Department for Energy Security & Net Zero

First phase regulations for energy smart appliances

Analytical Annex

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About this document

In 2021, emissions from heat in buildings (including indirect emissions from energy supply) was around 24% of the UK's total greenhouse gas emissions[1]. Meeting our legally binding target of a 77% reduction in carbon emissions by 2035, and to reach net zero emissions by 2050, means decarbonising virtually all heat in buildings and most industrial processes. Electrification of heat will be an important component of this decarbonisation. It presents a great challenge to the electricity system due to great additional demand. Residential electrical demand for heat could potentially increase two- to threefold[2]. It also presents a unique opportunity to embed demand side response (DSR) into UK homes, in line with the Government's ambition to install 600,000 heat pumps per year by 2028 and 7.1 to 11.5 million cumulative installations by 2035[3].

Most domestic consumers only engage in DSR if it can be automated[4] and a crucial prerequisite for that is smart functionality. This consultation sets out requirements for such a smart mandate for domestic heat appliances[5].

Besides the great opportunity for DSR, the mass rollout of smart technology in homes and small businesses introduces new risks to the electricity system. Remotely controllable electrical loads such as smart heat appliances could be an attractive target for cyber-attacks which can have serious consequences for the grid. Grid stability could also be at risk without a cyber-attack when many heat appliances turn on or off in synchrony (for instance, in response to a time of use tariff). This could create sudden spikes or drops in energy demand that could impact grid stability. This consultation alongside the smart mandate sets out the governments approach to cyber security and grid stability to ensure these risks are mitigated.

This document sets out the Government's value for money case underpinning the interventions in this consultation and to invite the public to feed back on the assumptions used. The background and rationale for intervention as well as wider benefits have been comprehensively set out in 2022 SSES consultation analytical annex[6] and the impact assessments produced for the Energy Act during its passage through Parliament[7]. Respondents to the SSES consultation overwhelmingly agreed with the case for intervention and benefits set out. This document thus presents an indicative impact appraisal of the requirements put forward in the consultation as first phase energy smart appliances (ESA) regulations as these are most developed. The impacts of the remainder of proposals in the consultation will be appraised as part of future consultations.

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[1] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2021https://www.gov.uk/government/statistics/energy-consumption-in-the-uk-2022

[2] Electricity Networks Strategic framework analysis p.13

[3] Carbon Budget Delivery Plan, https://assets.publishing.service.gov.uk/media/6424b2d760a35e000c0cb135/carbon-budget-delivery-plan.pdf

[4] Under market wide half hourly settlement electricity prices could change up to 48 times per day. Most consumers will not have the time to optimise their electricity consumption every 30 minutes. There are also technical limitations for consumers to engage in DSR manually. Grid services requiring DSR can have response times of less than one second, which only be served through automation.

[5] A key principle behind the smart mandate is that consumers will always retain the choice on whether, and to what extent, they will utilise the smart functionality that will be present in heat devices.

[6] Delivering a smart and secure electricity system analytical annex, https://assets.publishing.service.gov.uk/media/62c44e29e90e07748814bc66/smart-secure-energy-system-consultation-analytical-annex.pdf

[7] Energy Bill – Impact Assessments (IA), https://bills.parliament.uk/publications/47261/documents/2122

Government wants to improve its evidence further and would therefore encourage respondents to comment on the methodology and assumptions employed using consultation question 34.

Options and scope

This section sets out the devices in scope and the requirements of the proposed first phase ESA regulations put forward in the consultation. This note appraises the impact of these requirements as option 2 against a Do-Nothing counterfactual (option 1).

Scope

The following ESAs are in scope of the first phase ESA regulations.

Table 1. Appliances within scope of the first phase ESA regulations.

