D5.1: Cooling demand response programme designs in the UK

CoolDown: SIF Discovery Project

v0.2

10th May 2024

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List of abbreviations

Abbreviation	Definition
AC	Air Conditioning
BaU	Business as Usual
DFS	Demand Flexibility Service
DLC	Direct Load Control
DNO	Distribution Network Operator
DR	Demand Response
DSO	Distribution System Operator
ESO	Electricity System Operator
FSP	Flexibility Service Provider
HVAC	Heating, Ventilation and Air Conditioning
SIF	Strategic Innovation Fund

Executive summary

This report is an output for CoolDown, an Ofgem-funded Strategic Innovation Fund (SIF) Discovery project exploring the impact of space cooling on distribution network capacity and the potential need for cooling demand response (DR). The report summarises findings from work package five of CoolDown: longlisting commercial models. The report:

- Outlines the United Kingdom's (UK's) DR landscape and key lessons applicable to cooling DR design.
- Profiles design parameters for cooling DR programmes and evaluates UK-specific context where available.
- Longlists nine potential UK cooling DR programme designs.
- Evaluates each design's potential and shortlists five designs for further exploration.
- Identifies key barriers to the development of UK cooling DR and recommendations to overcome them.

Insights from this report can inform the development of future cooling DR initiatives in the UK. Key elements of the full report are summarised below.

The UK has a rapidly expanding DR landscape at both the transmission and distribution levels, which can inform UK cooling DR programme design.

In the UK, electricity networks do not interact directly with customers. Suppliers and aggregators, also known as Flexibility Service Providers (FSPs), act as intermediaries. The UK model demands that any DR offering be designed with both the electricity network to FSP and FSP to customer relationships in mind. This adds complexity to the design process but provides more optionality to customers; FSPs are market-driven and aim to develop attractive offerings to draw more customers.

At a distribution level, Distribution Network Operators (DNOs) procure flexibility for various use cases. DNOs have recently aligned on standardised flexibility products, designed to simplify the process for FSPs to offer their customers' DR to multiple networks. Future cooling DR programmes for distribution network flexibility should therefore be designed to be compatible with these standard products.

There is no UK precedent for DR tailored to cooling, but learnings from several heating DR trials and tariffs could be applied to the design of cooling DR programmes.

This includes EQUINOX, led by National Grid, which has trialled two iterations of FSP to customer commercial arrangements to incentivise domestic heat pump DR during the weekday evening demand peak. Key findings to date include:

- A two-hour DR event length is a sweet spot for heating DR.
- Customers respond more consistently if they are paid for their DR per event (utilisation) rather than paid upfront for participating in multiple events (availability).
- The small subset of direct load control (DLC) customers responded positively to their home heating being controlled by their supplier for DR events.

- DLC customers participated more consistently in DR events than those controlling their own heating, but DR magnitude depended on home characteristics rather than technology type.

Another relevant trial is Centre for Net Zero's HeatFlex UK, which tested DLC DR with tailored customer set points and pre-heating periods to minimise impact on comfort.

Finally, Octopus Energy's Cosy Octopus time of use tariff is a business as usual (BaU) product tailored to homes with heat pumps. It offers cheaper electricity during off-peak periods to incentivise pre-heating, offsetting more expensive electricity during peak hours. This sets a UK precedent for a similar tariff targeted towards customers with cooling.

Designing cooling DR programmes involves calibrating several key parameters. These are summarised below with context from the UK landscape and international cooling DR programmes.

- **Customer type:** DR programmes can target residential or commercial customers.
- **Programme type:** DR programmes can be either price-based or incentive-based[1].
- **Payment structure:** DR can be induced through tariffs which induce changes in consumption behaviours, or through some combination of availability and utilisation payments. The UK has examples of all of these.
- **Use case:** DR programmes address specific flexibility needs for UK networks, which vary depending on the use case. In the UK, these use cases are defined in the form of the standard DNO flexibility products mentioned above.
- **Notice period:** The amount of notice customers received of upcoming DR events varied by programme in our international cooling DR benchmark. The notice for cooling DR products in the UK will depend on the network use case being met.
- **Event length:** International cooling DR events last between one to six hours. Residential heating DR events in the UK typically last two hours maximum, though heating and cooling are different use cases so not directly comparable. Given the limited experience of cooling DR in UK, a wide range such as one to six hours is likely appropriate.
- **Eligible technologies:** DR programmes can target specific cooling technologies or remain technology agnostic. Eligible technologies to be trialled in the UK will depend on the current and future cooling technology mix in both commercial and residential spaces. Short-term cooling trial designs would likely focus on central air conditioning (AC), Heating, Ventilation and AC (HVAC) and split system ACs.
- **Event timing:** Most cooling DR events are timed based on peak cooling demand periods during the hottest afternoons in summer. According to the Met Office, the hottest time of day in the UK is between 11am and 3pm.
- **Time horizon:** The implementation timeline for DR programmes depends on factors such as technology adoption rates and DNO flexibility market maturity. While residential DR programmes may take longer to materialise due to nascent cooling technology adoption, programmes focused on commercial buildings with a higher adoption rate could become BaU in the shorter term.

[1] See Appendix for more details.

Varying the above parameters led to a longlist of nine potential programme designs for UK cooling DR. Each programme has a UK DR precedent and/or international cooling DR precedent. Of the longlist, five programmes are shortlisted as the most promising for further exploration in the near term.

Table 1 – List of potential cooling UK DR programme designs. Rows shaded blue are shortlisted as the most promising options to be explored for potential future trials.

