CEPA economics matters ESP Consulting

Cap and Floor Regime for Long Duration Electricity Storage: Setting the Cap and Floor

Department of Energy Security and Net Zero

10 March 2025

FINAL REPORT

Important notice

Contents

1. INTRODUCTION

CEPA and ESP Consulting have been commissioned by the Department for Energy Security and Net Zero (DESNZ) to develop different options for setting the cap and the floor within the proposed cap and floor regime for Long Duration Energy Storage (LDES).

The primary focus of this work package has been to explore the options and trade-offs involved in determining the level of the cap and the floor, consistent with the Government's objectives. The scope did not extend to setting the specific levels of the cap and floor themselves, or the detailed design of the regime.

1.1. Our approach to the research question

The aim of our work has been to explore cap and floor designs that are technology-agnostic in its application, though we have focused our thinking on its application to mature technologies at Technology Readiness Level 9 (TRL 9). We have also considered how to accommodate different financing structures, including both project finance and on-balance sheet arrangements.[1]

Our analysis draws significantly on the existing interconnector cap and floor regime, acknowledging the strong stakeholder preference for maintaining continuity with this established model. However, we have carefully considered the unique characteristics of LDES assets and their implications for the regime design, including:

- contract duration and the timing of the recovery of capital expenditure (capex); and
- incentive mechanisms for efficient LDES asset operation both above the cap and below the floor.

As part of our work, and as explained further in this report, we have developed a potential reference design for setting the cap and floor. This reference design will need to be subject to further stakeholder engagement, and we also recognise that specific technologies or projects may require deviations from a standard approach. However, any such variations must align with the fundamental objectives of the cap and floor regime.

We have also undertaken illustrative stochastic financial modelling to understand how different approaches to setting the cap and floor influence the range of possible outcomes for investors and consumers. We have used this modelling as a tool to understand the trade-offs between the objectives of the cap and floor regime and to illustrate the potential impacts of different options, rather than to determine appropriate cap and floor design choices.

While we have conducted informal stakeholder consultations during this process and drawn on our own understanding of lender and investor perspectives, we recommend undertaking more comprehensive formal engagement with a broader stakeholder group at an appropriate stage. This will ensure the framework effectively addresses the needs and concerns of all relevant parties.

1.2. Structure of this report

The remainder of this report is structured as follows:

- In **Section 2**, we present the background to the research question. We detail the objectives of the cap and floor regime for LDES, the design of the cap and floor for interconnectors, and key questions and considerations in relation to the design of the cap and floor in an LDES context.

[1] Under project finance, a separate legal entity is established for the project – e.g., Special Purpose Vehicle (SPV) – with one or more project 'sponsors' (shareholders) who own the SPV. Debt is raised at the project level i.e., issued directly to the SPV rather than the sponsors themselves. Debt is secured by the project cashflows, and lenders have no or limited recourse to the assets of the project sponsor(s) in the event of default. In contrast, if a project is financed on the sponsor's balance sheet, debt is raised at the company level and lenders have recourse to the company's assets and cashflows in case of default.

- In **Section 3**, we describe the key considerations for the design of the cap and floor, outline the choices available, and the benefits and drawbacks of each choice.
- In **Section 4**, we introduce three cap and floor models to illustrate a spectrum of options for the design of the cap and floor mechanism and evaluate them against the objectives introduced in Section 2.
- In **Section 5**, we present a potential reference design for the LDES cap and floor mechanism that could be used for regime development and negotiation, drawing on our evaluation of the models. This design has been informed by limited, informal engagement with LDES developers, but more extensive, formal consultation with stakeholders will be required to assess the suitability of the design.

In **Appendix A** of this report, we describe the simulation model we have used to quantify the effect of different cap and floor design choices, and in **Appendix B**, we discuss the merits of different options for retaining incentives for efficient operation above the cap and below the floor. Finally, in **Appendix C**, we provide further modelling results.

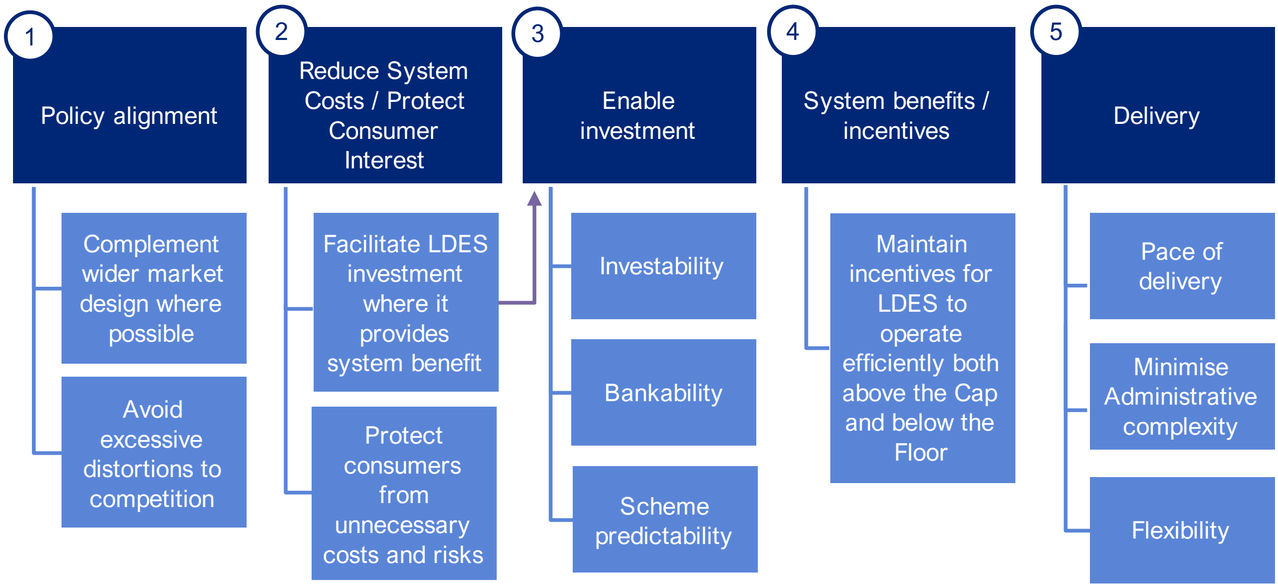
2. BACKGROUND

This section discusses the policy objectives of the cap and floor regime for LDES and what that means for the design of the cap and floor mechanism. It also describes how the interconnector cap and floor mechanism works and discusses the key issues to be considered when designing a cap and floor mechanism for LDES.

2.1. Objective of the cap and floor regime for LDES

The design of cap and floor regime for LDES must carefully balance multiple policy objectives. The Government has established five core policy objectives for the scheme,[2] which we illustrate in Figure 2.1 below (dark blue boxes). We have also illustrated (light blue boxes) a series of regime design considerations that we consider are associated with each of these policy objectives.

Figure 2.1: DESNZ policy objectives and CEPA/ESP design considerations for the LDES cap and floor scheme



Source: DESNZ and CEPA/ESP

The optimal cap and floor regime design must strike a careful balance between protecting long-term consumer interests and securing sufficient deployment of LDES capacity. In striking this balance, it is important to recognise that ensuring sufficient long-duration storage capacity within the GB power system is considered by the government to deliver a range of system benefits. While we have not considered the potential scale of system benefits attributable to LDES investment as part this work, we take as given that there are material benefits both in terms of improved system security as well as less volatile wholesale prices and temporal spreads (i.e. peak/off-peak). This position is supported by the analysis carried out by LCP Delta and REGEN for DESNZ.[3] We also take as given that any specific LDES project supported through a cap and floor contract will deliver sufficient consumer benefit, and that such benefit will be assessed by Ofgem at the project assessment window/cost benefit analysis stage (or equivalent) of the LDES cap and floor application process.

We therefore consider that the main objective of the cap and floor design is to deliver:

- expected returns which attract sufficient investment to meet system storage needs ("investability"); and

---

[2] DESNZ (2024), 'Long duration electricity storage: proposals to enable investment', p.15.

[3] DESNZ (2024) 'Scenario Deployment Analysis for Long-Duration Electricity Storage', DESNZ Research Paper 2023/047

- sufficient cashflow certainty to secure debt financing at competitive rates ('bankability') under a project finance model.

Subject to delivering on these objectives, we propose two further supplementary design criteria:

- minimise the net customer support expected over the life of the cap and floor contract, by which we mean the (net present) value of expected payments to investors below the floor less payments to consumers above the cap; and
- minimise risk transfer from LDES projects to consumers.

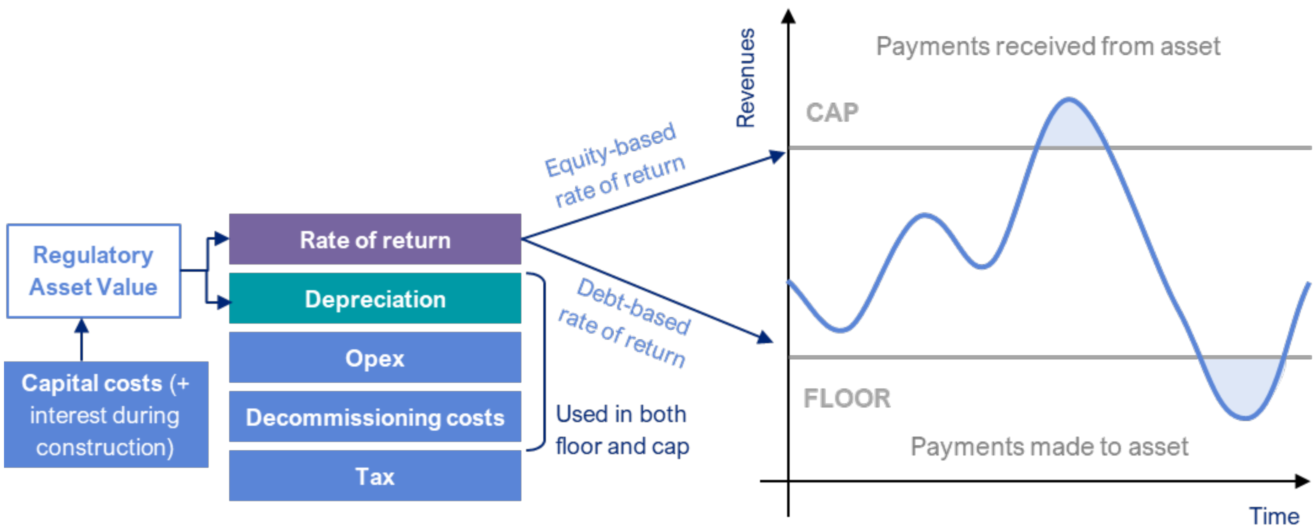
In line with the first criterion, we have sought to illustrate in our analysis the potential impact of cap and floor contract design choices on the (*ex-ante*) expected value of payments, based on a range of possible gross margin paths above the cap and below the floor using our stylised stochastic financial modelling framework.[4]

Subject to satisfying targets for investability, bankability and net support, the second criterion aims to ensure that these contracts interfere as little as possible in the normal functioning of the wholesale and ancillary markets. This implies that, **everything else equal**, the corridor between the cap and the floor should be as wide as possible.

2.2. How is the cap and floor set under the interconnector regime?

The cap and floor regime for electricity interconnectors provides a 25-year 'contract' (ultimately given effect through an interconnector licence) where project revenues are subject to a cap and a floor, the levels of which are set using a 'building blocks' approach. The regime seeks to enable the recovery of all efficiently incurred costs relating to the investment in and operation of interconnectors, as shown in Figure 2.2 below.

Figure 2.2: Building blocks of interconnector cap and floor regime



Source: CEPA/ESP

The recoverable elements of the cap and floor comprise:

- **return *of* the capital invested,** via regulatory depreciation of the Regulatory Asset Value or RAV;[5]
- **return *on* the capital invested**, calculated by applying a rate of return (in percentage terms) to the RAV;

[4] This illustrative modelling framework is set out in further detail in Appendix A.

[5] Capital expenditure (capex) and interest during construction are capitalised onto the RAV, which is subsequently depreciated over the 25-year contract. It is worth noting that this approach enables full capital recovery over the 25-year contract period, even though some interconnector assets are likely to have economic (operational) lives of up to 40 years.

- **operating expenditure;**
- **decommissioning costs;** and
- **tax obligations.**

The primary difference between the cap and floor thresholds lies in the treatment of the rate of return on capital. The framework applies different rates of return metrics to the full RAV:

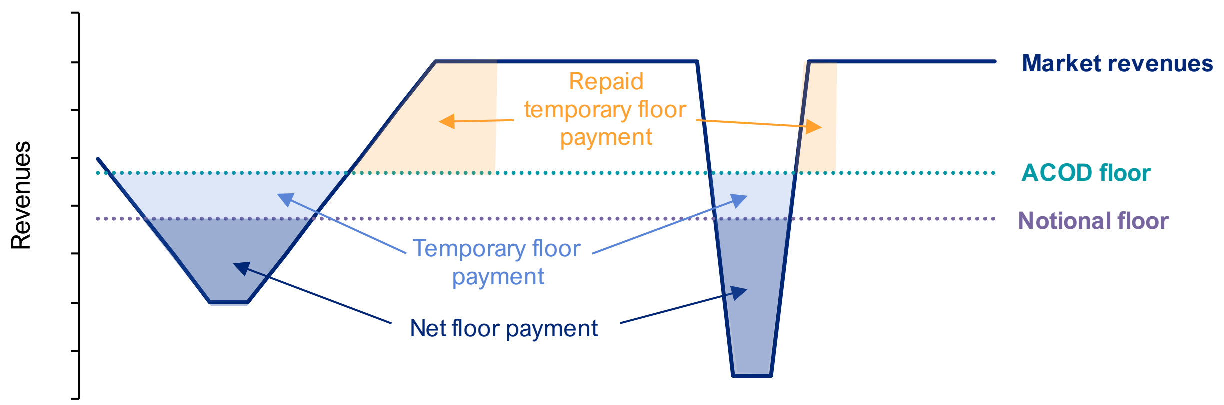
- the rate of return at the floor is calibrated to a cost of debt (CoD), applied to 100% of the RAV; while,
- the rate of return at the cap is calibrated to a cost of equity (CoE), again applied to 100% of the RAV.

While the capital, operating, and decommissioning costs which feed into the cap and floor calculations are specific to the project in question (although subject to Ofgem's cost assessment processes), the rates of return applied at the cap and floor are **notional.** In other words, they are not directly based on the project's actual cost of debt, cost of equity and related financing (capital) structure, but rather Ofgem's view of an appropriate balance of returns at the cap and the floor, given the risk profile of interconnector projects. They are **benchmark** rates of return with the effect of defining the distribution of returns on investment, subject to defined performance targets being met.[6]

There is one key exception to this 'notional' approach for interconnectors. For projects employing a project finance structure, Ofgem developed a 'hybrid' approach which permits developers to request a variation to how floor payments apply under the regime. Under this approach, the project sponsor leads a competitive debt-raising process overseen by Ofgem, and the *actual* debt service costs and required debt service cover ratio (DSCR) are used to derive an 'actual cost of debt (ACOD) floor'. Alongside this, Ofgem retains the notional floor, so that if revenues exceed the ACOD floor,[7] the project makes payments back to consumers up to the difference between the ACOD floor and the notional floor (with interest). The aim of this is to ensure that consumers are no worse off by underwriting a floor based on the ACOD. In addition, the project is not allowed to distribute any equity payments until any temporary ACOD floor payments that exceed the level of notional floor have been returned to consumers.

The mechanics of this hybrid floor arrangement is illustrated in Figure 2.3 below. So far, this approach has been used for the Greenlink and NeuConnect interconnectors.

Figure 2.3: Illustration of interaction between notional and actual floor



Source: CEPA/ESP

[6] For example, on minimum availability of the asset. See further discussion on this issue in the context of the LDES cap and floor design in Section 2.3 below.

[7] Assuming that the ACOD floor is higher than the notional floor.

2.3. What are the key questions to answer when designing an LDES cap and floor contract?

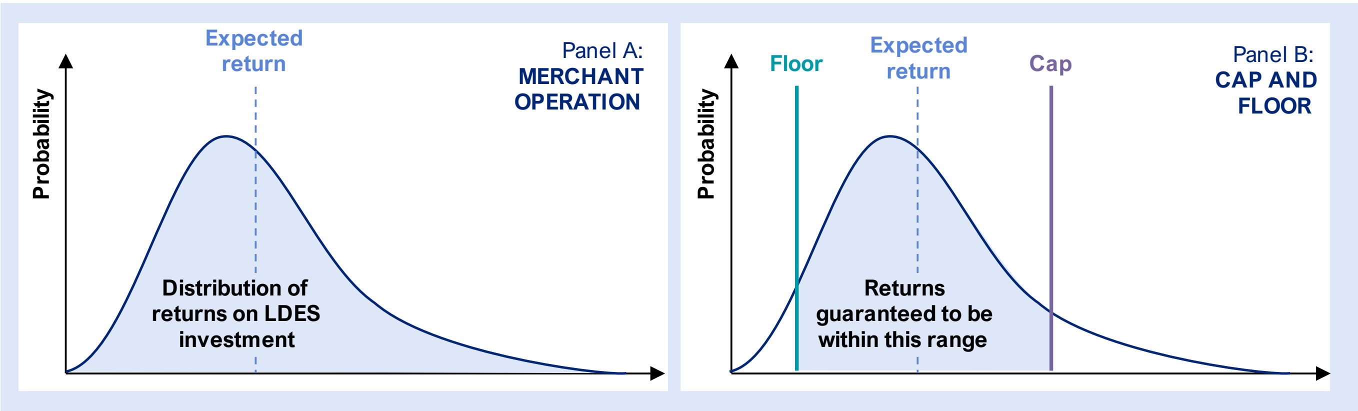
The interconnector cap and floor regime provides useful regulatory precedent when considering the design of a cap and floor regime for LDES. However, this precedent for interconnectors may not necessarily represent the best approach for LDES – for example, due to inherent differences between the technologies, or because experience with the interconnector regime has highlighted areas which could be reformed and improved.

In assessing the merits of different cap and floor designs for LDES, we have considered four overarching questions – the answers to which help to inform each aspect of the design.

1. What are the risks that we are trying to mitigate through the cap and floor regime, and what does that mean around the distribution of returns?

One of the main objectives of the cap and floor mechanism is to support investment in LDES. LDES assets rely on stacking multiple revenue streams to earn a return, each with their own price and volume risk. The logic of a cap and floor mechanism is that when operating on a merchant basis, LDES assets are perceived to be un-investable – the high degree of uncertainty around these revenue streams long out into the future means there is a high degree of uncertainty around project returns, reducing the attractiveness of such investments. A cap and floor mechanism serves to make LDES assets investable by limiting the exposure to market risk. We illustrate the uncertainty of project returns from a merchant LDES investment and with cap and floor support, in the figure below.

Figure 2.4: Illustration of distribution of returns under merchant operation and with cap and floor



Source: CEPA/ESP

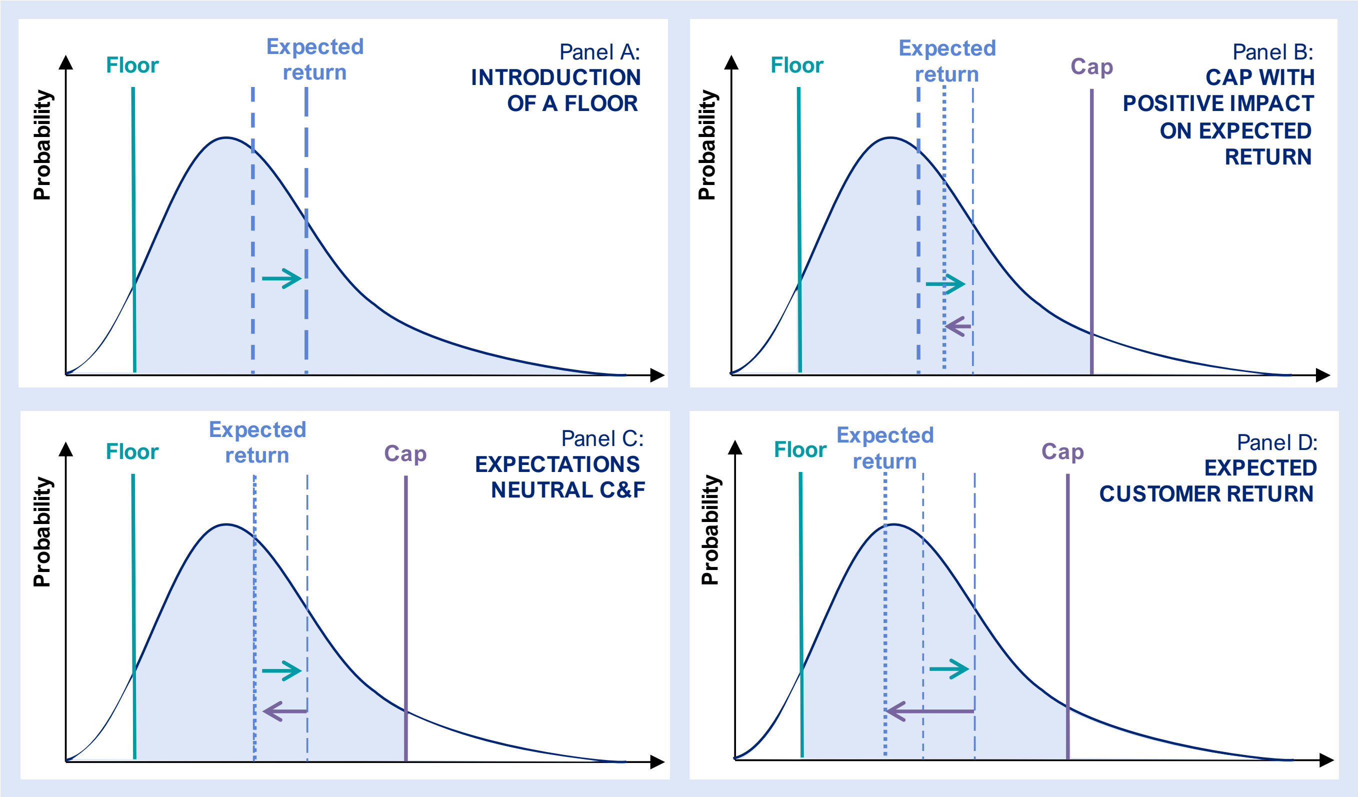
As shown in the figure, the fundamental aim of the cap and floor mechanism is to limit downside risk and, to ensure a degree of symmetry, to cap upside risk. However, the placement of both the cap and the floor can affect the expected returns as well as the distribution of returns, as illustrated in Figure 2.5 below.

As Panel A in Figure 2.5 below illustrates, introducing a floor and no cap will increase expected returns relative to a merchant LDES asset, by limiting downside risk. Introducing a cap would then serve to reduce expected returns, though the net impact on expected returns will depend on the relative placement of the cap and the floor.

In practice, however, the net impact of both the cap and the floor on expected cap and floor payments and on expected returns is inherently uncertain, as it depends on the underlying distribution of LDES gross margins. And so, setting the cap precisely so that expected returns are broadly unchanged through the implementation of a cap and floor mechanism, is challenging and unlikely to be an achievable outcome.

A related consideration is that a cap and floor mechanism, by reducing downside risk for investors, may affect the hurdle rate for investment, i.e. the expected rate of returns required by investors to make a positive investment decision. And so, the impact of the cap and floor on expected returns, considered alongside an investor's hurdle rate of return for investment, can be expected to drive how the regime influences the incentive to invest in LDES assets.