Appliance	Description
Electric Heat Appliances	
Hydronic Heat Pumps	A heating appliance that extracts low temperature heat from a renewable source such as the air, water or the ground and upgrades it to higher temperature heat to feed a central heating and/or a sanitary hot water system. This includes the hydronic heat pump element of any hybrid heating system which combines an electric heat pump with a combustion boiler using fossil fuels or low-carbon alternatives.
Storage heaters (space)	An established space heating appliance that can be used flexibly to utilise periods of cheap and clean electricity generation by using electricity to heat a solid storage medium which can be discharged to provide heating during peak demand.
Heat Batteries	An emerging electric heating appliance that can be used flexibly to utilise periods of cheap and clean electricity generation by using electricity to heat a thermal storage medium, which is then used to heat water to feed a central heating system and/or a sanitary hot water system. Also sometimes called a dry core storage boiler.
Indirect cylinders with electric heating elements	A water cylinder connected to a fossil fuel boiler, or heat pump, where the boiler, or heat pump, heats the water stored in the cylinder, and then that water flows through a central heating system when needed. The hot water storage cylinders have additional electric immersion elements to provide an alternative method for heating if required.
Standalone direct electric storage water heaters	A water cylinder heated by an electric immersion element only and not connected to a centralised space heating device like a boiler or heat pump.

Appliance	Description
Standalone Heat Pumps for DHW	A water cylinder with a heat pump element, often mounted on top, which heats hot water using energy extracted from the air. It could be a potential solution to decarbonise hot water demand, particularly in homes which use direct electric space heating because they cannot accommodate or need a heat pump for both.
Hybrid Heat Pumps	Hybrid heat pumps (or 'hybrids') combine a heat pump with another heat generation technology (usually a fossil-fuel boiler). Common controls are often used to manage how the component technologies operate together to create a single hybrid heating system.
Domestic Batteries	
Domestic electricity battery storage systems	Domestic electricity battery storage systems store surplus energy from residential renewable sources like solar panels. Stored electricity can be used during times of peak demand or when domestic renewable sources do not generate enough to meet household demand.

Option 1: Counterfactual

The current regulatory state of the heat appliance market would be preserved. Consumers would be able to buy appliances with and without smart functionality. The absence of smart mandates would mean consumers could chose to purchase appliances that have DSR potential but without internet connectivity. This would almost certainly prevent those consumers from participating in DSR in the future unless they purchased a new appliance. In the case of a heat pump, for instance, this would be unlikely due to their significant capital cost.

Option 2: First phase ESA regulations

As set out in the main consultation document, first phase ESA regulations will be focused on the following three requirements to come into force in circa 2026:

1 Establishing minimum requirements for cyber security for domestic heat appliances and batteries;

2 Establishing minimum requirements for grid stability through mandating randomised delay functionality for domestic heat appliances and batteries, and;

3 Introducing the "smart mandate" to heat appliances including smart functionality (remote device communication and output modulation) as well as requirements for personalised defaults and consumer interfaces.

Electric heat appliances are in scope for requirements 1 to 3, whilst domestic electricity battery storage systems are only in scope for requirements 1 and 2.

Table 2. Applicability of the three requirements on electric heat appliances and domestic electricity storage.

	Electric heat appliances	Domestic electricity battery storage systems
Minimum cyber security requirements	Applicable	Applicable
Minimum grid stability requirements	Applicable	Applicable
Smart mandate	Applicable	Not applicable

Appraisal

Benefits

The first phase ESA regulations will deliver a dual benefit: enabling mass participation of domestic consumers in demand side response (DSR)[8] through electric heat appliances as well as mitigating the associated cyber security and grid stability risks.

We expect heat pumps and other electric heat technologies to be the principle means of decarbonising heat over the next decade and potentially beyond. As outlined in our Smart Systems and Flexibility Plan, highly flexible use of heat pumps could enable annual demand to be shifted by up to 50TWh in 2050 and reduce peak demand by nearly 5GW[9]. Smart heating alongside storage – including thermal storage, or the thermal performance of a building's fabric – also has the potential to reduce costs for consumers by shifting demand. It has also the potential to give consumers greater ability to optimise their heating for comfort, cost and carbon, based on their preferences.

With rapid scale up of electrification of heat expected over the 2020s[10] the impact on the grid of electric heating will increase significantly, as well as the potential to provide flexibility. Mandating smart functionality is a key enabler in the participation of electric heating appliances in DSR and will unlock benefits for both consumers and the electricity system. Without government intervention at this stage, it is unlikely that smart heating will be taken up at the rate required to achieve the full benefits for consumers and the electricity system during the transition to electrification of heat.

Higher DSR uptake, in part through domestic electric heating, is a key component of achieving Net Zero at the lowest cost. DSR provides flexibility capacity to the electricity system. More system flexibility translates into cost savings for the system due to lower capital costs for generation and network infrastructure, as less excess generation capacity can be built to manage demand peaks. This will help to lower consumer bills. The total benefit of DSR to the UK electricity system has been estimated by the Electricity Networks Strategic Framework analysis (ENSF) to be between £40-50bn (cumulative, 2021-2050, 2020 prices)[11].