No.	Target customer type	Programme type	Payment structure	Notice period	Event length	Eligible tech.	DNO use case	Time horizon
1	Commercial	Price-based: peak time rebates	Availability and utilisation	15 mins	1-6 hours	Technology Agnostic	Operational utilisation + availability	Near
2	Commercial	Incentive-based: direct load control	Utilisation	2 mins, 15 mins or week ahead	1-6 hours	Central ACs	Operational utilisation	Near
3	Commercial	Incentive-based: direct load control	Availability and utilisation	Day ahead	1-6 hours	Central ACs	Operational utilisation + scheduled availability	Near
4	Residential & commercial	Price-based: time of use tariff	Tariff	At sign up	1-6 hours	Technology agnostic	Peak reduction	Medium
5	Residential	Price-based: peak time rebates	Availability and utilisation	2 hours	1-6 hours	Technology agnostic	Operational utilisation + availability	Medium
6	Commercial	Price-based: critical peak pricing	Tariff	Day ahead	1-6 hours	Technology agnostic	Operational utilisation	Near
7	Commercial	Incentive-based: interruptible load	Utilisation	At sign up	1-6 hours	Technology agnostic	Peak reduction	Near
8	Residential	Incentive-based: direct load control	Availability and utilisation	2 mins, 15 mins or day ahead	1-6 hours	Heat pumps or split systems	Operational utilisation + variable availability	Long
9	Residential	Incentive-based: direct load control	Availability	2 mins, 15 mins or day ahead	1-6 hours	Heat pumps or split systems	Operational utilisation + variable availability	Long

Four designs were discarded due to a lack of suitability for the UK market or because the required technologies are too nascent in the UK for near-term exploration.

- Programme design #6 centred around critical peak pricing, which has no UK precedent. Since energy suppliers are in competition for customers, it is unlikely that any would propose a tariff structure that penalises customers so highly for not responding to a price signal.
- Programme design #7 revolved around a DNO flexible connection type being designed specifically around cooling load. This is too niche to be realisable. Other programme designs are likely to be more effective in achieving flexible commercial cooling load.
- Programme designs #8 and #9 involved residential cooling assets being third-party controlled. The major near-term barrier to testing this design is the lack of smart residential cooling technology in UK homes. It is unclear whether or how split system AC in existing homes could be controlled, what technology compatibility issues there would be, or whether sufficient homes with the necessary technology could be recruited. These are challenges for third-party heating asset control. Given the rollout of heat pumps is more widespread than for AC, it is likely an even more pressing near-term test for cooling.

This report identifies six barriers to potential development of the shortlisted cooling DR programme designs (#1-5) in the UK and recommends next steps to overcome them.

Table 2 – Barriers to UK cooling DR and recommendations to overcome them.

Barrier	Recommendation
The network need for cooling DR programmes in the UK is still uncertain. More work is needed to accurately predict future cooling uptake, its impact on distribution network load and the potential benefits of cooling DR.	Build on CoolDown analysis[2] to explore cooling uptake across more distribution substations to account for more building typologies. Then analyse the network impacts of increased cooling across more primary substations and the impact of the shortlisted cooling DR programme designs on network reinforcement.
Knowledge is lacking on the willingness of UK residential and commercial customers to participate in cooling DR.	Survey residents and businesses on their space cooling behaviours (if they have it), likelihood of installing cooling (if they do not) and views on the shortlisted cooling DR programmes.
The relationship between thermal comfort and building type and demographic differences in the UK could be better understood to prevent cooling DR programmes being too aggressive or conservative, limiting participation and network benefits.	Seek to understand upper thermal comfort limits for homes and businesses. This could help optimise DR parameters like event length and pre-cooling windows.

[2] See CoolDown deliverables D2.1 and D3.1.

The parameters defined for the shortlisted DR programmes need to be validated. Event length, notice period and payment approach and amounts need to be optimised to customer preferences and network need.	Survey customers to gauge their preferences (in theory) for key parameters like DR event length, notice period, and incentives. These can then be validated via trials with both commercial and residential customers.
There is a knowledge gap on split system AC DR. Our benchmark found no DR programmes or trials exploring split system ACs in our international benchmark, although they could be a cooling technology of choice for existing UK homes.	Explore the DR potential of split system ACs through customer research and/or trials, should the rollout of cooling allow (see below).
The residential cooling rollout is nascent and its trajectory uncertain, possibly limiting or delaying the potential for cooling DR.	Monitor rollout of cooling in residential properties across existing and new build housing.

Introduction to CoolDown

As the UK warms due to climate change, homeowners and businesses are more likely to turn to space cooling. Despite modelling suggesting increasing cooling demand, cooling demand is currently poorly accounted for in distribution network planning. Cooling's potential to offer flexibility during periods of network stress has not been considered.

CoolDown is the first project in the UK to consider this potential, exploring the impact of cooling on distribution network capacity by producing improved cooling adoption and demand projections. The project is also developing commercial models to incentivise and unlock flexibility from space cooling. This will reduce or defer required network reinforcement and optimise value for consumers.

CoolDown is a Strategic Innovation Fund (SIF) Discovery project funded by Ofgem. The project is led by Electricity North West Limited (ENWL), supported by project partners Guidehouse and University College London Consulting (UCLC).

Scope of this report

This report is the output of CoolDown work package five: longlisting commercial models.

This report builds on the international benchmark of cooling DR from work package four by creating a longlist of potential UK cooling DR programme designs. Accounting for the existing UK DR landscape and cooling technology penetration reduces this longlist to a shortlist of programmes recommended for further exploration.

The report is structured into four sections:

DR landscape in the UK

- Explores the expanding set of BaU DR products procured by the Electricity System Operator (ESO) and DNOs or Distribution System Operators (DSOs).
- Outlines the commercial propositions that suppliers and aggregators offer to their domestic and commercial customers to enable them to meet the procured volumes they have guaranteed to the ESO or DSOs.
- Zooms in on offerings being trialled that focus on heating flexibility, and considers what learnings are applicable to potential space cooling DR trials.

Cooling DR programme design parameters

- Lists key parameters which form part of the design of any cooling DR programme.
- Outlines any UK-specific context which guides or constrains the scope of each parameter.

Longlist of cooling DR programmes

- Longlists nine potential cooling DR programme designs, varying the parameters outlined in the previous section.
- Describes each programme design in more depth, including potential suitability to UK context and applicable UK or international precedent.
- Shortlists the five most promising programme designs for further exploration, outlining the reasons for four being discarded.