Figure 2.5: Illustration of impact of different cap and floor levels on expected return



Source: CEPA/ESP

2. To what extent can key design parameters of the cap and floor be set competitively or informed through competition?

According to economic theory, market competition is useful for achieving 'efficient' outcomes in terms of the allocation of resources and revelation of private information, due to the incentives placed on market participants through competitive pressures. Therefore, exploiting competitive tension to inform key parameters of the cap and floor may help to set them more optimally than an administrative approach, by guarding against excess returns. Competition can, in theory, allow the floor to be set at the minimum level necessary to attract investment and the cap to be set to maximise the upside benefit to consumers whilst also providing an acceptable balance of returns to the LDES investor. However, the success of such an approach relies on there being sufficient competitive tension between market participants and on an effective competition mechanism.

As previously discussed, the interconnector cap and floor regime to date has primarily used an 'administrative' approach whereby the key design parameters of the cap and floor are set by Ofgem. The only exception is the competitive debt-raising process used to set the ACOD floor for project finance interconnectors. This precedent suggests that it may be possible to at least use a competitive approach to set an 'ACOD floor' for LDES projects which employ project finance. We have also considered where and whether there might be sufficient competition in the context of the LDES cap and floor regime to use a competitive process to set other regime parameters.

3. To what extent should the design of the cap and floor be adapted to the circumstances of a specific project or specific technology?

A variety of LDES technologies are likely to be eligible for a cap and floor contract – including pumped storage hydropower (PSH), compressed air electricity storage (CAES), liquid air electricity storage (LAES), and longer-duration lithium-ion (Li-ion) and flow batteries. These technologies differ in various aspects – including their expected economic lives, risk profile, and technological maturity. For example, the civil engineering components (caverns and reservoirs) associated with PSH have very long economic lives, potentially extending beyond 100 years.

In exploring possible designs for the cap and floor regime, we have considered how LDES projects may differ between technologies and between the projects themselves. We have then also considered the extent to which the design of the cap and the floor should reflect these differences – noting that there is a balance to strike between appropriately aligning the design to project- and technology-specific requirements, while maintaining a level playing field and not making the scheme overly complex.

4. How are LDES assets different to interconnectors and what implications does that have for the design of the LDES cap and floor?

When considering the regulatory precedent set by the interconnector cap and floor regime, it is important to note that LDES assets have several intrinsic differences compared to interconnectors. For example:

- **Operations:** Commercial management for interconnectors is essentially passive with capacity rights determined via auction. In contrast, commercial management of LDES assets is highly active, due to their participation in multiple electricity markets (day-ahead, capacity, balancing, ancillary services, etc.), with continuous re-optimisation up to gate closure.
- **Confidence in asset value / market returns**: Interconnector returns rely on spatial arbitrage *between* electricity markets, whereas LDES assets rely on inter-temporal arbitrage *within* electricity markets. As there are multiple technologies that can provide inter-temporal arbitrage, this difference means that LDES assets are more susceptible to cannibalisation; there could be an overbuild of storage, or other forms of inter-temporal flexibility, which erodes future returns.
- **Availability:** Similarly, it is straightforward to monitor interconnector availability (for the purposes of incentivising efficient operation). For LDES assets, it is more complex – as a period where the asset is neither charging nor discharging may represent unavailability or may simply be because it is not economically efficient to operate the asset.

These intrinsic differences may have implications for some aspects of the LDES cap and floor regime – such as the calibration of the cap and floor levels to ensure investability, and the design of incentive mechanisms to ensure efficient operation and protect consumers interests.

3. CONSIDERATIONS FOR CAP AND FLOOR DESIGN

This section examines the key elements of the design of a cap and floor mechanism, considering what options are available and the associated trade-offs between them. While we use the interconnector regime as a reference point, each design element is evaluated from first principles, taking into account the fundamental differences between LDES technologies and interconnectors.

3.1. Assessing the impact of different design choices

When assessing the impact of different design choices and the trade-offs between them, we use a mixture of quantitative modelling and qualitative analysis.

For our quantitative analysis, we use an illustrative stochastic simulation model that examines how different design choices affect LDES project cashflows and IRRs, and the resulting floor and cap payments between projects and consumers. Hence, its primary purpose is not to forecast precise revenue opportunities for LDES assets, but rather to illustrate how varying design choices within the cap and floor scheme influence the distribution of potential outcomes.

Rather than using project-specific data, we base our quantitative analysis on archetypes which represent our assumed project configuration for particular LDES technologies. For this report, we have defined project archetypes for PSH, LAES and longer-duration Li-ion batteries. And while the analysis presented in the body of this report is primarily focused on the PSH archetype, the conclusions generally apply to other LDES technologies. Appendix A details how our model functions and the assumptions that underlie the analysis.

When presenting the results of our quantitative analysis, we use the interconnector cap and floor design as our baseline against which we compare alternative options. This baseline design for LDES includes some illustrative assumptions around rates of return applied at the floor and at the cap, further detailed in Appendix A.[8] Unlike the interconnector cap and floor design, however, our baseline design assumes a 10% gross margin sharing factor above the cap – a 'soft cap' which we have identified as essential for the scheme's viability.[9] We then evaluate the impact of varying specific elements of this baseline cap and floor design.

Some design choices cannot be meaningfully quantified through our simulation model or only provide a partial perspective. In these instances, we rely solely on qualitative assessment of how different design choices affect bankability or investability, protect consumer interests, or affect system benefits.

3.2. Overarching design choices

3.2.1. Contract duration and speed of capital recovery

The design of the cap and floor mechanism for LDES requires careful consideration of how contract duration and the speed of capital recovery interact with the unique characteristics of LDES projects and different technologies. While the interconnector regime uses a 25-year contract period with full capital recovery, LDES projects present distinct challenges that may require a different approach.

Understanding time horizons

When considering the duration of the cap and the floor, there are several distinct issues that need to be considered:

---

[8] These assumptions are not based on any specific benchmarking and should not be considered CEPA, ESP, DESNZ or Ofgem's view of an appropriate rate of return at the floor and at the cap for LDES assets.

[9] The reasons for this are described in detail in Sections 3.3.2 and 3.4.2.

- **Technical asset life:** The operational lifetime of LDES assets before replacement is required (varies by technology and by asset).
- **Project life:** The operational lifetime of an LDES plant before major refurbishment is needed (flexible definition based on refurbishment scope).
- **Debt tenor:** The repayment (or amortisation) period for project debt, if project financed.
- **Financing horizon:** The period over which the investment case for the project is being considered. This would typically be closely linked to the project life and investors would typically expect to earn their target return over this horizon.
- **RAV depreciation:** The period over which capital costs are assumed to be recovered through the levels of the cap and floor.

These periods can be broadly grouped into operational timeframes (technical asset life and project life) and financial timeframes (debt tenor, financing horizon, and RAV depreciation). Understanding how these periods interact is crucial for developing an effective cap and floor mechanism.

Design options and trade-offs

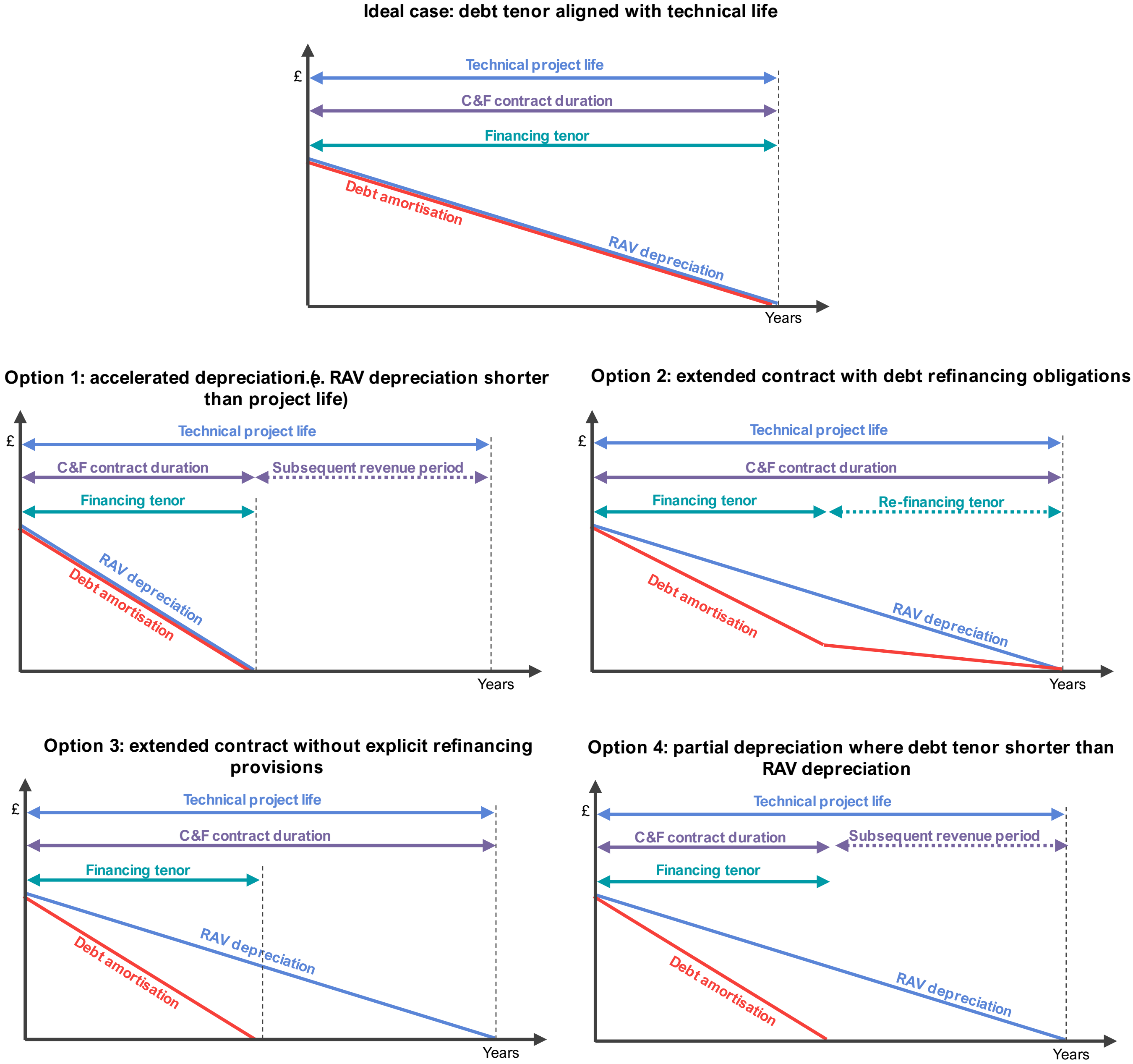
Regulatory practice tends to seek to align RAV depreciation with the expected depreciation of the underlying physical assets (their 'technical life'). In an ideal scenario, a project's operational life would match this technical life, with any 'major refurbishment' representing an investment decision comparable in scale to the initial project investment. Under such conditions, the cap and floor contract duration and RAV depreciation would align with the project life, and project sponsors would structure their financing to match this timeline. This alignment would ensure that projects generate sufficient revenue to meet financing repayment obligations throughout the asset's operational life.

However, LDES projects face two key constraints that often prevent this ideal alignment:

- **Technical and commercial constraints**: Many LDES technologies, particularly PSH, have components with vastly different lifespans. For example, civil engineering works such as reservoirs for PSH projects can remain operational for more than 60 years and often represent a substantial portion of the initial investment. While this suggests a very long theoretical project life, in practice, projects operate with shorter lifespans. This shorter operational period reflects the increasing uncertainty of future revenues – investors and operators typically assume a much shorter useful economic life than the technical capability of the assets.
- **Financing constraints**: Based on our experience of the UK infrastructure debt market and some informal stakeholder engagement we carried out for this assignment, there is a less liquid market for loans extending beyond 25 years, particularly in the case of bank lending. Securing debt financing for longer periods becomes more challenging and potentially more expensive. This creates a practical limitation on project financing structures, even when the underlying assets could operate for much longer periods. Even under corporate financed structures, the investment case may be reliant on the payback period for the project being within 25 years, to allow capital to be recycled or returned to shareholders. Project sponsors must therefore balance the technical potential of their assets against financing and commercial realities.

As illustrated in Figure 3.1 below, there are four main options for addressing these constraints.

Figure 3.1: Different illustrative options and scenarios around contract duration and RAV depreciation



Source: CEPA/ESP

Option 1 – Accelerated depreciation. Under this option the cap and floor contract duration and RAV depreciation schedule align with a target investment period or debt tenor (in this example, 25 years), allowing full capital cost recovery during the contract period. While this supports investability through enabling full cost recovery at the floor, the asset continues operating and earning revenue after the contract ends.

Option 2 – Extended contract with refinancing. An alternative would be to align the cap and floor contract and RAV depreciation with the asset's technical life (i.e. 40-60 years) but incorporate planned debt refinancing points. While this maintains long-term revenue certainty while accommodating market financing constraints, it introduces periodic refinancing risk. Key considerations include:

- How refinancing events affect cap and floor settings and how to consistently treat project and balance-sheet financing (we would suggest that introducing assumptions regarding refinancing is potentially in conflict with the design principle of a cap and floor regime that seeks as far as possible to be independent and neutral to financing choices and decisions of the developer); and

- Whether to profile RAV depreciation to match debt amortisation schedules.

Option 3 – Extended contract. This option is similar to Option 2 but without explicit refinancing provisions. In this case:

- Equity investors bear any timing mismatch between RAV depreciation and debt tenor;
- The extended contract provides floor-level revenue certainty for equity;
- Returns to equity may be delayed, particularly where projects are consistently earning revenues below the floor; and
- Project gearing would likely be limited unless RAV depreciation is accelerated over the initial debt financing period.

Option 4 – Partial RAV recovery. This approach aligns the cap and floor contract with the debt tenor while extending RAV depreciation to match the asset's technical life. This option:

- May restrict gearing levels to ensure debt repayments align with RAV depreciation;
- Leaves investors largely exposed to revenue risk after the cap and floor contract ends; and, therefore,
- Is likely to be least attractive to investors.

All four options have shortcomings. Accelerating depreciation ensures that a project can meet a return equivalent to at least a cost of debt return benchmark over a 25-year contract – supporting investability. On the other hand, the project may continue to earn returns beyond the end of the contract, which increases the chances of the project being subsidised through the scheme and still earn sufficient or even supernormal returns over its full project life. Extending RAV depreciation beyond the initial debt term, as per Options 2 to 4, may remove concerns around unduly subsidising the asset. However, the slower RAV depreciation schedule will result in lower floor payments, which may provide insufficient revenues to service debt unless gearing is reduced.

One option for mitigating the risk of excess returns under accelerated depreciation would be to extend the cap beyond the initial cap and floor contract term. This would ensure that where long-lived LDES assets continue to generate revenues beyond the cap and floor contract term, there is a mechanism for sharing those revenues with consumers, particularly in scenarios where the revenue prospects of the LDES asset increase significantly over time.[10]

It must be noted that while Figure 3.1 focuses on the debt financing issues of project finance, these issues will also be important to LDES projects who do not adopt project finance structures. Accelerated depreciation is – all else equal – likely to be viewed as more investable compared with other options (such as partial RAV recovery) by investors. And although the technical life of an LDES asset may extend well beyond the standard 25-year contract length that Ofgem has used for interconnectors, this may be the maximum period that investors in LDES – not just project debt finance – are seeking a payback and return on their investment.

As a result, the financing constraints and issues that we seek to highlight in Figure 3.1 should not be considered as solely confined to facilitating debt finance in project finance structures. Nevertheless, considerations around contract duration and RAV recovery impose a more direct and practical constraint in a project finance context, even if the period of investment payback is relevant for all financing models.

Analysis of impacts

To quantify these trade-offs, we modelled different RAV depreciation schedules using our PSH archetype. Using our baseline cap and floor design as a starting point, we test three scenarios for our PSH archetype:

[10] For example, as the energy system transforms, and there are increasing volumes of variable, low carbon, generation connected to the electricity grid.

- **Accelerated depreciation:** cap and floor contract duration and RAV depreciation schedule are set to 25 years (in line with the baseline design);
- **Partial depreciation:** cap and floor contract duration is set to 25 years, but the RAV is depreciated over 40 years; and,
- **Extended contract:** cap and floor contract duration and the RAV depreciation schedule are set to 40 years.

Table 3.1 shows how cap and floor levels vary by scenario, while Figure 3.2. shows the distribution of project returns and Figure 3.3 the distribution of cap and floor payments, by scenario.

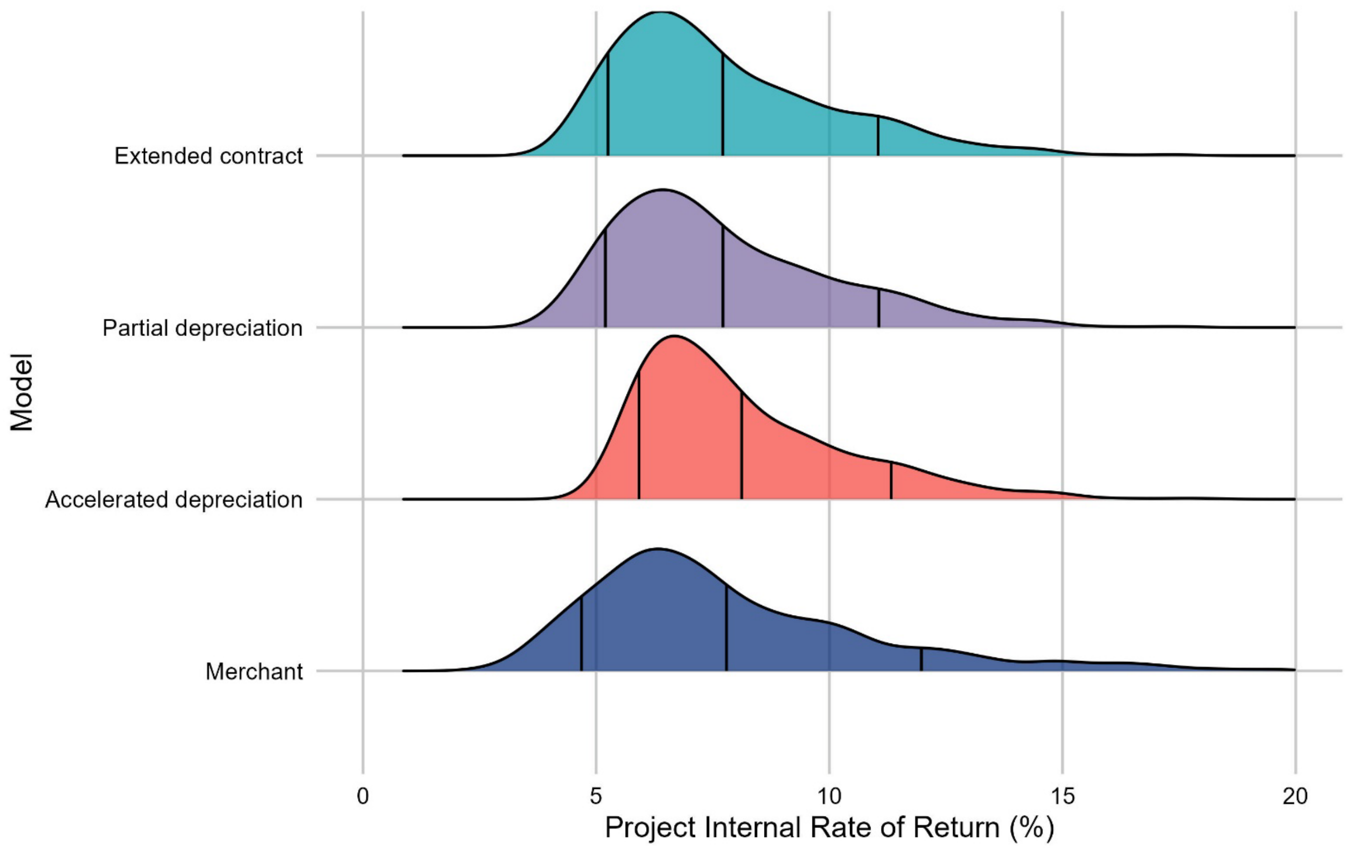
Table 3.1: Modelled cap and floor levels under accelerated depreciation, partial depreciation, and extended contract, for PSH archetype

	Accelerated depreciation	Partial depreciation	Extended contract
Floor level (£m/a)	67.6	55.5	55.5
Cap level (£m/a)	132.8	127.9	127.9

Source: CEPA/ESP analysis

Figure 3.2 shows the distribution of project returns for a PSH asset under a merchant and under the three cap and floor scenarios we discuss above. The figure shows that the merchant PSH operation has a relatively wide distribution of potential project returns. In contrast, all three cap and floor scenarios show a narrower distribution of project returns relative to the merchant case, implying a lower likelihood of extreme outcomes (i.e. very low or high project IRRs). This can be seen both from the shape of the distributions and from the narrower ranges between the 10th percentile (first vertical line on the left) and the 90th percentile (last vertical line on the right).

Figure 3.2: Distribution of project returns under different depreciation options for PSH archetype



Source: CEPA/ESP analysis
Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs.

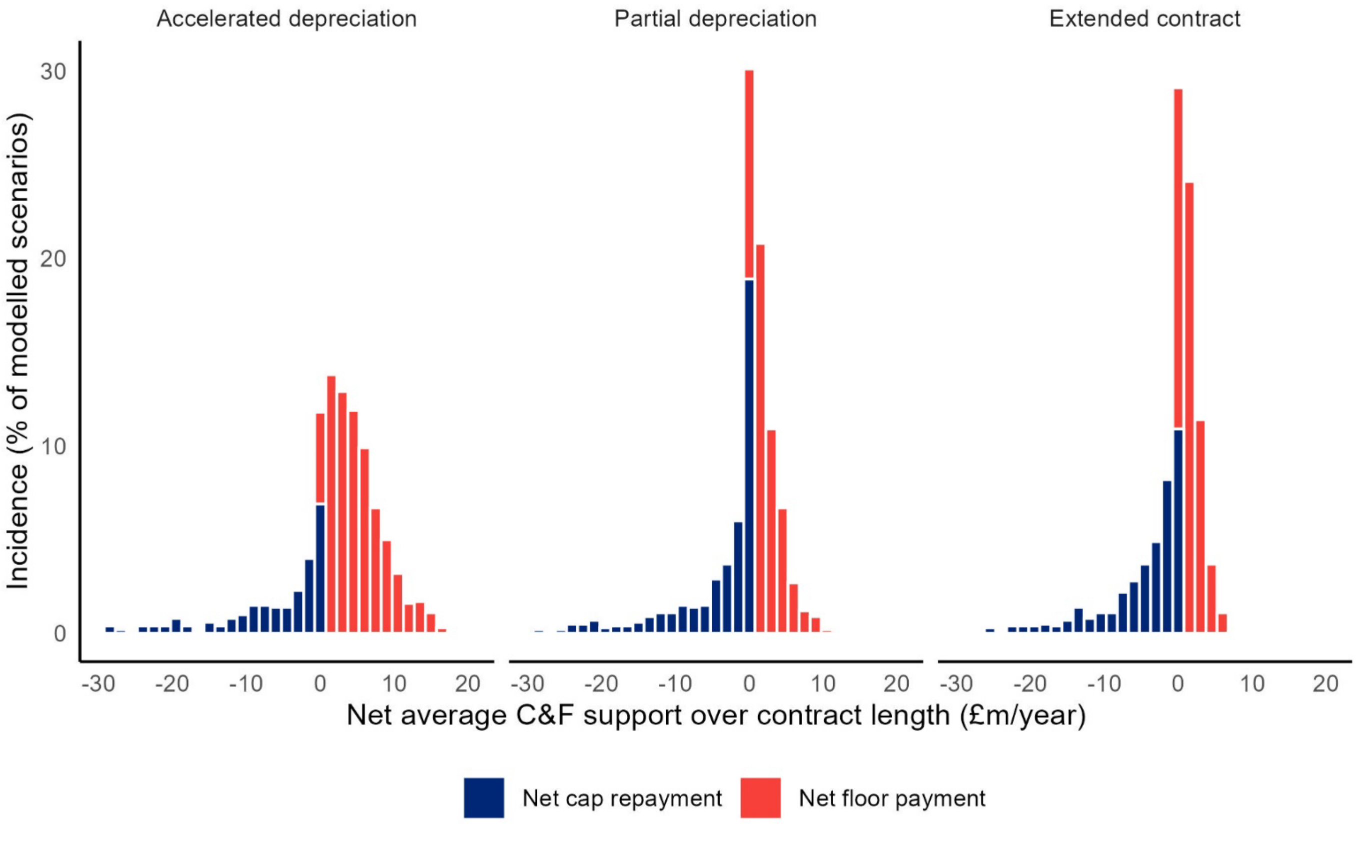
As shown in Figure 3.2, accelerating depreciation results in significantly more favourable project IRRs relative to a merchant counterfactual and relative to extended RAV depreciation. It also results in larger, and more frequent, floor payments from consumers to the project. As expected, accelerating the RAV depreciation schedule leads to a significant increase in the level of the floor, as well as a – less significant – increase in the level of the cap.[11]

The difference between partial depreciation and extended contract approaches is less pronounced because both use the same RAV depreciation schedule, resulting in identical floor and cap levels. However, the extended contract approach leads to a slightly narrower range of potential project IRRs and a slightly wider range of potential average cap and floor payments, reflecting a longer revenue support period under the cap and floor contract.

