that cooling uptake is directly linked to building overheating. This leads to 30% of all buildings installing active cooling technologies by 2050, up from 5% in 2023.
- Non-domestic buildings are at greater risk of overheating, and thus see a greater uptake of cooling, than domestic buildings. This is due to higher "internal gains" from greater building occupancy and poorer energy efficiency across these building types.
- By 2050, **all** substations have cooling demand. This growth causes maximum peak hourly cooling demand to rise across all substations. Compared to 2023, six times as many substations have a peak cooling load between 100-300kW by 2050.

Domestic cooling consumption is expected to grow significantly to aid home comfort in hot weather

Reasons for AC installation amongst the 1,000 survey participants



Survey participants' AC usage patterns (AC users only)



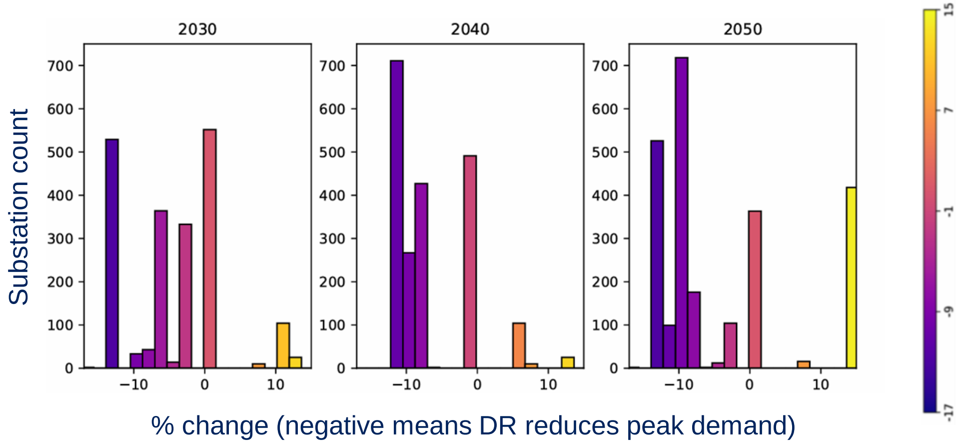
We conducted an online surveys, interviews and focus groups with 1,000[1] domestic AC and found that:

- 8% of UK households currently have an AC unit and 20% plan to purchase AC in the next two years, indicating a growing trend.
- The primary motivators for AC purchase include improving comfort in hot weather, improving sleep, and managing health concerns.
- Nighttime AC usage is an increasing priority for cooling when getting ready for bed. 17% have their AC on for most of the night. Daytime usage is often limited due to electricity cost concerns.
- 64% of users turn their AC on at >24°C. The preferred cooling temperature set-point is 19-22°C.
- When presented with peak time rebate and time of use (ToU) tariff DR programme designs, the peak time rebate programme proved more popular. People wanted at least 24 hours notice of a DR event and preferred that events be no more than 1-2 hours long and a maximum of 3-4 times daily.
- Results highlighted that clear communication, flexibility, and voluntary opt-in mechanisms are critical to engagement in DR programmes.

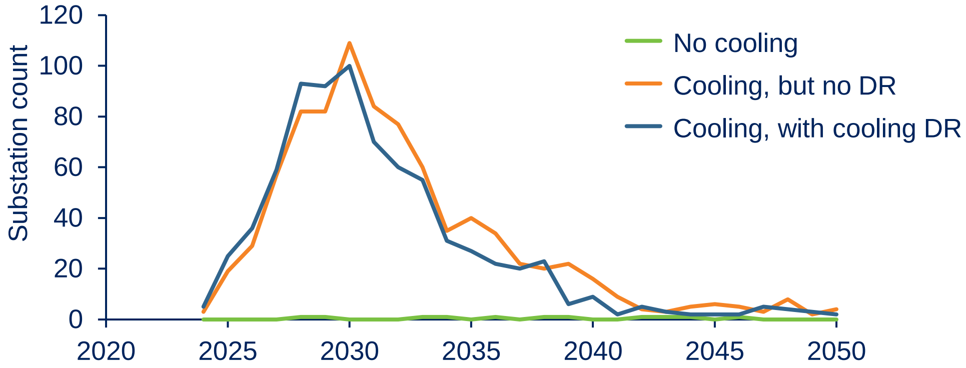
[1] 278 AC users and 722 AC considerers

Unmanaged cooling growth will result in accelerated substation reinforcements. Cooling DR could mitigate this

Modelled change in maximum peak demand from implementing cooling DR across 2,438 ENWL substations



Modelled number of summer-peaking ENWL substation reinforcements triggered per year for the Holistic Transition DFES[1]



We modelled the impact of growing SC demand on ENWL's network, plus the impact of DR:

- The modelled growth in cooling demand drives hundreds of substations to peak in summer instead of winter.
- This often drives earlier substation reinforcement needs than current network forecasts, which predominantly see reinforcements triggered in the winter (e.g. heat pump load growth). The split between summer and winter triggered reinforcements varies across Distributed Future Energy Scenarios (DFES).
- If unmanaged, cooling could significantly alter network planning, accelerating reinforcement needs and delaying the connection of other low carbon and electrified demands.
- Cooling DR can help mitigate against the network impact caused by this growth in peak demand.
- Cooling DR decreases the peak load in most substations by at least 9% by 2040 (in >50% of the 2,438 substations modelled).
- Some substations are modelled to experience an increase peak demand due to secondary, post-DR event peaks. This could be avoided by accounting for when designing and iterating the DR programmes designed.
- This overall decrease in peak load translates into deferred reinforcement needs and fewer substations having summer-triggered reinforcement – see the Holistic Transition example left.

[1] Note that the Electric Engagement and Hydrogen Evolution DFES have similarly shaped summer substation reinforcement profiles, though the substation counts differ.

We designed two cooling DR programmes for commercial cooling customers and two for domestic

Commercial cooling DR arrangements designed		
Programme	**Cooling DR mechanism**	**DR parameters**
Scheduled Direct Load Control	FSP turns down customer's cooling via direct load control.	**Event length**: 60–90 mins. **Notice Period**: At least 4 hours. **Event frequency**: 60-90 mins between events if multiple per day.
Peak Time Rebates	Customer turns down their own cooling to receive financial rewards from their FSP.	

Domestic cooling DR arrangements designed		
Programme	**Cooling DR mechanism**	**DR parameters**
Peak Time rebates	Customer turns down their own cooling to receive financial rewards from their FSP.	**Event length**: 1-2 hours preferred, max 4 hours. **Notice Period**: At least 24 hours. **Event frequency**: 1-2 events per day.
Fixed Time of Use Tariff	Customer turns down their own cooling in response to tariff price signals.	Tariff structure fixed and agreed at sign-up.

Roles of the stakeholders in a DR programme

£/kW/h Availability and/or £/kWh Utilisation payment

Contracted kW of flexibility delivered

DNO sets flex requirements on annual/biannual basis

FSP / Supplier assesses participation and provides customer payment

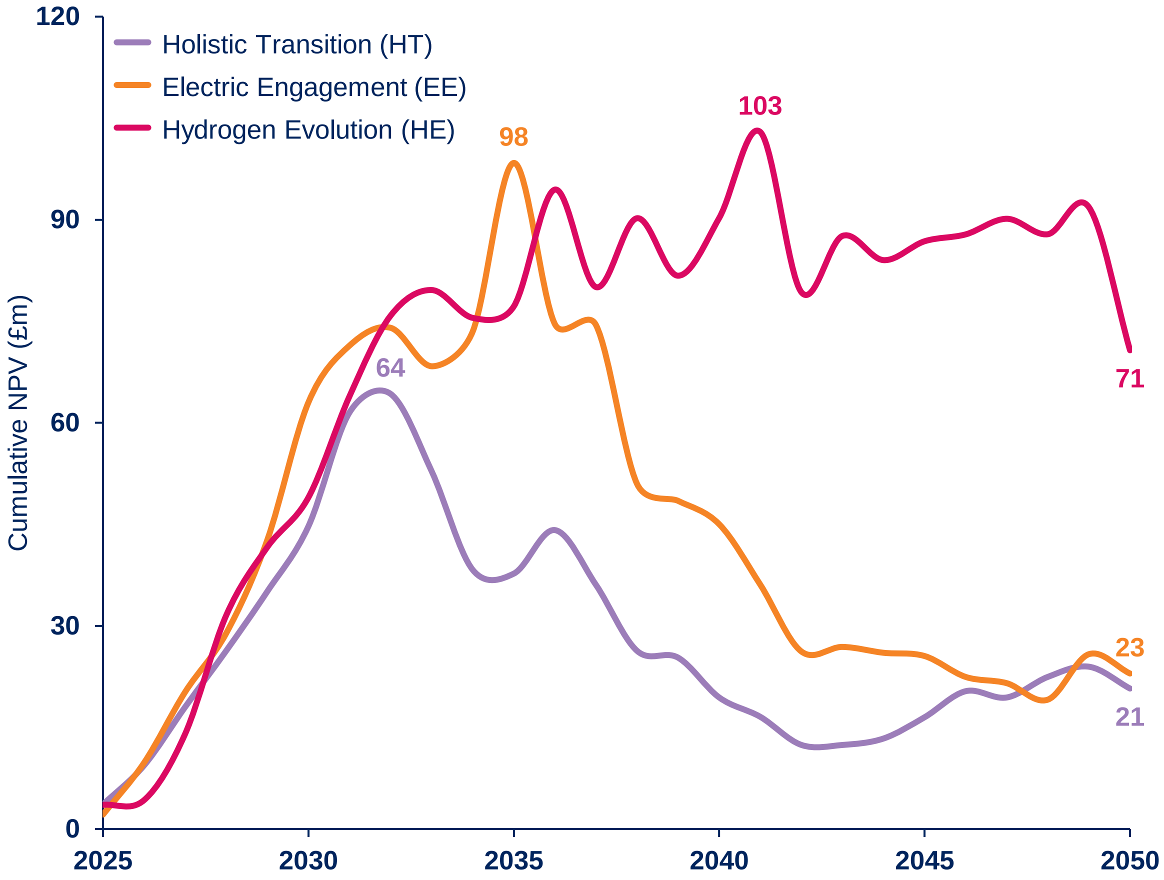
Fixed upfront payment and/or £/kWh payment for cooling turn down

Cooling consumption turned down as per DR programme

Customers turn down cooling consumption

Cooling DR can deliver up to £103m net discounted financial benefits to GB energy consumers by 2042

Cumulative discounted net present value (NPV) of cooling DR rollout GB wide – core modelling scenario



We explored the costs and benefits of cooling DR and found that:

- Cooling DR could deliver £20 - £71m in cumulative net discounted benefits to GB energy consumers by 2050, depending on the DFES scenario modelled.
- Benefits accrue more in earlier years as reinforcement is delayed by cooling DR to a winter peak trigger a few years later. The peaks are:
  - Holistic Transition: £64m in 2032.
  - Electric Engagement: £98m in 2035.
  - Hydrogen Evolution: £103m in 2042.
- The cost of procuring flexibility reduces the net financial benefits from DR reinforcement deferral. Without it, the cumulative benefits by 2050 are:
  - Holistic Transition: £66mn.
  - Electric Engagement: £107mn.
  - Hydrogen Evolution: £167mn.
- Certain substations showed an increase in peak demand post DR (see slide 14) due to customers potentially operating their cooling devices at a higher power than they normally would in the absence of DR.
- If this snapback effect is mitigated against in the design of the DR programmes, the NPV attainable increases by £8-25mn. (see slide 41).

WP2: Modelling SC uptake and DR

Bringing energy to your door

WP2 – Modelling SC uptake and DR

UCLC Consulting with Experts

Modelling SC uptake and DR

Objectives

- Refine existing forecast model to enable a significant number of substations to be explored to provide a greater understanding of SC uptake and SC DR across a series of substation archetypes.
- Update the existing model to include the year 2040.

