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BARRIERS TO FINANCING ADAPTATION ACTIONS IN THE UK

An evidence report

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CONTENTS

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EXECUTIVE SUMMARY

OBJECTIVES OF THIS REPORT

The Climate Change Committee (CCC) commissioned this report to add to the existing evidence base about the barriers to adaptation financing in the UK. A particular focus was given to private sector financing of adaptation, given the relative lack of evidence in this area.

This report, written by Frontier Economics and Paul Watkiss Associates, sets out the findings from the literature and a series of case studies in order to draw conclusions and recommendations for overcoming barriers to financing adaptation projects.

The report will feed into the CCC's wider adaptation work programme and in particular ongoing work around what policy actions could deliver the necessary investment in adaptation and indicators of progress on adaptation. The report provides a series of recommendations for consideration by the CCC. These recommendations are not intended to be exhaustive of all possible recommendations. They cover the particular evidence examined in this report. The CCC may also wish to consider recommendations in other areas of adaptation financing that fall outside the scope of this work (e.g. public funding, international dimensions of adaptation and financing).

STRUCTURE OF THIS REPORT

The report is divided into three sections:

1. The first section summarises the results of a rapid literature review to identify the major barriers preventing investment in adaptation in the UK.
2. The second section discusses a mixed set of case studies, with a diversity across the type of risks (e.g. to buildings, natural environment, infrastructure), investment type (public, private or mixed) and finance model applied (e.g. borrowing, customer financed, matching approaches).
3. Finally, the report discusses a set of policy recommendations which are based on learnings from the literature review and the case studies.

There are also three annexes alongside an extensive bibliography. The first annex provides a more detailed description of the findings from the literature review. The second annex provides more detailed descriptions of the case studies, and the third annex sets out some specific detail about sustainable urban drainage systems.

FINDINGS FROM CASE STUDIES AND LITERATURE REVIEW

CONSENSUS EXISTS IN THE LITERATURE THAT THERE ARE SIGNIFICANT BARRIERS TO INVESTING IN CLIMATE CHANGE ADAPTATION IN THE UK

The review of the literature established that adaptation financing is hindered by the existence of multiple barriers. These barriers are more pronounced in some areas (for example, such as revenue related barriers in nature environment projects), and less pronounced in others (for example, those with supportive

regulation), but there is a consensus from the literature that investing in adaptation (particularly in the private sector) is currently difficult. The barriers are discussed further below, and in detail in the main report.

THE CASE STUDIES SUPPLEMENT THE LITERATURE REVIEW WITH NEW EVIDENCE

The review of the evidence in the literature highlighted a lack of first-hand evidence about the successes and the barriers faced in the UK by projects involving adaptation investment. Gathering evidence for these case studies involved primary data collection by engaging with stakeholders from various sectors in order to bring together a set of evidence that is otherwise spread across many projects and firms.

Case study information was drawn from desk research and interviews with relevant stakeholders. The case studies were selected to ensure diversity across the dimensions of sector, risk area, and financing type. The table below shows the case studies and additional stakeholder input contained within this report.

TABLE 1 CASE STUDIES AND ADDITIONAL STAKEHOLDER INPUT

CASE STUDY	SECTOR	RISK	FINANCING
Water case study	Frontier's expertise in the Water sector, plus two sub-case studies.		
Wessex Water	*Water*	*Droughts and flooding*	*Private*
Anglia Water	*Water*	*Droughts and flooding*	*Private*
Platforms case study			Includes two sub-case studies
EnTrade	*Water*	*Threat of droughts and flooding*	*Blended*
Landscape Enterprise Network (LENS)	*Water*	*Biodiversity loss / resilience, flood risk*	*Private, Public*
Nature case studies			
Californian Resilience bonds	Forestry	Wildfires	Blended
Kent Downs	NBS	Biodiversity loss, Carbon sequestration. Flooding.	Public
Other case studies			
Glasgow tenements renovation	Housing	Extreme cold and extreme heat due to changing weather conditions. Increased rainfall	Blended
Climate Resilience Demonstrator (CReDo)	Digital	Flooding risk to infrastructure (Energy, water, telecoms sectors)	Public
Abundance Investment	*Not adaptation – focus is on the financing model of place based crowdfunding*		Private finance (for public bodies)
Ignition: SUDS	Water	Floods; Habitat degradation; Health impacts	Blended
Additional stakeholder input			