While this analysis uses a PSH archetype, the conclusions apply to any LDES technology with a technical project life beyond 25 years. Similar patterns emerge in our LAES archetype modelling, though the effects are of smaller magnitude due to LAES's shorter project life.

Figure 3.3 shows the distribution of average cap and floor support payments under the three depreciation options that have been modelled. This shows how accelerated depreciation leads to a wider distribution of potential net support, with a higher likelihood (and magnitude) of floor payments. In contrast, the "Partial depreciation" and "Extended contract" designs result in a narrower distribution, with floor payments significantly less likely.

Figure 3.3: Distribution of net average cap and floor support under different depreciation options for PSH archetype



Source: CEPA/ESP analysis

Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

[11] The level of the cap is less affected by accelerated depreciation because the rate of return at the cap is much higher. Hence, revenues in the later years of the project's life are more heavily discounted.

3.2.2. Assessment period

The interconnector cap and floor regime uses two different assessment periods for determining whether cap and floor payments are required. Revenues are assessed against the notional cap and floor every five years. Where an ACOD floor supplements the notional floor for project financed interconnectors, revenues will be assessed against the ACOD floor annually.

For the notional cap and floor, each five-year assessment period operates independently, with no carryover between periods. This structure avoids lots of frequent payments if projects are below the floor some years and above the cap other years. The annual assessment windows for the ACOD floor provide short-term cash flow support to project financed interconnectors where needed.

Design options and trade-offs

In general, longer assessment periods reduce the likelihood of triggering cap or floor payments, as short-term fluctuations in market revenues will average out over time.[12] At the extreme, using the entire contract duration as the assessment period would only trigger payments if average performance consistently remained outside the cap and floor corridor.

Longer assessment periods, however, create two key challenges, namely introducing cashflow uncertainty for project sponsors and exposing consumers to credit risk. When projects consistently earn revenues below the floor, longer assessment periods extend the waiting time for floor payments and increase the risk that project revenues are insufficient to maintain operations. Conversely, longer periods also potentially build up cap payment obligations and hence potential losses to the consumer in the event the project defaults before the contract term. In both cases, these risks can be addressed through interim payments, with subsequent 'true-up' adjustments based on the asset's performance over the complete assessment period.

Illustration of long assessment periods with interim payments

To illustrate how this model would work in practice, consider a project with a 25-year cap and floor contract, with a floor of £100m/year and a cap of £200m/year. Suppose that after the first five years of operations, the project's gross margin averages £90m/year. The project would then receive a floor payment of £50m (equivalent to £10m/year).

Now, let us assume that in the subsequent five years the gross margin increases significantly to £220m/year. If the two periods were assessed independently, the asset would be required to pay back consumers £100m in cap repayments (£20m/year). However, at the end of the tenth year the average gross margin across the full 10 years of operation is £155m/year, which falls within the cap and floor corridor. As such, the project is not required to make cap payments but instead is required to pay back the original £50m floor payment as a true-up.

At each subsequent assessment point – at the 15th, 20th, and 25th year of operations – cap and floor payments would only be made if the average gross margin up to the point of assessment falls below the floor or above the cap. After 25 years, the final assessment considers the average gross margin during the entire contract duration, and any final true-up payments are made.

Source: CEPA / ESP

To avoid distorting incentives around the timing of payments, cap and floor balances (in either direction) would need to accrue some interest during the time which precedes true-up payments. The choice of this interest rate should ideally be set in a such a way that the timing of true-up payments has limited or no impact on the project's financial performance so reflects an appropriate time value of money for the project.

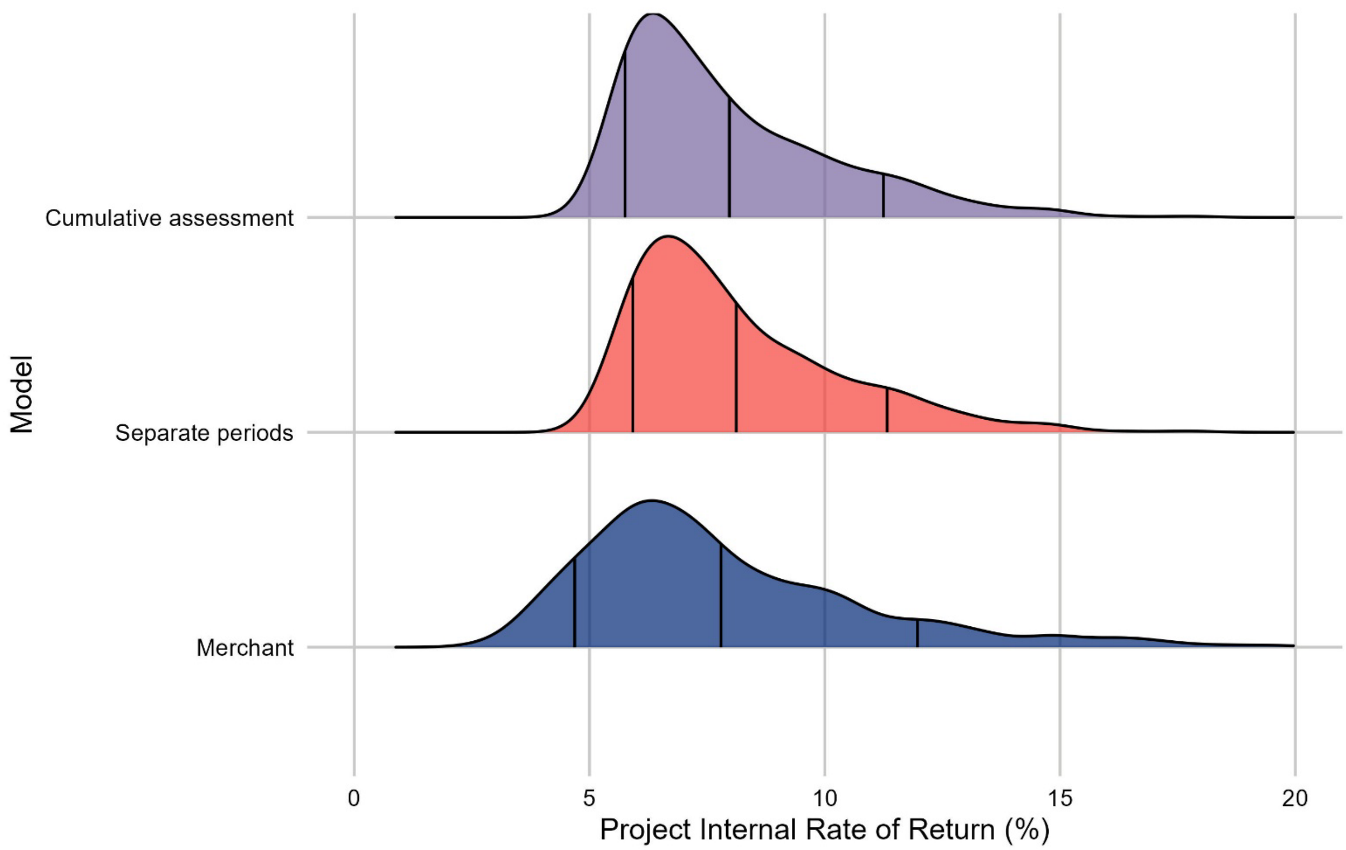
[12] Note that this is true as long as the expected gross margin is within the cap and floor corridor. We assume this to be the case, since we assume that the rate of return at the floor will be insufficient to justify investment into the asset if project sponsors did not believe there to be a reasonable chance of exceeding those returns.

Analysis of impacts

Figure 3.4 shows the impact on project returns of moving from separate 5-yearly cap and floor assessment period to cumulative 5-yearly periods which are eventually trued up based on the average gross margin over the full contract length. For ease of comparison, we use the same PSH archetype used in Section 3.2.1, assuming accelerated depreciation in line with the baseline design discussed in Section 3.1.

In line with the discussion above, the chart shows that introducing a cap and floor narrows the distribution of project returns relative to a merchant LDES operation. It also shows that the choice of whether to have separate assessment periods or cumulative periods, results in similarly shaped distributions. Having cumulative assessment periods results in a marginally lower mean project IRR relative to separate assessment periods.

Figure 3.4: Distribution of project returns under different cap and floor assessment periods for PSH archetype

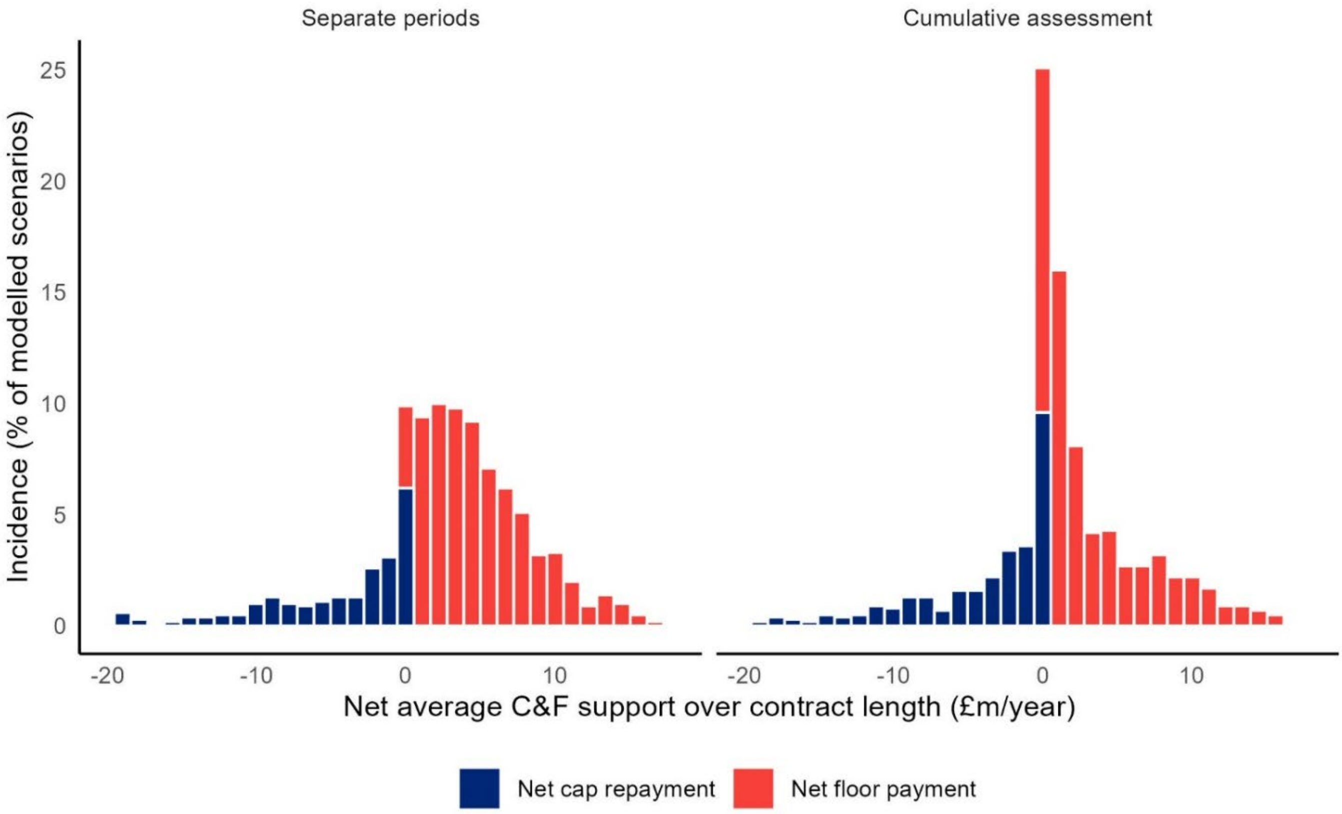


Source: CEPA/ESP analysis
Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs.

As expected, and as shown in Figure 3.5, one notable impact of extending the cap and floor contract term to match the full duration of the contract is a significant reduction in average cap and floor payments, which drops from an average floor payment £0.8m/year to an average cap repayment of £0.2m/year. The range of potential cap and floor payment outcomes is also significantly narrower – although there is no difference in the most extreme scenarios, where the gross margin is below the floor or above the cap, on average, for the entire duration of the contract. Interestingly, this significant narrowing of the range of average cap and floor payments only appears to imply a modest widening of the distribution of returns. The cumulative approach to assessment periods also leads to slightly lower IRRs on average: since in our baseline model the scheme is more likely to result in floor payments than in cap repayments, a higher likelihood of no cap and floor payments in either direction implies slightly lower expected IRRs. However, the change appears to impact expected consumer costs (in the form of cap and floor payments) much more than it affects expected project returns.

It is worth noting an important caveat of the above analysis; for simplicity, we have not assumed that any interest is charged on the balance accruing between interim cap and floor payments and subsequent true-up payments. In reality, however, not accruing any interest on these balances may distort incentives around the timing of payments; early floor payments that are subsequently returned as a true-up would effectively constitute a zero-interest loan for the project, increasing its IRR. Likewise, early cap payments would be akin to the project lending money to consumers with zero interest, which would reduce the IRR. To minimise such distortions, some interest will need to be accrued on these balances.

Figure 3.5: Distribution of net average cap and floor support under different cap and floor assessment periods for PSH archetype



Source: CEPA/ESP analysis
Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

3.2.3. Role of competition in setting cap and floor parameters

As discussed in Section 2.3, competition could be an effective way of setting cap and floor design parameters and avoiding the need for an administrative determination. However, effective competition relies on the availability of a suitable competition mechanism and sufficient competitive tension between participants. Another complicating factor with applying competition to the cap and floor regime is the fact that it is made up of multiple elements that collectively determine the overall level of support provided to the project. Unlike the Contract for Difference (CfD) mechanism used to support low carbon generation, the allocation of cap and floor support cannot be easily simplified into an auction where projects compete on a single element.

In light of these complexities, we are doubtful that it will be possible to rely on competition as *the sole* means of simultaneously determining the level of the cap and the level of the floor, and hence the award of cap and floor contracts. However, it might be possible to use competition between projects to inform specific cap and floor parameters. Below, we discuss how competition could be used in this way, and potential benefits and drawbacks.

Options for introducing competition

There are five competitive models that we have considered:

- **Auction-style competitive bidding on specific parameters**. Under this approach, most elements of the cap and floor design would be set administratively, but a single element (e.g., the rate of return at the cap) would be subject to competitive bidding. This could be implemented either on a 'pay-as-bid' basis, where successful projects receive contracts based on their bid parameters, or a 'pay-as-clear' basis, where all successful projects receive contracts with parameters based on the marginal project's bid. A key feature is that project selection directly follows from the competition outcome – projects with the most competitive bids are selected.
- **Competitive bidding with truth-telling incentives:** This approach is similar to auction-style bidding, with competitive bidding on a single cap and floor design element. However, project selection would be independent of these bids. Instead, the parameter would be set using either the most competitive bid or the median bid, with a separate mechanism to encourage truthful bidding. This might include bonuses for competitive bids, similar to Ofgem's RIIO-3 business plan incentive mechanism.
- **Using downstream competition to inform specific parameters:** Some design parameters, such as the rate of return at the floor, could be informed by downstream competition. For example, the ACOD floor under the interconnector regime, is set with reference to debt funding competitions run by project sponsors.
- **Allowing project sponsors to propose alternative parameters for their project:** Under this approach, Ofgem would maintain a reference cap and floor design but allow project sponsors to propose alternative parameters for their specific project (e.g., a longer contract length). Competitive tension during project assessment would help determine whether such adjustments serve consumer interests – for example, projects proposing adjustments that significantly increase floor payments may risk failing at the project selection stage.
- **Allowing project sponsors to propose scheme variants:** This alternative to project-specific proposals would allow project sponsors to propose scheme variants that would be available to all successful projects. Ofgem would consult with project sponsors on proposed variants before making final decisions. Under this approach, competitive tension is not used to inform specific parameters but instead, to select the projects that provide the best overall value, as discussed further below.

Benefits and drawbacks of each option

Auction-style competitive bidding

For a competitive bidding process to work effectively, it needs to focus on a single, clear parameter – or use a predetermined method for combining multiple parameters into one score. For example, Ofgem could ask projects to bid their acceptable rate of return at the cap, selecting those with the lowest bids. With sufficient competition (meaning excess LDES capacity in any given allocation round / window than is required), this would encourage projects to bid the minimum rate of return that is required to provide a plausible upside.

However, there are challenges to this approach which would make it difficult to deliver benefits in practice. For example, even with strong competition, this approach may not deliver optimal outcomes for the energy system. Selecting projects solely on the bid rate of return could exclude those offering greater system benefits despite bidding less competitive returns. It may also favour projects benefitting from accelerated depreciation, as they can bid lower caps to offset generous RAV depreciation schedules at the floor, or it may favour projects that do not expect the cap to act as a binding constraint and so, can bid low rates.

The approach also faces challenges in comparing different LDES technologies fairly. Technologies at different maturity levels have varying risk profiles and return expectations. A less mature technology might require a higher cap to justify its riskier investment profile, yet this could still serve consumer interests if the technology offers learning benefits and lower costs in future. While technology-specific auctions could address this, they would reduce the pool of competing projects, thus reducing competitive tension.

More complex competitive processes could potentially address these issues by adjusting bids based on system needs or technology type. However, this would introduce new challenges in designing the adjustment methodology – for instance, how to weight different criteria – and would lose the simplicity that makes this approach attractive.

The choice between pay-as-bid and pay-as-clear structures also affects outcomes. Under pay-as-bid, successful projects receive contracts based on their bid parameters, potentially encouraging gaming through inflated bids. Pay-as-clear structures, where all successful projects receive terms based on the marginal project's bid, better encourage truthful bidding when competition is sufficient.

Competitive bidding with truth-telling incentive mechanism

This option addresses the gaming risks inherent in pure auction-style bidding while maintaining competitive pressure. By separating project selection from bid outcomes, projects can be evaluated primarily on system benefits while using competition to set specific parameters of the supporting cap and floor contract. The addition of explicit incentives for truthful bidding helps encourage project sponsors to reveal their true costs and requirements. However, the separation of project selection from bid outcomes also reduces the competitive pressure to bid truthfully, even with an incentive mechanism. And designing effective truth-telling incentives requires careful calibration and may increase scheme complexity.

Additionally, careful consideration would also need to be given to how bids are used to inform the parameter. In the example where the rate of return at the cap is bid competitively, setting the rate of return equivalent to the lowest bid may provide insufficient upside for some projects and undermine incentives to bid truthfully. Conversely, setting the rate of return equivalent to the median or upper quartile bid may result in an overly generous upside for some projects.

Finally, the challenge around comparing different LDES technologies fairly would remain.

Using downstream competition to inform specific parameters

This approach uses market mechanisms to inform the value of specific parameters, particularly for elements like the floor rate of return. Its effectiveness has been demonstrated in the interconnector regime, where actual debt funding competitions set ACOD floor levels. This provides market driven evidence for cap and floor design decisions and reduces gaming risks. However, its application is likely to be limited to setting a floor intended to reflect debt service requirements, given these obligations can be observed directly from the outcomes of a debt funding competition.

Allowing project sponsors to propose alternative parameters for their project

Under this approach, projects would first undergo needs-case assessment, as in the interconnector regime. Project sponsors could then propose modifications to the reference cap and floor design for their specific project. Competitive pressure would come from the project assessment process itself – projects proposing modifications that significantly increase consumer costs would face a higher risk of non-selection.

This approach offers flexibility, allowing Ofgem to select projects based on system needs while considering specific characteristics such as technical life, technology maturity, and efficiency potential.

However, it has two significant drawbacks. First, projects offering unique system benefits may secure overly generous terms due to their strong negotiating position – such as large projects that are especially valuable to the GB energy system. The project selection process, while providing some competitive pressure, is likely to be limited in terms of how much competitive tension it introduces. Second, it creates substantial administrative burden for Ofgem in assessing requests, particularly if project sponsors are able to propose adjustments to multiple parameters.

Allowing project sponsors to propose scheme variants

This approach most closely resembles the current interconnector regime where the competitive tension relates to the project selection process. In other words, projects would be subject to the same overall cap and floor design, with the projects competing to provide best overall value. Rather than individual project-level negotiations on specific parameters, project sponsors could propose scheme variants that would be available to all successful projects.

Ofgem would maintain some flexibility over multiple design choices, such as RAV recovery approaches for long-lived assets or rate of return at the cap. Input from project sponsors and other stakeholders would come through standard consultation, leading to administrative decisions on final scheme design. This helps balance investability with consumer protection while avoiding project-by-project negotiations.

The approach could also accommodate a menu-based approach where project sponsors are provided a choice between multiple options for the design of the cap and floor mechanism – for example, offering projects a choice between partial depreciation for long-lived assets or extended cap and floor contracts beyond 25 years. This maintains competitive pressure while protecting against individual projects securing advantageous terms through strong negotiating positions.

One downside of this approach could be the potentially high administrative burden associated with it, which could be mitigated by restricting this flexibility to some pre-determined design choices. Only allowing scheme variations, as opposed to project-specific changes, should also reduce the resource burden as Ofgem would not have to consider a potentially long list of project-specific circumstances.

3.3. Design of the floor

The primary purpose of the floor is to limit the downside risk of LDES projects, to support investment in such assets. In a project finance context, this has been interpreted to mean ensuring projects are bankable, i.e. ensuring the floor provides sufficient revenue to recover debt costs. Lenders are generally unwilling to take on market risk and require strong guarantees that debt financing and additional cashflow requirements will be met. From a broader investor perspective, the design and terms of the floor will also be crucial to whether the regime is ultimately viewed as investable when considered alongside a project's underlying commercial business case and revenue projections.

3.3.1. Level of the floor

The level of the floor depends on three key parameters:

- The RAV depreciation term (discussed in Section 3.2.1);
- The rate of return on the RAV at the floor; and
- The proportion of the depreciation and return building blocks that is recovered at the floor.

While the interconnector regime sets the floor to recover full RAV depreciation over the contract length with a rate of return set using a notional cost of debt (a benchmark 'debt-like' rate of return) applied to 100% of the RAV, alternative approaches could be considered for LDES.