Building on Discovery:

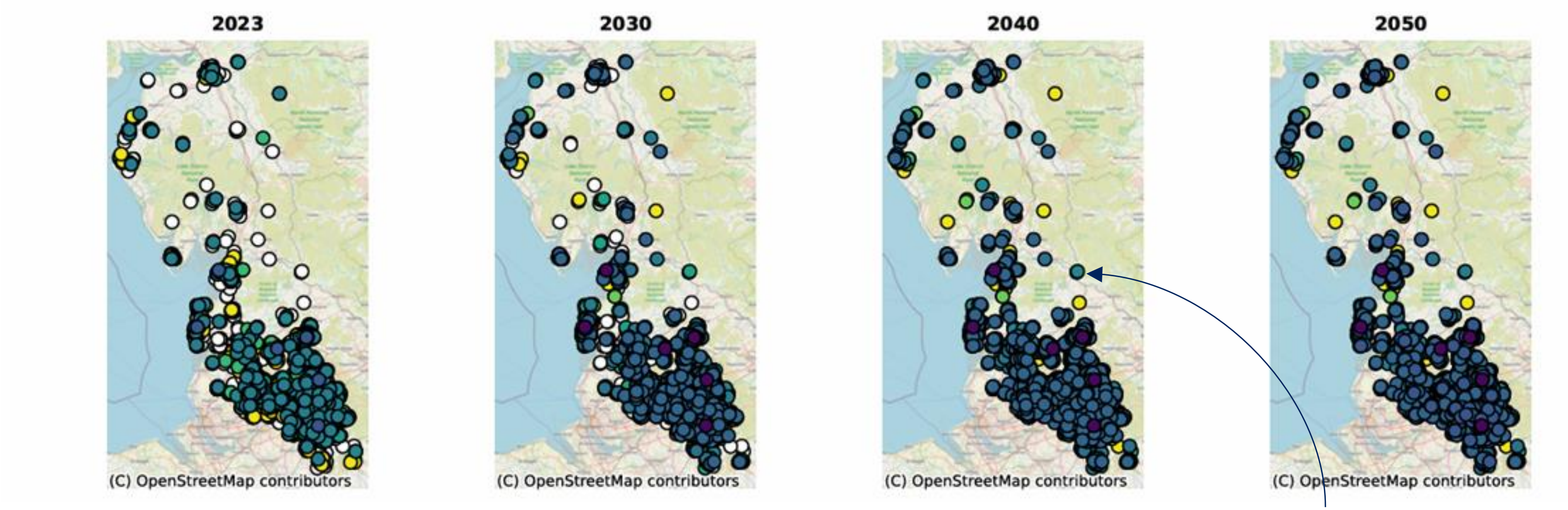
- Discovery modelled distribution network SC demand on a peak summer day and assessed the potential impact of cooling DR on the network.
- The Discovery modelling was conducted on two ENWL substations and extrapolated across ENWL's network.
- Alpha built on this by developing a method to represent thousands of substations using a small number of archetypes derived from monitored load data.

Approach

1. Refine, update and define the SC uptake and DR model from Discovery phase.
2. Characterise >2,000 substations into 20 archetypes using monitored load data.
3. Model baseline cooling uptake in the archetypal substations for 2023, 2030, 2040 and 2050.
4. Model cooling DR scenarios for 2030, 2040 and 2050, informed by DR programmes developed in WP5.
5. Scale up the results from the 20 archetypes back to the 2,438 ENWL substations.
6. Synthesise results into a report.

Peak cooling demand at ENWL substations will increase by 2050 due to 39% of buildings overheating

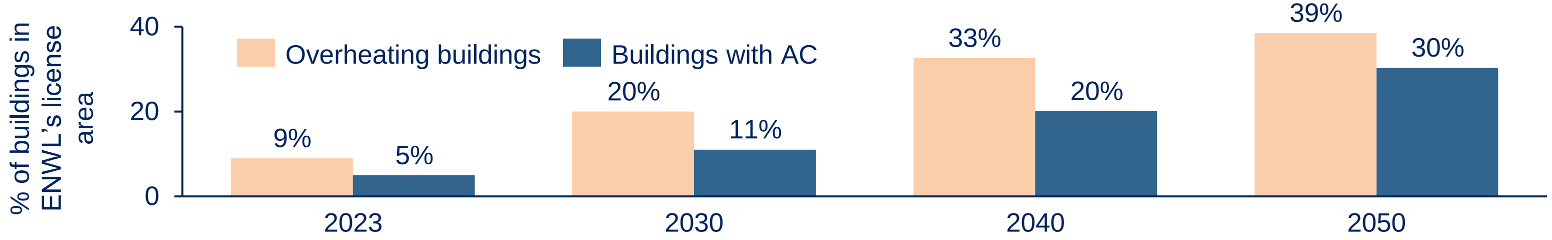
Growth in peak hourly cooling demand (kW) across the 2,438 ENWL substations modelled from 2023 to 2050



Max peak cooling power of ENWL substations modelled (kW)

Each circle represents one substation in ENWL's license area

Modelled growth in building overheating and cooling demand across 2,438 substations in ENWL's license area



We modelled building overheating and cooling demand growth and found that:

- Climate change is expected to result in increased overheating amongst all building types.
- 39% of all buildings are predicted to overheat by 2050 in ENWL license areas.
- The modelling assumes that cooling uptake is directly linked to building overheating. This leads to 30% of all buildings modelled to install active cooling technologies by 2050.
- Non-domestic buildings are at greater risk of overheating, and thus see a greater uptake of cooling, than domestic buildings. This is due to higher "internal gains" from greater building occupancy and poorer energy efficiency across these building types.
- By 2050, **all** substations have cooling demand. As a result, the max peak hourly cooling demand of ENWL substations will rise significantly by 2050.

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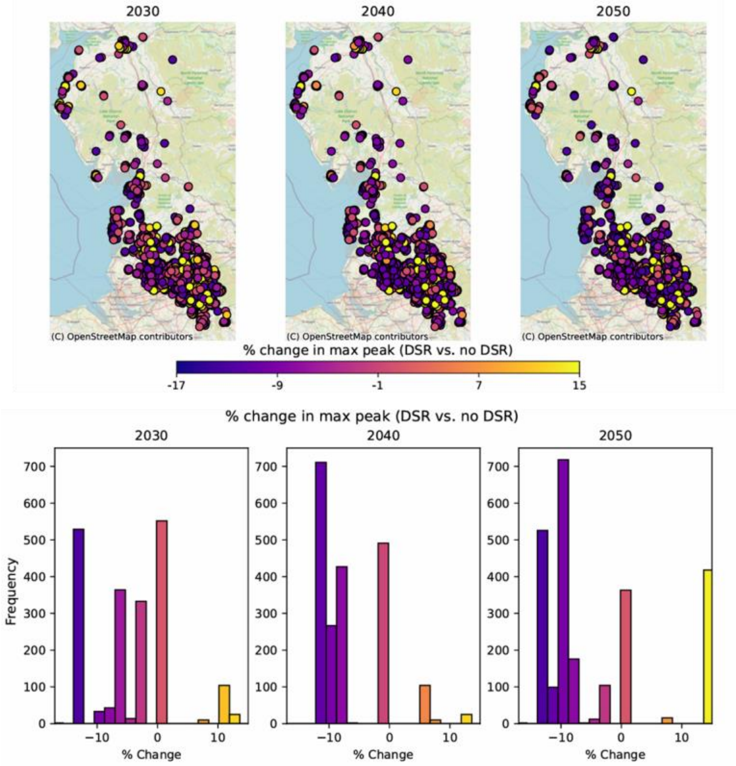
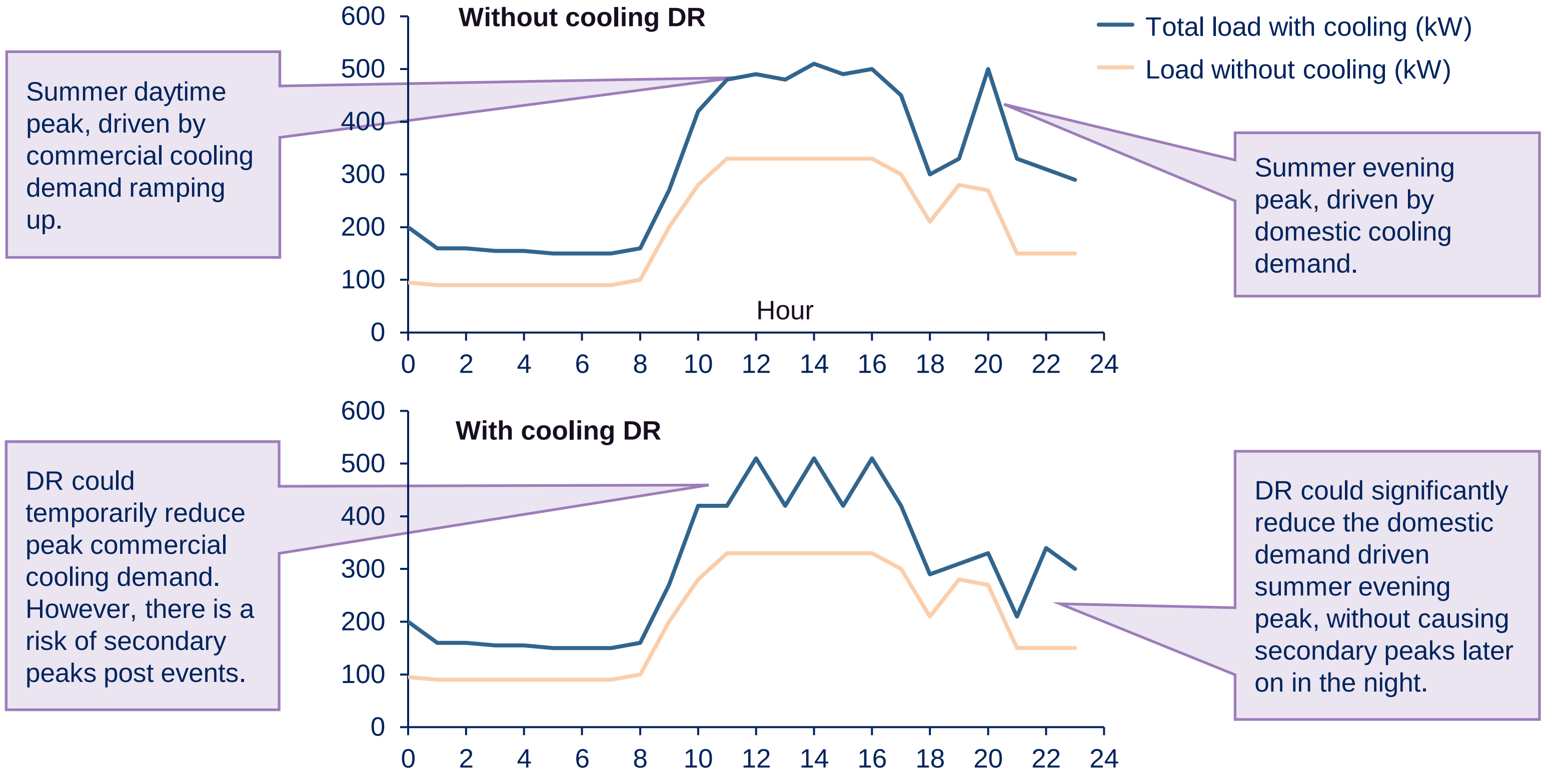
Cooling DR could reduce substation and network level peak demand, but may result in secondary peaks

Cooling DR decreases peak load in most substations by at least 9% by 2040 in over half of the 2,438 substations modelled. Some substations experience an increase peak demand due to secondary, post-DR event peaks. This could be avoided by accounting for when designing and iterating the DR programmes designed.[1]

Change in peak hourly cooling demand due to DR across 2,438 ENWL substations



Hourly load profile (kW) without (top) and with (bottom) DR on the hottest day of 2050. The plots are for an example substation serving domestic and commercial buildings.



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[1] For example, the second round of heat pump DR trials in the EQUINOX project designed DR programmes to mitigate the post-DR snapbacks observed in the first trial.