CASE STUDY	SECTOR	RISK	FINANCING
Inspired Villages	*Housing*	*Extreme cold and extreme heat due to changing weather conditions.*	*Private*
Wyre River catchment	*NBS*	*Biodiversity loss and habitat destruction, Carbon sequestration. Flooding.*	*Blended*
Trafalgar Fisheries	*Environment*	*Increases in water temperature resulting in greater infectious disease prevalence amongst fish.*	*Private*

Source: Frontier Economics

THE EVIDENCE FROM THE CASE STUDIES, ALONG WITH THE LITERATURE REVIEW, PROVIDE A CLEAR ARTICULATION OF SOME SUCCESSES AND SIGNIFICANT ONGOING BARRIERS

The case studies illustrate many successful efforts to establish adaptation measures in areas ranging from housing to the natural environment. The case studies suggest a large number of elements within the current framework that work well. For example: improving communication between stakeholders, increased development of projects that are specific to local circumstances, a flexible approach to developing projects and engaging stakeholders, and increasing learning from each other.

There continue to be significant barriers alongside the notable successes. Taking the evidence relating to barriers in the literature review, and supplementing with those articulated in the case studies, this report has created a typology for barriers facing adaptation projects in the UK; with successes discussed below. The barriers are presented individually, but they will also involve interdependencies and linkages. The key barriers faced in financing climate change adaptation projects in the UK include:

- **Markets and revenue:** Many adaptation measures do not create revenue streams (either positive revenues or cost savings), or a financial rate of return. Finding revenue to repay finance is challenging. This was reinforced from evidence in the case studies, where stakeholders noted that often the fundamental difficulty with financing adaptation project is finding revenue streams. Adaptation projects can take time to develop and establish benefit or revenue streams, which makes financing difficult even when the adaptation is reactive. Furthermore, investments designed to prevent costs in the future (anticipatory adaptation) are hard to fund publicly (e.g. due to uncertainty, discounting and coordination required in public projects) or privately (given the expected rate of return for private sector projects).
- **Information and lack of support available:** There are barriers to investing in adaptation because of the information gaps (information failures) around future climate risks, but also information gaps about the effectiveness and benefits of adaptation measures. Future investment is dependent on this willingness to pay, which is affected strongly by the level of awareness, understanding and engagement with adaptation issues. This was highlighted in the case studies, where stakeholders described the challenges of getting adaptation investments approved due to the higher uncertainty and information gaps that existed around them. There also exists uncertainty about the exact costs and benefits of each project, often caused by a lack of precedent. Most adaptation projects are context and site

specific, and costs and benefits from one project can not necessarily be translated to another.

- **Bankability (project structuring preparation and risk, including co-ordination failures):** A general barrier is that adaptation projects currently tend to take more time and resources to develop than other projects, such as mitigation projects. This is because of the site and context specific nature of adaptation projects, and the greater complexity in assessing benefits. Similarly, adaptation often involves numerous stakeholders, or many diffuse actors, which complicates financial structuring (co-ordination failures). This was particularly pronounced in case studies that involved both private and public funding. It is more difficult to develop investment ready adaptation projects, as well as more difficult to subsequently get them financed, compared to other investment projects. There is also a lack of skills to undertake the development of projects, and among financiers of potential projects.
- **Regulation**: Investing in adaptation, especially in innovative areas, sometimes requires changes in regulatory frameworks or permissions. These regulatory issues can be a significant barrier to project developers, but also act as a barrier to investors until they are resolved. The evidence from stakeholders in the case studies highlighted the challenges that regulation can create for adaptation project, but also highlighted how future regulation can support future adaptation projects.