Barriers to DR and recommendations

- Outlines six barriers to the potential development of the shortlisted cooling DR programme designs in the UK.
- Identifies recommended next steps to overcome each barrier.

DR landscape in the UK

UK DR process

The general DR process in the UK is illustrated in Figure 1.

Figure 1: General DR process in the UK

The ESO and DSOs procure DR volumes from suppliers and aggregators. Suppliers and aggregators are the intermediaries between the electricity networks who need the DR and the energy end users who provide it by changing their consumption. Customers pay their energy bill to suppliers. Aggregators combine DR provided by multiple individual energy end users into a total DR volume which can be used to meet procurement targets. Suppliers and aggregators can be bundled as FSPs.

For a particular DR event:

- The ESO/ DSO procures DR from FSPs.
- FSPs reach out to customers asking them to provide DR.
- Customers change their consumption as directed.
- Where needed, FSPs combine individual customer DR into a volume committed to the ESO/ DSO.
- The ESO/ DSO pays the FSPs for successful delivery.
- FSPs passes on payments to customers via pre-agreed arrangements.

The UK's model of separation between network and customer is not universal. For example, utilities in the USA manage both the network and their customers. They therefore directly request DR from their customers. The UK's model demands that any DR offering be designed with both the network to FSP and FSP to customer relationships in mind. This adds complexity to the design process but provides more optionality to customers; FSPs are market-driven and aim to develop attractive offerings to draw more customers.

DR landscape

The design of UK cooling DR trials should be informed by the existing landscape for DR in the UK, including both BaU offerings and those still in development. The next sections look at existing and proposed flexibility services procured by the ESO and DSOs.

ESO DR

The ESO's key DR product is the Demand Flexibility Service (DFS)[3], which has run in winters 2022/23 and 2023/24. DFS shifts electricity usage out of peak demand hours and allows the ESO to manage supply through periods when margins are tight. The service works as follows:

- The ESO issues a requirement to the market either day ahead, within day morning or within day midday for a specific delivery period.
- The delivery period is typically 1-4 consecutive half-hour periods between 5-7pm.
- FSPs ask their customers to voluntarily reduce demand following delivery.
- Businesses and households voluntarily reduce their demand at the specified time and are rewarded accordingly by their FSP.

DFS nicely demonstrates the divide between the network to FSP and FSP to customer commercials. Over 32 half hour event windows during winter 2023-24, ESO paid FSPs between £590 – £5,070 per MWh of DR provided[4].

Meanwhile, FSPs adopted customised approaches to passing this payment through to customers. Octopus Energy's Octoplus Saving Sessions programme rewarded customers for providing DR when requested by giving them points which could be redeemed in various ways, including converting them into account credit[5]. Ovo Energy's Power Move Plus scheme rewarded customers with account credit for reducing consumption below a personalised target[6]. Other FSPs like Conrad Energy[7] helped businesses flex their usage during DFS events and manage their bidding strategy for events without a guaranteed acceptance price[8].

DSO DR

Distribution networks procure flexibility for various use cases, including:

- Preventing the network going beyond its firm capacity.
- Managing a network abnormality like an asset going offline.
- Restoring the network following a loss of supply.
- Responding to changes in real-time network conditions.

[3] ESO, Demand Flexibility Service
[4] ESO, Demand Flexibility Service 2023/2024
[5] Octopus Energy, Octoplus Saving Sessions
[6] OVO Energy, Power Move Plus
[7] Conrad Energy, Save Energy – Demand Flexibility Service (DFS)
[8] As DFS is still not a fully BaU product, winter 2023/24 saw a mix of test events with a guaranteed price of £3,000 per MWh and test and live events with prices set by bidding as per other ESO flexibility services.

The networks have recently aligned on standardised flexibility products[9]. This should simplify the process for FSPs to offer their customers' DR to multiple networks. These products are summarised in Table 3.

FSPs must tailor any potential cooling DR offerings to customers so that the resulting DR can be used to meet one of these standard products.

Table 3 – List of standard distribution network flexibility products

Product	Payment Structure	Description	Utilisation agreed by
Peak Reduction	Utilisation	Seeks reduction in peak power utilised over time. Could be used where long-term energy efficiency measures are planned that would reduce a site's overall electricity consumption across the year, but specifically during high peak periods	At time of trade
Scheduled Utilisation	Utilisation	Seeks pre-agreed flexibility. Useful for customers that cannot respond in or near to real-time. Networks could use this to manage seasonal peak demands or defer network reinforcement	At time of trade
Operational Utilisation	Utilisation	Seeks flexibility delivery agreed closer to real-time. Facilitates change in demand profile from customers based on network conditions. Networks could use this to restore network supplies following an unplanned outage/fault	2 mins, 15 mins or week ahead of event
Operational Utilisation + Scheduled Availability	Availability and utilisation	Procures agreed change in consumption following a network abnormality. Change is procured ahead of time. Availability defined at point of procurement. Assets dispatched for required level of service required based upon actual network data	2 mins or day ahead of event
Operational Utilisation + Variable Availability	Availability and utilisation	As operational utilisation + scheduled availability, but availability requirements can be refined closer to the event. Networks could use this when planning for sufficiency of flexibility contracts based upon long range forecasting of network constraints. The above option would be more suitable for short – medium range forecasting	2 mins, 15 mins, day ahead or week ahead of event

Heating DR

Several UK innovation projects have explored potential DR from electric heating assets. Learnings from these projects can be applied to the design of cooling DR programmes – noting that customers may respond differently to requests for cooling DR than heating DR.

One such project is EQUINOX. Led by National Grid[10], EQUINOX has trialled two iterations of FSP to customer commercial arrangements to incentivise domestic heat pump DR during the weekday evening demand peak. Some key findings include[11]:

- A two-hour maximum DR event length is a sweet spot for heating DR. This is based on feedback from customers on when they start noting the impact on comfort in their home, especially on colder days or in less insulated homes.
- Customers respond more consistently if they are paid for their DR per event rather than paid upfront for participating in multiple events. In other words, utilisation payments are preferable for domestic customers.