The mass rollout of smart heat devices as well domestic electric battery storage systems introduces two new risks to the integrity of the energy system due to cyber-attacks and grid stability incidents. The requirements of the first phase ESA regulations will protect the system against these risks. Third party organisations will be able to remotely control and influence significant amounts of electrical load through smart heat appliances. If these organisations or their systems are subjected to cyber-attack without preventative or mitigation measures in place, there could be significant challenges for the system operator in balancing the grid. Without proper protections, a cyberattack on large number of devices could have very serious consequences. An attacker with control of many devices – or the systems used by

[8] Demand side response (DSR) refers to the shifting of demand to cheaper times, such as through tariffs that reward flexibility and reflect generation costs

[9] Smart Systems and Flexibility Plan 2021, Technical Appendix I, www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

[10] For instance we expect a scale up of heat pump deployment to at least 600,000 heat pump installations a year by 2028 as stated in the Carbon budget delivery plan 2023.

[11] Electricity Networks Strategic Framework analysis 2022, https://www.gov.uk/government/publications/electricity-networks-strategic-framework

organisations to control them – would be able to freely shift large volumes of demand up or down. If the amount of demand they control is large enough, they could cause damage to infrastructure used to distribute electricity and/or loss of electricity supply to consumers.

Grid stability could also be at risk without a cyber-attack when many heat appliances turn on or off in synchrony (for instance, in response to a time of use tariff). This could create sudden spikes or drops in energy demand that could impact grid stability. For example, the August 2019 power outage (which affected over 1 million consumers as well as transport and water infrastructure[12]) was caused by a sudden loss of 892MW from the system. This is equivalent to a sudden change in demand or approximately 50,000 heat pumps. Shifting demand into off-peak hours without more nuanced interventions could lead to very high secondary peaks in demand (for instance if all heat pumps turned on at the same time at night).

Mandating ETSI EN 303 645 as well as randomised delay functionality (requirements 1 and 2 in the first phase ESA regulations) will act to mitigate the cyber security and grid stability risks associated the mass take up of domestic DSR.

Costs

Qualitative summary

The following table sets out the costs associated with each requirement within the first phase regulations (Option 2) that were appraised in this analysis.

Table 3. Costs associated with each additional requirement.

Additional Requirement	Qualitative cost description
Cyber security requirements	Feedback from industry engagement on the EVSCP[13] indicated that hardware modifications may not be required. However, fully complying with the ETSI will require new firmware and software development. Annual review/check-up and security testing.
Grid stability: Randomised delay	Feedback from industry indicated that this is a relatively simple firmware feature. Additional training and documentation as well as additional customer support may be required.
Smart functionality	Additional hardware is required when manufacturing a smart heat appliance. This includes: • Communications module so that the heat appliance can send and receive data. This will enable remote access and allow the appliance to receive and respond to

[12] GB Power System Disruption – 9 August 2019 Energy Emergencies Executive Committee: Interim Report, BEIS, https://assets.publishing.service.gov.uk/media/5d96100340f0b61743bd4cc3/20191003_E3C_Interim_Report_into_GB_Power_Disruption.pdf

[13] The Electric Vehicles (Smart Charge Points) Regulations 2021

Additional Requirement	Qualitative cost description
	instructions. This cost will depend on the type of module (e.g., Wi-Fi, GPRS41, ethernet). • Additional processing power and RAM There are also additional development costs that need to be considered. These include: • Development of bespoke firmware so that the heat appliance can perform additional functions. The cost will depend on whether this is sub-contracted. • Additional testing and certifications
Personalised default settings	No hardware modifications would be necessary to meet this requirement. Instead, this would require software development / adjustments and the subsequent internal training and documentation updates. It may also require additional customer support.
Assurance of requirements	This isn't fully defined, but may require external testing. Also likely to require annual updates and audits.
Familiarisation Costs	Costs associated with reviewing the requirements, planning and implementation.