THESE BARRIERS, ALONGSIDE THE SUCCESSES, SUGGEST A SERIES OF RECOMMENDATIONS TO HELP INCREASE FUNDS AVAILABLE FOR ADAPTATION

These barriers to financing adaptation measures, as well as learning from successes, suggest recommendations. Below we list the recommendations under each category of barrier. A full discussion of the recommendations and their motivation is in the main report. A condensed summary is provided here.

The recommendations were discussed in draft form with many stakeholders and adjusted in light of feedback. We have chosen not to include an indication of how widely particular recommendations were supported. We have not included previous draft recommendations that received no support. Where there has been debate we have used our judgment and experience, along with the evidence from the case studies and literature review, to decide whether and how to frame recommendations.

These are not intended to be a comprehensive list of recommendations needed to solve adaptation financing. The CCC may want to add further recommendations based on its thinking and review of areas beyond the scope of this work (e.g. areas of significant existing funding such as flood defence or the UK's role in funding adaptation efforts overseas).

Markets and revenue

Given the prominence of the barrier relating to the difficulty of finding revenue streams for adaptation projects, many of the recommendations address the issue of identifying and capitalising on revenue streams. Understanding financing need and building up an inventory of business models will be key to unlocking future investment.

Evidence from the literature and case studies indicated the importance of public finance in regards to both de-risking private investments and providing public funds through blended financing. This can be particularly useful in cases where the economic benefits of adaptation are larger than the private financial benefits or revenue streams (positive externalities), or to help in de-risking of private sector adaptation..

Recommendations cannot create revenue streams but they can help to better understand the nature and scale of the issues and who is best placed to help meet the need.

> **Recommendation #1:** Work should be undertaken, by the CCC and Defra, to identify the financial benefits and revenue streams from adaptation measures, by sector and risk, aligned to the priorities in the NAP. There is a need for the government to review how to assist the creation of markets and additional revenue streams This work should allow the next NAP to extend beyond its historic list of actions and owners to also consider the funding of those actions.
>
> **Recommendation #2:** Defra should request each Department estimate its funding requirements for adaptation measures as part of the NAP process.
>
> **Recommendation #3:** Defra should update the Adaptation Reporting Powers (ARP) to ask reporting firms to set out information on adaptation costs and financing.
>
> **Recommendation #4:** The terms of reference for the fourth Climate Change Risk Assessment should include explicit reference to the improving understanding of the financing gap, drawing on this and related evidence.
>
> **Recommendation #5:** The CCC should identify public bodies (notably local authorities) that are well placed to de-risk projects through co-financing and the extent to which they are constrained through existing regulations, rules or other barriers from doing so.

Information and support

The case studies highlighted the significant impact that informational barriers can have on adaptation projects, which was further evidenced in the literature review. These recommendations focus on the key ways in which projects can be facilitated through the dissemination of information relating to adaptation projects, through the use of project preparation facilities and the development of institutional mechanisms which can highlight to investors opportunities that could be good quality investments.

The recommendations in this section focus on how to reduce the informational barriers faced by those considering investment into adaptation project, helping to support those projects. This includes through targeted actions local and central government can make to help align their public sector funding for new investments most effectively.

> **Recommendation #6:** Defra should identify, and then implement and champion, the best institutional mechanism to deliver adaptation project and financing advice and support. There are a number of examples to draw upon, for example: support and funding provided by UK Research and Innovation through Catapults and Challenge Funds, the models developed by What Works Centres, more bespoke teams within departments (e.g. BEIS support for hydrogen investments, BEIS/DfT support through the Office for Zero Emission Vehicles). These provide options that could be drawn upon to provide more focused support for adaptation projects and their financing.
>
> **Recommendation #7:** a kite-mark or similar scheme should be set up to certify trading platforms and similar activities that support new investment opportunities.
>
> **Recommendation #8:** the CCC should undertake a stock-take of whether the main public sector lenders and funders (e.g. HM Treasury, UK Infrastructure Bank, British Business Bank, local authorities) are properly incorporating climate risk management into their review of business cases

and funding decisions. Based on the findings of that stocktake, also informed by international best practice, recommendations should be made about how to improve consideration of climate issues in public funding.