Notional vs actual rate of return at the floor

Under the interconnector cap and floor regime, the downside risk of an interconnector project is limited to the project earning a debt-like return at the floor, with the debt-like return being set on a notional basis using benchmark estimates. However, the project-financed variant of the interconnector regime, which sets a second floor with reference to a project's actual debt costs, offers an alternative approach to setting the floor – on an actual basis, using project-specific debt costs (if competitively obtained).

The notional approach has the advantage of being set without regard to a project's financing approach, maintaining consistent treatment between projects. It provides a simple method, independent of choices of financing structure or a project's cost of capital. However, to the extent that the floor is aimed at supporting project bankability, it also introduces basis risk – there may be a mismatch between notional returns at the floor and actual debt costs.

Experience from the interconnector cap and floor regime suggests that a notional floor alone may not provide sufficient certainty for lenders under a project finance structure. This may be due to the actual debt costs being higher than the notional benchmark, the term of the debt being shorter than assumed, or due to debt service cover ratio requirements. In such cases, lenders' actual annual cashflow requirements may exceed the level of the notional floor, potentially compromising project bankability.

Setting the floor on an actual basis, based on competitive debt raising could effectively address these project finance concerns. It may help to reduce the cost of capital faced in practice by the project. However, this changes the purpose of the floor – from existing to limit downside risk to existing to help ensure project bankability. While these issues are linked, they are not the same. Seeking to set the floor to reflect actual debt costs inherently changes the balance of risk between consumers and investors, and to the extent it may support higher levels of gearing in a project finance context, may also raise financial resilience considerations for the regime design.

Additionally, using an actual cost of debt regime for balance sheet financed projects is less practical to implement. Corporate debt, raised on balance sheet, is typically general-purpose rather than project-specific, with debt costs reflecting the overall credit rating of the business rather than individual project risk. This creates a practical challenge in identifying an "actual" cost of debt to use as a reference for the rate of return at the floor. For example, while the coupon on a corporate bond issued by a company could be used as a reference, it may be a poorly suited reference point if the tenor on the bond is short, or if the bond was issued significantly earlier than the investment, or if the credit rating of the company is a lot higher or lower than what may be considered appropriate.

This – at least in part – explains why the interconnector regime eventually adopted a hybrid arrangement, as described in Section 2.2, with an ACOD floor allowing temporary payments and a longer-term true-up to the notional floor based on a benchmark debt-like return. The hybrid approach supports project bankability under project finance structures, whilst maintaining the original purpose of the floor; a defined downside floor on returns that is independent of choices of capital structure, ensuring a level playing field between different financing approaches. The ACOD floor is designed to ensure that project-specific debt issued under a project finance structure can be serviced, including provisions for debt service coverage. True-up payments back to the notional floor level ensures consistency across all forms of finance / capital structures, if projects ultimately receive floor payments based on a notionally set benchmark.[13]

Depreciation and returns at the floor

While the interconnector regime seeks to limit downside risk to projects earning a debt-like return, in theory, projects could be exposed to greater downside risk at the (notional) floor. One mechanism for doing so is by adjusting the proportion of the depreciation and return on capital building blocks that is recovered at the floor.

If the purpose of the floor is, at least in part, to maintain bankability in a project finance approach, the floor could be set such that the depreciation building block is sufficient to cover the repayment of a debt principal, while the return component covers interest payments. In such a case, if correctly calibrated, the floor could be set to shield lenders from market risk while exposing equity investors to greater market risk.

[13] It is worth noting that, to avoid incentive distortions around the timing of revenues under a hybrid ACOD approach, any true-up payments to the notional floor level would need to accrue some interest. The considerations for setting this interest rate are akin to those discussed in the context of true ups for interim cap or floor payments. It may also be necessary to impose limits on the balance of potential ACOD true-up payments that projects would be able to accumulate if they earn a lower gross margin than the ACOD floor, or a minimum availability target is not met for a sustained period of time (e.g., multiple years) as we understand exists with the interconnector ACOD regime. Similar to the approach adopted for the ACOD floor in an interconnector context, we would also expect that the project would face restrictions on the ability to make equity distributions until the project has been able to pay back the additional support that is provided by the ACOD floor, given that the ACOD floor will need to be set to provide a level of debt service coverage that provides a level of revenue above what is strictly needed to meet debt service requirements.

We consider three approaches that the LDES regime could, in principle, take to adjusting the depreciation and return building blocks to expose projects to more or less market risk:

- Enabling the recovery of and return on only part of the RAV (e.g. with the proportion set with reference to a notional or actual gearing ratio);
- Enabling the recovery of the entirety of the RAV (based on the depreciation profile), but enable only a partial return (e.g. a return on an assumed debt-financed component only); or
- Follow the interconnector approach, by enabling the recovery of and return on the entirety of the RAV, in effect allowing a debt-like return for both debt and equity finance.

Assuming that all three options provide a sufficiently high floor level to make LDES projects bankable, the trade-off is between ensuring investability by offering some level of return to equity investors at the floor and increasing the risk of consumers subsidising the project via floor payments. However, this must be considered in the context that an expectation of sustained debt-like returns for equity investors would likely be insufficient to justify the investment on its own. The hurdle rate for equity investors is likely to be significantly higher than a cost-of-debt-like return, and the investment will only go ahead if investors expect to be able to earn their hurdle rate. However, allowing for a small return on equity at the floor reduces the downside risk of the project, potentially making it more investable on balance.

Impact of different options for setting the floor level

While securing debt financing is likely to be a crucial consideration for setting the floor level, the impact on equity returns also requires careful consideration. Although equity investors generally accept greater market risk and longer return periods, our stakeholder engagement suggests many expect terms similar to (or potentially better than) the interconnector regime, which allows for a cost-of-debt-like return on equity at the floor over a 25-year horizon.

The relationship between floor design and RAV depreciation is also important. Under accelerated depreciation, investors may effectively be guaranteed some level of return on investment even if the rate of return at the floor is notionally calculated to only cover the debt component of the RAV. In a project finance setting, all returns generated by the asset after the end of the contract will benefit equity investors, with the debt being fully repaid during the contract period.

Quantitative modelling

The impact of different options regarding the implied level of equity return at the floor can also be illustrated through quantitative modelling. As expected, and as shown in Figure 3.5 and Figure 3.6, the modelling suggests that the main trade-off to consider is between enabling investability and protecting consumers from the risk of excessive subsidies.

Table 3.2 shows how different rates of capital recovery and return at the floor affect floor levels, for our LAES archetype. We test three options:

- Debt-like return for all investment at the floor;
- Recovery of all investment at the floor but return applied to only 80% of the RAV (an illustrative assumption to imply recovery of equity investment but no or limited return on that investment); and
- Recovery of capital and return on capital applied to only 80% of the RAV (an illustrative assumption to imply no or limited recovery of or return on equity investment).

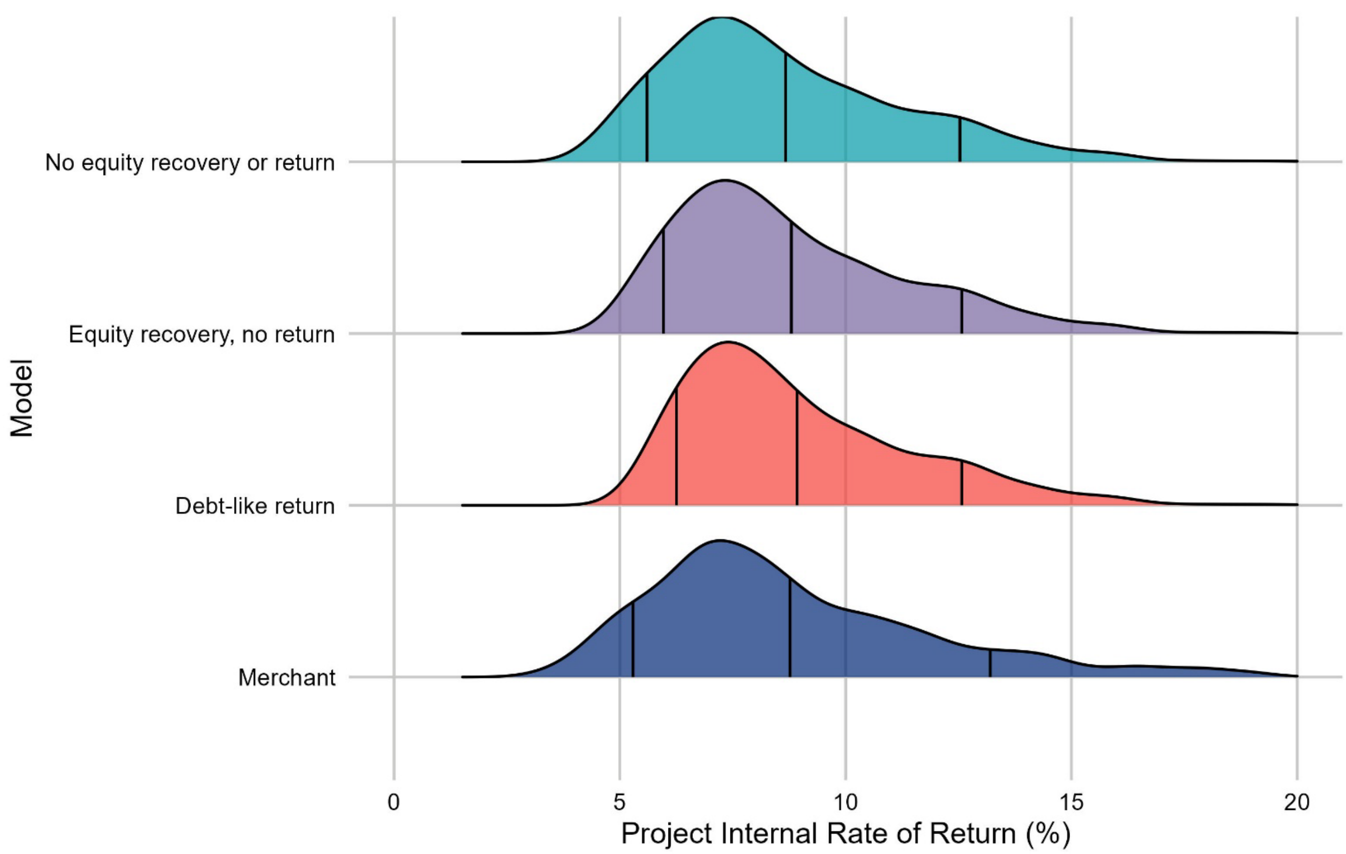
The model outputs paint a similar picture to that discussed when comparing options around RAV depreciation in Section 3.2.1 – allowing a limited equity return at the floor (or at least recovery of the equity investment, i.e. a return of zero) significantly reduces the downside risk around project IRRs. However, this comes at the cost of higher mean expected floor payments. We have chosen to show results for our LAES archetype in order to illustrate the impact of these choices on a technology with a technical project life longer than 25 years, but shorter than that of PSH. The full details about the baseline assumptions used for the LAES archetype can be found in Appendix A.[14]

Table 3.2: Modelled cap and floor levels under different rates of capital recovery and return at the floor, for LAES archetype

	Debt-like return	Equity recovery, no return	No equity recovery or return
Floor level (£m/a)	27.2	25.0	21.9
Cap level (£m/a)	57.5	57.5	57.5

Source: CEPA and ESP analysis

Figure 3.6: Distribution of project returns under different rates of capital recovery and return at the floor, for LAES archetype

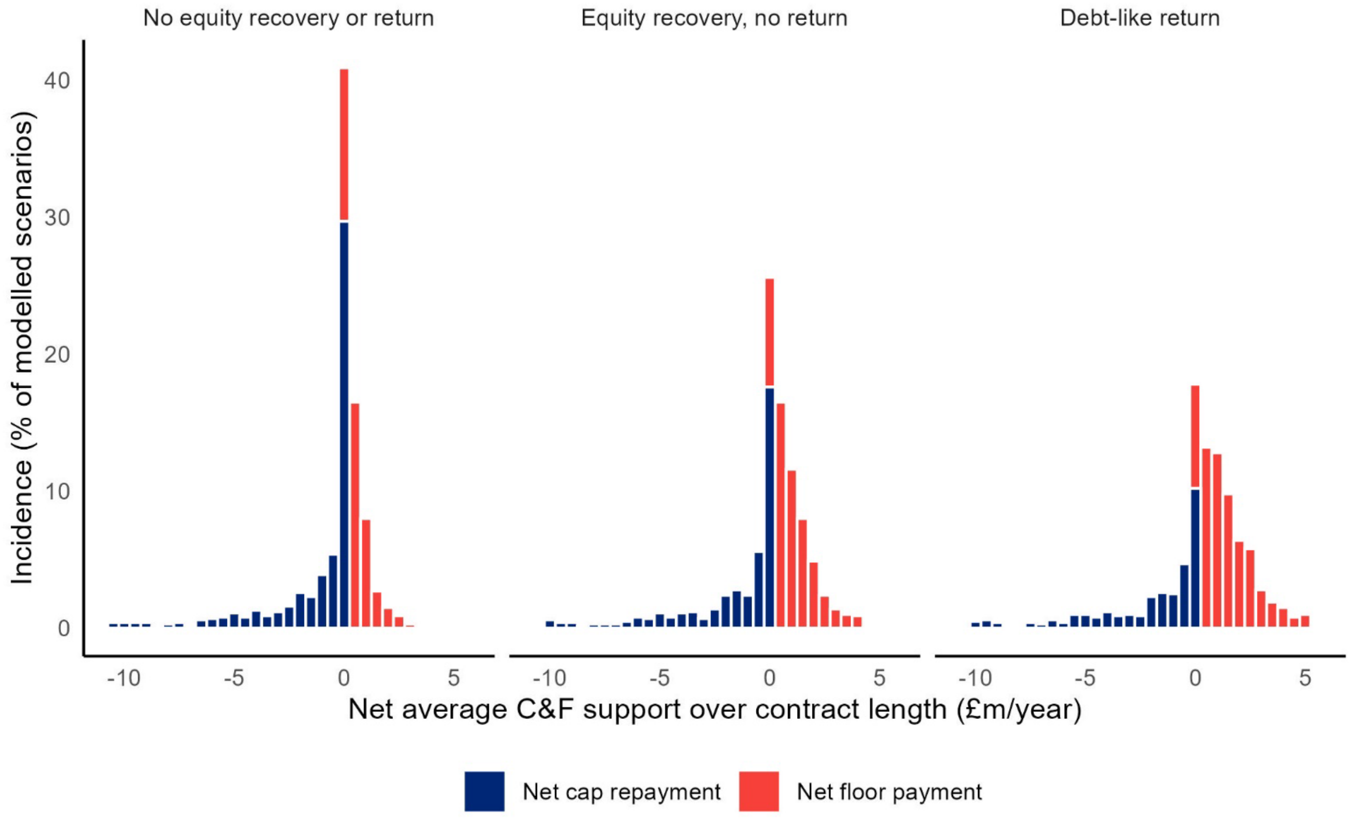


Source: CEPA/ESP analysis
Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs.

Figure 3.6 shows that providing a debt-like return for all investment at the floor results in the largest increase in 10th percentile returns relative to the merchant case. Providing for some assumption of equity recovery at the floor but no return results in smaller increase in 10th percentile returns, while providing for no equity recovery or return at the floor results in a much smaller increase in 10th percentile returns. While we have presented our analysis in terms of providing equity recovery or equity return, the floor level could be set to expose projects to greater market risk without reference to capital structure.

[14] Appendix C shows equivalent results for the PSH and Li-ion archetypes, for comparison.

Figure 3.7: Distribution of net average cap and floor support under different rates of capital recovery and return at the floor, for LAES archetype



Source: CEPA/ESP analysis
Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

3.3.2. Operational incentives below the floor

Design options and trade-offs

As discussed in Section 2.3 and in our previous advice to DESNZ on gaming risks under an LDES cap and floor regime, there is a stronger need to implement measures to preserve operational incentives below the floor (and above the cap) for LDES assets, compared to interconnectors. This can be achieved through a variety of different measures, such as:

- Longer cap and floor assessment periods;
- Availability incentives;
- Revenue sharing; and
- Handing over the asset's operations to an independent Third-Party Optimiser (TPO).

In this report, we focus on the first three of these. While TPOs may play an important role in operating LDES assets, alleviating concerns around operational incentives, our previous analysis carried out for DESNZ found that mandating TPO operations to all LDES plants may overly restrict LDES business models. We discuss the potential to extend the cap and floor assessment period to the entire duration of the contract in depth in Section 3.2.2. In this section, we therefore focus on availability incentives and revenue sharing.

The interconnector regime primarily relies on **availability incentives** to avoid incentive distortions below the floor (and above the cap). Similar incentives could be implemented under an LDES cap and floor contract, for example requiring a target for minimum availability to be met in order to be eligible to receive floor payments. However, such an approach, while necessary, is unlikely to be sufficient to incentivise LDES assets to operate efficiently when the gross margin is below the floor. Unlike for interconnectors, an LDES asset may be available and yet not be dispatching energy into nor drawing energy from the system. Such a dormant state may be completely legitimate and need not signify unavailability. Even where an LDES asset is available and there are observable spreads in the day-ahead market, an LDES asset may choose to wait for higher spreads to become available, or instead it may choose to provide ancillary services. Hence, monitoring the operations of LDES assets is far more complex than for interconnectors, since the latter can largely be expected to be flowing whenever the asset is technically available. This is one area in which the cap and floor arrangements for interconnectors cannot simply be copied for LDES. The issues this raises are discussed in more detail in Appendix B.

A complementary way to preserve the incentive for assets to respond to market signals in the same way regardless of whether their gross margin is likely to be below the floor or above the cap, is revenue sharing. If a proportion of the achieved gross margin below the floor or above the cap is retained by the asset, so is the incentive to seek market opportunities to increase the gross margin.

However, while revenue sharing above the cap is relatively straightforward to implement, the same is not true of revenue sharing below the floor. Limiting floor payments to cover only a proportion of the difference between the achieved gross margin and the level of the floor would be the simplest approach. For example, a 10% sharing factor could be applied by only paying the project 90% of the difference between the achieved gross margin and the floor level whenever the gross margin is below the floor. However, depending on the level of the floor, the additional risk introduced by the sharing factor may undermine the purpose of the floor, which is to limit downside risk.

A somewhat more complex but insightful way to approach this problem could be to break down ‘soft’ floor payments into two components. The first would provide a minimum floor level that applies regardless of the achieved gross margin. The second component might be calculated as a percentage of the achieved gross margin. Depending on the size of the first component, this arrangement may preserve operational incentives below the floor without undermining the overall purpose of the floor. For example, the minimum floor might be set to cover assumed (notional) debt repayments, while floor payments above this minimum floor are subject to sharing based on the achieved gross margin.[15]

A detailed explanation of how a ‘soft floor’ arrangement of this kind could be implemented in practice can be found in Appendix B.

3.4. Design of the cap

The purpose of the cap, in our view, is two-fold:

- To compensate consumers for the downside risk they take on through the floor, by transferring some of the upside risk to them; and,
- To balance overall expected project returns to a level broadly in line with what is required to achieve investability, given that the floor protects LDES assets from very low returns.

Another related consideration when setting the cap is ensuring that investors can still expect to earn a return equivalent to, or higher than, their hurdle rate. However, as noted earlier, setting the cap precisely to ensure that expected returns are aligned with a project’s hurdle rate, is challenging.

[15] This could be made more explicit if the mechanism was implemented as part of a hybrid ‘ACOD’ floor mechanism similar to the scheme that Ofgem has developed for project financed interconnectors (see discussion above). Access to the ACOD floor would provide the ‘hard’ floor necessary for project finance bankability purposes, whilst the notional floor would be ‘soft’ and used to preserve operational incentives on the project below the floor.

3.4.1. Level of the cap

Options for setting the cap

The level of the cap is determined by the rate of return at the cap. The two key questions are:

- Whether the rate of return should be set administratively, or set through a competitive process; and
- Whether a single rate of return should apply to all projects, or whether there should be some differentiation by technology or risk profile.

We do not consider this second question in detail within this report, focusing primarily on the first question.

In the interconnector regime, the rate of return at the cap is set administratively by Ofgem, at a level intended to provide a reasonable upside risk. It is entirely possible that a lower return at the cap would remain acceptable to most investors – although this would be difficult to assess ex-ante. In other words, setting the rate of return at the cap entails a trade-off between increasing the chances of consumers benefitting from cap repayment and maintaining investability.

In principle, competitive pressures of the kind described in Section 3.2.3 may lead project sponsors to reveal the minimum rate of return they require at the cap to provide a plausible upside. However, this is only true if the competition is effective, which may not be the case if the number of potential projects is small in comparison to system needs, or if some specific projects are particularly beneficial to the system.

Analysis of impacts

We have discussed the potential impact of competitive pressure on the determination of cap and floor parameters, including the return at the cap, in Section 3.2.3. Below, we illustrate the impact of different rates of return at the cap, modelling three scenarios, which as shown in Table 3.3 leads to three different cap levels:

- A rate of return at the cap of 13%, in line with our baseline design;
- A lower rate of return of 8%; and
- A higher rate of return of 18%.

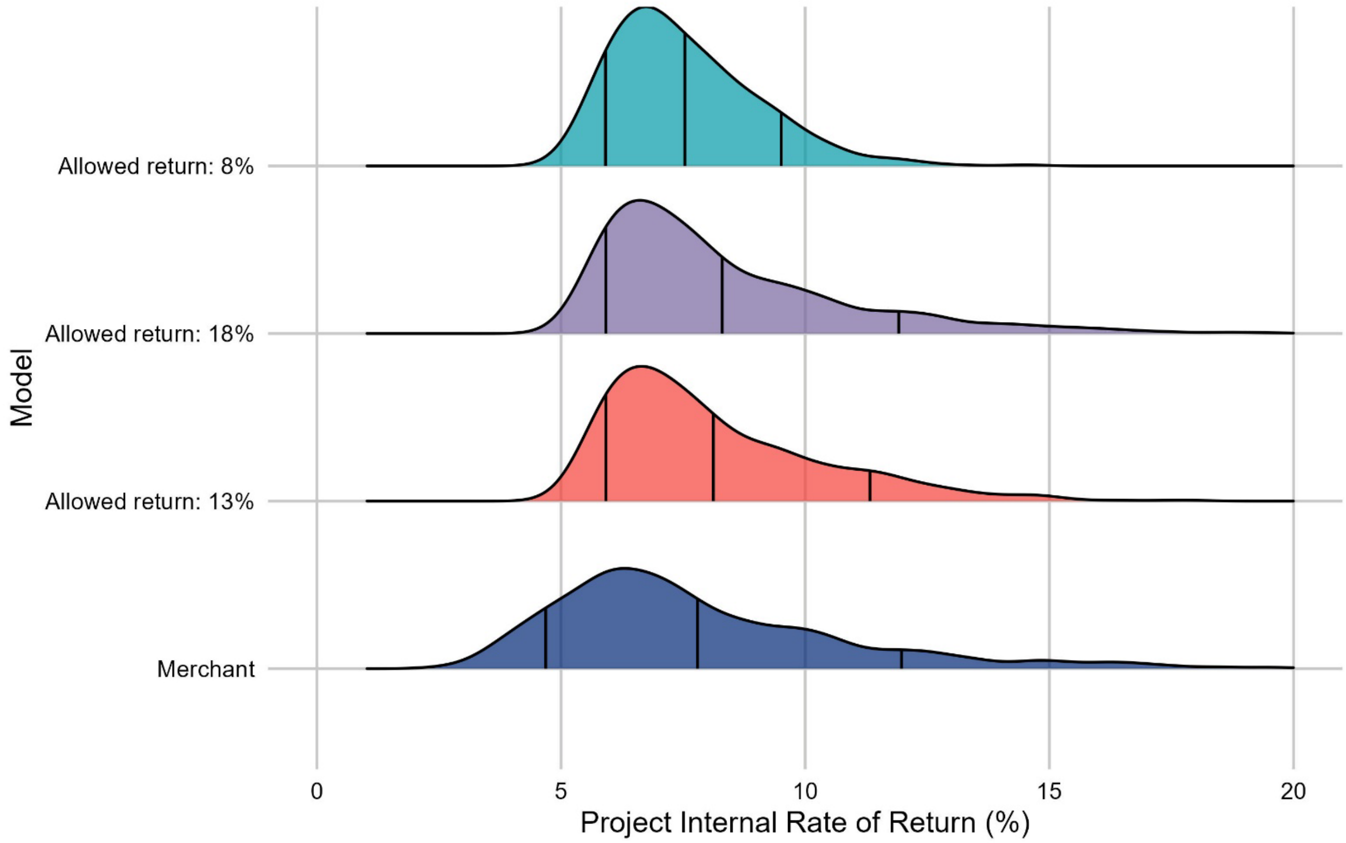
As expected, the analysis shows how higher cap levels are associated with higher average project IRRs and higher expected net cap and floor support, by changing the likelihood and magnitude of cap repayments in higher gross margin scenarios. This is shown in Figure 3.8 and Figure 3.9.