Assumptions

Cost assumptions

Capitalised costs

There are one-off costs such as the costs of modifying or developing software, or recurring costs such as the cyber security annual review. These costs arise once per business and will be recovered via sales. These costs are expected to vary by manufacturers and the unit cost would depend on sales volume. We have limited evidence at this stage. The assumptions below are based on the estimates used in The Electric Vehicles (Smart Charge Points) Regulations 2021.[14]

Please use consultation question 34 to comment on the validity of these assumptions for smart heat appliances and domestic battery systems.

[14] The Electric Vehicles (Smart Charge Points) Regulations 2021 Impact Assessment, https://assets.publishing.service.gov.uk/media/61324b8ee90e070437d8b9f8/electric-vehicles-smart-charge-points-regulations-2021-impact-assessment.pdf

Table 4. Cost assumptions, impacted groups, and high and low cost assumptions.

Requirement	Impacted businesses	Occurrence	Central cost assumption	High cost assumption
Smart development costs	Manufacturers	One-off	£300,000	£300,000
Personalised defaults	Manufacturers	One-off	£20,000	£30,000
Cyber - firmware and software	Manufacturers	One-off	£100,000	£300,000
Randomised delay	Manufacturers	One-off	£20,000	£20,000
Assurance - testing	Manufacturers and importers	One-off	£30,000	£30,000
Familiarisation	Manufacturers and importers	One-off	£20,000	£80,000
Cyber - annual review	Manufacturers and importers	Annual	£50,000	£100,000
Assurance - audits	Manufacturers and importers	Annual	£10,000	£10,000

Unit costs

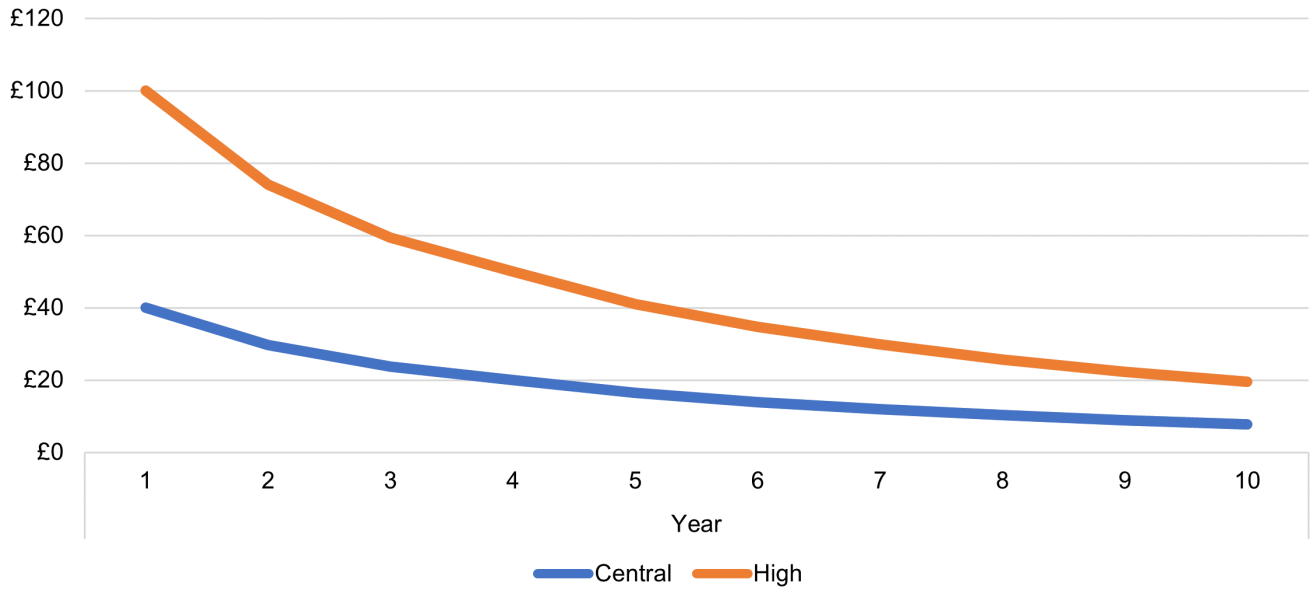
The additional cost per appliance in making a non-smart heating appliance to comply with the proposed regulation will differ between manufacturers depending on the design solution. The exact costs will be driven by the precise details of the standards and functionality requirements set out in secondary legislation. At this stage we have used evidence from smart EV charging points to infer about the likely cost per unit, assuming that the hardware and software requirements for smart functionality will be similar. This suggests an additional unit cost of £40. A sensitivity assumption of £100 per unit is assumed based on market review of current retail price of heat pump smart controls. This is considered to be conservative given that add-on modules often come as a bundle with the heat pump unit, which would be cheaper compared to buying the module separately. Due to limited evidence, we've applied the same cost assumption for all the heating appliances.