WP3 – Explore the network impacts of SC

WP3 – Exploring network impact of SC

Exploring network impact of SC

Objectives

- Explore the impact of SC uptake and SC DR on a large sample of substations using refined modelling from WP2.
- Assess impact of load diversity.
- Assess relationship between other low carbon technologies and impact on wider network forecasting.

Building on Discovery:

- Discovery explored the network impact of increased space cooling demand and SC DR on a small subset of ENWL substations.

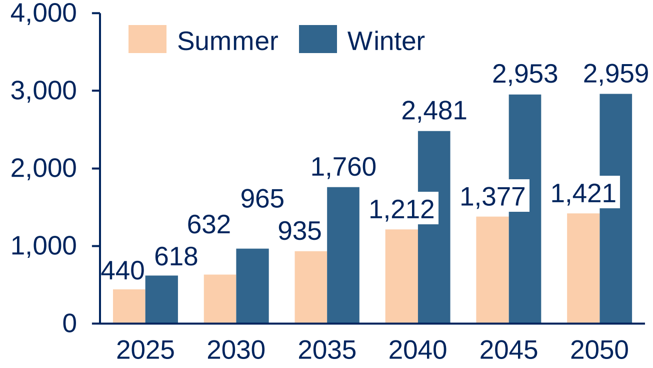
Approach

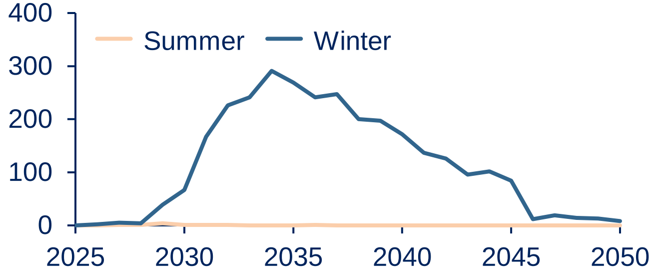
1. Gather the substation data required for network impact analysis.
2. Input the cooling uptake and DR projections from WP2 and analyse its impact on shortlisted ENWL substations.
3. Scale up the results of the analysis ENWL network-wide.
4. Further scale up the results of the analysis to all substations GB-wide.

Without cooling uptake, network peaks and reinforcements are driven by heat pump and EV demand in the winter

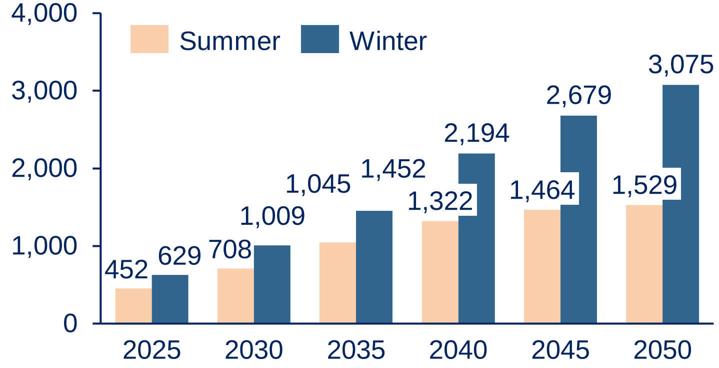
The peak demand in winter across 2281 substations considered in this analysis is significantly higher than the summer for each DFES scenario[1]. The demand in winter triggers the vast number of reinforcements across all three DFES scenarios.

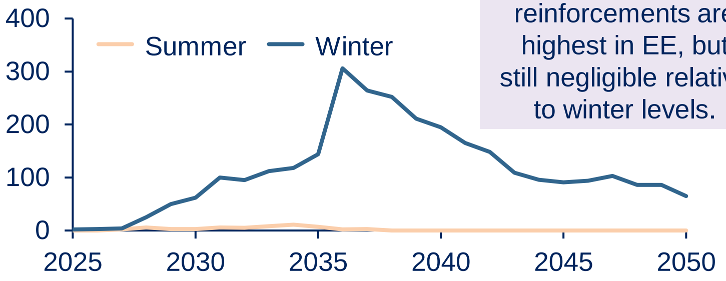
Holistic Transition (HT)





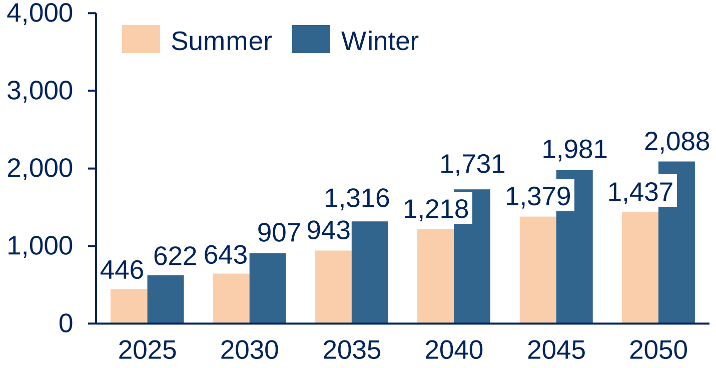
Electric Engagement (EE)

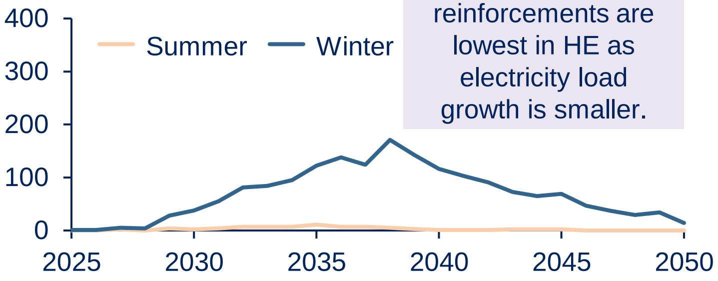




Summer reinforcements are highest in EE, but still negligible relative to winter levels.

Hydrogen Evolution (HE)





Winter reinforcements are lowest in HE as electricity load growth is smaller.

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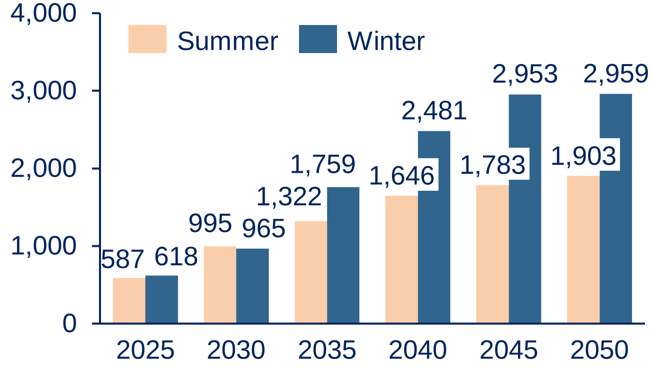
With cooling, hundreds of substations reinforce due to summer load – total numbers vary by DFES

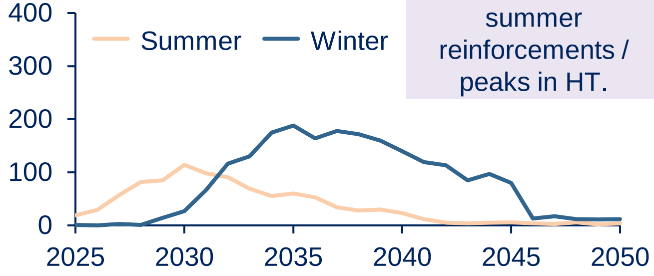
Substation reinforcements increase significantly once forecasted cooling loads are added. There is a negative correlation between the number of heat pumps in winter and the number of summer reinforcements. The highest number of summer reinforcements occurs in the Hydrogen Evolution scenario, which has the lowest heat pump uptake.

Holistic Transition

Annual total peak demand (MW)



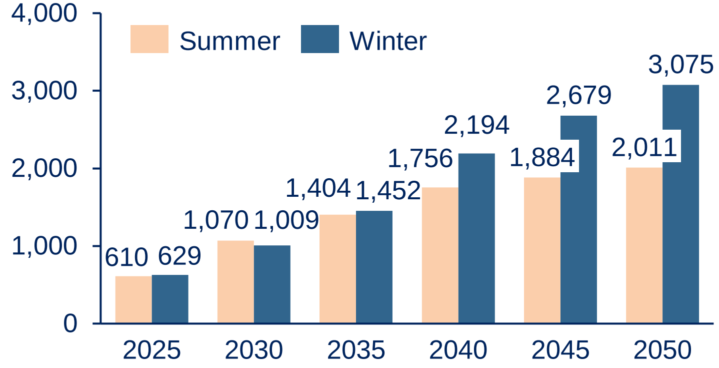
Substation reinforcements



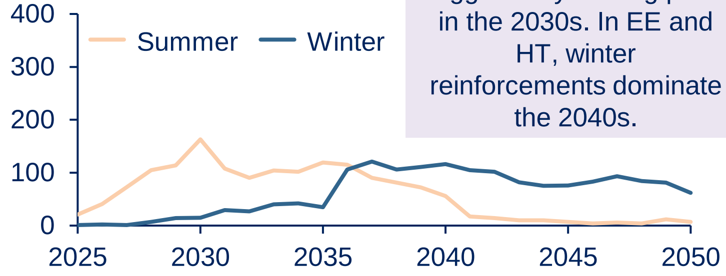
Highest winter and lowest summer reinforcements / peaks in HT.

Electric Engagement

Annual total peak demand (MW)



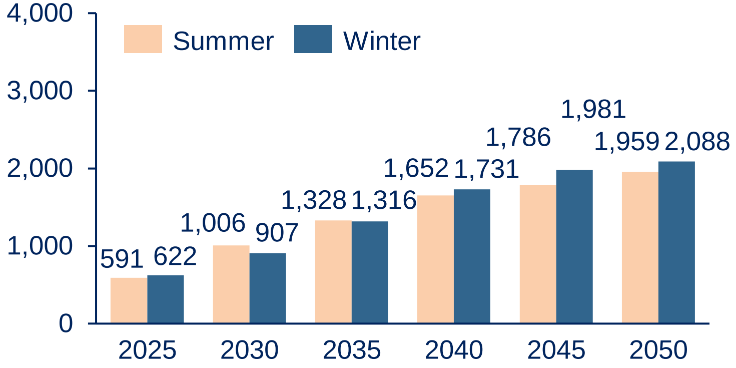
Substation reinforcements



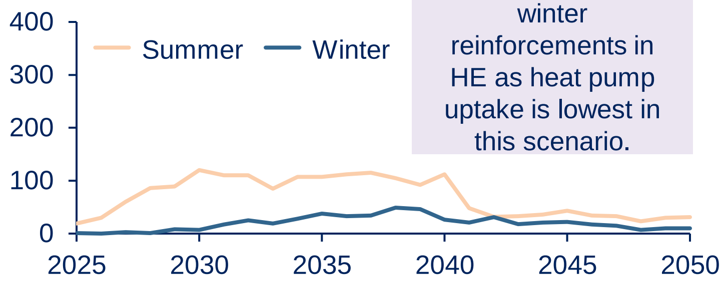
Across all DFES, summer reinforcements triggered by cooling peak in the 2030s. In EE and HT, winter reinforcements dominate the 2040s.

Hydrogen Evolution

Annual total peak demand (MW)



Substation reinforcements



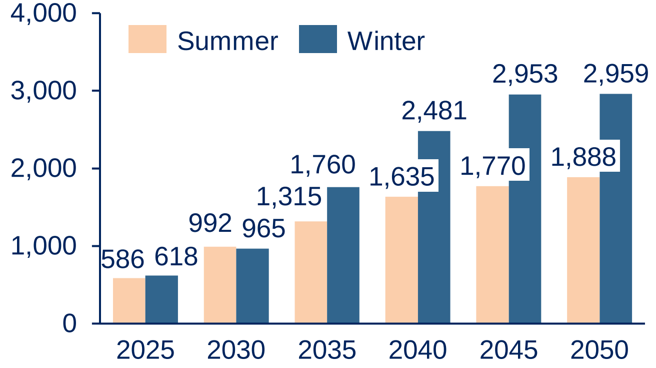
Summer reinforcements always exceed winter reinforcements in HE as heat pump uptake is lowest in this scenario.