Table 3.3: Modelled cap and floor levels under different rates of return at the cap for PSH archetype

	13% rate of return	8% rate of return	18% rate of return
Floor level (£m/a)	67.6	67.6	67.6
Cap level (£m/a)	132.8	94.3	174.6

Source: CEPA/ESP analysis

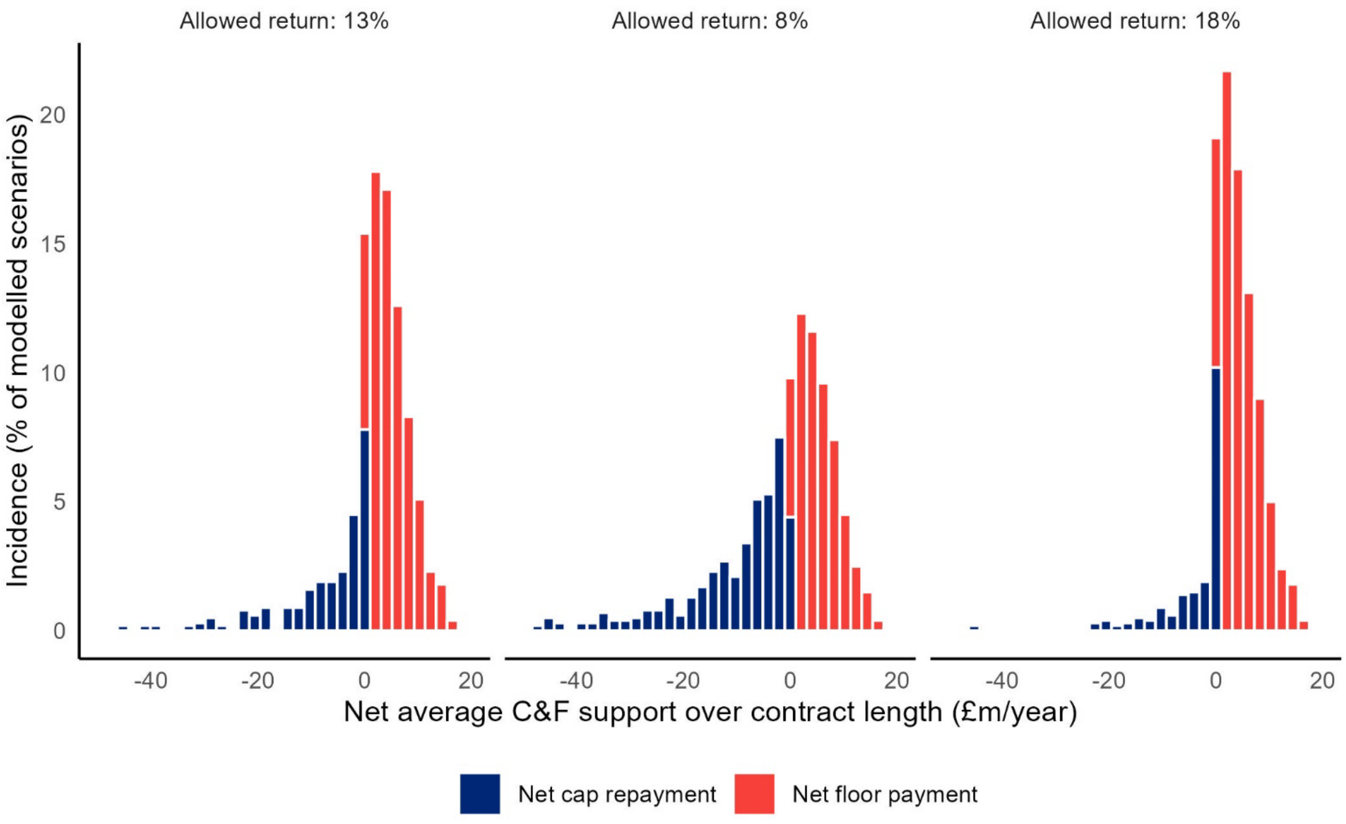
Figure 3.8: Distribution of project returns under different rates of return at the cap for PSH archetype



Source: CEPA/ESP analysis
Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs.

Figure 3.8 shows that, as expected, changing the cap level does not affect the distribution of returns at lower levels (e.g. the 10^{th} percentile). However, the different levels of allowed return at the cap does change the distribution of returns at higher-levels; the lower the allowed return at the cap, the lower the mean (central vertical line) and 90^{th} percentile (third vertical line on the right) project IRRs.

Figure 3.9: Distribution of net average cap and floor support under different rates of return at the cap for PSH archetype



Source: CEPA/ESP analysis
Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

3.4.2. Operational incentives above the cap

Design options and trade-offs

As discussed in Sections 3.3.2 and 3.4.2, there are several ways to ensure that LDES assets retain an incentive to operate efficiently even when their gross margin is below the floor or above the cap. This section primarily focuses on revenue sharing.

In many ways, implementing revenue sharing above the cap is more straightforward than below the floor; the asset can simply be allowed to retain a proportion of the gross margin above the cap. The cap sharing factor does not affect project bankability, and provided the level of the cap is high enough, any sharing factor above it can only positively impact investability.

Appendix B discusses how high the sharing factor might need to be in order to preserve operational incentives with a high degree of confidence. In any case, however, higher sharing factors are likely to preserve operational incentives more effectively than lower ones. However, they also constitute a potential opportunity cost for consumers, as they reduce the amount repaid by the project if the gross margin exceeds the level of the cap. Any chosen sharing factor as part of the design of a 'soft cap' needs to account for this trade-off.

Analysis of impacts

To illustrate the impact of different sharing factors on LDES cashflows and expected cap and floor payments, we have modelled three potential designs, using our PSH baseline archetype:

- A baseline scenario with a 13% rate of return at the cap and a 10% sharing factor;
- A scenario with a 13% rate of return at the cap and a 50% sharing factor; and
- A scenario with an 8% rate of return at the cap and a 50% sharing factor.

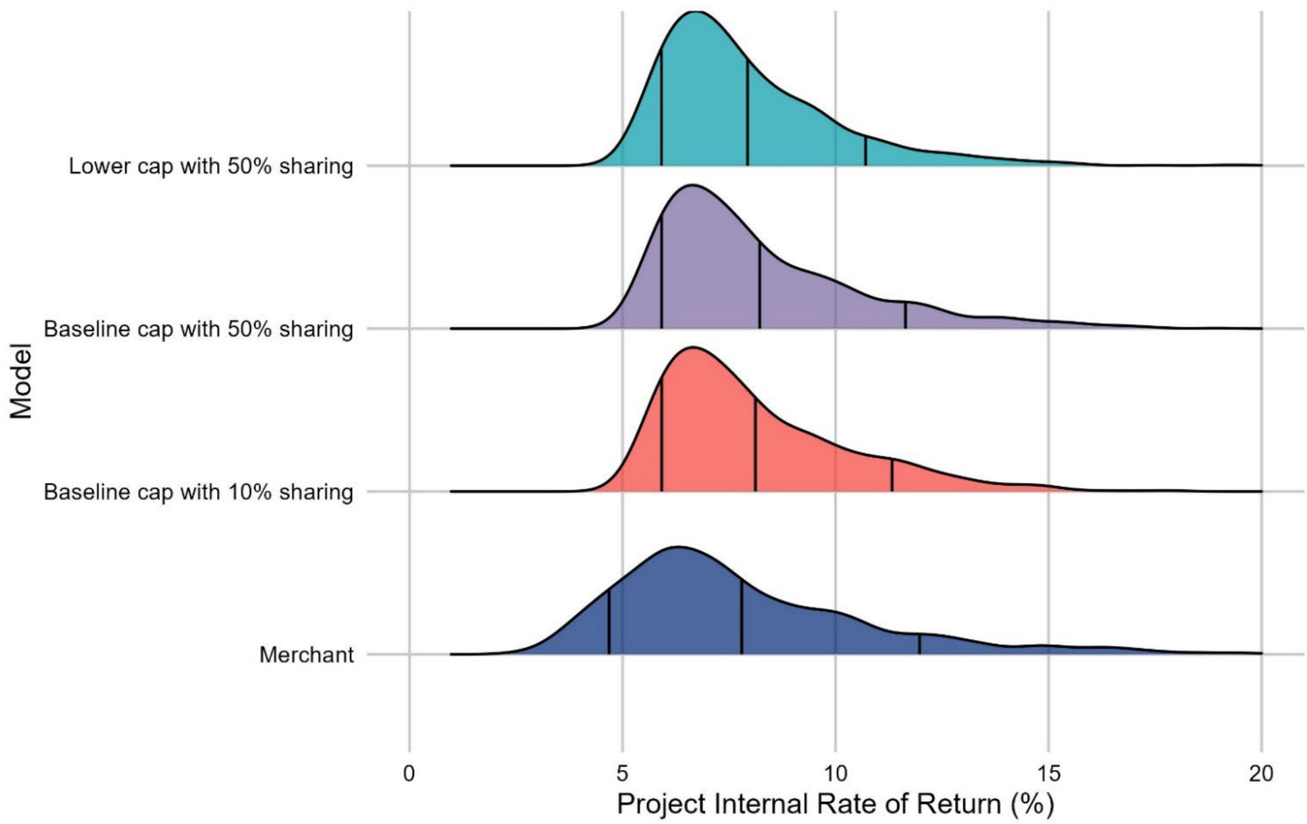
The purpose of the third scenario is to compare the impact of increasing the sharing factor with that of decreasing the rate of return at the cap. The assumed cap levels under each scenario is shown in Table 3.4, while the impact on project returns and net cap and floor payments is illustrated in Figure 3.10 and Figure 3.11, respectively. Interestingly, with these assumptions we find that in the third scenario, the impact of a lower cap level outweighs that of a higher sharing factor, leading to lower expected average cap and floor payments and a lower mean project IRR. Generally, this suggests that the level of the cap is a more important driver of consumer impacts than the sharing factor above the cap – at least within the range considered in this analysis.

Table 3.4: Modelled cap and floor levels and average expected cap and floor payments under different combinations of sharing factors and rates of return at the cap for PSH archetype

	Baseline	Higher sharing factor (50%)	Higher sharing with lower cap
Floor level (£m/a)	67.6	67.6	67.6
Cap level (£m/a)	132.8	132.8	94.3
Net average cap and floor support (£m/a)	0.8	1.5	0.2

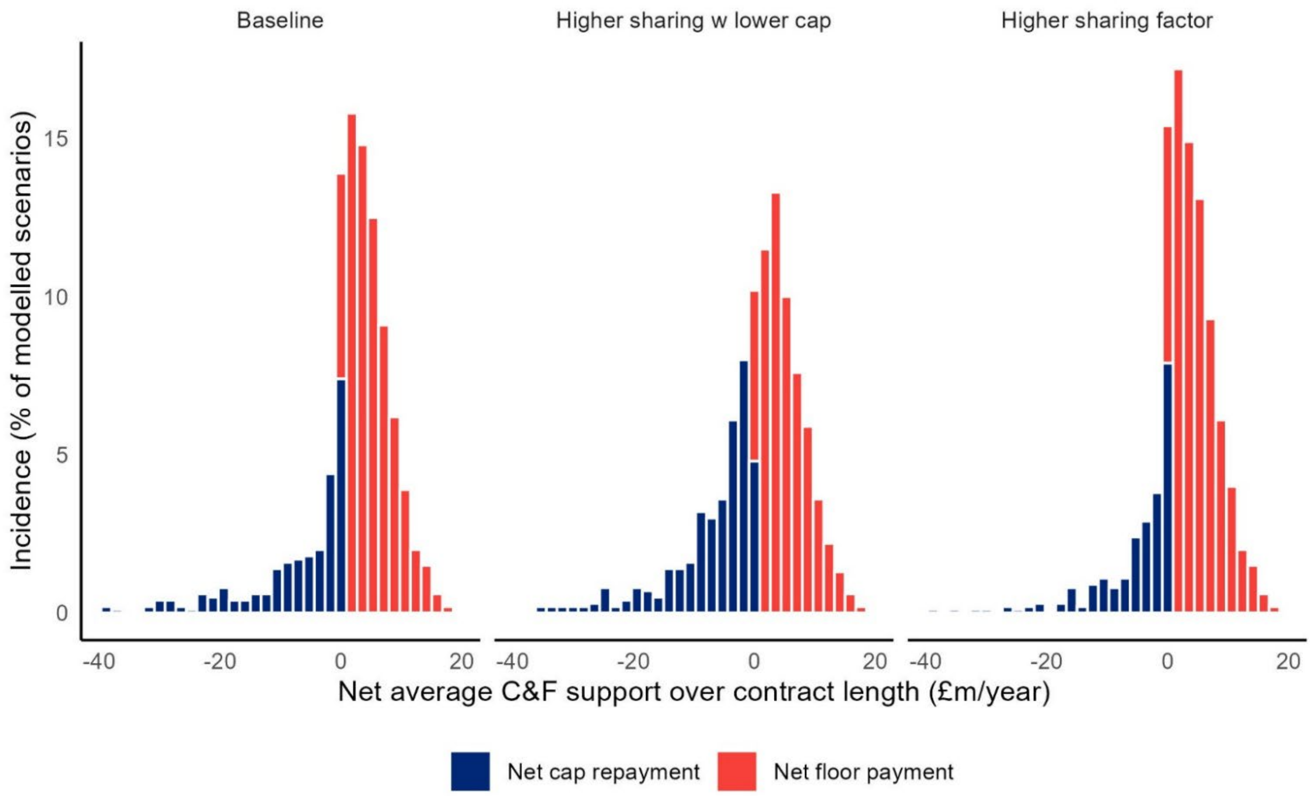
Source: CEPA/ESP analysis

Figure 3.10: Distribution of project returns under different combinations of sharing factors and rates of return at the cap for PSH archetype



Source: CEPA/ESP analysis
Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs.

Figure 3.11: Distribution of net average cap and floor support under different combinations of sharing factors and rates of return at the cap for PSH archetype



Source: CEPA/ESP analysis
Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

Figure 3.10 shows that both increasing the sharing factor from 10% to 50% and lowering the allowed return at the cap from 13% to 8% impact affected returns on the right-hand side of the distributions. However, the increase in returns driven by the higher sharing is by far outweighed by the decrease in the allowed return at the cap. The higher sharing factor also has a relatively small impact on the average cap repayments, as shown in Figure 3.11, whereas the lower cap level again outweighs the impact of the higher sharing factor.

4. CAP AND FLOOR MODEL DESIGNS

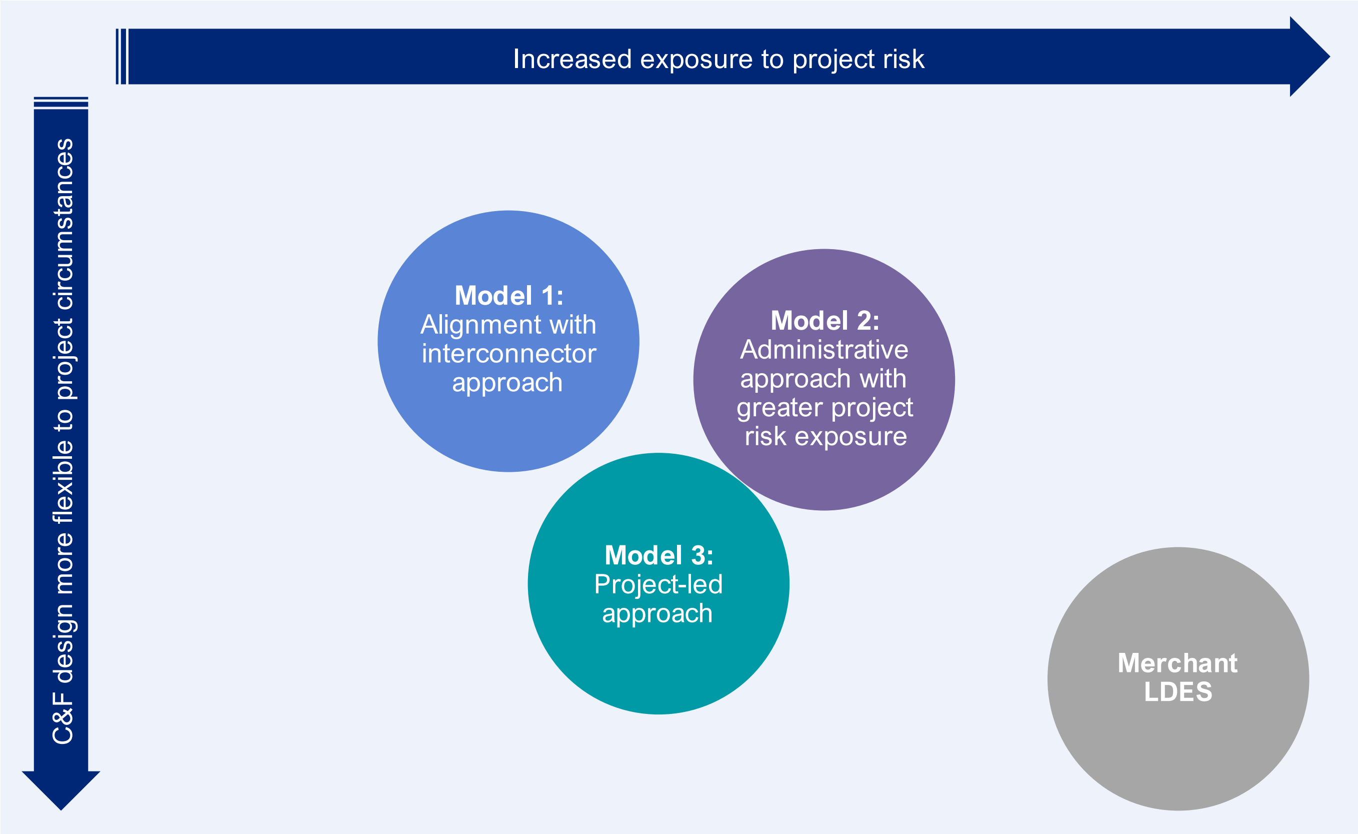
Having examined the various considerations and choices for cap and floor design, we now bring these choices together into three overarching models. These models represent different philosophical approaches to structuring a cap and floor regime for LDES, developed to highlight the inherent trade-offs between them.

The following section details and evaluates these three models against the objectives introduced in Section 2.

4.1. Introduction to the cap and floor models

The three models we have considered (there are, of course, others that could in principle be considered for an LDES cap and floor scheme) are summarised in the figure below:

Figure 4.1: Illustration of three cap and floor model designs and relative differences between them



Source: CEPA/ESP

Model 1: Alignment with interconnector approach. The first model closely mirrors the existing interconnector regime, retaining an administrative approach to setting the key parameters of the cap and floor design, and retaining the balance of risks between LDES projects and consumers as per the interconnector regime. The one difference is the inclusion of a soft cap, which has been introduced to enhance incentives for LDES assets to operate efficiently above the cap (see discussion in section 3.4.2 above). This approach prioritises consistency with the interconnector regime as a means of providing investor certainty.

Model 2: Administrative approach with greater project risk exposure. The second model maintains the administrative framework of Model 1 but introduces greater risk exposure for LDES projects, both at the cap and at the floor. Relative to Model 1, customers are exposed to lower risk through three key design changes:

- For long-lived assets the capital investment is recovered more slowly, leading to a lower floor (and cap) and, therefore, reducing the likelihood of customers making floor payments.

- Floor and cap payments are assessed over the full contract length, in effect widening the corridor between the cap and floor and, therefore, reducing the likelihood of both floor and cap payments.
- The floor is set as a soft floor exposing project investors to greater market risk at the floor, and conversely, exposing customers to less market risk at the floor.

This approach aims to balance investment certainty with maintaining incentives to operate assets efficiently.

Model 3: Project-led approach. The third model represents a significant departure from the administrative approach, allowing project promoters to drive key design parameters through their applications. This model allows project sponsors to set out the speed of capital recovery and the rate of return at the cap. The rate of return at the floor is also project-specific, informed by debt raising competitions. This approach provides greater flexibility for project promoters to propose parameter values, as a means of reducing the administrative burden on Ofgem and to introduce greater scope for competitive bidding.

These models represent distinct points along a spectrum of possible approaches, and elements from each could be combined to create hybrid solutions tailored to specific requirements.

In the table overleaf, we detail the design of each of the three models.

Table 4.1: Detailed designs of the three cap and floor models

Parameter	Model 1: Alignment with interconnector approach	Model 2: Administrative approach with greater project risk exposure	Model 3: Project-led approach
Contract duration (initial term) and speed of capital recovery	Contract duration is the lower of project life to first major refurbishment, or 25 years. Full capital recovery on straight-line basis over contract length, i.e. accelerated depreciation is applied when: • Project life exceeds 25 years, or • Substantial portion of initial capital investment is in very long-lived assets	Project life (i.e. up to first major refurbishment), with either: **A.** Maximum contract length of 25 years and capital recovery in line with project technical life, OR **B.** Maximum contract length of 40 years and capital recovery in line with contract length.	Contract duration chosen as lower of project life to first major refurbishment or 25 years. Capital recovery on a straight-line basis, over: **A.** Project life, for short-lived projects, OR **B.** Project sponsor proposed schedule for long-lived projects.
Assessment period	Cap and floor payments assessed over five-year periods. No carryover between periods. Separate annual assessment period for floor payments related to the actual cost of debt if an 'ACOD floor' mechanism is in place.	Cap and floor payments assessed over contract length, with five-year interim assessments, i.e. cap and floor payments are carried over between each five-year interim assessment. Separate annual assessment period for floor payments related to the actual cost of debt if an 'ACOD floor' mechanism is in place.	
Level of the floor	Hybrid floor arrangement as per interconnector regime, comprising: • A **notional floor** set administratively using a benchmark estimate of the Cost of Debt. This is applied to 100% of the RAV and applies to all projects. • A second **ACOD floor**, available to developers and set on a project-specific basis, with the aim of allowing a project to earn sufficient revenues at the floor to recover actual debt costs plus debt service coverage. The ACOD floor is assessed annually and is used specifically for projects financed on a non-recourse basis to limit lenders' risk exposure. The ACOD floor is applied only temporarily until project revenues exceed this floor, wherein excess floor payments relative to the notional floor are repaid.		Single floor set through competition, with gearing limited to 80%: • **Project-finance:** project-specific debt funding competition, with the floor analogous to the ACOD floor. • **Balance-sheet finance:** project sponsors would need to demonstrate competitive debt pricing, which would then be benchmarked by Ofgem.
Sharing of revenues below the floor	No revenue sharing below the floor – project revenues topped up to floor regardless of actual gross margin earned, subject to an availability incentive.	Soft floor that exposes investors to some market risk below the floor. Sharing of floor payments based on earned gross margin, where sharing percentage is structured to ensure that there is a minimum floor below	As per Model 1, no revenue sharing below the floor.