Table 5. Costs per unit from additional smart hardware in year 1.

Costs per unit in year 1	Central	High
Additional smart hardware	£40	£100

Given the rate of change in this market, it is expected that significant developments will be made that will allow these technologies to be produced more economically as production expands. To account for this, we have used "learning rates" to estimate cost decreases over time. How costs will change over time is dependent on many factors making accurate forecasting difficult. Due to the infancy of the market, it is not possible to determine these rates from historical trends. Instead, we used the learning rate employed in the EVSCP IA[14] which, has been inferred from historical rates observed from general learning rates for computers[15]. They are assumed to be representative of the added software and hardware which makes an appliance "smart".

Figure 1. Cost reductions due to learning.



Population assumptions

Number of companies

The table below sets out the number of businesses in scope of the first phase ESA regulations we have assumed for the appraisal. The high assumption is derived by doubling the central assumption to reflect the uncertainty on the estimate.

We estimate that there are above 30 Air Source Heat Pump (ASHP) and Ground Source Heat Pump (GSHP) manufacturers with market presence in the UK- the majority of which are foreign manufacturers[16], plus up to 10 storage heater manufacturers[17].

[15] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy (2011): Using the Experience Curve Approach for Appliance Price Forecasting, https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/experience_curve_appliance_price_forecasting_3-16-11.pdf

[16] Heat pump manufacturing supply chain research project, Eunomia (2020) https://www.gov.uk/government/publications/heat-pump-manufacturing-supply-chain-research-project

[17] The scope of the policy is for GB. UK sales figure is used as a proxy. Evidence gathering for electric heating options in off gas grid homes, Element (2019), Table 8-13, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831079/Electric_heating_options_in_off-gas_grid_homes.pdf

Table 6. Number of businesses in scope of the first phase regulations.

Appliance	Number of firms affected (central)	Number of firms affected (high)	Source
Hydronic Heat Pumps	30	60	BSRIA: 30 firms for 95-99% of the market[18]
Storage heaters (space)	10	20	Element Energy Report[19]
Heat Batteries	4	8	This is an emergent technology. Currently there are around 4 firms based in the UK including Caldera, PCM Products, SunAmp and Tempo.
Indirect cylinders with electric heating elements	9	18	BSRIA: 9 firms for 99% of the market[18]
Standalone electric storage water heaters	8	16	BSRIA: 8 firms for 98% of the market[18]
Standalone Heat Pumps for DHW	8	16	BSRIA: 8 firms for 95-99% of the market [18]
Hybrid Heat Pumps	10	20	Indicative business estimate, to be revised in the final impact assessment
Number of domestic battery manufacturers	3	6	Bloomberg New Energy Finance (BNEF): UK battery manufacturers;[20] 1 currently active and 5 more planned

For manufacturing businesses, they will need to spend time familiarising themselves with the new rules and requirements. Reflecting that electric heating manufacturers are typically large

[18] Heat pumps market analysis 2022. Report 104744/10, BSRIA
[19] Evidence gathering for electric heating options in off has grid homes: final report, Element Energy for BEIS, https://assets.publishing.service.gov.uk/media/5d78ed6be5274a27c2c6d50c/Electric_heating_options_in_off-gas_grid_homes.pdf
[20] Battery Cell Manufacturers Asset Map, BloombergNEF, Accessed 23/11/23, https://www.bnef.com/interactive-datasets/2d5d59acd9000002?data-hub=1

multinational companies that would be engaging with EU and other international regulatory bodies irrespective of UK regulation, and dependent on the extent to which the UK aligns with international requirements, these additional costs of UK regulation are expected to be low.
Number of appliances in scope

We assumed the following trajectories of heat appliances.

Table 7. Annual sales assumptions for appliances.