With cooling DR, summer reinforcements reduce but remain much higher than without cooling

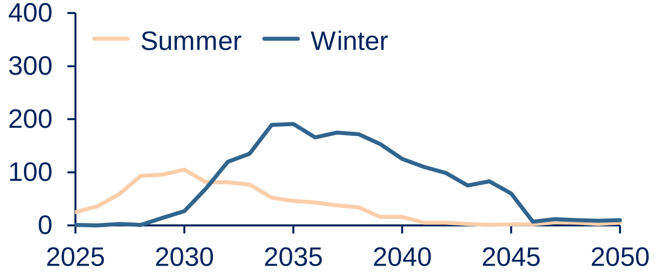
When DR is applied to the cooling load, the number of Summer reinforcements decreases somewhat across all scenarios as the reinforcement is deferred – either to a later summer or to a later winter.

Holistic Transition

Annual total peak demand (MW)

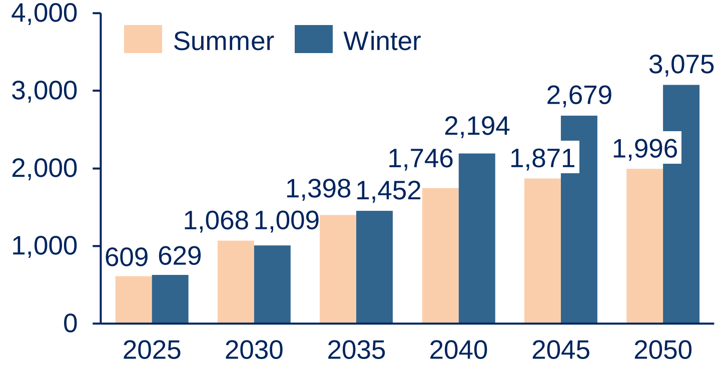


Substation reinforcements

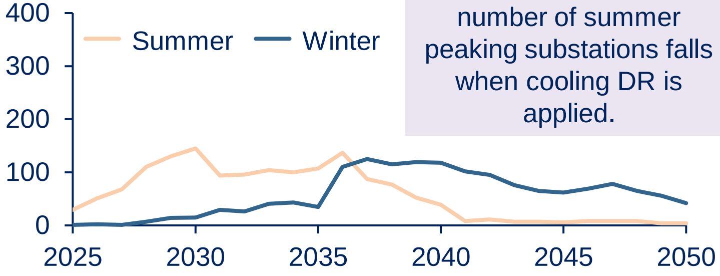


Electric Engagement

Annual total peak demand (MW)



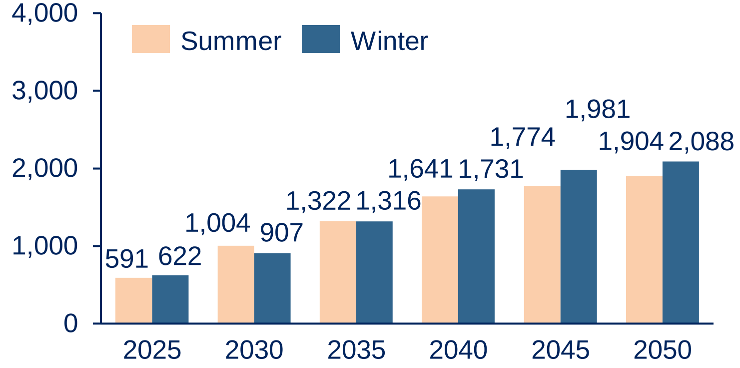
Substation reinforcements



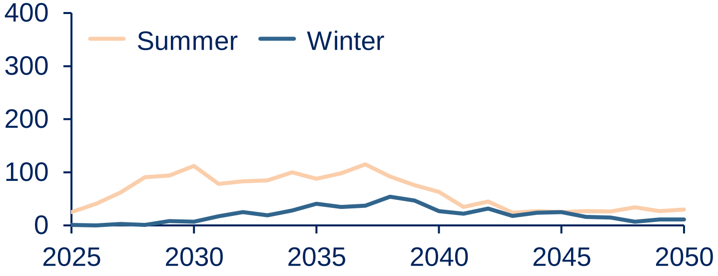
Across all DFES, the peak and overall number of summer peaking substations falls when cooling DR is applied.

Hydrogen Evolution

Annual total peak demand (MW)



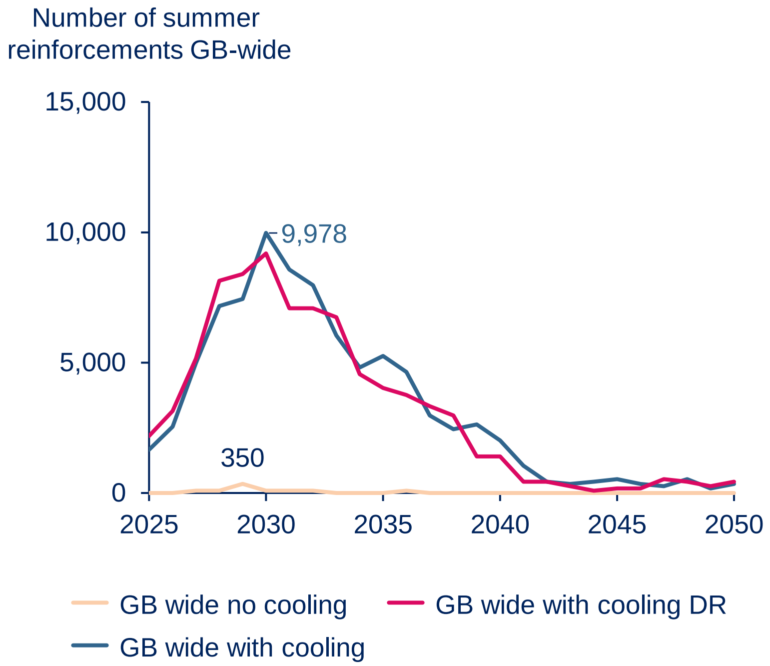
Substation reinforcements



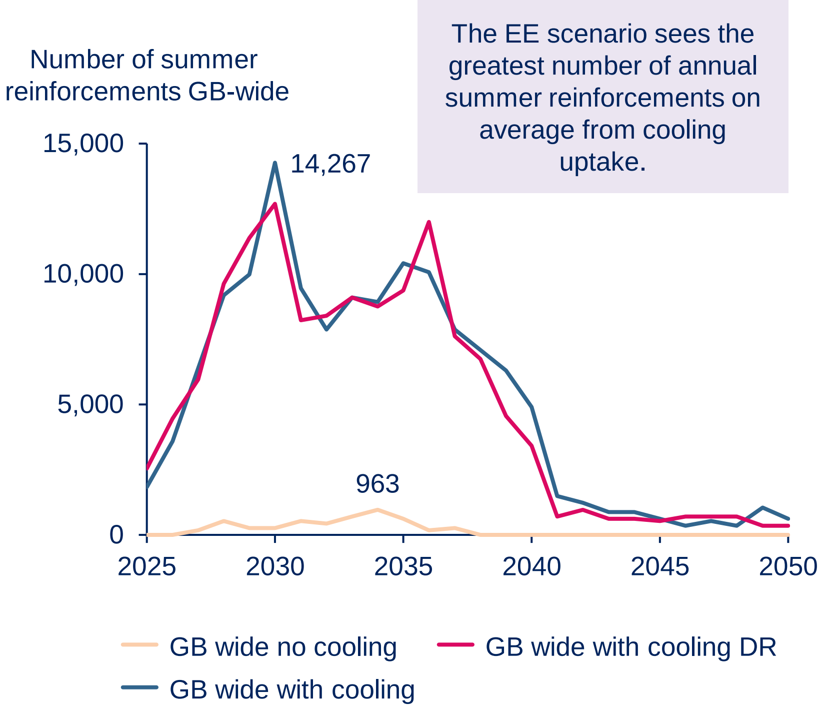
Scaled GB-wide, thousands of additional substations will need to be reinforced, highlighting the need for DR

The rapid growth in cooling demand GB-wide triggers large-scale reinforcement that DNOs should consider when planning their networks. Without adequate early intervention through reinforcement planning or flexibility procurement, the potential magnitude of network constraints could compromise security of supply.

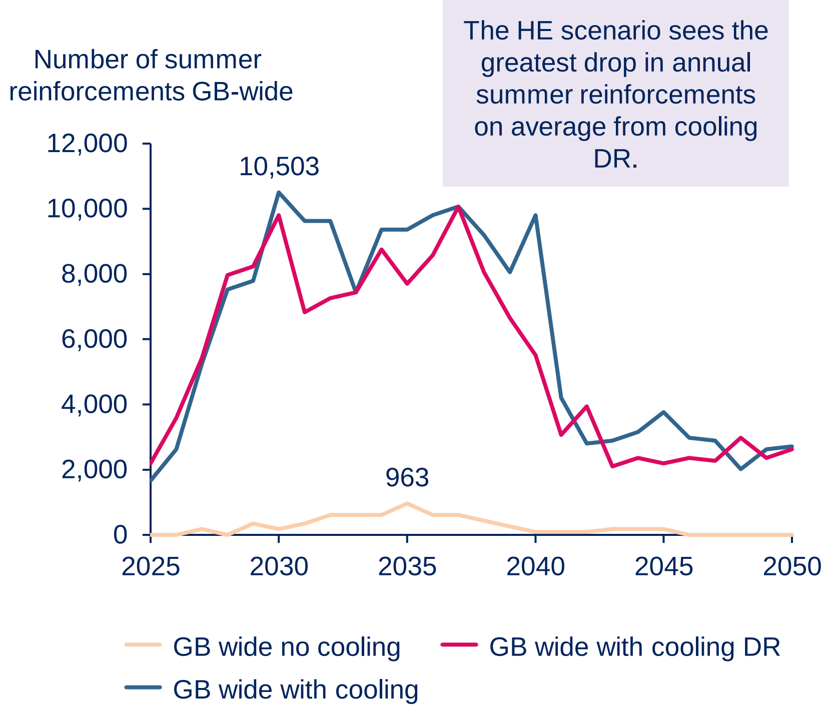
Holistic Transition



Electric Engagement



Hydrogen Evolution



WP4: Domestic customer insights

Bringing energy to your door

WP4 – Domestic customer insight

IMPACT FROM INSIGHT TO INFLUENCE

Domestic customer insights

Objectives

- Carry out a domestic customer online survey, focus groups and in-depth interviews to gain insight into the understanding of cooling technologies and their potential for uptake and DR.

Building on Discovery:

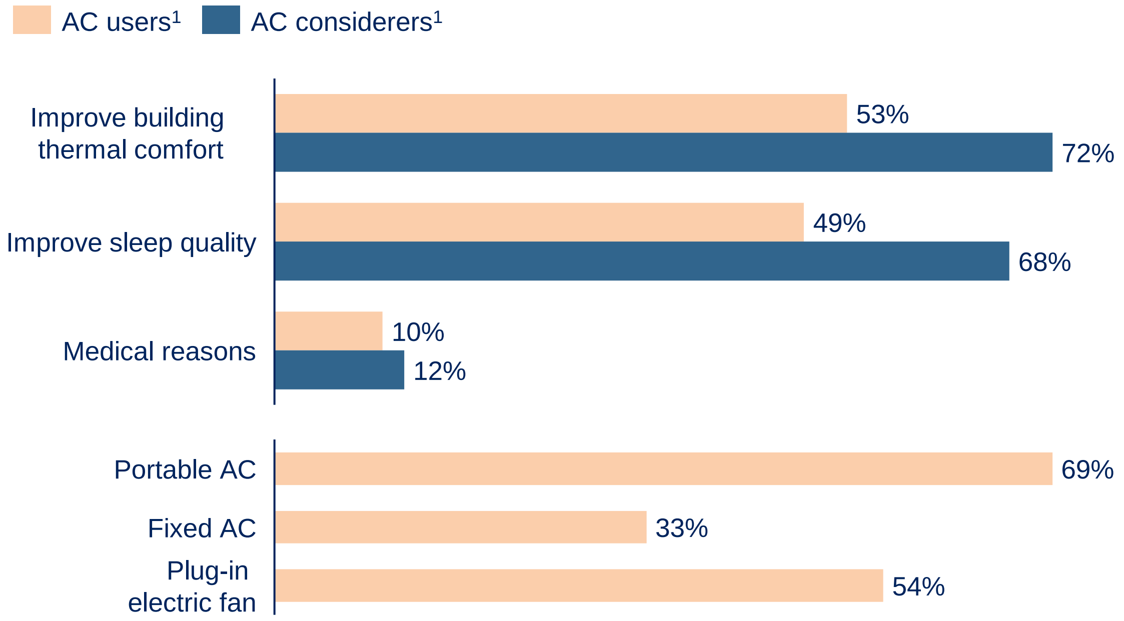
- We found there was little understanding of domestic customers' cooling consumption patterns, their views on adopting cooling and their ability / willingness to flex their cooling demand.