[9] Energy Networks Association, Flexibility Products Review and Alignment, 2024
[10] National Grid, EQUINOX
[11] National Grid, Initial Insights on the Effectiveness of Commercial Methods, 2023

- The small subset of direct load control (DLC) customers responded positively to their set points being automatically shifted for DR events.
- DLC customers participated more consistently in events than those controlling their own heating, but DR magnitude per customer depended on home characteristics rather than technology type. Most customers do not have the right technology to enable DLC at this stage of heat pump market development.

The results of the second trial are expected in Q3 2024 – this will offer more learnings.

The other relevant trial is Centre for Net Zero's HeatFlex UK[12], which tested DLC DR for domestic heat pumps over winter 2022/23 and 2023/24. The events incorporated pre-heating to minimise the impact of the DR events on comfort. Events involved altering set points rather than interacting directly with the heat pump. Customer feedback on their heating being automated and levels of comfort was positive, though the sample size was small as interoperability issues limited the participant pool[13].

Contrasting with the above trials, Octopus Energy's Cosy Octopus time of use tariff is a BaU product tailored to homes with heat pumps. Customers on Cosy are charged significantly less between 4 am – 7 am and 1pm – 4pm. This incentivises them to pre-heat their homes before the morning and evening peaks. A peak rate 45% above the standard rate further incentivises heating being off during the evening peak[14]. Tariffs like Cosy set a UK precedent for a similar tariff targeted towards customers with cooling.

[12] Centre for Net Zero, Heatflex UK
[13] Nesta, Automating heat pump flexibility: results from a pilot, 2023
[14] Octopus Energy, Cosy Octopus

Cooling DR programme design parameters

Several design parameters have been used to create a long list of potential cooling DR offerings in the UK. These parameters are rooted in learnings from existing UK DR and international cooling DR programmes. These parameters are detailed below with context specific to the UK, where relevant.

Customer type: DR programmes can target different customer segments including commercial or residential.

Programme type: Several programme types exist across the DR landscape[15]. This report will focus on price-based programmes and retail incentive-based programmes, aligning with the distribution network-level scope of the CoolDown project.

Payment structure: DR can be induced through tariffs which use variable electricity prices to change consumption behaviours. Alternatively, event-by-event DR incentives take the form of availability payments, utilisation payments, or a combination of both. Availability payments guarantee compensation for participation and monetary value could differ based on notice period e.g., customers that agree to a lower notice period are paid more than others. Utilisation payments are rewarded based on the energy reduction achieved during the DR event, typically on a per kWh basis.

Notice period: CoolDown's international cooling DR benchmark[16] showed that notice period varied by programme. Most had a notice period between real time to two hours before the DR event. Time of use tariffs require no notice period as the DR incentive for customers is purely price driven. The notice period for cooling DR products in the UK will depend on the network use case being met by the DR provided (see below).

Event length: Cooling DR events or peak pricing periods for time of use tariffs in international programmes last between one to six hours. In the UK, domestic-facing DR events typically last two hours. The longest DSO flexibility product utilisation period is four hours. National Grid's EQUINOX innovation project exploring low carbon heating flexibility has to date found that two hours is the sweet spot for domestic heating DR event length for domestic customers[17]. However, heating and cooling preferences vary so this is potentially not directly applicable to cooling. Given the limited knowledge of cooling DR in the UK, event length is a critical parameter to explore further. For now, the full 1–6-hour range is listed as possible for all programme designs outlined in this report.

Eligible technologies: DR programmes can target specific cooling technologies or remain technology agnostic. The most common cooling technology observed in CoolDown's international benchmark is central AC. Some programmes also looked at HVACs and heat pumps.

[15] These are detailed in the Appendix.
[16] These are detailed in CoolDown deliverable D4.1.
[17] National Grid, Initial Insights on the Effectiveness of Commercial Methods, 2023

Central ACs and HVAC systems are commonly used in commercial spaces in the UK, particularly offices and retail outlets. However, these cooling technologies are rarely found today in UK domestic buildings. As new homes are built, heat pumps could be installed with dual heating and cooling capabilities. Alternatively, new builds connected to ground source heat pumps could use the ground to passively cool their homes. For existing housing stock retrofits, cooling is likely to be installed separately to heating. Even if the heating is supplied with a heat pump, cooling needs are likely to be met by split AC systems incorporating outdoor and indoor units.

Eligible technologies to be trialled in the UK will depend on the current and future technology mix in both commercial and residential spaces. expect that short-term cooling trial designs would focus on central ACs and HVACs for commercial buildings, split systems for existing residential buildings and possibly dual use heat pumps in new build residential homes.

Event timing: Most cooling DR event timing options are based on peak cooling demand periods during the hottest summer afternoons. July is the warmest summer month in the UK[18] and the hottest time of day is between 11am and 3pm[19]

Use case: DR programmes address specific flexibility needs within UK networks, which vary depending on the use case. In the UK, these use cases are defined around the standard DNO flexibility products described in Table 3 further up this report.

UK precedent: The previous section of this report detailed relevant DR programmes and trials in the UK. Such programmes give us a better understanding of what programme design could potentially work in the UK.

International precedent: The cooling DR programmes identified in CoolDown's international benchmark[20] serve as a good baseline for what has been achieved already in the cooling DR space. They can help inform cooling DR offerings which could be trialled in the UK, though some parameters may need to change to account for the UK context, as detailed throughout this section.

Time horizon: The implementation timeline for cooling DR programmes depends on factors such as technology adoption rates and DNO flexibility market maturity. While residential DR programmes may take longer to materialise due to nascent cooling technology adoption rates, programmes focused on commercial buildings with a higher adoption rate could become BaU in the shorter term. The time horizon is considered near-term if it could be implemented within the next 5 years, medium term for 5-10 years, and long-term for implementation beyond 2035.