Bankability

These recommendations relate to the importance of some of the practical elements required to facilitate adaptation investment, and shorten the process of preparing adaptation projects. Many coordination failures were identified in the case studies, particularly those involving multiple asset operators. Support to reduce coordination issues is important to developing bankable projects. These recommendations are linked to the aforementioned information and support recommendations, but focus more on supporting coordination of projects after the point of inception and raising the public's awareness of the growing climate risks in order to raise their willingness to pay.

Recommendation #9: The Cabinet Office should clarify and codify how sensitive information can be shared between infrastructure providers for the purpose of resilience. This could be by certifying independent third parties to hold and aggregate such information or through other means.

Recommendation #10: Business case guidance and best practice in Defra and elsewhere in the public sector, should proactively look for opportunities to stimulate adaptation financing in emerging Government policies.

Recommendation #11: Defra should develop a specific communications strategy (potentially informed by public surveys and other engagement) for how to discuss the financial consequences of climate risks and measures that will be required to address them. Such a strategy should give particular consideration to the distribution of the risks (and costs) to ensure it is appropriately focused on those most vulnerable.

Regulation

The need for changes to regulation came out strongly in this report's evidence review, and particularly in the case studies. Our case studies identified that certain areas of regulation have hindered the progress of adaptation while the case studies also showed an opportunity for future regulation to play a key role in facilitating larger flows of adaptation investment.

Recommendation #12: Infrastructure regulators (e.g. Ofwat, Ofgem, Ofcom) should move more quickly towards a fully outcome-based approach to regulation to support adaptation outcomes.

Recommendation #13: A systematic review of building regulations — including guidelines for planning and related consents —should be undertaken by the Department for Levelling Up, Housing and Communities to identify measures that are inconsistent between different types of buildings or not consistent with proper preparation for climate change.

1 INTRODUCTION

The availability of finance is an important constraint to measures designed to adapt to climate change. Globally, there has been a major uplift in climate finance flows for mitigation (actions to reduce greenhouse gas emissions) but the level of adaptation finance is much lower (estimated at about 5% of total flows).. Furthermore, adaptation funding has primarily come from the public sector and delivered through grants (Climate Policy Initiative, 2021).

This report, undertaken over a two month period by Frontier Economics and Paul Watkiss Associates, seeks to explore the barriers to financing adaptation projects, with a particular focus on how those barriers manifest in the UK. The report is divided into three section: a rapid review of relevant literature, a series of case studies looking at adaptation finance and recommendations drawn from the literature and case studies that, if implemented, would help overcome some of the barriers to financing adaptation measures.

1.1 REVIEW OF LITERATURE

The first section summarises the results of a rapid literature review of the academic and grey literature to identify the major barriers preventing the investment in adaptation in the UK. This includes a clear typology that categorises the main barriers, in addition to the types of investment. The rapid literature review investigates which barriers correspond to which types of finance, identifying where differences and similarities lie. In addition, the rapid literature review investigates the differences between the barriers faced by different sectors.

1.2 CASE STUDIES OF ADAPTATION FINANCE

The second section discusses a mixed set of case studies, with a diversity across the type of risks (e.g. to buildings, natural environment, infrastructure), investment type (public, private or mixed) and finance model applied (e.g. borrowing, customer financed, matching approaches). A variety of case studies have been chosen to ensure that a wide set of policy recommendations can be considered. Where possible, cases studies with innovative funding models have been selected.

The case studies are the result of desk research and in-depth stakeholder interviews. The annex contains the full case studies with summaries provided in the main report.

1.3 RECOMMENDATIONS TO IMPROVE ADAPTATION FINANCE

Finally, a set of policy recommendations are presented. They are based on learnings from the literature review and the case studies.

The recommendations are grounded in the evidence, specific in terms of sector and finance type, and target a particular barrier. The set of recommendations are varied, to avoid focusing too much on one barrier. The recommendations identify, where possible, the organisations who should be responsible for implementing the actions. They are not intended to be comprehensive of all recommendations or changes required to stimulate adaptation financing. They focus on the scope of evidence and work covered in this report.