Parameter	Model 1: Alignment with interconnector approach	Model 2: Administrative approach with greater project risk exposure	Model 3: Project-led approach
		which projects are not exposed to market risk.	
Level of the cap	Cap set administratively using a notional rate of return that provides reasonable upside risk, applied to 100% of the RAV.		Cap set through a competitive process, where project sponsors bid their expected rate of return at the cap.
Sharing of revenues above the cap	Low sharing percentage (10-20%) applied to revenues above the cap, i.e. project retain 10-20% of gross margin earned above the cap, with remaining 80-90% paid back to customers as cap payments.		

Source: CEPA/ESP analysis

4.2. Evaluation of the models

In the table below, we summarise our evaluation of the three cap and floor models presented in the previous section.

Table 4.2: Summary of evaluation of three cap and floor model designs

	Model 1: Alignment with interconnector approach	Model 2: Administrative approach with greater project risk exposure	Model 3: Project-led approach
Policy alignment	Aligned with interconnector regime, but generosity of the floor relative to other models could risk exacerbating competitive distortions with other storage technologies.	Relatively aligned with the interconnector regime. While there is some general risk around competitive distortions, model does not worsen them.	Some risk of competitive distortions between long-lived and short-lived LDES assets, and with other storage technologies.
Reduce system costs / protect consumer interest	Relatively generous floor increases the risk of net customer support payments and net positive impact on project returns.	Customers exposed to less risk, but greater potential for high returns at the cap due to longer assessment period.	Lower floor means that customers are less at risk of making floor payments, with exception for long-lived assets.
Enable investment	Uses proven interconnector model and provides debt-like return for all investment at the floor.	Floor does not provide a debt-like return for investors, due to presence of soft floor. Investors may also face a long wait to see a return.	Floor may imply a negative return for investors, undermining investability.
System benefits / incentives	Limited incentive for efficient operation below the floor.	Strong incentives for efficient operation above cap and below floor.	Strong incentives for efficient operation above cap and below floor
Delivery	Familiar regime to investors but may be complex for Ofgem to administer.	Familiar regime to investors but complex for Ofgem to administer, particularly with soft floor mechanism.	Potentially reduced burden on Ofgem with setting cap level.

Source: CEPA/ESP analysis

4.2.1. Policy alignment

The existence of a cap and floor mechanism for LDES inherently creates some risk of distorting competition with other forms of flexibility, such as short-duration batteries, that do not have access to such revenue support. However, this must be balanced against the wider system and consumer benefits that LDES assets are assumed to provide, as recognised in Section 2.1.

The primary strength of Model 1 lies in maintaining consistency with the established interconnector regime, providing regulatory coherence across the two flexibility technologies. However, by providing a debt-like return on the entirety of the RAV and by accelerating RAV depreciation, the floor could be considered generous relative to the other models, particularly for long-lived assets. This could potentially exacerbate competitive distortion risks in two ways: in relation to other flexibility providers that are not eligible for a cap and floor mechanism, and in relation to other LDES technologies that have shorter asset lives (e.g. longer-duration Li-ion batteries).

As shown in Figure 3.4, the relatively high floor may elevate expected returns, which may in turn promote investment in longer-lived LDES projects over alternative solutions and impose greater costs on consumers than might strictly be required. In the broader market context this may lead to a suboptimal technology mix, unless mitigated through the project selection process.

Model 2 achieves a more neutral position regarding policy alignment. Relative to Model 1, this model exposes projects to more revenue risk (both upside and downside), which helps align LDES projects more closely with storage and flexibility technologies that are fully exposed to merchant risks. In doing so, this model helps to reduce potential market distortions.

Model 3 demonstrates similar neutrality to Model 2 regarding general competition with other flexibility solutions. However, there remains a potential distortion between long-lived and shorter-lived LDES assets, as the model retains accelerated depreciation for long-lived assets.

4.2.2. Reduce system costs and protect consumer benefits

The three cap and floor models we present differ in terms of how much project risk – both upside and downside – they transfer from the project itself to consumers. In transferring this risk, the models can improve the bankability and investability of LDES projects though they also expose consumers to costs and risks.

Model 1 presents some challenges from a consumer protection perspective. For long-lived projects, this model establishes both a higher floor and a higher cap compared to the alternative approaches. The elevated floor level increases the likelihood that consumers will need to provide net support to projects. Similarly, the higher cap level creates a risk that projects could earn excessive returns before triggering revenue sharing mechanisms, again at consumers' expense; though our analysis in Section 3.2.1 shows that the level of the cap is much less affected by the acceleration of depreciation than the level of the floor. These risks could be mitigated by at least partly moving away from the accelerated depreciation approach for the longest-lived projects.

Model 2 offers stronger consumer protections through reduced risk transfer from consumers to project sponsors. By maintaining a lower floor and implementing wider assessment periods, this model better aligns project returns with actual market performance while still supporting beneficial LDES investment.

Model 3 similarly protects consumer interests through reduced risk transfer, primarily achieved through its lower floor and the wider assessment period. However, for long-lived projects, the floor remains higher than it would otherwise be due to the ability to accelerate depreciation, increasing the risk of consumer support that might ultimately have been avoided without preventing investment into projects. Despite this limitation, the model generally maintains good alignment between project returns and system benefits.

The impact of each model on project and investor returns at the cap level remains uncertain. While Model 3's competitive approach could potentially drive down returns at the cap if effectively implemented, insufficient competitive tension could result in elevated returns. Similarly, the administrative approaches in Models 1 and 2 risk allowing high returns if the rate of return at the cap parameter is calibrated sub-optimally. Additionally, the wider assessment periods in Models 2 and 3 expose projects to more *upside risk* as well as downside risk and so, reduce the likelihood of cap payments to consumers and increase project returns at the cap.

Model 3 presents additional complexity in how a competitive process for setting the cap will interact with project assessment and selection, as discussed in Section 3.2.3. A selection process driven primarily by cap return bids would create strong incentives for competitive bidding but might not optimise system and social benefits. Conversely, prioritising system and social benefits in project selection would likely reduce competitive pressure on project promoters to bid a competitive rate of return at the cap, even with a truth telling incentive mechanism.

4.2.3. Enable investment

As noted above, the cap and floor models we present improve the investability and bankability of projects by transferring some project risk, mostly revenue risk, to consumers. Below, we compare the relative effectiveness of these models at improving the investability and bankability of projects.

By building directly on the interconnector regime, which has proven successful in delivering investment in new interconnectors, Model 1 provides investors with a familiar and tested revenue support framework. Moreover, the model offers particularly robust support for investment through the floor's provision for full RAV recovery and a debt-based return on all investment over the contract length.

Model 2 may be considered more challenging from an investor perspective. While the hybrid floor arrangement should be sufficient to allow the project to be bankable under project financing structures, the design of the floor is less attractive to investors relative to Model 1. The three key limitations from an investability perspective are as follows:

- The assessment period over the life of the cap and floor contract means that there is a lower likelihood of a project receiving floor payments for a given gross margin relative to Model 1, which uses five-year assessment periods.
- The floor mechanism does not provide a debt-like return on the entirety of the RAV, given the presence of a 'soft floor'.
- For long-lived assets, investors face a choice between being exposed to merchant tail risk after a 25-year revenue support period or waiting up to 40 years before recovering their investment.

In essence, Model 2 shifts the cap and floor regime away from an investment proposition that a 'debt like' return can be earned on the full value of investment, provided core asset performance (availability) targets are met.

Relative to Model 1, Model 3 is also likely to be considered less attractive from an investability perspective. By setting the floor to provide a debt-based return for only a proportion of the RAV, the floor mechanism may not allow investors to earn any return on their investment. The introduction of a competitive cap mechanism may be considered both positive and negative from an investability perspective. On the one hand, allowing investors to bid their own preferred rate of return at the cap may reduce perceived regulatory risk, though on the other hand, introducing a novel rate of return selection mechanism may increase uncertainty and regulatory risk. Similar to Model 2, the investment proposition is shifted from an expectation that provided core performance obligations are met (namely availability) that a debt like return is earned on the full value of the investment.

Ultimately, there is a trade-off between enabling investment in LDES assets by reducing the degree of revenue risk that projects are exposed to while protecting consumers from risk and unnecessary costs. While Model 1 prioritises investability, Models 2 and 3 both use different approaches to improve the value for money of the cap and floor model from a consumer perspective. A key uncertainty is around how far projects can be exposed to revenue risk without making them un-investable.

4.2.4. System benefits

In assessing the models against the system benefits they provide, we primarily focus on how each model maintains incentives for efficient LDES asset operation, particularly when the asset is operating below the floor or above the cap. We conclude that all three models provide effective incentives to operate efficiently above the floor through the soft cap mechanism. In Appendix B, we discuss why we consider a sharing factor of 10-20% is likely to be sufficient for incentivising efficient operation.

However, Model 1 demonstrates some weakness in promoting efficient operation where revenues fall below the floor level. The model is primarily reliant on there being an availability incentive, which as discussed in Section 3.3.2 is likely to be insufficient at providing incentives to operate efficiently. As such, there is a risk that assets might not respond optimally to market signals in these conditions, potentially reducing overall system benefits. Nevertheless, the risk should not be overstated – an equity return equivalent to a debt like return is unlikely to be satisfactory for investors and so, we would expect projects to take measures to ensure that their asset operates above the floor.

Model 2 provides a stronger framework for operational efficiency below the floor, by using longer assessment periods and implementing a soft floor mechanism. Both mechanisms expose investor returns to greater risk if LDES assets are insufficiently responsive to market signals.

Model 3 similarly promotes strong operational efficiency through its incentive structure. It does this primarily through the low floor and the longer assessment period.

4.2.5. Delivery

In assessing how well each model supports the delivery of LDES investment, we consider the practicality and administrative complexity of each model, and the flexibility needed to accommodate different technologies.

Model 1 offers mixed implications for delivery. Its alignment with the existing interconnector regime provides familiarity to investors, potentially supporting faster project development and financing. However, we understand that this model can be administratively burdensome for Ofgem in terms of implementation and oversight, particularly in a context where certain scheme parameters may need to differ by technology maturity or risk profile. Conversely, while Ofgem could take a standardised approach across technologies to reduce the administrative burden, this may lack the flexibility needed to accommodate diverse LDES technologies.

Model 2 presents similar advantages and challenges to Model 1 regarding investor familiarity and administrative complexity. However, it also introduces additional complications through its soft floor mechanism, which increases both implementation complexity and ongoing administrative requirements. This added complexity could potentially slow delivery timeframes and increase the burden of administering the scheme during operation.

Model 3 also presents similar advantages and challenges to Model 1 but also introduces a potential benefit in terms of practical delivery. By reducing Ofgem's role in determining rate of return parameters at both cap and floor levels, it potentially streamlines the administrative process, though this will depend on the exact competitive mechanism. If, instead of relying on a simple ‘auction-style’ competition, Ofgem decided to rely on negotiations with individual project sponsors, this may impose much more significant delivery challenges.

5. POTENTIAL BASELINE LDES CAP AND FLOOR DESIGN

In this section, we set out a potential 'baseline design' for the LDES cap and floor scheme. In our view, the development of such a design is critical for:

- Ensuring that the cap and floor arrangements reflect informed and deliberate design choices; and
- Establishing a baseline for assessing any changes proposed during potential negotiations with prospective investors as well as contract parameters potentially delivered through competitive processes.

This baseline represents our view of an appropriate initial reference design which should meet the specific needs of LDES assets, while retaining continuity with the existing interconnector cap and floor model where possible. This design has been informed by limited, informal engagement with LDES developers, but more extensive, formal consultation with stakeholders will be required to assess the suitability of the design.

In Section 3.2.3, we discussed how competition and negotiation might play a role in informing elements of the cap and floor scheme for LDES. In our view, while competition could be used to inform specific parameters of the cap and floor mechanism, and there may be elements of the cap and floor design that could be reasonably subject to negotiation, any such engagement with project sponsors will still need to be anchored in a robust baseline design which clearly articulates and safeguards DESNZ and Ofgem policy objectives.

Similarly, other aspects of the scheme will still need to be established administratively by Ofgem. Accordingly, the potential baseline LDES cap and floor design we outline seeks to standardise parameters as much as possible to ensure equitable treatment between different projects.

Below, we first provide an overview of the baseline design in Table 5.1, before setting out our supporting rationale for each of the key elements:

Table 5.1: Potential baseline reference design for the LDES cap and floor regime

Design parameter	Proposed baseline model
General design parameters	
Contract duration	Equal to project life (time to first major refurbishment), up to 25 years.
Capex recovery	Allowed capex is captured in the RAV and recovered over the contract through RAV depreciation. The scheme design should signal that capex associated with long-lived civil engineering assets may only be partially recovered over the project life based on a depreciation schedule set by Ofgem after consulting project sponsors.
Assessment period	Cap and floor payments are assessed over the entirety of the cap and floor contract, with interim payments made every five years.
Design of the floor	
Level of the floor	Equal to a notional cost of debt, applied to 100% of the RAV. For project finance solutions, a hybrid solution including an alternative floor based on *actual* debt costs provides reassurance on debt costs on a time-limited basis.
Sharing factor below floor	Floor payments have a fixed and a variable component: the fixed component is always guaranteed, regardless of asset performance, while the variable component depends on the achieved gross margin below the floor.
Design of the cap	
Level of the cap	Administratively set by Ofgem for each application window based on an estimated rate of return that provides a plausible upside risk and applied to 100% of the RAV.
Sharing factor above cap	A sharing factor of 10% to 20% is applied so that this proportion of gross margin above the cap is returned to the project.

Source: CEPA/ESP

5.1. Overarching design choices

5.1.1. Contract duration

Contract duration	Equal to project life (time to first major refurbishment), up to 25 years.

As previously discussed in Section 3.2.1, different LDES technologies have different typical project lives.

For those with relatively short operational lifespans, such as batteries, there would be limited value in mandating a contract extending beyond project life. Doing so would necessitate complex assumptions regarding repowering potential, replacement expenditure requirements, and post-project financing costs. For these assets, we recommend setting the contract equal to the project life.

For longer-lived assets, there is a trade-off in providing investors and consumers with long-term certainty while not locking consumers into long-term commitments. Similarly, there is a trade-off between spreading the cost of the investment over a reasonable time frame while recognising financing and commercial realities and investors requirements. We have anchored the maximum contract length to the 25 years that exist for the interconnector regime, recognising the likely expected timeframe for investor returns and a more optimal debt tenor for project-debt under a cap and floor contract. However, we argue that there may be value in allowing project sponsors to propose a longer contract duration where this is necessary to ensure bankability or investability, and they can demonstrate clear consumer benefits from the extended duration. This could be on a project-specific basis or on a scheme-level basis. The net impact on consumers of a different contract length will largely be dependent on the proportion of capex that is recovered at the floor over the contractual period – which we discuss further below. In any case, Ofgem should consider the impact on consumer benefits and overall value for money before agreeing to a different contract length for specific projects.

5.1.2. Speed of capital recovery

Capex recovery	Efficient capex is captured in the RAV and recovered over the project life through RAV depreciation. The scheme design should signal capex associated with long-lived civil engineering assets may only be partially recovered over the project life based on a depreciation schedule set by Ofgem after consulting project sponsors.

For LDES assets with shorter asset lives, **aligning capex recovery with the contractual period serves as a fundamental principle to ensure project bankability and investability** by providing both lenders and investors with a clear pathway to recover their investment over the contracted timeframe. Furthermore, this alignment also ensures that the capex recovery period underwritten by the cap and floor contract corresponds directly with the period during which consumers derive value from the asset.

For longer-lived LDES assets, we recommend adopting (or at least Ofgem signalling developers must consider) a different approach wherein the capex is not fully recovered over the contractual period, instead retaining a 'residual value' at contract termination. **This approach acknowledges that these projects, or at minimum their core infrastructure assets, will maintain significant value beyond the 25-year contract period.**

Careful consideration must be given to the scale of this residual value, to avoid compromising investability and bankability. The return of the investment associated with the residual value will be dependent on market conditions beyond the 25-year contract period. While equity investors may be willing to accept a certain degree of risk on the residual value, exposing them to too much market risk will undermine the investment case. As discussed in section 3, regardless of the technical life of the asset, investors may still expect their investment to be paid back with a return over a 25-year long-term infrastructure investment horizon. Our stakeholder engagement also strongly indicates that lenders will not accept market risk under a project finance structure, and so will limit their investment to a level that will ensure debt recovery over the contractual period.

Given the challenges of determining an appropriate residual value and balancing concerns around investability, bankability and intergenerational fairness for consumers, **Ofgem could also allow project sponsors to inform the RAV depreciation profile**. For example, Ofgem could allow project sponsors to propose or choose:

- a less accelerated depreciation schedule but with a longer contract duration; or
- a more accelerated depreciation schedule, but with a whole life cap that extends beyond the cap and floor contract period (in order to compensate for the higher chance of floor payments from consumers).

5.1.3. Assessment period

Assessment period	Cap and floor payments are assessed over the entirety of the cap and floor contract, with interim payments made every five years.

As discussed in Section 3.2.2, all else equal, longer assessment periods reduce the likelihood of any cap and floor payments being made – in either direction. Consequently, a longer assessment period offers two key advantages:

- **It reinforces project bankability** through providing for debt recovery at the floor over the assessment period, while reducing risk exposure to consumers.
- **It reduces incentive distortions**, as widening the assessment period means that a project is less likely to be below the floor or above the cap over the full contractual period.

However, extended assessment periods introduce potential credit risk for both parties if substantial floor or cap allowances accumulate over time. Investors may perceive this approach to carry greater uncertainty of what the overall financial position and return on investment will ultimately be and, particularly for an asset trading at or below the floor, could mean the project will have to wait a long period of time before receiving any true-up payments from the support scheme. To address this risk, we would propose implementing interim payment mechanisms, potentially at five-year or annual intervals, to manage exposure levels effectively.[16]

5.2. Design of the floor

5.2.1. Level of the floor

Return at the floor	Equal to a notional cost of debt, applied to 100% of the RAV. For project finance solutions, a hybrid solution including an alternative floor based on *actual* debt costs provides reassurance on debt costs on a time-limited basis.

We propose a hybrid floor design, which includes an ACOD floor for project finance solutions, for two main reasons:

- It ensures bankability under both project finance and balance sheet finance models, as experience from the interconnector regime suggests a notional floor alone may be insufficient.
- It avoids distorting incentives over how to finance LDES projects, as an ACOD-only floor is more challenging to implement for balance sheet financed projects.

In line with the existing interconnector model, our baseline model sets a notional floor based on a debt-like return on **100% of the RAV**, effectively allowing the full value of the investment to earn a debt-like return at the floor. However, we also propose exposing an element of this return to some market and performance risk depending on the achieved gross margin, to reflect the objective that there should be some risk to project returns if the LDES asset is operating at the floor. This is described further below.

[16] We understand a similar arrangement exists for the cap on profits for the Eleclink interconnector, which applies a full life project assessment on whether a given project IRR cap will be exceeded or not. Any true-up payments against the cap or floor would be charged an interest rate designed to avoid distorting any incentives associated with the timing of cashflows.

There are advantages and disadvantages to allowing a debt-like return on 100% of the RAV at the floor; in effect incorporating a modest return on equity at the floor. Firstly, doing so would clearly improve the investability of any LDES project. Ensuring bankability may not be sufficient for a project to go ahead, if it is still perceived as too risky by equity investors, particularly given the development and construction risks they face before an LDES project is able to reach commercial operations and start earning revenues. Furthermore, there is clear precedent for this approach in the interconnector regime. It also avoids Ofgem having to assume a notional gearing ratio in setting the floor, which may create some incentive distortions around financing.

However, as discussed in Section 3.3.1, increasing the RAV base on which a return is earned at the floor raises the *level* of the floor. This increases the likelihood of the gross margin being below the level of the floor and accompanying payments from consumers. In turn, this may reduce incentives for the asset to respond effectively to market signals.

We consider that both of these disadvantages could be mitigated by the same solution: a ‘soft floor’. This would reduce the expected level of floor payments from consumers whilst also creating stronger incentives for the asset to operate efficiently below the floor. We explain this approach further below.

5.2.2. Sharing of revenues below the floor

Sharing factor below floor	Floor payments have a fixed and a variable component: the fixed component is not subject to market risk, while the variable component depends on the achieved gross margin below the floor.

As discussed in Section 3.3.2, **availability incentive mechanisms, while necessary, are unlikely to be sufficient to encourage LDES assets to operate efficiently above the cap and below the floor**. For this reason, we believe that the LDES cap and floor regime should introduce a gross margin sharing factor above the cap and below the floor, so that the cap and floor are both “soft”.

There are various ways in which a soft floor could be implemented. One option is to allow a minimum floor payment assumed to be sufficient for the project to remain investable – e.g., sufficient to cover notional debt costs at an assumed level of notional gearing. This minimum floor payment, while subject to an availability incentive like with the interconnector regime, would not be subject to market risk. There would then be a second floor that would be subject to market risk, based on a sharing factor. This would both reduce the expected level of floor payments from consumers and create stronger incentives for the asset to operate efficiently below the floor.

Our modelling of incentive distortions above the cap and below the floor indicates that a relatively low sharing factor (10-20%) should be sufficient to largely preserve operational incentives. We discuss the design and calibration of the “soft” cap and floor further in Appendix B.

One of the implications of the above approach is that it may start to introduce regulatory assumptions of capital structure into the regime design. This is because, if the minimum floor payments is to cover (notional) debt costs, the proposed “soft floor” design requires an implicit assumption about the notional gearing ratio. One of the advantages of the interconnector regime is that – with exception of the ACOD floor mechanism – the regime is neutral to financial structure choices and decisions. There may be other options for implementing a “soft floor” that are not related directly to debt costs and capital structure, and we would recommend that DESNZ and Ofgem carefully consider the design of a “soft floor” as part of the development of the LDES scheme.

5.3. Design of the cap

5.3.1. Level of the cap

Return at the cap	Administratively set by Ofgem for each application window based on an estimated rate of return that provides a plausible upside risk and applied to 100% of the RAV.

Our initial view is that retaining the administrative approach to setting the rate of return at the cap will ultimately be more straightforward, and in line with the interconnector regime, than a competitive process, for the reasons outlined in Section 3.2.3.

Under our proposed approach, the implied equity return at the cap would be significantly higher than the headline rate of return applied to the RAV at the cap, due to the effect of gearing: we expect that most projects would be at least partly financed by debt, and typically the cost of debt is lower than the cost of equity due to the differing risk borne by lenders versus shareholders. If the project is funded from a company's balance sheet, the level of gearing of the company as a whole will still imply a higher contribution of the project to equity returns than the headline RAV rate of return at the cap implies.

In practice, the likelihood of a project consistently operating above the cap and thus earning such a large equity return is, in our view, less likely than that of it operating above the cap for more limited periods of time. We assume that a project sponsor has an ex-ante expectation of a project return in a reasonable range around their hurdle rate of return, and that the project sponsor is seeking cap and floor support to ensure bankability, reduce downside risk, and improve their risk adjusted return. If a project sponsor had an ex-ante expectation that annual gross margin would be at the cap level in most years, we assume that the project sponsor would seek alternative ways to ensure investability rather than have an ex-ante expectation of a large transfer of value to consumers.