[18] Met Office, Summer
[19] Met Office, Hot weather and its impacts
[20] Ibid. 16

Longlist of cooling DR programme designs

Combining learnings from the international benchmarking with the current UK DR context enabled creation of a longlist of nine potential UK cooling DR programme designs, summarised in Table 4. The parameters outlined in the previous section were varied across each programme design to provide a diverse mix. Each prospective programme design has a UK DR precedent and/or international cooling DR precedent. Of the nine programme designs longlisted, the five most promising are highlighted for further exploration.

Table 4 – List of potential cooling UK DR programme designs[21]. Rows shaded blue are shortlisted as the most promising options to be explored for potential future trials.

No.	Target customer	Programme type	Payment structure	Notice period	Event length	Eligible tech.	DNO use case	UK precedent	Int'l precedent	Time horizon[22]
1	Commercial	Price-based: peak time rebates	Availability and utilisation	15 mins	1-6 hours	Technology Agnostic	Operational utilisation + availability	N/A	Enel X ARENA trial	Near
2	Commercial	Incentive-based: direct load control	Utilisation	2 mins, 15 mins or week ahead	1-6 hours	Central ACs	Operational utilisation	N/A	EnergyWise Business	Near
3	Commercial	Incentive-based: direct load control	Availability and utilisation	Day ahead	1-6 hours	Central ACs	Operational utilisation + scheduled availability	N/A	DR programme	Near
4	Residential/ commercial	Price-based: time of use tariff	Tariff	At sign up	1-6 hours	Technology agnostic	Peak reduction	Octopus Cosy	ME TOU trial	Medium
5	Residential	Price-based: peak time rebates	Availability and utilisation	2 hours	1-6 hours	Technology agnostic	Operational utilisation + availability	EQUINOX, Power Move	N/A	Medium
6	Commercial	Price-based: critical peak pricing	Tariff	Day ahead	1-6 hours	Technology agnostic	Operational utilisation	N/A	Critical Peak Pricing	Near
7	Commercial	Incentive-based: interruptible load	Utilisation	At sign up	1-6 hours	Technology agnostic	Peak reduction	Flexible Connections	Interruptible Service	Near
8	Residential	Incentive-based: direct load control	Availability and utilisation	2 mins, 15 mins or day ahead	1-6 hours	Heat pumps or split systems	Operational utilisation + variable availability	EQUINOX	Smart AC	Long
9	Residential	Incentive-based: direct load control	Availability	2 mins, 15 mins or day ahead	1-6 hours	Heat pumps or split systems	Operational utilisation + variable availability	HeatFlex	BYOT	Long

Below, we expand on all nine potential programme designs, describing key features. We also provide reasoning for the four designs that did not make the shortlist.

[21] For an explanation of programme types, see the Appendix. International precedent programmes are described in CoolDown deliverable D4.1.
[22] Near-term could be implemented within the next 5 years, medium term within next 5-10 years, and long-term for implementation beyond 2035.

Shortlisted programme designs

Programme Design #1: Commercial peak-time rebate

Target customer	Commercial	**Eligible technology**	Technology agnostic
Programme type	Price-based: peak time rebates	**Notice period**	15 minutes
Payment structure	Availability and utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation + availability	**Recommendation**	Explore further
UK precedent	N/A	**Int'l precedent**	Enel X Arena trial

In this peak-time rebate programme design, commercial customers would be paid to reduce their load consumption during peak hours. They would be paid upfront for being available to respond to DR events at short notice (15 minutes) and then receive a utilisation payment post-event for any reduction they provide. The availability payment could be scheduled or variable, depending on network needs. The two options could be compared in a trial setting.

In BaU, commercial customers could likely use any lever they wish to reduce consumption. In a trial setting, however, the focus should be on asking commercial customers to isolate their reductions to cooling load. This would enable understanding of how far commercial cooling can contribute to DSO DR needs under these parameters.

Since cooling is already widespread in commercial buildings like retail and office spaces, this programme design would be suitable for trialling in the shorter term. There is no cooling-specific UK precedent for this programme design, but Australia's Enel X ARENA[23] trial[24] provides an international example.

Programme Design #2: Commercial direct load control

Target customer	Commercial	**Eligible technology**	Central AC
Programme type	Incentive-based: direct load control	**Notice period**	2 mins, 15 mins, week ahead
Payment structure	Utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation	**Recommendation**	Explore further
UK precedent	N/A	**Int'l precedent**	EnergyWise Business

This design is based on US utility Duke Energy's EnergyWise Business[25] programme. Duke Energy pays businesses to take direct control of their ACs during hours of high network stress when immediate demand reduction is needed.

In the UK, this design would fit within the operational utilisation DNO use case. Commercial customers would be paid per kWh of demand reduction against their normal baseline that is achieved through the direct load control.

[23] Australian Renewable Energy Agency
[24] ARENA, Enel X Demand Response Project
[25] Duke Energy, Energy Wise Business

A current unknown is what proportion of existing AC in office and retail spaces could be directly controlled, or whether additional technology would be needed to enable it. If it were needed, a trial might consider covering the costs of installation to enable testing and maximise business participation.

Another factor that could be trialled is how much notice commercial customers would need to decide whether they would opt into a specific DR event. Duke Energy's EnergyWise Business gives customers two hours' notice. The standard UK DNO product for operational utilisation includes options for 2 minutes, 15 minutes and week ahead notice.

Programme Design #3: Scheduled commercial direct load control

Target customer	Commercial	**Eligible technology**	Central AC
Programme type	Incentive-based: direct load control	**Notice period**	2 hours, day ahead
Payment structure	Availability and utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation – scheduled availability	**Recommendation**	Explore further
UK precedent	N/A	**Int'l precedent**	DR programme

This design is a variation on programme design #2. It combines a pre-determined consumption reduction in a Middle East DR trial[26] with the direct load control element of Duke Energy's EnergyWise Business programme.