Approach

1. Design quantitative survey for AC users and considerers across the UK.
2. Administer quantitative survey, plus cognitive interviews.
3. Analyse results of surveys and initial interviews and create discussion guide for qualitative stage (focus groups and in-depth interviews).
4. Conduct focus groups and in-depth interviews to gain deeper insights into customer behaviour.
5. Analyse data across all surveys focus groups and interviews.
6. Synthesise findings into a final report.

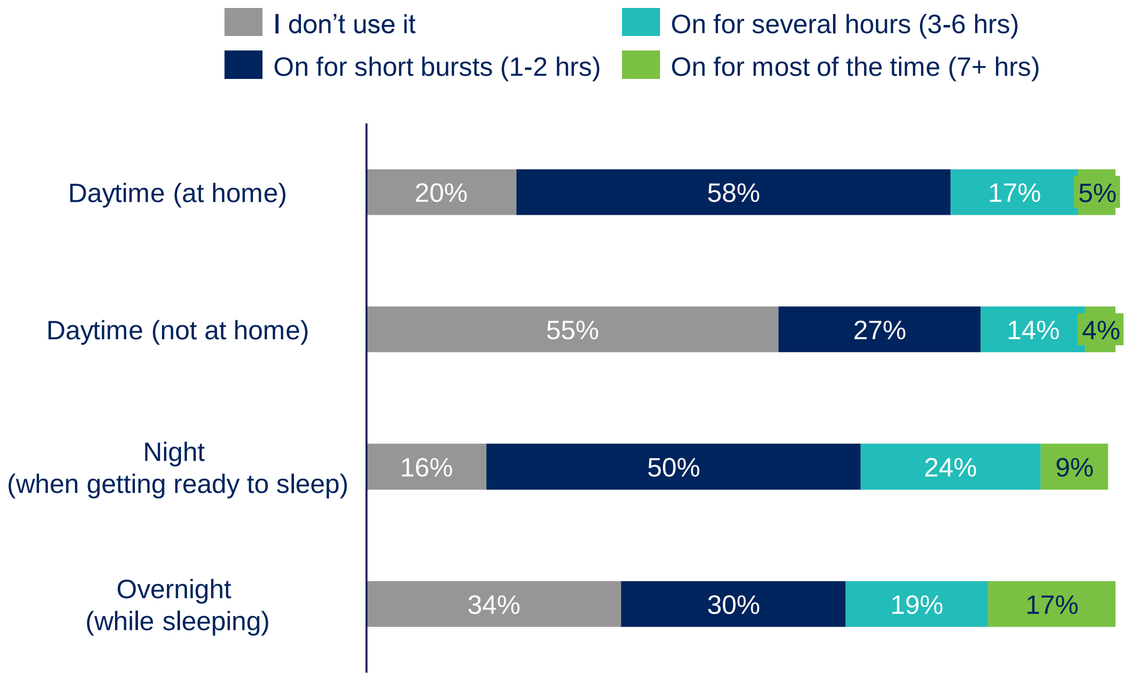
Domestic cooling demand is set to rise in the future, particularly in the nighttime on warm summer days

Why do domestic customers install cooling (top chart) and what type of technology do they get (bottom chart)?



- Primary motivators for AC adoption include improving building thermal comfort, managing heat during sleep, and addressing health concerns.
- 69% of AC users surveyed had a portable unit and 33% had a fixed unit. 54% of users also use plug in electric fans.
- 85% of AC users were satisfied or very satisfied with their unit/s.
- Vulnerable households make up a notable segment of AC users/ considerers.

How and when do domestic customers use their cooling?



- Domestic cooling usage is likely greater in the late evening/early night when residents get ready for bed. Depending on future uptake, this could result in distribution network congestion, and the need for cooling demand flexibility during these hours.
- Daytime domestic cooling consumption may be high for short periods of times on weekends, when people are more likely to be at home.

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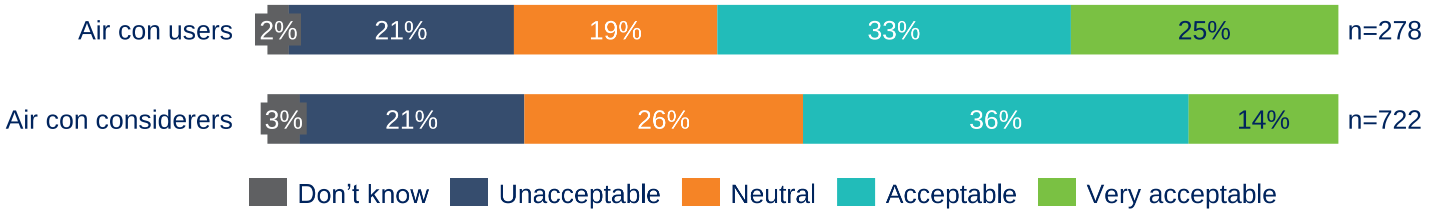
[1] 278 AC users and 722 AC considerers were surveyed.

Around half of respondents were amenable to flexing their cooling demand to help the network

Acceptability of being asked to change the way AC is used on hot days on behalf of the amongst survey respondents



Qualitative research findings relating to minimum notice period

*"I think **the day before** personally that's what Octopus do." (Female, aged 52, AC user)*

*"**You want to be able to plan in advance a bit**. You wouldn't want to be like, there's an event in 30 minutes, I guess turn your AC off or whatever. So maybe just say as long as possible, **at least a couple hours before**." (Male, aged 30, AC considerer)*

Maximum DR event duration acceptable amongst survey respondents

	Accepting of network control		Less accepting of network control	
	AC users	AC considerers	AC users	AC considerers
< 1 hour	3%	4%	17%	14%
1 or 2 hours	33%	47%	51%	55%
3 or 4 hours	53%	38%	22%	16%
5 or 6 hours	8%	5%	3%	4%
All day	1%	2%	2%	1%

Consumer preferences for DR programme design:

- **Event duration:** Most respondents agreed that 1-2 hours would be the most acceptable duration. AC users who were more accepting of flexing their cooling demand to support network constraints were willing to accept 3–4-hour event lengths.
- **Event frequency:** AC users said they would accept 1-2 events per day, while considerers said they would accept 3-4 events per day. Some respondents said they would rather have a greater number of shorter events.
- **Min. notice periods:** Respondents generally preferred a 24-hour minimum notice period. Anything below 2 hours was deemed undesirable. They would also need reminders on the day to turn down their cooling consumption.
- **Method of flexibility delivery:** Methods varied, but most respondents said they would turn their AC unit off rather than power it down/turn the thermostat up.

Participants preferred the Peak Time Rebates programme over the ToU tariff DR programme

1. Peak time rebates[1]

Positives:

- Rebates are seen as an incentive. Participants expressed that it felt like their electricity company is giving them something 'for free'.
- Participants can choose whether to participate or not, allowing them to feel in control of their cooling consumption.

Negatives:

- Difficult to envisage how much money could be made without prior experience, hindering initial sign up.
- AC users do not want to change their behaviour drastically; they only use AC when they really need to due to 'AC guilt' and cost concerns.

2. TOU tariff[1]

Positives:

- Appealing for those whose work schedule is complementary to the off-peak hours.
- Tariff schedule set at sign up, so customers get a greater notice period.
- Potentially greater returns can be made in the long run in comparison to the Peak time Rebates programme if peak and off-peak prices are set optimally.

Negatives:

- Tariffs perceived as a penalty, leading to participants preferring the Peak time rebates programme.
- Lack of control of cooling consumption. Once signed up, participants cannot choose to opt out of participation as they will be penalised by peak pricing for not providing DR.

Recommendations to fine-tune DR programme designs to maximise flexibility unlocked:

1. Ensure DR programmes are voluntary and flexible, with options for users to opt in and out as needed.
2. Provide at least 24 hours notice for peak demand events to allow users to plan accordingly. Peak event times should not be more than two hours and should (where possible) follow a regular routine so that it is easier for users to form a habit of participating in events.
3. Utilise multiple communication channels, including apps, texts, and emails, to ensure timely and effective notifications.
4. Consider a calculator / tailored quote to demonstrate how different types of household might benefit from the cost savings (and other any other efficiency advice / support available) from opting into demand management.
5. Consider tiered rebate structures to reward sustained participation in demand management once the initial novelty wears off.

[1] See WP5 – Cooling DR programmes section for detail on the programme designs

WP5: Cooling DR programmes design

Bringing energy to your door

WP5 – Cooling DR programmes

Guidehouse

Cooling DR programmes

Objectives

- Engage with customers, suppliers and flexibility aggregators to develop DR programmes for the use of SC DR.
- Explore the potential and limits for ground source heat pumps (GSHPs) to provide passive cooling.

Building on Discovery:

- Discovery identified current domestic and international SC DR landscape and best practices.
- Discovery further longlisted 9 potential DR programmes to explore in more detail in the Alpha phase.

Approach

1. Develop guiding principles for the DR programmes.
2. Assess commercial arrangement outputs from Discovery and identify design gaps.
3. Design 2-3 DR programmes for commercial cooling through a series of workshops.
4. Design 2-3 DR programmes for domestic cooling through a series of workshops.
5. Undertake stakeholder engagement and literature review on GSHP passive cooling potential (see appendix).
6. Summarise designed DR programmes for Beta testing.

9 guiding principles underscored the design of the cooling DR programmes

These guiding principles were agreed collaboratively with project partners through a workshop. They were used to develop the cooling DR programme designs and fed into discussions in WP6 regarding which programme designs are the highest priority to be trialled.

#	Guiding principle	Description
1	Customer satisfaction	Customers should trust their DNO/supplier and feel like they are being compensated fairly for their participation in the DR programmes.
2	Measurable impact	Flexibility provided at an individual and aggregated level needs to be measurable to understand the micro & macro impacts delivered by the programme designs.
3	Customer safety	Trials must not put customers in positions of unsafe living/operating conditions.
4	Scalability	Programme designs should be scalable across the UK in BaU.
5	Customer comfort	Programmes should deliver a reasonable alteration in comfort levels with respect to the payments received for flexibility delivery.
6	Simplicity of design	Programmes should be easy-to-understand, consistent across all customers regardless of localised network impact.
7	Transition to BaU	Programme design should closely reflect reality to gain insights into realistic domestic and commercial customer behaviour.
8	Transparency	Stakeholders across the flexibility value chain should be aware of all contractual obligations and associated fees within the programme.
9	Universality	Programme design should be as accommodating as possible to the customer types in the regions where flexibility is being procured.

We designed three cooling DR programmes for commercial buildings

WP5 designed three cooling DR programmes for commercial buildings. WP6 (High-level trial design) decided that the Fixed ToU tariff should not be trialled as OakTree Power already know from experience that commercial buildings are typically less amenable to tariff based programmes. It would therefore be better to focus on optimising design of the other two programmes.