5.3.2. Sharing of revenues above the cap

Sharing factor above cap	A sharing factor of 10% to 20% is applied so that this proportion of gross margin above the cap is returned to the project.

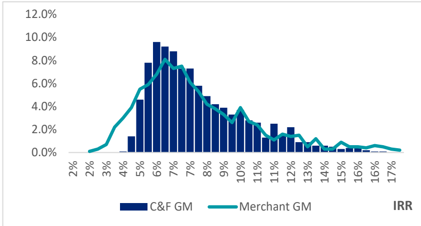
As previously discussed, we believe that the LDES cap and floor regime should introduce a gross margin sharing factor above the cap and below the floor. As with the 'soft floor', our modelling suggests that a relatively low sharing factor (10-20%) should be sufficient to largely preserve operational incentives. Please see Appendix B for further details.

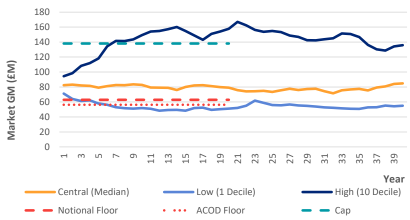
Appendix A SIMULATION MODEL AND THE ARCHETYPES

A.1. Introduction

This appendix provides further details on the simulation model which we developed to support our analysis of alternative cap and floor structures set out in this report. This model is designed to illustrate the impact of a cap and floor design on project cashflows and returns as well as payments to and from consumers. Using a stochastic simulation approach, the model estimates the Gross Margin outcomes over a 40-year modelling horizon for:

- A set of defined project archetypes, which represent an assumed typical project configuration for each of the cap and floor technologies under consideration (e.g. PSH, Li-ion, LAES); and
- Alternative designs of the cap and floor structure under the cap and floor contract as well as a merchant outcome (in which the archetype project is fully exposed to the market without any cap and floor support).





These simulations allow us to compare the distribution of gross margins for each project archetype with and without the cap and floor contract, over both the cap and floor contract term and the asset life. In turn, this supports assessment of:

- The impact of alternative cap and floor structures on the project's gross margin performance and internal rates of return (IRRs);
- The net cashflow and IRR benefit of such support on both project and equity returns compared to the merchant case; and
- The net value and balance of consumer floor payments and project cap payments over the cap and floor contract term.

The various outputs and statistics produced by the model are set out in a dashboard, an example of which is given in Section A.5 of this appendix. The remainder of this appendix provides further details on the definition of Project Archetypes, the modelling of alternative cap and floor design as well as the 40-year simulations of gross margin outcomes.

A.2. Project Archetypes

Archetypes capture the assumed project configuration in terms of archetype technology, capex and opex as well as financing assumptions. The table below illustrates the data and parameters which define the configuration of an archetype for the PSH, Li-ion and LAES technologies referenced in this report:

Archetype		PHS	Li-on (long duration)	LAES
Financing model		Project finance	Project finance	Project finance
Capacity	Power (MW)	500	100	100
	Duration (Hours)	12	7	12
	Storage (MWh)	6,000	700	1,200
Project life	Years	50	20	35
Finance (actual)	Debt tenor	25	20	25
	% Hurdle rate	8%	8%	9%
	% Gearing	70.0%	70.0%	70.0%

Our assumptions around the capex and opex costs of each archetype were chosen to provide a reasonable illustration of costs, in line with the report prepared by LCP Delta on LDES for DESNZ wherever possible.[17] However, these assumptions are not central to our analysis as our modelling is focused on comparing the impact of different design choices rather than seeking to accurately estimate potential cap and floor levels, payments or returns for different LDES technologies. The table below summarises the rationale, and where relevant the data source, for each of the parameters which make up these particular archetypes:

Assumption	Source/Rationale
Project life	• 50 years for PSH. While some elements may last for 100+ years, we went with the lower end based on informal stakeholder engagement. • Li-ion and LAES – Midpoint in DESNZ consultation – LCP Delta Report and DESNZ LDES consultation document.[18]
Capacity	• Power capacities reflect typical project scale across the various LDES technologies and in line the ranges indicated in the DESNZ consultation responses. • Storage capacity reflects the charge/discharge duration assumptions, also broadly in line with the ranges indicated in the DESNZ consultation responses.
Finance	• Debt tenor set to project life up to 25 years. This reflects our experience from previous work on infrastructure debt financing in the energy sector of more standard loan durations. • Hurdle rate assumptions are calibrated based on survey results in the LCP Delta Report. • Cost of debt assumptions reflect internal CEPA analysis and previous work on infrastructure debt financing in the energy sector. • Assumed gearing ratios similarly based on internal CEPA analysis and previous work on infrastructure debt financing in the energy sector.

A.3. Cap and Floor Design Modelling

A.3.1. RAV depreciation

The model is able to represent alternative RAV depreciation regimes set out in Section 3:

- **Accelerated depreciation** where the RAV is depreciated fully over the term of the cap and floor contract even though the LDES asset's project life extend beyond this term;
- **Partial depreciation** where the RAV is depreciated over the project life. For LDES asset with a life span beyond the contract term, this results in only partial depreciation under the cap and floor contract; and
- **Extended contract** where both the cap and floor contract term and the RAV depreciation schedule is set to the project life.

The table below summarises the parameters which define the RAV depreciation regime within the model:

[17] DESNZ (2024) 'Scenario Deployment Analysis for Long-Duration Electricity Storage', DESNZ Research Paper 2023/047

[18] See DESNZ (2024) 'Long duration electricity storage: proposals to enable investment' and DESNZ (2024) 'Scenario Deployment Analysis for Long-Duration Electricity Storage', DESNZ Research Paper 2023/047

Parameter	Model Settings
Project life	• Gross margin contributions are modelled for the entire project life up to 40 years. • Where the Project Life exceeds this modelling horizon, a residual value is calculated as the share of RAV remaining at the end of the 40-year period. • Where the Project Life exceeds the cap and floor contract term (refer below), gross margin contributions beyond the cap and floor contract term are calculated on merchant basis.
Cap and floor term	• The term of the cap and floor contract.
Debt tenor	• The tenor of project debt up to a maximum of 25 years, which is considered the longest term for which a sufficiently liquid debt market exists with a range of financing solutions. • Where the project life is less than 25 years, the debt tenor is equal to the project life. Where it is longer, the debt tenor stays at 25 years.
RAV term	• The number of years over which the project RAV is depreciated.

A.3.2. Cap

The model reflects a **single cap** above which the investor returns all or a share of the gross margin earned by the project to the consumer. The table below summarises the parameters which define the cap:

Parameter	Model Settings
Rate of return at the cap	• The rate of return at the cap above which the project returns all or a share of the gross margin earned (depending on the sharing factor). • The model is able to simulate any rate of return requirement.
% of RAV	• The percentage of the RAV to which the cap applies. • As explained above, when combined with the settings for Project Life and the Cap and Floor Contract Term, this enables the model to represent the RAV depreciation regimes discussed above.
Assessment period	• Set for one, two, five years or the full contract length. • Where the assessment period is set to full contract term, five years interim settlements are assumed in advance of a final balancing payment at the end of the contract. This serves to avoid build-up credit risk against the project.
Sharing factors	• Sharing factors express the share of gross margin retained by the investor above the cap • If set to 0%, the cap is firm, and all gross margin earned above the cap returned to the consumer. Likewise, a 20% sharing factor implies a soft cap in which the project retains 20% of the gross margin above the cap, with the remainder 80% returned to the consumer.

Given these parameters, the annual cap thresholds are calculated as an annuity set to recover the rate of return on the share of RAV over the cap and floor contract term. Once set, the model evaluates the cap credit annually for each of the 1000 simulated gross margin outcomes (see section A4 below) and consolidates these into period payments in accordance with the assumed assessment period. When calibrating our baseline cap and floor design parameters for the purposes of this report, we set the rate of return at the cap at 13% in real terms for the PSH and Li-ion archetypes, and at 14% in real terms for the LAES archetype. This level is five percentage points higher than the assumed hurdle rate. While we believe this to be a reasonable assumption for illustrative purposes given the hurdle rates used in the modelling and the risks of LDES investment, it is not based on any benchmarking or detailed analysis of potential required returns for LDES, and does not constitute CEPA's or ESP's view of what a reasonable upside rate of return at the cap might be.

A.3.3. Floor

The model is able to represent three alternative methods for setting and structuring the floor:

- A **notional floor** set administratively using a benchmark estimate of a debt like return. This is applied to 100% of the RAV and applies to all projects;
- An **'ACOD' floor** set on a project-specific basis, with the aim of allowing a project to earn sufficient revenues at the floor to recover actual debt costs plus debt service coverage. The ACOD floor is assessed annually and is used specifically for projects financed on a non-recourse basis to limit lenders' risk exposure; or
- A **Hybrid floor** which applies the ACOD floor only temporarily until project revenues exceed this floor, whereafter any excess floor payments relative to the notional floor are repaid. Hence, at the point where the project starts earning gross margins in excess of the ACOD floor, repayments are made to come back to the notional floor values (see illustration of this approach in section 2).

The table below summarises the parameters which define the floor (for a given method):

Parameter	Model Settings
Rate of return at the floor	• The minimum notional or actual return (depending on the chosen floor method) below which the project receives support under the cap and floor scheme. • While this minimum return in most scenarios is set with reference to an estimate of the cost of debt (CoD), the model is able to simulate any stated return and hence arrangements in which the investor receives some compensation for equity.
% of RAV	• The percentage of the RAV to which the floor applies. • For the ACOD method is typically set at the project's actual gearing (but need not be). For the notional and hybrid methods, the RAV% can be set to allow investors to earn some return on equity at the floor. For example, if the floor is set on 100% of the RAV, both debt and equity will earn the assumed debt-like/minimum return.
Assessment period	• Set for one, two, five years or the full contract length up to a maximum of 25 years. Where the assessment period is set to the minimum of the contract length and 25 years, five years interim settlements are assumed in advance of a final balancing payment at the end of the contract.
Sharing (soft floor)	• In contrast to the cap functionality, the model does not incorporate explicit sharing factors for the floor. However, a soft floor can be approximated by setting the share of RAV included in the floor at a level below 100%

Given these parameters, the annual floor threshold is calculated as an annuity set to recover the notional or actual CoD/minimum return on the allowed share of RAV over the lesser of the cap and floor contract term and 25 years. Once set, the model evaluates floor debits/credit annually for each of the 1000 simulated gross margin outcomes (see section A4 below) and consolidates these into period payments in accordance with the assumed assessment period.

All results presented in this report assume a hybrid floor, which is also the method adopted in the cap and floor arrangements for the two recent project financed interconnectors.

When calibrating our baseline cap and floor design parameters for the purposes of this report, we set the rate of return at the floor at 4% in real terms for the PSH and Li-ion archetypes, and at 4.5% in real terms for the LAES archetype. This level is higher than the floor rate of return for Window 2 interconnector projects, to reflect the changed macroeconomic environment. While we believe this to be a reasonable assumption for illustrative purposes, it is not based on any benchmarking or detailed analysis of potential required returns for LDES, and does not constitute CEPA's or ESP's view of what a reasonable rate of return at the floor might be.

A.3.4. Baseline cap and floor modelling parameters

In order to meaningfully illustrate the impacts of different design choices through our simulation model, we must set some baseline parameters, both in terms of the LDES archetypes we chose to represent, and in terms of the starting point for several regime parameters. These baseline parameters are not based on particular benchmarks or financial analysis, but allow us to illustrate some of the trade-offs and impacts of deviating from the baseline by changing each parameter, one at a time.

In order to set the baseline assumptions in line with the interconnector approach (with the exception of a soft cap) we assume the following for our PSH archetype:

- That the allowed return at the floor is 4% in constant prices, applied to 100% of the RAV (see above).
- That the allowed return at the cap is 13% in constant prices, applied to 100% of the RAV (see above).
- The assessment period for the cap and floor is set at 5 years.
- The RAV is fully depreciated in line with the duration of the cap and floor contract.
- The 'soft cap' sharing factor is 10%.

It is worth noting that these assumptions are purely illustrative, and do not represent CEPA or ESP's view of what would be an appropriate, or realistic set of scheme parameters. While we have attempted to set this baseline in line with the interconnector regime – making adjustments to be consistent with other assumptions made in the modelling – we have not carried out any explicit benchmarking of returns to derive these assumptions.

A.4. Gross Margin Simulations

The net payment (to consumers or to LDES asset owners) after settlement of the cap and floor contract depends on the evolution of the LDES gross margin over time. This is inherently uncertain ex ante. To reflect this uncertainty, we have assessed cap and floor designs for each of the project archetypes against 1000 simulations of the future gross margin on a merchant basis (i.e., before application of the cap and floor) over the next 40 years. These simulations assume that gross margin performance over time follow a mean-reverting lognormal random walk (geometric Brownian motion, with drift). The simulation is conducted in annual resolution and hence a full model run spans 40,000 simulated merchant gross margin values. Where the asset life assumed for the archetype is longer than the 40-year modelling horizon (e.g., PSH), a residual value is included in the modelling results based on straight-line depreciation of the RAV.

A.4.1. Calibration of expected (mean) project returns

Each simulated random walk is started at (and reverts back towards) an assumed expected (mean) project return, seen from the point of view of project sponsors[19]. Assuming that the project sponsor's cost of equity is materially above the project cost of debt, then a candidate LDES project sponsor will have an ex-ante expectation that the project return will not be substantially below the project's hurdle rate on merchant basis. We make this claim by noting that a project whose expected return on a merchant basis is significantly below the hurdle rate is very unlikely to be made investable by a cap and floor scheme where the level of the floor is set at the cost of debt (even if the floor is calculated on 100% of the RAV so that the equity funding earns the cost of debt at the floor). However, if a project's expected return is only slightly below (rather than significantly below) the project's hurdle rate, then such a project may become investable after the application of a cap and floor contract if:

- There is an expected subsidy from consumers to the project via the floor, and/or

[19] We are speaking here about the expected project return as seen from the point of view of project sponsors – Ofgem or other stakeholders may legitimately have a different outlook of the future market outlook for LDES assets and therefore a different expectation of the expected return of a candidate project before application of the cap and floor settlement.

- The reduction in downside risk as a result helps to reduce the target hurdle rate for the project, considering that investors typically require a higher return to compensate for higher risk.

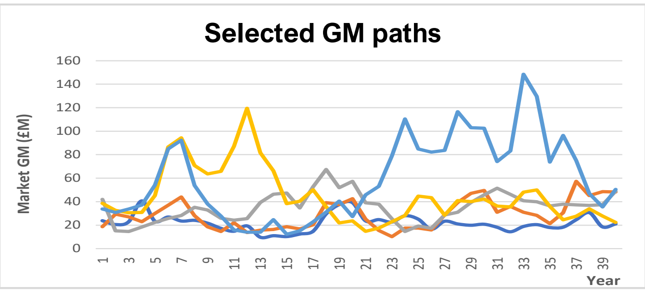
We would also make the (maybe somewhat less certain) claim that the project sponsor's ex ante expectation of the merchant return of a candidate LDES project cannot be significantly above the project hurdle rate. We justify this by noting that a project whose expected return is already quite high is less likely to need floor support to be investible. If the project sponsor does need some support to ensure an investible project, they may prefer in the first instance to achieve this by some other financial structure, rather than risking that a large proportion of asset revenue will be transferred to consumers via the cap. We therefore would not expect project sponsors whose ex-ante expectation of an LDES project's return is very high to apply for cap and floor support for these projects.

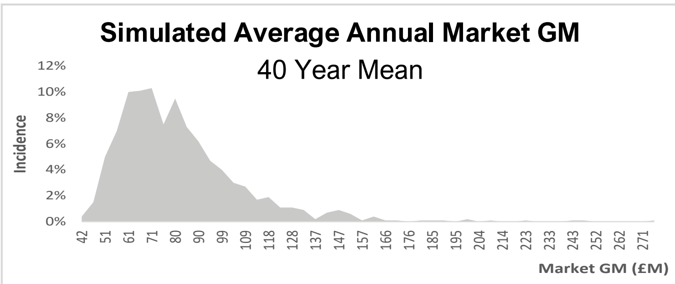
Given the above, our stochastic modelling of the cap and floor contracts starts with an assumption that the expected project return on a merchant basis of a candidate LDES project is approximately equal to the hurdle rate. Hence, the mean across all 1000 simulations is calibrated to come back to the assumed notional investor WACC requirement for each archetype as set out earlier in the table in Section A.2. For the purpose of the analysis presented in this report, the mean is implemented as a flat constant value in all years. However, the model is capable of profiling the mean data as well as taking a scenario or forecast as its expectation over the 40-year modelling horizon for example generated by a market modelling tool.

A.4.2. Stochastic Simulation Process

Given this mean value, each simulation is created by applying random shocks to the log-normal random walk, given assumed volatility (variance) and mean-reversion parameters. Since the purpose of the modelling presented in this report is to test the cap and floor design, these parameters have been chosen to ensure that a sufficient number of simulations breach these thresholds. Our choice of these parameters is somewhat arbitrary. While a different choice of these parameters would change the actual model results (e.g., the particular value of the expected net payment to or from consumers resulting from cap and floor settlement), our overall conclusions are robust against different choices for the volatility and mean reversion rate.

The shocks applied in the random walk are simulated only once and then converted to static data. This serves to avoid random white noise and ensure stability of results. The left-hand figure below illustrates 5 individual gross margin simulations over the 40-year modelling horizon. The right-hand graph shows the distribution of average annual gross margin across all simulations and all years:

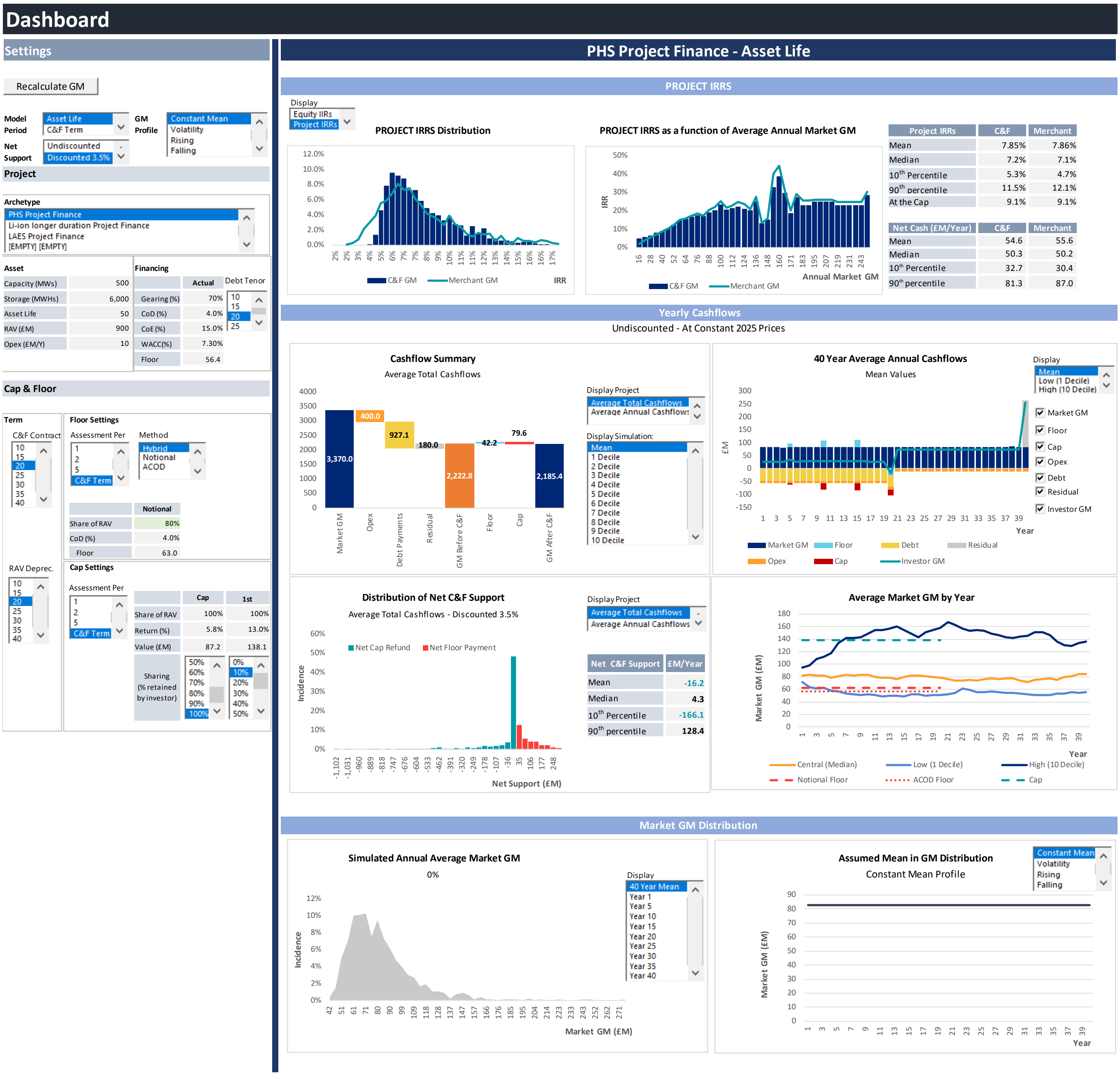




For each of the 1000 simulations of the merchant gross margin, the model computes floor and cap payments to enable assessment of the outcome under the assumed cap and floor contract design.

A.5. Model Dashboard

The simulation results are bucketed to present distributional analysis and statistics in the model dashboard, an example of which is illustrated below:



Appendix B REVENUE SHARING TO PRESERVE INCENTIVES

The cap and floor regime may distort the market behaviour of an LDES asset, where the cap and floor regime utilises a hard cap and floor. When an asset's expected gross margin exceeds the hard cap (prior to the application of the cap and floor), the asset owner's final gross margin will equal the cap level once cap payments are settled, irrespective of the storage asset's trading performance. A similar argument can be made when the expected gross margin is below the floor. Therefore, there is no incentive for such a storage asset to make optimal trading and dispatch decisions, as any gross margin earned above the cap would be returned to consumers as cap payments, and thus the consumer and energy security benefits of the LDES are eroded.

The cap and floor regime for interconnectors does not face a similar distortion of operational incentives. Interconnectors earn revenue by selling capacity, rather than by active trading in the market. To preserve the desired behaviours when interconnector revenues are above the cap or below the floor, it is sufficient to ensure that the interconnector capacity is available to third parties. To achieve this, the cap and floor regime provides incentives to the interconnector owner to ensure maximum availability of the asset. These incentives are an increase in the level of the cap when asset availability is above a target level, and a suspension of floor payments when asset availability is below a minimum threshold.

An availability incentive is insufficient to preserve incentives for an LDES asset, which may be available and yet not be dispatching energy into nor drawing energy from the system. Such lack of activity may be completely legitimate: even if an LDES asset is available and there are observable spreads in the day-ahead market, an LDES asset may choose to wait for higher spreads to become available, or instead it may choose to provide ancillary services. No asset has perfect foresight, and different assets will have different trading strategies, making it difficult and burdensome to determine ex-post whether a given asset adequately responded to market signals at a given time.

If the gross margin of an LDES asset is above the cap or below the floor, the asset owner may be worse than indifferent to trading and dispatching the asset optimally. There is rather a small incentive to cycle less frequently than is otherwise optimal. The cycling of an asset is associated with variable operations and maintenance costs (e.g., wear and tear on generators and pumps in the case of a PHS; or degradation of the energy storage capacity in the case of a lithium-ion battery), and these variable costs are a disincentive to cycle the asset in the absence of any associated marginal revenue. Secondly, there is the risk of an unplanned outage of the asset in which case there may be imbalance costs together with potentially significant costs associated with unwinding executed trades and other market commitments. Furthermore, operation of a complex asset comes with the very small probability of more catastrophic failure, resulting in damage beyond normal wear and tear. These costs and risks can be accommodated by allowing a fixed cost per cycle in the gross margin, which restores the asset owner to being at least indifferent to optimal operations.