2 EVIDENCE FROM THE LITERATURE

The literature review considers all sources of financing for adaptation, including from the private sector, public sector and from blended sources. Similarly, all financial instruments are included including grants, debt, equity and other. This follows the convention in the adaptation finance literature (Climate Policy Initiative, 2021) and uses '*finance'* as a broad term to represent all investment in adaptation.

Financing and funding are sometimes defined differently in the literature. Funding is sometime defined as money (especially grants) that is provided by government or the public sector. Finance can be defined as capital raised from financial institutions or other lenders (such as debt) which requires repayment. The term 'finance' for all investment is therefore used in this report, although the differences between public and private sources and various instruments are noted. The box below provides more detail.

Funding and financing – terminology

This study includes all sources of funding and financing for adaptation from the public, private and third sectors, and all financial instruments including grant, debt, equity and other. This follows the convention in the adaptation finance literature (see CPI, 2021) and uses '*finance*' as a broad term to represent all investment in adaptation. Financing and funding are sometimes defined differently. Funding is sometime defined as money (especially grants) that is provided by government or the public sector. Finance is often defined as capital raised from financial institutions or other lenders (such as debt) which requires repayment. However, these definitions might be confusing here, for example, public funding of adaptation can be through debt that has to be repaid. We use the generic term of 'finance' for all investment in adaptation but note the differences between public and private sources and various instruments.

The study has undertaken a rapid literature review of the barriers and constraints to adaptation financing. This has considered the literature from the Intergovernmental Panel on Climate Change (IPCC), which has a strong focus on technical and socio-institutional factors, but also includes the economics literature, which primarily considers barriers as market failures. It has also considered an emerging literature on the practical issues of adaptation programming and financing (sometimes termed bankability).

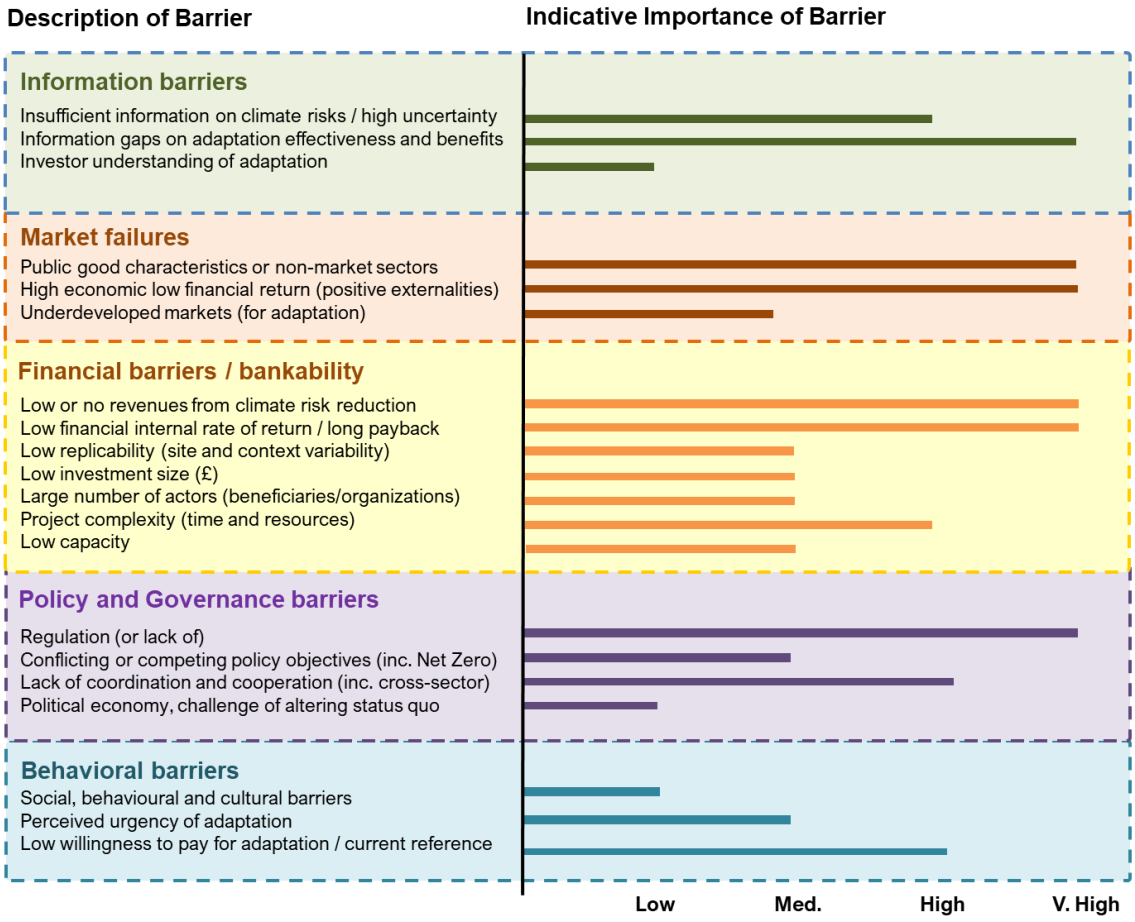
This review has identified five major groups of barriers:

- Information gaps;
- Economic (market failures);
- Financing and bankability;
- Policy, regulatory and governance;
- Social and cultural.

Within each of these groups, a number of barriers and constraints have been identified. The importance of each of these has then been ranked, based on the literature review findings (the number of studies where the barrier is mentioned, and any evidence on magnitude), as well as the findings about the barriers experienced from the case studies. The overall scoring is presented below. Given the small evidence base, the ranking should only be considered indicative.

The importance of individual barriers will vary with public and private projects, for example, to raise private finance for adaptation, a revenue stream is likely to be a key condition. They will also vary with sector and risk, and for each adaptation project, due to the type of adaptation, finance sources, organisations, etc. The barriers are presented individually, but they will also involve interdependencies.

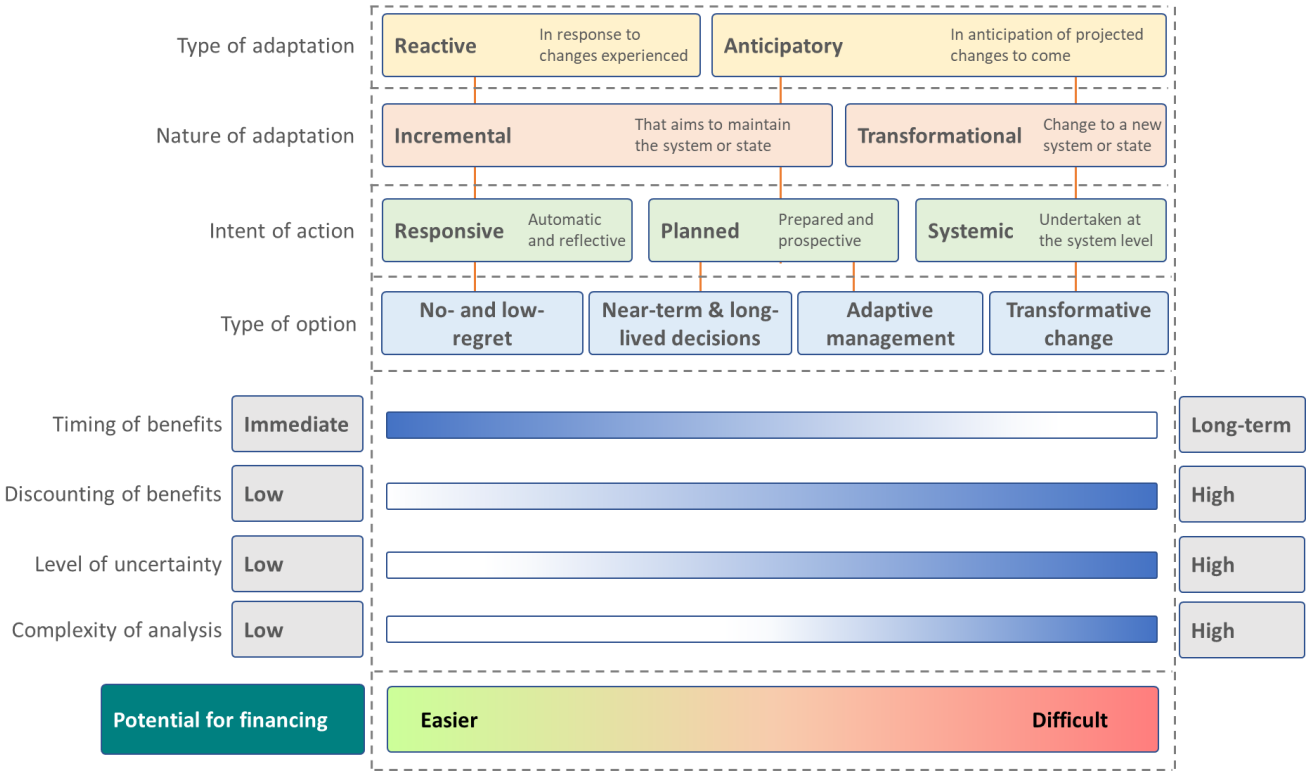
FIGURE 1 BARRIERS TO ADAPTATION FINANCE AND INDICATIVE IMPORTANCE



Source: (Watkiss, 2022)

The type of adaptation strongly influences its financing potential. The importance of the barriers above will vary with the type of adaptation. Adaptation can range from reactive to anticipatory, and from incremental to transformational. These involve different challenges for financing, as shown in the figure below (from Watkiss, 2022). In general, it is more difficult to finance adaptation as one moves from left to right. It is easiest to finance no- and low-regret, reactive and incremental adaptation (left) and more challenging to finance anticipatory and transformational adaptation (centre and right). This will be the case for both public and private sectors. However, it will be exacerbated for private finance, which is thus likely to gravitate more towards the left, due to its preference for earlier benefits (return) and lower risk appetite. These challenges will also influence the financial instruments needed for adaptation, and it is likely that a larger proportion of grant finance will be needed to deliver adaptation in the centre and right.

FIGURE 2 TYPOLOGY OF ADAPTATION, KEY BARRIERS AND FINANCING CHALLENGES