Appliance	Assumptions
Hydronic Heat Pumps	Industry estimates that up to 70,000 heat pumps were sold in the UK in 2022, and a rapid scale up of deployment is needed to reach 600,000 installations a year by 2028 and around 1.6 million in the mid 2030's consistent with Government's ambitions.[3]
Storage heaters (space)	Currently around 100,000 are installed in the UK each year. For this simplistic illustration is assumed to remain at this level.[19]
Heat Batteries under 45kW	This is an emerging technology; the current market is in the low thousands annually.
Indirect cylinders with electric heating elements	The current market is around 80,000 annually. [21] For this simplistic illustration is assumed to remain at this level.
Standalone electric storage water heaters	The current market is around 110,000 annually. **Error! Bookmark not defined.** For this simplistic illustration is assumed to remain at this level.
Standalone Heat Pumps for DHW	The current market is around 3,000 annually**Error! Bookmark not defined.**, For this simplistic illustration is assumed to remain at this level.
Hybrid Heat Pumps	The current market is around 3,000 annually. **Error! Bookmark not defined.** For this simplistic illustration is assumed to remain at this level.
Domestic battery	The volume is expected to grow to support DSR and self-generation, to around 40,000 annually in 2030's.[22]

In the counterfactual scenario we assumed that a proportion of devices would be smart without regulation. For modelling purposes we have made the following conservative assumptions that the following proportion of the current market sales have energy smart functionality. These

[21] Water Heating and Solar Thermal Markets. Report 61435/17 June 2019, BSRIA
[22] European Market Monitor on Energy Storage 7.0, LCP-Delta, https://research.lcpdelta.com/reportaction/ESRS_EMMES_7/Toc

assumption is likely to be conversative as the market share of smart heat pumps and heat batteries is expected to grow.

Table 8. Assumptions of the current proportion of appliances that are already "smart".

Appliance	% smart compliant	Comment
Hydronic Heat Pumps	50%	Based on interviews with manufacturers
Storage heaters (space)	0%	Based on interviews with manufacturers
Heat Batteries	50%	Based on interviews with manufacturers
Indirect cylinders with electric heating elements	0%	Given the electrical heating is used as emergency backup it is unlikely to be smart
Standalone electric storage water heaters	33%	BSRIA Report[Error! Bookmark not defined.]
Standalone Heat Pumps for DHW	0%	Could not identify any reliable sources so therefore for the purposes of this analysis we assume no compliance and therefore the maximum costs.
Hybrid Heat Pumps	50%	Assume same as hydronic heat pumps
Electric Domestic Batteries	100%	Assume that smart operability is an essential requirement of domestic battery storage