		DR programmes for commercial customers		
	Parameters	**1) Scheduled direct load control**	**2) Peak time rebates**	**3) Fixed Time-of-Use tariff**
DNO-FSP Interaction	ENWL flexibility product	Operational Utilisation & Variable Availability		Peak Reduction
	DNO-FSP payment structure	Availability: £/kW/h Utilisation: £/kWh		Utilisation: £/MWh
	Notice period given to FSP	Availability terms agreed at time of trade, refined week-ahead. Utilisation instruction issued day-ahead.		Utilisation agreed at time of trade
FSP-Customer Interaction[1]	Technology eligibility criteria	Centrally controlled cooling tech. only	Any cooling tech.	Any cooling tech.
	FSP/supplier-customer payment structure	Will vary by FSP/supplier. Examples include fixed upfront payments, £/MWh compensation for flex delivered, etc		FSP/supplier designs tariff to incentivise cooling usage outside these windows
	DR event length and frequency	60 mins – 90 mins, with at least 60-90 minutes between events to allow for recovery. Will be a variable parameter in the trials		
	Notice period given to customer	DR event schedule released week-ahead. Day-ahead utilisation instruction given to FSP by DNO. FSP can inform customer up to 4 hours before event. Will be a variable parameter in the trials		Tariff structure agreed upon sign-up
	Likely customer response to event	FSP will turn down/off their customers' cooling. Customer override is allowed.	Customers will turn down/off their cooling themselves.	

[1] Note that the FSP may not necessarily have direct contact with the consumer. The FSP may partner with an electricity supplier that deals directly with customers.

We designed two cooling DR programmes for domestic buildings

Work Package 5 (WP5) designed two domestic DR programmes for domestic buildings. WP6 (high-level trial design) decided that both domestic DR programmes should be trialled as domestic cooling DR is still nascent and the priority should be to maximising learnings.

		DR programmes for domestic customers	
	Parameters	**1) Peak time rebates**	**2) Fixed Time-of-use tariff**
DNO-FSP Interaction	ENWL flexibility product	Operational Utilisation & Variable Availability	Peak Reduction
	DNO-FSP payment structure	Availability: £/kW/h Utilisation: £/kWh	Utilisation: £/MWh
	Notice period given to FSP	Availability terms agreed at time of trade, refined week-ahead Utilisation instruction issued day-ahead	Utilisation agreed at time of trade
FSP-Customer Interaction[1]	Technology eligibility criteria	Any cooling tech.	
	FSP/supplier-customer payment structure	Will vary by FSP/supplier. Examples include fixed upfront payments, £/MWh compensation for flex delivered, etc.	Supplier designs tariff to incentivise cooling usage outside these windows
	DR event length and frequency	1 - 4 hours, with up to 1-2 events per day depending on event length. Will be a variable parameter in the trials	
	Notice period given to customer	Availability terms agreed upon sign-up, months in advance of event. Utilisation instruction issued day-ahead. Will be a variable parameter in the trials	Tariff structure agreed upon sign-up
	Likely customer response to event	Customers will turn down/off their cooling themselves	

[1] Note that the FSP may not necessarily have direct contact with the consumer. The FSP may partner with an electricity supplier that deals directly with customers.

WP6 – Cooling DR trial design

WP6 – Cooling DR trial design

Guidehouse

Cooling DR trial design

Objectives

- Define high level criteria and logistics for a trial of the cooling DR programmes in a potential trial of cooling DR programmes designed in WP5.
- Logistical elements include location, DR programmes and customer engagement approach.

Building on Discovery:

- Discovery created a longlist of 9 potential SC DR programmes for detailed exploration and shortlisting in Alpha and potential future trials.
- Alpha built on this by designing an initial trial at a high level.

Approach

1. Design trial criteria and assess feasibility through group workshops.
2. Explore high-level trial logistics through workshops.
3. Summarise approach to trial design in a report.

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We defined trial criteria that will ensure diverse and meaningful results

Meeting the five trial criteria and the partner requirements outlined will make sure cooling DR trials are large and diverse enough to deliver meaningful, BaU replicable learnings on cooling flexibility GB-wide. They were developed by the work package partners collaboratively via group workshops.

Trial Criteria	Importance of meeting this criteria
1) At least 1 MW aggregated cooling demand amongst participating commercial buildings	Recruiting too small a group of commercial and domestic trial participants will lead to statistically insignificant results.
2) At least 200 participating households/domestic buildings with AC (fixed or portable) installed.	
3) At least 2 participating DNOs.	Widens pool of potential trial participants and will ensure the learnings are not ENWL and/or FSP specific.
4) At least 2 participating FSPs – one with commercial customers and one with domestic customers who is an energy supplier too.	
5) Participating commercial buildings must be willing to allow Direct Load Control over their cooling assets.	One of the DR programmes for commercial cooling customers involves Direct Load Control of cooling assets by the FSP.

Stakeholder to involve in future trials	Justification
Domestic FSP/ energy supplier	Needed to enable a cooling DR trial with domestic customers.
Additional commercial FSP	To provide a wider pool of commercial customers.
Technology companies	Subcontracted by FSPs. Will be responsible for the installation of asset level monitoring and direct load control technologies.
Local Authorities / Councils	Could expand communication avenues regarding a trial and maximise potential participation, particularly among vulnerable/fuel poor domestic cooling consumers.
Additional DNOs	ENWL and NGED are already project partners, so less immediate need for additional DNO involvement in initial trials.
Community groups and charities	Can inform vulnerable/fuel poor customer engagement and support trial design to ensure these customers are not put in positions of harm.

Trial partner	Engage as interested party

We considered various logistical elements for trialling cooling DR, making decisions as outlined below

Trial location:
- Network-wide. Focus on ENWL's license areas initially.
- Potentially expand into NGED's license areas in future trial phases.

Trial variables:
- External temperature
- DR event length and frequency
- DR event payment amount
- Notice period given to customers by the FSP/supplier

Recruitment criteria:
- Target office/retail buildings for commercial DR trials.
- No restrictions for domestic DR trials.

Impact evaluation:
- Conduct the trials as a Randomised Control Trial.
- Use the Differences in Differences approach to calculate the aggregate flexibility unlocked in each event.

Priority DR programmes:
- Scheduled Direct Load Control and Peak Time Rebates for commercial DR trials.
- Peak Time Rebates and Fixed ToU tariff for domestic DR trials.

Customer engagement:
- Regularly engage with participants through surveys, focus groups and interviews before, during and after the trials.

Payment approach
- Mirror payment approach in DR programmes designed.
- Add participation incentives in initial trials to maximise participation.

Vulnerable customers:
- Establish envelopes within which domestic customers should operate their AC.
- Post trial, check if they have not exceeded these limits.

[1] See Appendix slides; [2] p376 baselining methodology

WP7: CBA

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WP7 – CBA

CBA

Objectives

- Using the findings identified in WP3, carry out a network CBA to determine the financial, environmental and societal benefits of this stage of the project.

Building on Discovery:

- The Discovery CBA was based on two substations analysed by UCLC's model, scaled up to 36 substation.
- Alpha builds on this by scaling to many thousands of substations and substantially improving the depth and granularity of assumptions and benefit calculations.

Approach

1. Set up CBA to identify cost and benefit streams, input assumptions, and scenarios.
2. Produce first draft CBA and circulate to supporting partners for review.
3. Produce second draft CBA and review.
4. Finalise CBA and summarise CBA outputs in a report.

One cost stream and two benefit streams were identified

Approach

1. Development of the counterfactual
The counterfactual shows the number of distribution substation reinforcements associated with the increased uptake of domestic and commercial cooling demand on GB distribution networks.

2. Development of the CoolDown Solution
The CBA options show a reduction in the number of distribution substations being reinforced due to novel cooling DR programmes.

3. Identification of Benefits and Cost streams

4. Quantification of anticipated net benefits and scalability
Change in investment costs and carbon usage. Analysis to be extrapolated to all ground mounted substations GB wide.

5. Sensitivity Analysis
Heat pump and electric vehicle rollout across ENWL license areas, DFES scenarios, flexibility costs reduction profile.

Benefits

B1: Financial benefits due to deferred reinforcement cost
Lifetime net financial benefits ranging from £20.0m to £71.0m dependant on DFES scenario.

B2: Financial benefits due to lower CO_2 emissions, achieved through B1
Lifetime net environmental benefits ranging from £3.2m to £7.5m dependant on DFES scenario.

Assumptions:

1. Distribution substations will firstly be upgraded on the same footprint to 1000kVA if not already so, they will secondly be reinforced with additional new 1000kVA substations in the local vicinity.
2. Upgrades on an existing footprint will cost [redacted]. Subsequent new substations will cost [redacted] with the increased cost accounting for additional works such as HV looping, trench digging and jointing.
3. 2.4tCo2e per MVA assumed. Cost of carbon to increase with time.

Costs

C1: Flexibility payment.
Costs to the GB DNOs in the form of a payment to the flexibility service provider for providing flexibility as a service to the electricity network.

Assumptions:

1. The cost of flexibility will change dependant on whether the substation is upgraded or whether an additional one is installed.
2. The starting cost for upgraded substations in 2024 is £1.10/kW/hr reducing to £0.55/kW/hr by 2050.
3. The starting cost for additional substations in 2024 is £1.43/kW/hr reducing to £0.72/kW/hr by 2050.
4. The payment consists of availability and utilisation and assumes a DR event length of two hours, taking place twice a week for six weeks a year.

Overview of key inputs and assumptions used in modelling

Key assumptions

Item	Value	Unit	Note / Source
Substation upgrade on existing footprint to 1000kVA	£[redacted]	Per substation upgrade	Connections estimate
Additional 1000kVA substation on new footprint	£[redacted]	Per additional substation	Connections estimate (cost is higher due to HV loops, trench digging and jointing)
2024 Cost of flexibility for deferral of substation upgrade	£1.10	kW/h	Based off ENWL accepted flexible services
2024 Cost of flexibility for deferral of additional substation	£1.43	kW/h	Addition 30% added on to account for increase in reinforcement cost
2050 Cost of flexibility for deferral of substation upgrade	£0.55	kW/h	Assumed flexibility cost to half by 2050
2050 Cost of flexibility for deferral of additional substation	£0.72	kW/h	Assumed flexibility cost to half by 2050
Carbon saving from reinforcement deferral	2.4	tCo2e per substation upgrade/additional substation	
Number of GB wide ground mounted distribution substations (excluding ENWL)	199654	Number of substations	Median value of distribution substations in ENWL and NGEDs license areas multiplied by 13

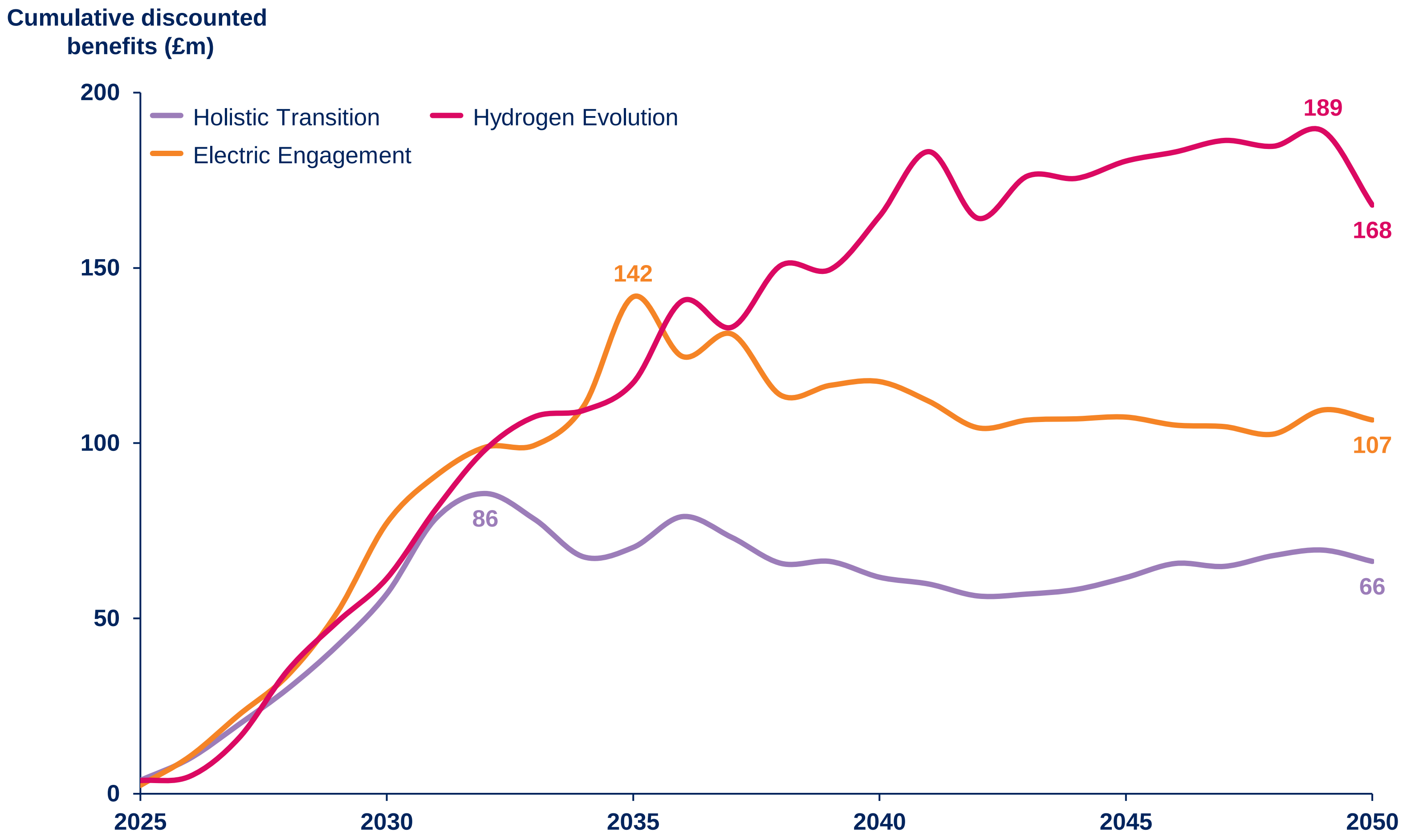
ENWL investment strategy

[redacted]