In this design, each commercial customer would aim for a pre-determined reduction in consumption during DR events. This amount would be agreed with their supplier or aggregator. They would receive an availability payment for their commitment to meeting that amount. Their AC load would be directly controlled as in programme design #2 and they would receive a utilisation payment per kWh reduced. This meets the operational utilisation – scheduled availability DNO use case. The notice period for a DR event under this use case can be either 2 hours or day ahead. Customer preference and ease of providing the determined reduction for these notice periods could be tested via customer engagement and/or a trial.

Programme design #2 and #3 could also be trialled alongside each other to see which set up delivers more reliable flexibility to DNOs.

Programme Design #4: Time of use tariff

Target customer	Commercial or residential	**Eligible technology**	Technology agnostic
Programme type	Price-based: time of use tariff	**Notice period**	At sign up
Payment structure	Tariff	**Event length**	1-6 hours
DNO use case	Peak reduction	**Recommendation**	Explore further
UK precedent	Octopus Cosy	**Int'l precedent**	ME TOU trial

[26] Country and company confidential.

This programme design involves giving residential or commercial customers a time of use tariff option that varies prices across the day to incentivise them to shift cooling demand away from peak cooling periods in the summer.

The period of peak pricing could last 1-3 hours, for instance around midday. Cheaper electricity during pre-cooling periods could be built in, similar to pre-heating periods in the Cosy Octopus tariff. As a time of use tariff, it would cover all electricity usage, not just cooling demand. This means it could incentivise wider demand reduction beyond space cooling.

This design would also encourage wider behavioural shifts since the tariff would apply on all days, meeting the peak reduction DNO use case.

The tariff would likely only be beneficial to residential users in the summer when cooling is needed. This may limit its appeal, or necessitate an impractical summer-only usage, whereby customers switch to different electricity price periods outside the summer.

✓ Programme Design #5: Residential peak-time rebate

Target customer	Residential	**Eligible technology**	Technology agnostic
Programme type	Price-based: peak time rebates	**Notice period**	Minimum 2 hours
Payment structure	Availability and utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation + availability	**Recommendation**	Explore further
UK precedent	EQUINOX, Power Move	**Int'l precedent**	N/A

This is a residential version of programme design #1. National Grid's EQUINOX trial is testing a similar set up for heating DR. Elements of other programme designs could be incorporated, for instance a pre-determined turn down amount.

This design could be tailored to several residential cooling technologies. The most important is split system ACs, which are likely to be the most common technology for providing cooling in existing properties.

Unsuitable programme designs

✗ Programme Design #6: Commercial critical peak pricing

Target customer	Commercial	**Eligible technology**	Technology agnostic
Programme type	Price-based: critical peak pricing	**Notice period**	Day ahead
Payment structure	Tariff	**Event length**	1-6 hours
DNO use case	Operational utilisation	**Recommendation**	Not suitable
UK precedent	N/A	**Int'l precedent**	Critical Peak Pricing

This programme design would see commercial customers facing peak prices at short notice on the hottest days as a strong market signal to reduce their cooling demand. In Southern California Edison's Critical Peak Pricing service, customers face 3-5x higher prices on the hottest afternoons and are informed day ahead of when their tariff will spike.

There is no UK precedent for critical peak pricing. Since energy suppliers compete against each other for customers, it is unlikely that any of them would propose a tariff structure that penalises customers so strongly for not responding to a price signal. This programme design is therefore not suitable for the UK market at this time.

✕ Programme Design #7: Flexible connections for commercial customers

Target customer	Commercial	**Eligible technology**	Technology agnostic
Programme type	Incentive-based: interruptible load	**Notice period**	At sign up
Payment structure	Utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation	**Recommendation**	Not suitable
UK precedent	Flexible Connections	**Int'l precedent**	Interruptible Service

DNOs already offer flexible connections, which define network use conditions for the network user. This includes limited import or export capabilities through passive or active management, or time-limited connection capacity[27]. In the context of cooling, a new connection type could be created which limits capacity for new commercial network connections during peak summer hours – this would then limit cooling load and network stress. The closest precedent is Tucson Electric Power's Interruptible Service[28] in Arizona, where customer supply is interrupted during periods of network stress.

Arizona is far hotter than the UK and for a more sustained period. The UK's more forgiving climate makes this type of programme design likely not applicable to the UK, especially at this stage. Additionally, whilst flexible connections are an important tool in building resilient low carbon electricity networks, a connection type centred around cooling load specifically is too niche to be realisable. The other programme designs are likely to be more effective ways of achieving flexible cooling load in commercial buildings.

✕ Programme Design #8: Residential direct load control with utilisation payment

Target customer	Commercial	**Eligible technology**	Technology agnostic
Programme type	Incentive-based: direct load control	**Notice period**	2 mins, 15 mins or day ahead
Payment structure	Availability and utilisation	**Event length**	1-6 hours
DNO use case	Operational utilisation + variable availability	**Recommendation**	Too early to explore
UK precedent	EQUINOX	**Int'l precedent**	Smart AC

This is a variation on programme design #2 suitable for residential customers and with a different payment structure. Residential customers would indicate their willingness to have their cooling device or thermostat directly controlled by their supplier and be paid an availability payment for doing so. They would then be informed of DR events ahead of time – a trial could explore whether this should be minutes or days – and given a utilisation

[27] ENWL, Flexible Connections
[28] Tucson Electric Power, Interruptible Service

payment for demand reduction achieved while their cooling is controlled. EQUINOX has trialled a similar approach with controllable heat pumps.

The major barrier to testing this programme design in the near-term is that residential cooling technology is nascent in the UK. It is unclear whether or how split systems in existing homes could be controlled, what technology compatibility issues there would be, or whether sufficient homes with the necessary technology could be recruited. The UK government is currently consulting on proposals for all flexible heating technologies to be smart as standard and be able to act on external price signals from 2026[29]. It is unclear whether this also includes cooling technologies like central and split system ACs. If not, smart residential cooling may be limited even in the medium term.

A trial of third party controlled residential cooling could be more feasible in the late 2020s, dependent on the above.