Results

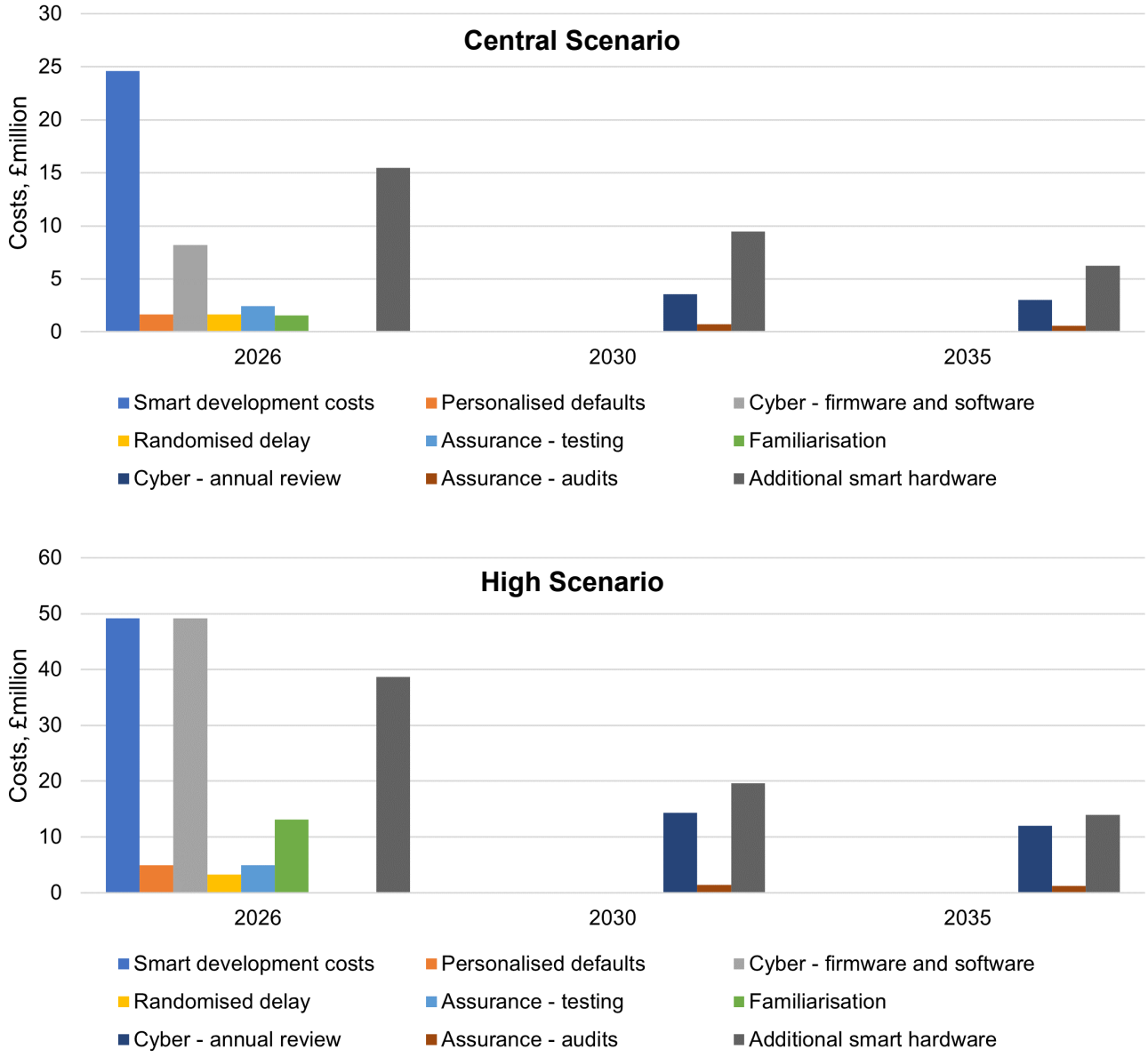
A 10-year period from 2026 is used to estimate costs presented here in 2023 prices. Table 9 sets out the high level cost estimates of the first phase ESA regulations (Option 2) against the counterfactual (Option 1).

Table 9. Summary of cost estimates in £m (2023), C and H denote Central and High estimates, respectively.

Appliance	Year 1 costs		Annual costs from year 2, discounted		Cumulative costs 2026-35, discounted	
	C	H	C	H	C	H
Hydronic Heat Pumps	20	20	63	174	83	232
Storage heaters (space)	9	25	17	32	26	58
Heat Batteries	2	6	2	7	4	13
Indirect cylinders with electric heating elements	8	22	14	28	22	50
Electric storage water heaters	7	20	13	31	20	51
Standalone Heat Pumps	4	12	4	14	8	26
Hybrid Heat Pumps	5	15	5	17	10	33
Batteries	1	5	1	5	3	10
Total	**56**	**163**	**120**	**308**	**175**	**471**