The use of a third-party optimiser (TPO) can mitigate these distortions. If we assume that the TPO is compensated with a proportion of the total gross margin earned by the LDES asset (before application of the cap and floor), then the TPO has the correct incentives to trade and dispatch the asset optimally over all values of expected gross margin, including above the cap and below the floor. In this case, to solve the problem of the distortion caused by the cap and floor contract, it is sufficient to have availability incentives, similar to those for interconnectors.

To solve the distortion problem for an LDES asset where a TPO is not responsible for trading and optimisation, we recommend a "soft" cap and floor design. This approach is explained in Sections 3.3.2 and 3.4.2. Distortion of operational incentives can be further mitigated by extending the assessment period for settlement of the cap and floor, as discussed in Section 3.2.2.

Calibrating the sharing factor

When the gross margin of an LDES asset is above the cap or below the floor, if the asset were perfectly indifferent about whether to trade the asset or not, even a very low sharing factor (say, 1%) should be sufficient to incentivise optimal operation. For a given observed spread in the market, if the asset is indifferent between cycling and not cycling, retaining even a small percentage of the spread would be sufficient for the asset to cycle. However, as discussed above in this appendix, in reality there is a small incentive to cycle less frequently than otherwise optimal, due to variable operations and maintenance costs and small risks of unplanned outages.

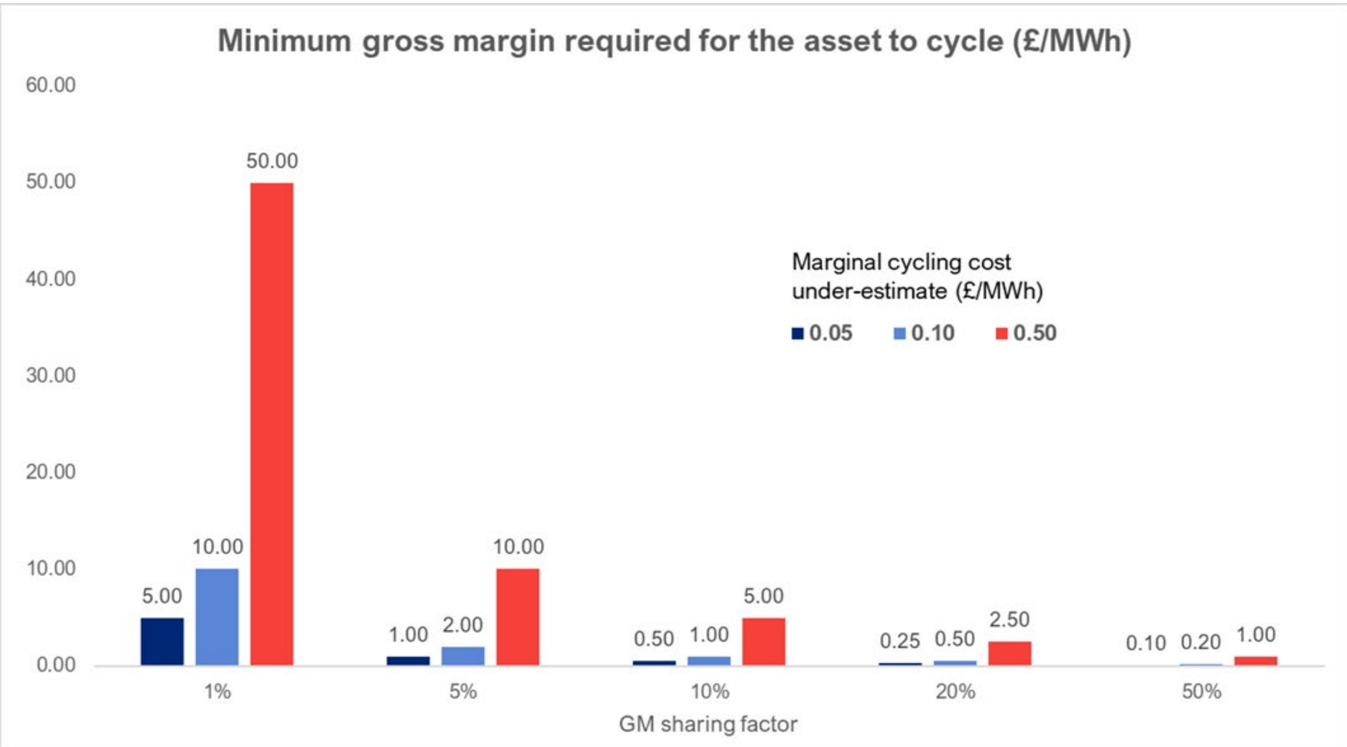
Ideally, these costs and risks should be accounted for when calculating the achieved gross margin of the asset under the scheme – e.g. by discounting them from the gross margin in proportion to the cycling volumes over the period in MWh. However, the true value of these costs on a per MWh basis is not directly observable and would have to be estimated based on any available benchmarks and information provided by project sponsors.

As a result, there will always be a risk of a mismatch between the value of these costs assumed under the cap and floor regime and the value considered by the asset operator when deciding whether to cycle the asset. The impact of this mismatch will be to change decisions over whether or not to cycle the asset at the margin. For example, a slight underestimate of the marginal cycling costs would likely not affect the asset's response to very large spreads – which would make up for the small cycling cost unaccounted for under the scheme – but it may prevent the asset from cycling when spreads are more modest, but otherwise sufficient given the asset's efficiency.

As a practical example, we can consider the case of an LDES asset subject to a cap and floor regime with a 10% sharing factor, and an estimate of marginal cycling costs which underestimates them by £0.50/MWh. If the gross margin is in the cap and floor corridor, the asset is incentivised to cycle whenever it has an opportunity to earn a positive gross margin, however small (unless that implies foregoing the opportunity to earn an even higher gross margin). If the gross margin is above the cap or below the floor, however, the asset will only cycle if it can earn a gross margin of at least £5/MWh (taking into account the true marginal cycling costs). This is because with a gross margin of £5/MWh and 10% sharing factor, the asset retains £0.50/MWh, which is just enough to cover the marginal cycling costs which are not covered as part of the scheme design.

More generally, Figure B.1 provides an illustration of the minimum gross margin that would incentivise an asset to cycle under different combinations of sharing factors and under-estimated marginal cycling cost values.

Figure B.1: Quantification of incentive distortions for different combinations of sharing factors and marginal cycling costs estimate errors



Source: CEPA-ESP analysis

When marginal cycling costs are underestimated by £0.05, even a low sharing factor between 1% and 5% may be sufficient to minimise incentive distortions. When they are underestimated by £0.50/MWh, however, incentive distortions of a similar scale are achieved for higher sharing factors, in the 10-20% range. Note that if the marginal cycling cost were *over*estimated, the reverse effect would apply and assets would be incentivised to cycle even for marginally negative gross margins.

Based on our qualitative analysis of publicly available data on marginal operations and maintenance costs for PSH plants, a conservative estimate of these costs for PSH plants would be about £0.50/MWh. However, this may not apply to other LDES technologies, may vary from project to project, and does not account for the risk of unplanned outages. As a result of this analysis, we recommend a sharing factor of at least 10%, alongside a careful consideration of what marginal cycling costs should be assumed under the scheme, in order to minimise the chances of significant incentive distortions above the cap or below the floor.

Implementing a "soft floor" in practice

One of the challenges with implementing a soft floor, is designing it without undermining the bankability and investability of the LDES project. As discussed in Section 3.3.2, simply reducing any floor payments by the desired sharing factor (say, 10%) would be the simplest way to implement revenue sharing below the floor. However, such a model might undermine the purpose of the floor if it results in an insufficient minimum floor payment – i.e. if the component of floor payments that does not depend on the achieved gross margin is too low. This may be true if the minimum floor is insufficient to cover debt costs and/or requirements of investors in general.

This potential trade-off between providing sufficient protection at the floor and preserving operational incentives would occur when the level of the minimum floor required to make an LDES project bankable and/or investable is too close to the original floor level to allow for meaningful revenue sharing (say 10%) between them. One solution in such a scenario would be to only share revenues above a certain level of the floor, which would imply a "hard" floor for low levels of merchant gross margin but then ensure a sufficient sharing factor for higher – and presumably more likely – levels of gross margin below the floor.

To enact such a model, the "soft" floor would need to be made up of the following four components:

- **A.** A minimum floor, set below the notional floor, which allows the recovery of the original investment into the asset and/or cover debt servicing costs. Regardless of the asset's achieved gross margin, this level would always be guaranteed.
- **B.** The original notional floor, which would no longer apply in all cases but instead be partially tied to the asset's performance.
- **C.** A pre-determined gross margin threshold, above which revenue sharing is applied.
- **D.** A sharing factor for gross margin levels between the pre-determined threshold and the level of the floor.

The floor payment (FP) would then be determined by the gross margin (GM) and these four components (A, B, C and D), based on the following formula:

$$FP = \max\{A + \max(D \times (GM - C);\ C); 0\}, \text{ with:}$$

$$D = \frac{B - A}{B - C}$$

Whilst seemingly complex, this formula is flexible enough to work with any chosen parameters for the level of the floor, the minimum floor, and the gross margin threshold. The latter threshold (C in the above equation) could be chosen ad hoc to ensure that the sharing factor (D in the equation) is sufficiently high.

As an example, we can take our PSH archetype and assume that the original floor level (B) will allow recovery of 100% of the RAV and provide a debt-like return to the full investment base. Suppose that the minimum floor were set at a level that enables full recovery of a notional level of equity investment but no returns on this notional equity (equivalent to the floor in the second scenario in Figure 3.7), and that we wanted to ensure a sharing factor of at least 10% below the floor. This could be achieved by the combination of parameters in Appendix Table B.1 below.

Appendix Table B.1: Illustration of "soft floor" parameters to achieve a 10% sharing factor with a minimum floor set to allow cost recovery (with zero return) for the notional equity share of costs, PSH archetype

Symbol	Name	Value
A	Minimum floor	£63.3m
B	Original notional floor	£67.6m
C	Gross margin threshold	£24.3m
D	Sharing factor (calculated based on previous three parameters)	10%

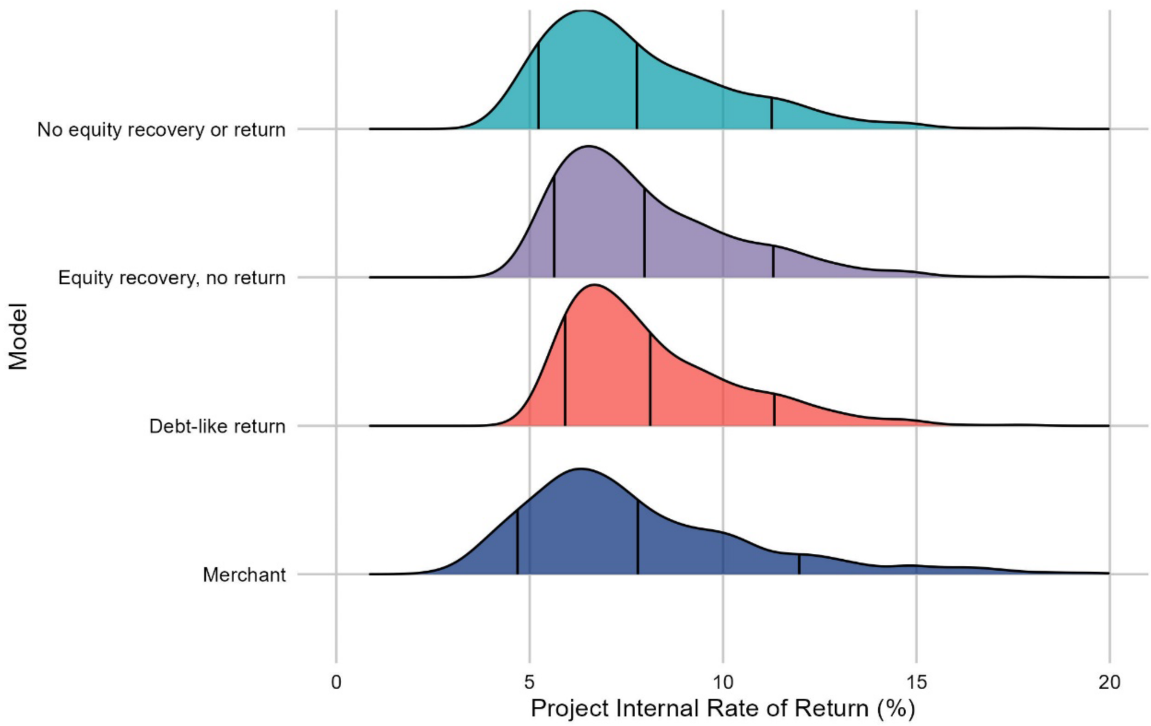
Following the "soft floor" formula above, this set of parameters would result in the following outcomes:

- If the gross margin is lower than £24.3m, the asset always receives a floor payment such that it exactly earns the minimum floor level of £63.3m.
- If the gross margin is higher than £24.3m, but lower than £67.6m, the asset will receive a floor payment such that it earns the minimum floor level (£63.3m) plus 10% of its achieved gross margin.
- If the gross margin is higher than the floor level (£67.6m), the asset receives no floor payments and earns its achieved gross margin.

In cases where the minimum floor is set at a sufficiently lower level than the floor, the gross margin threshold (C) could be set to zero, which simplifies the "soft floor" formula. For example, still using our PSH archetype, if it was concluded that guaranteeing full cost recovery for the full RAV was not necessary for investability reasons, and instead it was decided to set a minimum floor at 90% of the original notional floor – i.e. at a level which allows cost recovery and a cost-of-debt return on 90% of the RAV. This would simplify the formula, as a 10% sharing factor would be achieved simply by paying project floor payments up to the minimum floor, plus 10% of their merchant gross margin.

Appendix C ADDITIONAL MODELLING RESULTS

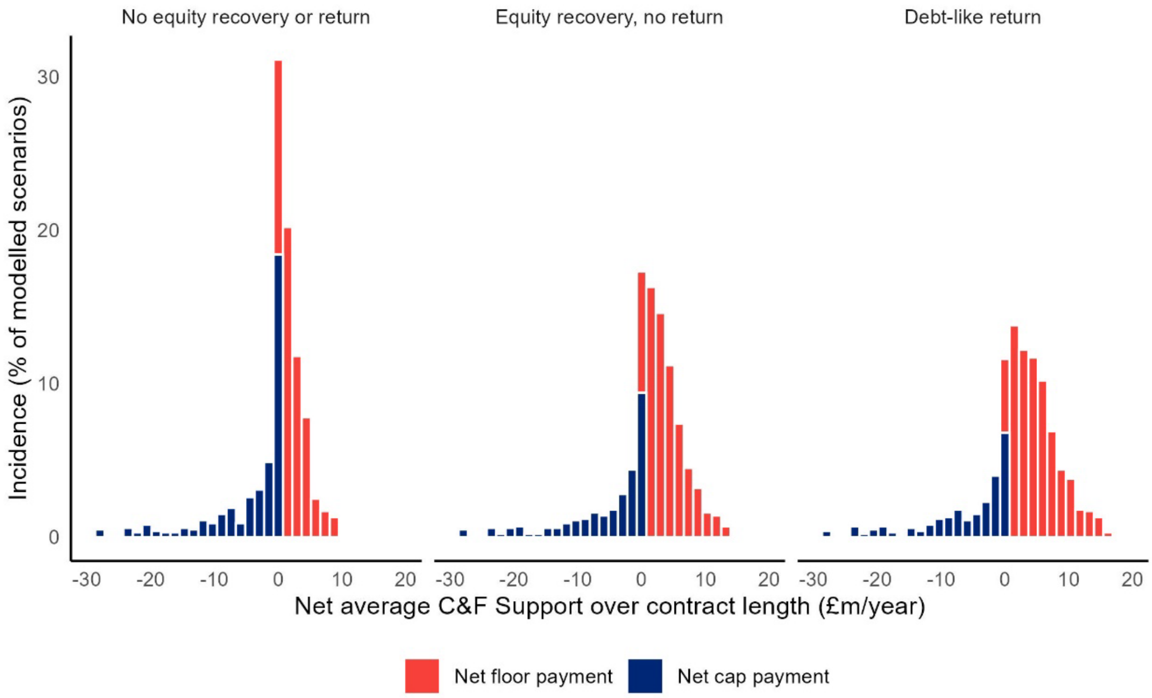
Appendix Figure C.1: Distribution of project returns under different capital recovery and return options at the floor for PHS archetype



Source: CEPA/ESP analysis

Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs

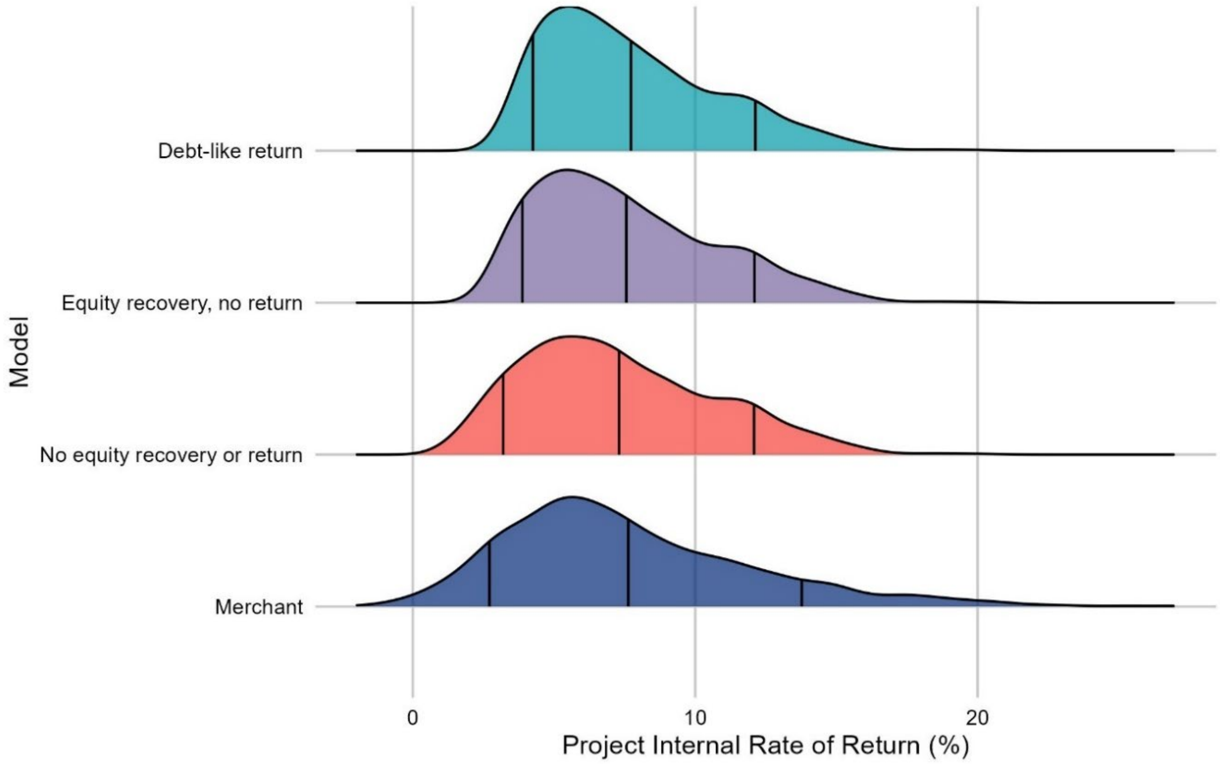
Appendix Figure C.2: Distribution of net cap and floor support under different capital recovery and return options at the floor for PHS archetype



Source: CEPA/ESP analysis

Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

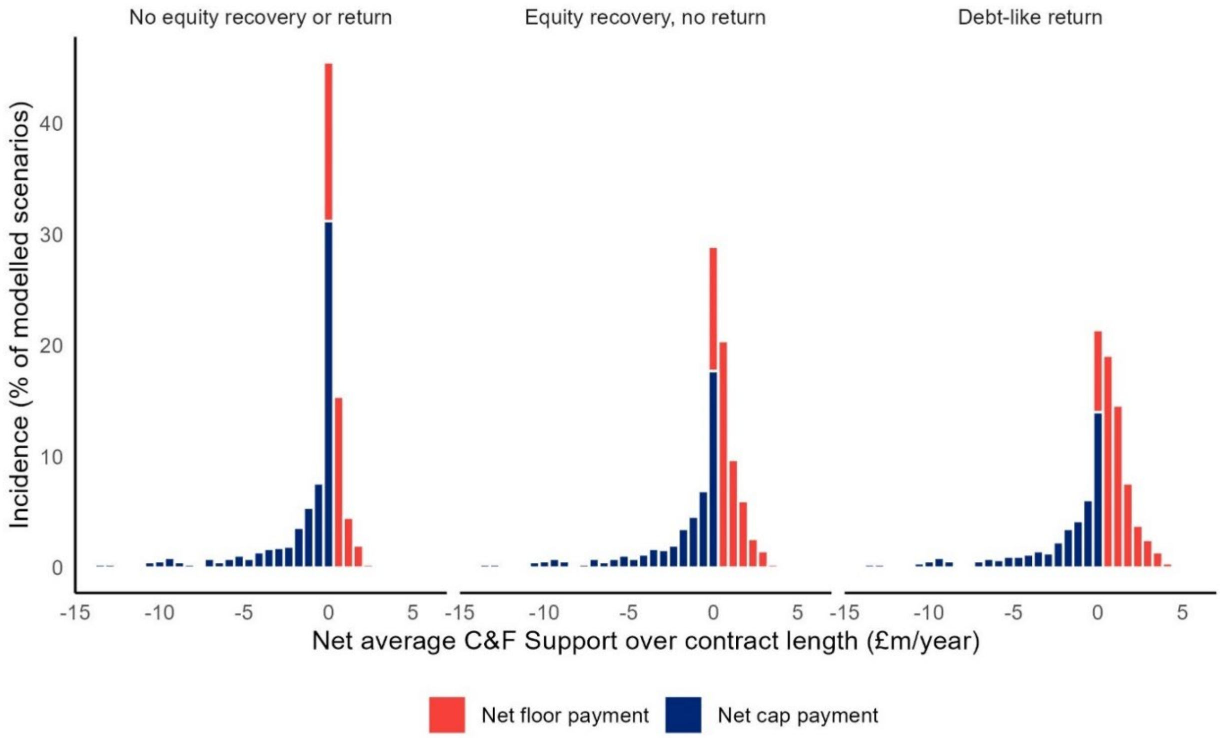
Appendix Figure C.3: Distribution of project returns for Li-on archetype under different equity return options at floor



CEPA/ESP analysis

Note: Vertical lines show the 10th percentile, mean, and 90th percentile of modelled project IRRs

Appendix Figure C.4: Distribution of net average cap and floor support for Li-on archetype under different equity return options at the floor



Source: CEPA/ESP analysis

Note: Net cap and floor support is discounted using a 3.5% discount rate. Negative cap and floor support represents cap repayments.

UK

Queens House

55-56 Lincoln's Inn Fields

London WC2A 3LJ

T. **+44 (0)20 7269 0210**

E. **info@cepa.co.uk**

www.cepa.co.uk

Australia

Level 20, Tower 2 Darling Park

201 Sussex Street

Sydney NSW 2000

T. **+61 2 9006 1308**

E. **info@cepa.net.au**

www.cepa.net.au

Cepa-ltd **@cepaltd**