Only when all other options have been exhausted will ENWL invest to reinforce the network taking a one touch approach, a single intervention to cover foreseeable future upgrades. The substations will be uprated firstly to 1000kVA if there is not one already installed. Then if this rating is exceeded, further additional 1000kVA substations will be installed adjacent to the existing site.

Cooling DR's cumulative benefits excluding flexibility payments is between £66m-£168m for DNOs by 2050

Cumulative discounted financial benefits (excluding flexibility payments) – Core scenario

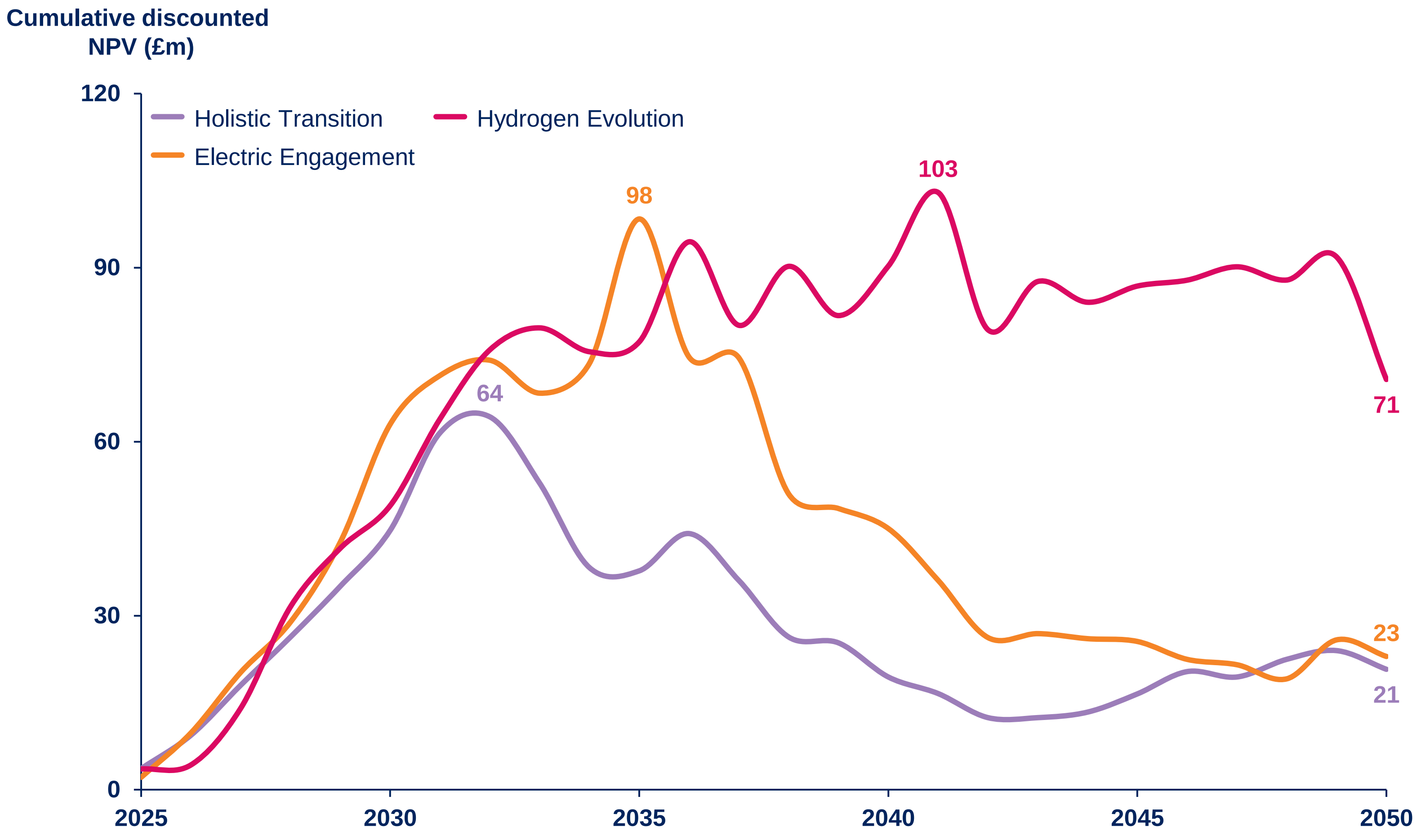


We did a CBA of cooling DR and found that:

- Cooling DR can deliver £66mn - £168mn in cumulative discounted financial benefits by 2050 to DNOs and GB energy consumers, depending on the DFES scenario modelled. The cost of flexibility procurement has a counteracting effect on the benefits stated above. See slide 41 for the cumulative net present value cooling DR can deliver accounting for the cost of flexibility procurement.
- The total benefits attainable, and the cost of flexibility procurement is highest in the Hydrogen Evolution scenario. This is because there are more instances of summer reinforcements required in the Hydrogen Evolution scenario (see the network impact analysis section), indicating a need for a greater volume of cooling flexibility.

Cooling DR can deliver up to £103m net discounted financial benefits to GB energy consumers by 2042

Cumulative discounted net present value (NPV) of cooling DR GB wide – core modelling scenario

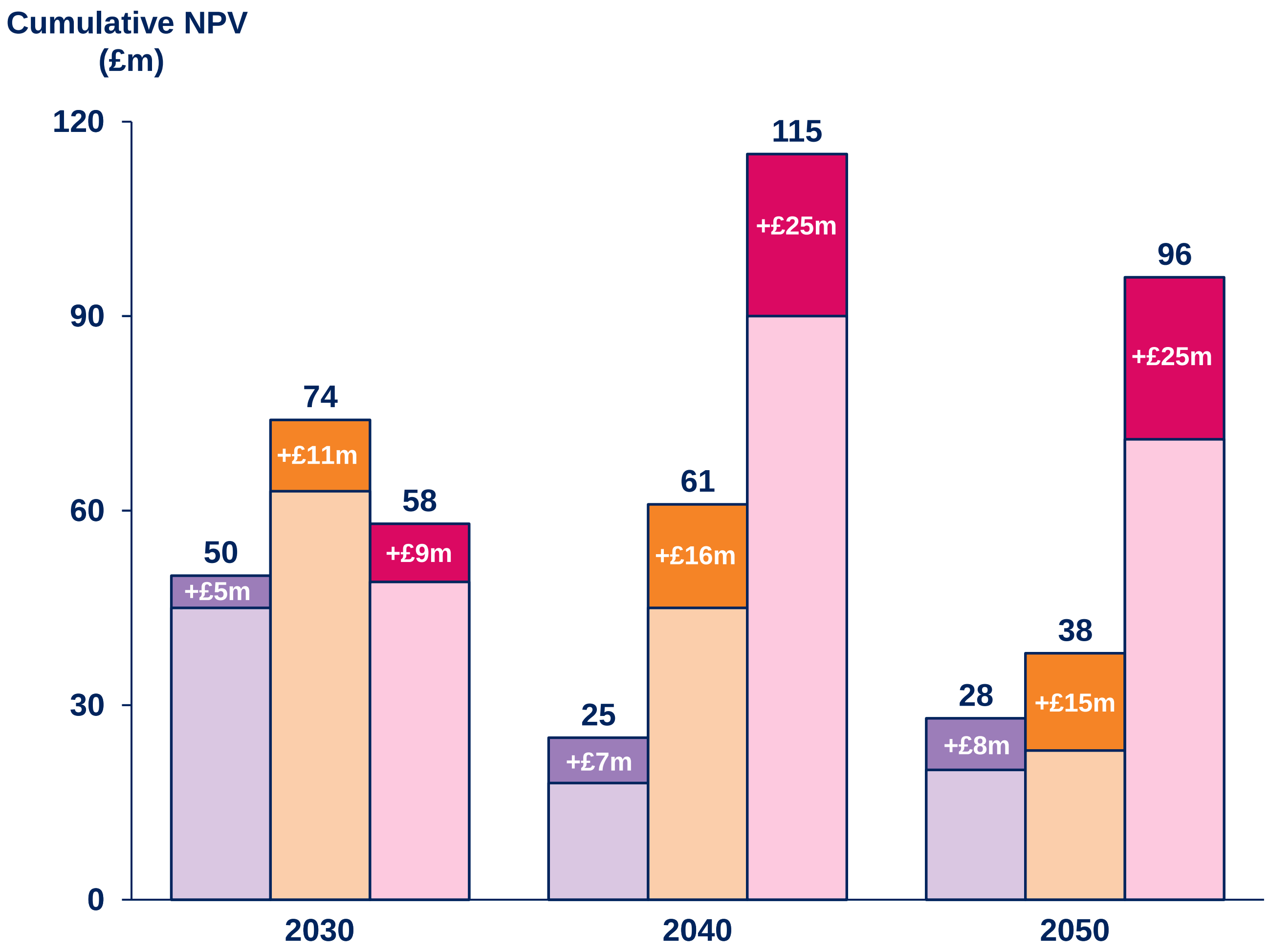


We explored the costs and benefits of cooling DR and found that:

- Cooling DR can deliver £21 - £71m in cumulative net discounted benefits to GB energy consumers by 2050, depending on the DFES scenario modelled.
- Benefits accrue more in earlier years as reinforcement is delayed by cooling DR to a winter peak trigger a few years later. The peaks are:
  - Holistic Transition: £64m in 2032
  - Electric Engagement: £98m in 2035
  - Hydrogen Evolution: £103m in 2042
- Certain substations showed an increase in peak demand post DR (see slide 15).
- If this snapback effect is mitigated against when trialing the DR programmes, the NPV attainable increases (see slide 42).