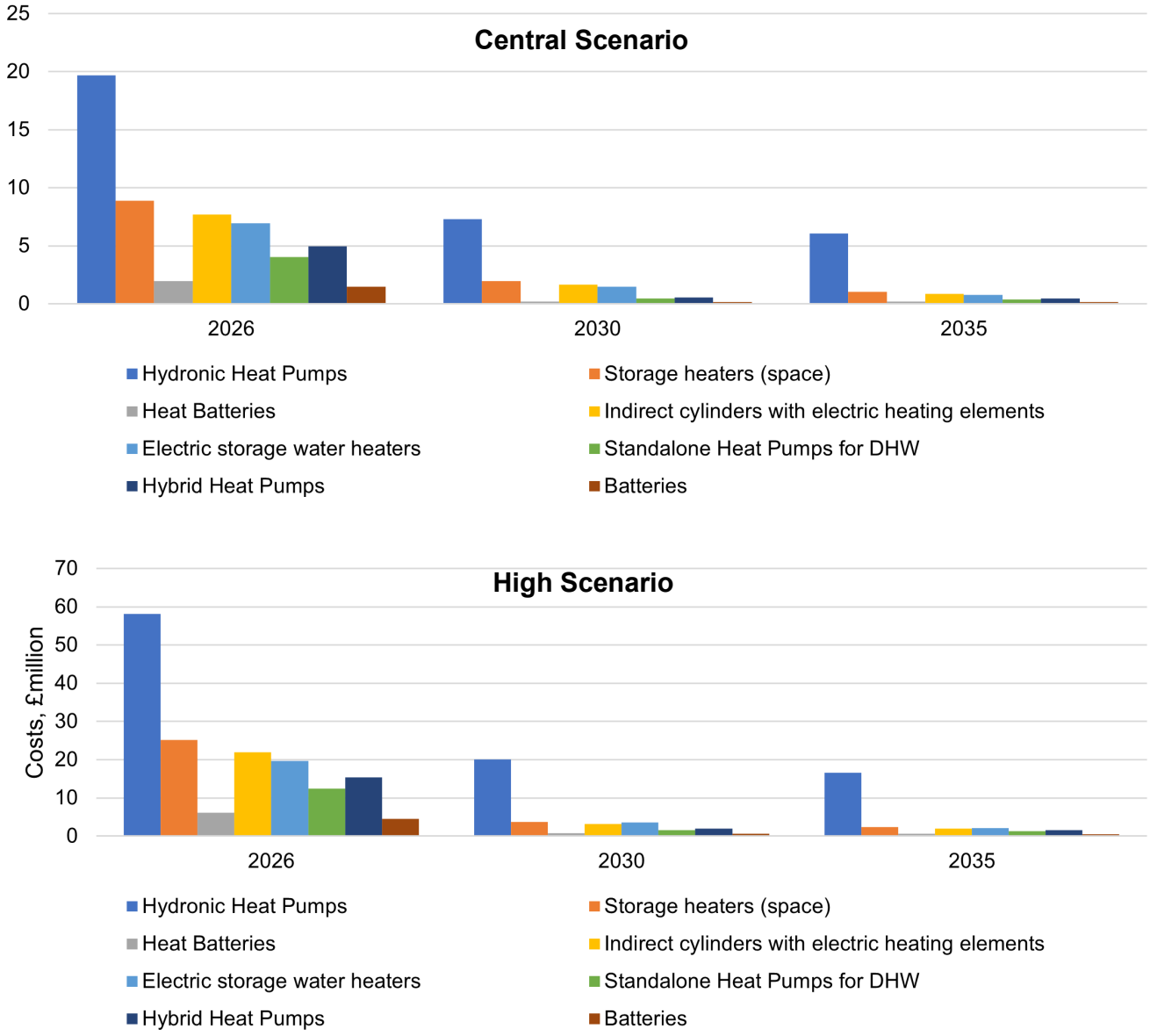
In the central scenario the total cumulative cost of the first phase ESA regulations to business is £175m (2023 prices, present value) over the ten-year appraisal period. Almost a third of the total costs (56m) arises in the first year as Figure 2 also demonstrates. This is due to businesses facing a series of one-off costs when requirements take effect. Over the course of the appraisal period the main impact are the smart hardware costs per device. These fall driven the learning rate assumption we used. The high sensitivity reflects a higher number of companies incurring familiarisation costs and other transitioning costs and higher manufacturing costs per unit, as discussed in earlier sections. In this scenario the total cumulative costs are £471m (2023 prices, present value) over the ten-year appraisal period.

Figure 2. Indicative costs to business stratified by requirement, £2023, discounted.



As Table 9 and Figure 3 show, the main cost burden on business stems from hydronic heat pumps. In the central scenario hydronic heat pumps make up of 47% of the total discounted cost, £82 million of £175 million. This is mainly driven by the smart hardware costs per appliance and our annual sales assumptions for hydronic heat pumps which outgrow the sales assumptions of other appliances tenfold from 2033 onwards.

Figure 3. Indicative costs by appliance, £2023, discounted.



Conclusion

We have estimated the total costs to business of the first phase ESA regulations over a ten year period as £175m (cumulatively, discounted 2023 prices) in the central scenario and £471m (cumulatively, discounted 2023 prices) in the high scenario. We have not been able to quantify the specific benefits associated to this policy. However, domestic heat is major source of future electrical demand growth and has great potential for DSR and system cost savings[23]. Thus, it is likely that the first phase ESA regulations do provide value for money. We will continue to develop our value for money appraisal to publish updated estimates alongside future consultations.

[23] From the Electricity Network Strategic Framework analysis 2022 we know that total system benefit for DSR is between £40-50bn, albeit over a longer appraisal period (2022-2050).

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