Programme Design #9: Residential direct load control without utilisation payment

Target customer	Commercial	**Eligible technology**	Technology agnostic
Programme type	Incentive-based: direct load control	**Notice period**	2 mins, 15 mins or day ahead
Payment structure	Availability	**Event length**	1-6 hours
DNO use case	Operational utilisation + variable availability	**Recommendation**	Not suitable
UK precedent	HeatFlex	**Int'l precedent**	BYOT

This is identical to programme design #8, except homes would only receive an upfront availability payment. This is more akin to a programme design like Orange & Rockland's Bring Your Own Thermostat[30] in New York State, where customers received an $85 payment for participating.

As well as the current technology limitations and low cooling adoption rate discussed in programme design #8, EQUINOX found that UK customer participation in heating DR events was more reliable when they received utilisation payments after each event rather than upfront payments. This programme design is likely not suitable for the UK in the near term.

[29] Department for Energy Security and Net Zero, Delivering a smart and secure electricity system: implementation, 2024
[30] Orange and Rockland, Bring Your Own Thermostat Program

Barriers to DR and recommendations

There are several more general barriers to cooling DR trials and deployment beyond those cited in the previous section as reasons for not shortlisting four of the proposed programme designs. These general barriers are outlined below.

1. **The network need for cooling DR programmes in the UK is still uncertain**. This stems from ongoing challenges in accurately predicting future cooling uptake, its impact on distribution network load and the potential benefits of cooling DR.

   CoolDown is the first UK project to tackle these challenges for UK distribution networks. The project has pioneered a building-by-building approach to predicting residential and commercial cooling uptake in different climate scenarios, applying this methodology to two of ENWL's distribution substations. The model also calculates the additional load on the substation due to cooling and the potential reduction in load due to DR[31]. ENWL scaled the results across two primary substations to provide an initial view of how many substations exceed their transformer rating due to growing cooling demand. They repeated this analysis with DR applied to the midday peak in cooling demand to see how much network reinforcement could be deferred or avoided[32].

   Recommendations: The efforts described above provide a springboard for more detailed analysis on the network need for cooling DR. The analysis should be expanded across more:

   - Distribution substations to account for more residential and commercial building typologies.
   - Primary substations to build an understanding of the overall network impacts of increased cooling.
   - Cooling DR programme designs, as shortlisted above, to model how the DR delivery method changes the network impacts.

2. **The customer perspective on cooling DR in the UK is a black box.** There is a lack of clarity and knowledge regarding residential and commercial customers' willingness to participate in cooling DR in the UK. UK heating DR and international cooling DR programmes offer some applicable learnings, as detailed in this report. However, research to understand customer preferences in the UK climate would be even more helpful in defining which of the shortlisted DR programmes would be most effective in the UK.

   Recommendations: Primary research with UK electricity customers from the commercial and residential space would build a better understanding of knowledge of and views on various cooling technologies and the potential to use them flexibly.

[31] For more information, see CoolDown deliverable D2.1.
[32] For more information, see CoolDown deliverable D3.1.

- For commercial buildings, where cooling is already widespread, customers could be asked about their own understanding of their cooling system, how they use it, and their views on the four shortlisted DR programmes suited to commercial buildings.
- For residential buildings, where cooling is a nascent market, customers could be asked about their knowledge of different cooling technologies, their likelihood of installing cooling in their household if they do not already have it, and their views on the two shortlisted DR programmes suited to residential buildings.

3. **There is room for individual thermal comfort in buildings to be better understood.** Thermal comfort is a subjective view of what a person considers to be the optimal temperature in the room or building they are in. Although studies have considered this internationally and for UK office buildings[33], research clarifying thermal comfort for different UK building types would be beneficial. Without conclusive insights into how occupants of UK residential and commercial buildings perceive and respond to changes in indoor temperature, there is a risk of implementing cooling DR programmes that are either too aggressive or too conservative. This could lead to a potential resistance to participation in, or limited network benefits from, a DR programme.

   Recommendations: It would be beneficial to survey customers on their upper thermal comfort limit. This could help define parameters like DR event length and pre-cooling windows. Residents and businesses would need to be surveyed differently. One interesting factor to probe would be gender, as studies have shown that men and women perceive thermal comfort differently[34]. Another important nuance to explore is on how customers with vulnerabilities or health conditions might be at particular risk to changes in internal temperature. For example, recent studies[35,36] indicate higher heatwave-related mortality rates in older age groups. Cooling DR programmes may therefore need to be tailored differently to customers with vulnerabilities.

4. **The parameters defined for the shortlisted DR programmes need to be validated.** We have outlined the key parameters for each programme design based on available evidence, and to align closely with the standard flexibility products adopted by all UK DNOs. Nevertheless, the shortlisted designs need to be explored in more detail. Parameters like event length and notice period need to be optimised based on customer preferences and network need. The payment approach and

[33] Aghniaey, S., The impact of increased cooling setpoint temperature during demand response events on occupant thermal comfort in commercial buildings: A review, 2018
[34] Haselsteiner, E., Gender Matters! Thermal Comfort and Individual Perception of Indoor Environmental Quality: A Literature Review. In: Andreucci, M.B., Marvuglia, A., Baltov, M., Hansen, P. (eds) Rethinking Sustainability Towards a Regenerative Economy, 2021
[35] Kollanus V., Mortality risk related to heatwaves in Finland – Factors affecting vulnerability, 2021
[36] Rodrigues Diniz F., Heat Wave and Elderly Mortality: Historical Analysis and Future Projection for Metropolitan Region of São Paulo, Brazil, 2020

payment amount also need to be pitched to provide cost-effective DR to networks and incentivise customer participation.

Recommendations: Primary research with customers can gauge their theoretical preferences for key parameters like DR event length, notice period, and incentives. These can then be validated via trials with both commercial and residential customers.

5. **There is a knowledge gap on split system AC DR.** We found no DR programmes or trials exploring split system ACs in our international benchmark. Programmes typically focus on central AC, HVACs and occasionally heat pumps. Space constraints and water-based heating systems mean that split system ACs are the most likely cooling solution for the UK's existing housing stock. Many households may only install cooling in one room, which could make them more or less likely to provide DR when requested.