Mitigating against secondary peaks from DR can further increase cumulative net benefits by £8-25m by 2050

Comparison of cumulative NPV from cooling DR with and without substations seeing secondary peaks

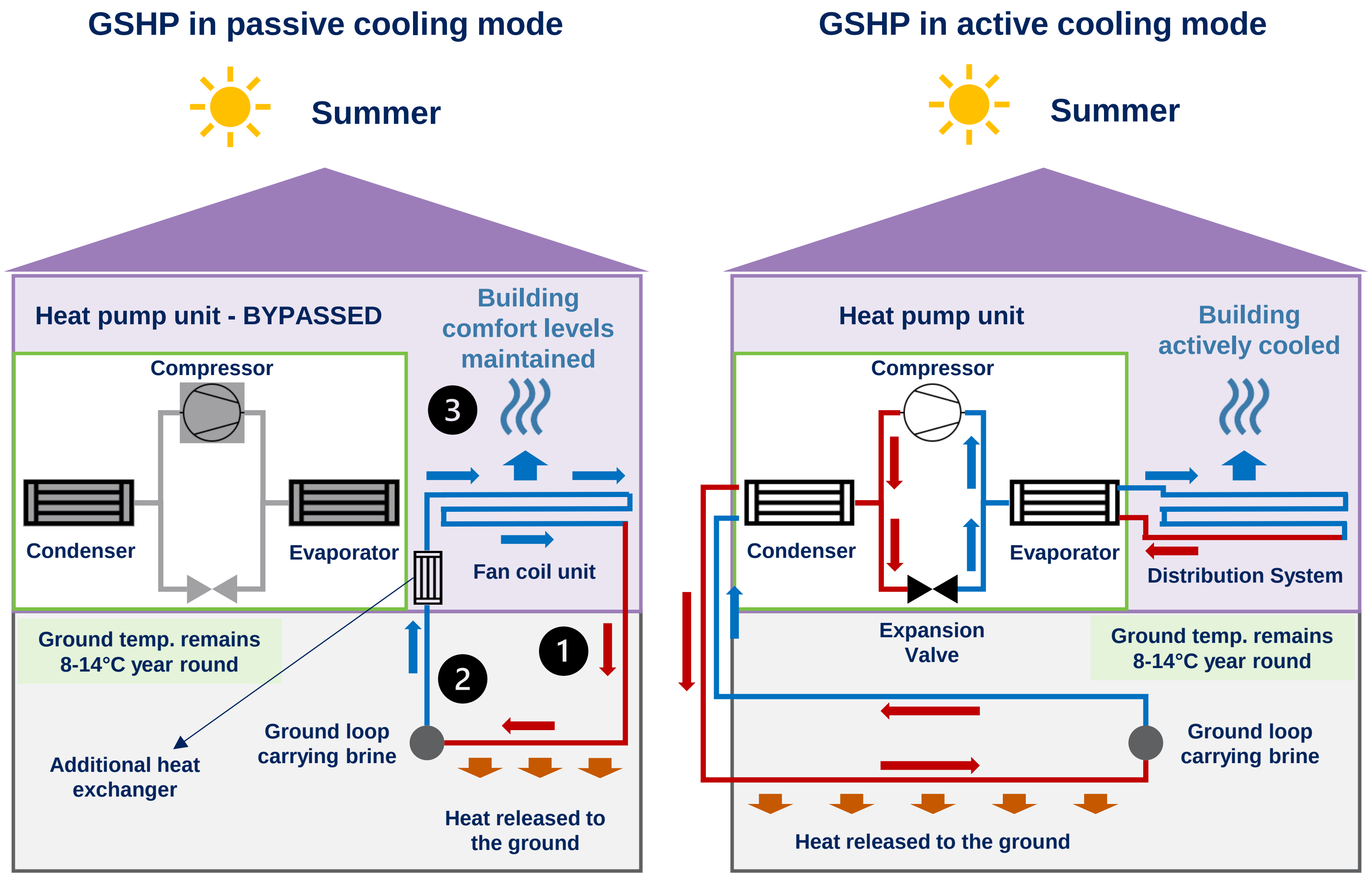


We did a sensitivity analysis on the substations experiencing secondary peaks from DR and found that:

- There were certain substations within the modelling that showed an increase in demand after the DR was applied.
- These substations had adverse 'recovery rates' with the peak demand shifting to a time when the rating of the substation could still be exceeded. This results in 'secondary peaks' which may be greater than the original peak demand of the substation.
- The core scenario accounts for this by reinforcing these substations. The secondary scenario discounts these substations from the modelling anticipating that future work on the DR programme design will sensibly stagger the response times to avoid the adverse recoveries.
- Designing the DR programmes to avoid secondary peaks could increase the cumulative benefits for DNOs and GB energy consumers by £8-25m across DFES scenarios by 2050.

Appendix: GSHP passive cooling exploration

GSHPs can cool buildings through active or passive cooling



How does a GSHP work in passive cooling mode?

1. The water/refrigerant fluid (often referred to as brine) is circulated through the ground loop directly, bypassing the heat pump completely.
2. The fluid is cooled by the lower temperature of the ground before being circulated to a heat exchanger which further reduces the temperature, providing chilled water.
3. The chilled water is then circulated through the distribution system, maintaining building comfort levels on hot summer days.

Comparison to active cooling

- Electricity is only needed to run the circulation pumps, heat exchanger and fan coil unit.
- GSHP passive cooling, therefore, represents a cost-effective and low-energy solution to maintaining building comfort on hot days.

GSHP passive cooling can offer customer and network benefits, primarily in new build homes

GSHP passive cooling of a building can save up to 80% of electricity costs related to SC compared to traditional AC and active cooling technologies. However, its installation can be disruptive and capital intensive, especially if retrofitted into existing buildings.

Benefits of GSHP passive cooling systems

- Approximately five times less electricity consumption relative to active cooling technologies, resulting in large cost savings for customers.
- Improved heating efficiency in the winter from running the passive cooling system in summer can lower running costs by ~£11 per year[1] for every 1°C rise in soil temperature.
- Can be easily installed, without much disruption, in new build properties already installing a GSHP and commercial buildings with existing cooling distribution systems.
- Reduced peak demand resulting from increase future cooling load on the networks, potentially resulting in network reinforcement deferral/avoidance savings.

Disadvantages of GSHP passive cooling systems

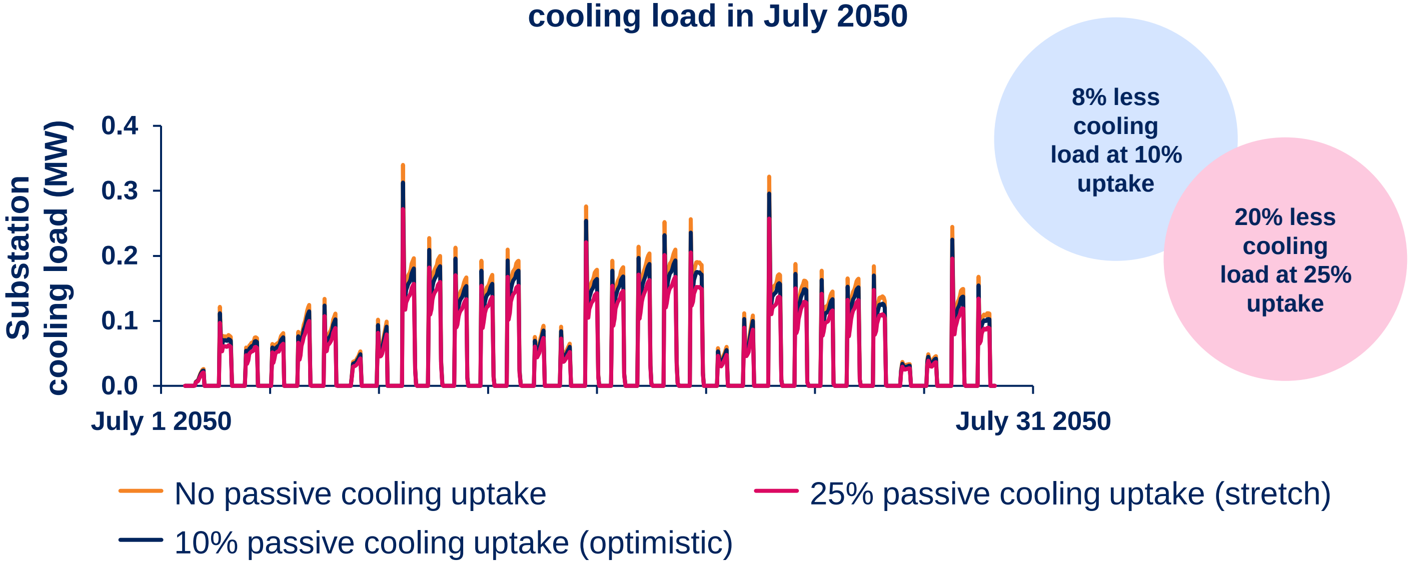
- Additional capital investment (~£500 extra[2]) and disruption in existing homes from installation of an additional heat exchanger, controls and pipework.
- Current heat distribution systems in most existing UK buildings (radiators and underfloor heating) are not suited for cooling and will need to be supplemented by fan coil units.
- Not as effective as active cooling technologies for lower desired temperatures. Passive cooling struggles to reach set points below 21°C, especially in larger buildings.
- Possible interference between heating and cooling control systems if detached, resulting in heating being turned on if the cooling set point is below a certain threshold.

1 Compared to a home powered by a GSHP without passive cooling unit.
2 Interviews with Kensa Heat Pumps and Sero.

GSHP passive cooling could provide similar benefits to cooling DR assuming high uptake

Cooling DR could reduce peak summer demand by ~1% ENWL wide[1]. GSHP passive cooling could provide similar substation and network level benefits depending on uptake. However, the barriers to adoption of GSHP passive cooling are significant - a 10% uptake by 2050 is optimistic.

GSHP passive cooling uptake's potential impact on a summer peaking substation's[2] cooling load in July 2050



- GSHP passive cooling's uptake, and benefits deliverable, is expected to be limited by the many technical, economic, behavorial and regulatory barriers that exist today (see the next slide).
- A 10% uptake of GSHP passive cooling to replace air conditioning demand is an optimistic assumption, with 25% uptake being a stretch. In reality, GSHP passive cooling's uptake is expected to be between 0-10%.

Network impact of GSHP passive cooling

Substation level

- A 10% uptake of GSHP passive cooling, replacing air conditioning demand, could reduce **summer peak cooling demand by 8%** in **2050[3]**. This is similar to the **~9-15% decrease in peak load achieved by cooling DR** in >50% of substations modelled in WP2[4].
- Either method therefore could offer significant **network reinforcement deferral benefits in summer peaking substations**, whose peak demand is driven by cooling demand.

ENWL network level

- The **total air conditioning demand** only accounts for **~25% of total network load[1] in summer in 2050.**
- A 10% uptake of GSHP passive cooling would potentially reduce **peak summer demand by ~2% network-wide by 2050.** This is **similar to the ~1% summer peak demand reduction achievable by cooling DR[1]** in the same time period.

[1] Refer to WP3 – Network impact of SC – outputs for more details on this; [2] Refer to appendix for methodology behind this; [3] Assuming GSHP passive cooling uses 5x less power than equivalent AC; [4] Refer to WP2 – Modelling SC uptake and DR – outputs for more details

Barriers to adoption of GSHP passive cooling

High costs, regulatory barriers, and the need for additional retrofit work in existing homes/buildings all limit the potential for GSHP passive cooling to deliver widespread benefits.

	Barrier to widespread adoption	Impact of barrier	Type of barrier
1	**Incompatible with the heating distribution systems (radiators) in existing homes**. Fan coil units, a separate circulation and control system, an additional pump and a heat exchanger all need to be installed to enable passive cooling.	• Installing passive cooling in existing homes is disruptive and expensive, disincentivising residents from doing so.	Technical
2	**Technology is yet to be proven at scale.** There have only been a few small-scale, individual house level trials of GSHP passive cooling in the UK.	• Poor GSHP passive cooling uptake due to low confidence in the efficacy of the technology.	Technical
3	**GSHP uptake is low for heating, even in new builds.** This is because of the large capital costs associated with the boreholes, disparity between electricity and gas prices and the Standard Assessment Procedure (SAP) calculation and EPC methodology focussing energy costs rather than energy efficiency.	• Poor uptake of GSHPs as a replacement for gas boilers. • Energy consumers may prefer cheaper, less efficient alternative heating technologies (Air source heat pumps).	Economic
4	**Limited understanding of the factors impacting building comfort amongst developers and building tenants.** Developers follow an internal temperature driven assessment of building comfort instead of considering factors such as air movement, humidity, evaporation, etc.	• Developers choose to install active cooling in buildings instead of, or along with, passive cooling measures.	Behavioural