   Recommendations: The DR potential of split systems should be explored in more detail through primary customer research and trials. A blocker to trials could be the slow rollout of cooling technologies.

6. **The residential cooling rollout is nascent and its trajectory uncertain.** This could make it difficult to canvas residential views on cooling technologies as they will have little exposure to or understanding of these technologies in a home setting. It also complicates efforts to recruit for and implement residential cooling DR trials. Sample sizes could be limited, exacerbating any issues with technology compatibility. Initial trials may need to incorporate the installation of cooling technology as a participation incentive.

   An element to highlight is that third-party control for cooling DR is in theory feasible but could face the same challenges as those being faced currently for heat pump DLC DR around interoperability and technology availability.

   Recommendations: The rollout of cooling in residential properties should be closely monitored across existing and new build housing. The residential surveys recommended under barrier 2 can help provide a more accurate growth trajectory for residential cooling. This can supplement the modelling already undertaken in the CoolDown project and any improvements made as per the recommendations for barrier 1.

   For DLC cooling DR, it is worth exploring the standards which would be needed to embed smart capabilities in cooling technologies as soon as possible in this nascent stage of market growth.

Appendix: types of DR programme[37]

Most DR programmes operate through monetary instruments like variable electricity prices (price-based) or payments for shifting usage (incentive-based)[38].

Price-based programmes leverage price signals and tariffs to encourage consumers to adjust their consumption patterns. Price-based programmes can be divided into four categories:

- **Real-time pricing tariffs**: rate structure in which energy price per kWh changes hourly or half-hourly for the consumer, for instance by tracking wholesale prices. Also known as dynamic or spot pricing.
- **Peak time rebates**: customers are credited or provided an incentive (typically monetary) for reducing their load consumption during peak hours.
- **Time of use tariffs**: rate structure in which the utility charges different electricity prices to customers at different times of day e.g., off-peak rates, on-peak rates, night-time rates, etc.
- **Critical peak pricing tariffs**: rate structure in which the utility spikes electricity prices during a narrowly defined peak period (e.g., two-hour weekday evening peak). These peak prices are predetermined and can be up to ten times higher than normal rates.

Incentive-based programmes provide direct payments to consumers who participate in DR events by shifting their demand when prompted. These programmes can be split across the wholesale and retail markets.

There are three typical programme types within the **retail market**:

- **Direct load control**: mechanism in which customer appliances are directly controlled by a utility or other third-party aggregator and are turned off or adjusted to a lower energy consumption (e.g., increasing thermostat setpoint to reduce cooling energy usage).
- **Interruptible load**: customers agree for a utility to turn off the power supply to a part of their load during peak periods in exchange for monetary compensation.
- **Demand bidding/buyback**: customers offer bids to reduce their load based on electricity market prices; programme is usually offered to larger consumers (> 1MW), although smaller consumers could participate via an aggregator.

There are also three programme types within the **wholesale market**:

- **Ancillary services**: consists of several speciality services that are typically provided by generators to ensure safe operation of the transmission grid. For

[37] Note this is an excerpt from CoolDown deliverable D4.1.
[38] IEA, DR overview

example, energy users may be paid to provide frequency control by reducing demand to keep the grid operating.

- **Emergency DR programme**: incentive payments are provided to customers for load reduction achieved in response to an emergency on the transmission system.
- **Capacity market programme**: customers offer load reductions as system capacity to replace conventional generation sources during peak demand periods; incentives are usually upfront reservation payments.

Figure 2 provides an overview of these main DR programme categories.

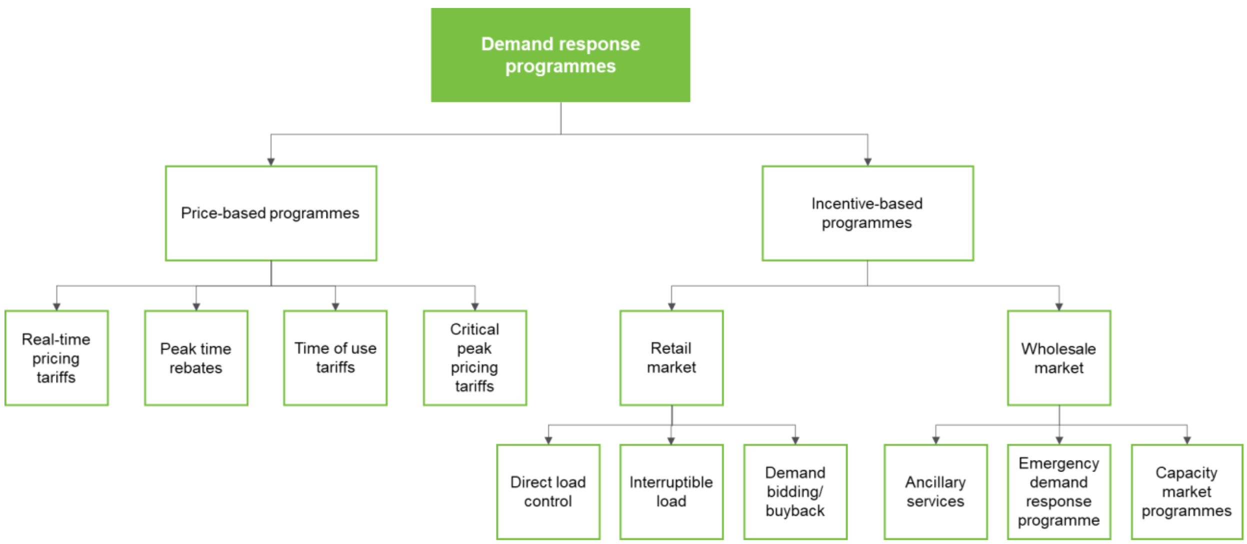

Figure 2. Flowchart categorising DR mechanisms[39]

[39] Adapted from Alasseri et al., Conceptual framework for introducing incentive-based DR programs for retail electricity markets, 2017.

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