Source: (Watkiss, 2022)

How much finance is needed? There are no aggregate estimates of the costs of adaptation for England or the UK, and thus no reliable estimates of financing needs. This is highlighted as a key gap and feeds into our recommendations.

Sources and Instruments for financing A further issue is around the potential sources of finance (public, private, third sector, blended), and the incentives for different actors to finance adaptation, as well as the financial instruments involved (grants, loans, equity, guarantees, etc.)

At the global level, climate finance analysis (Climate Policy Initiative, 2021) reports that public finance dominates current adaptation finance flows, and primarily uses grants, concessionary, and commercial loans (debt), although there is relatively little data on private flows. It is expected that this pattern also applies to England and the UK. The public financing of adaptation is generated from government budgets, taxes or charges, and borrowing from public and private financial institutions. Note that while it is possible to raise finance for adaptation from the private sector, for public sector adaptation, there is still the question of who pays (i.e., how debt finance is repaid).

There are also reasons why the private sector might invest and finance adaptation for its own interests. These could include defensive expenditures to protect revenues or assets (e.g., on-site protection), or it could be investment to reduce costs (e.g., water efficiency to respond to rising risks and charges). However, it may also act to take advantage of new adaptation services or goods in response to emerging risks (whether by extending existing market offerings, e.g. new insurance products, or creating new opportunities, e.g., selling household resilience), often called the adaptation economy. The private sector can also be incentivised to adapt through regulation or through economic or financial incentives. These various activities can be financed internally or through financial institutions.

A summary of the landscape on who finances and who delivers adaptation is presented in the figure below. While there will be a need for public investment and financing of adaptation (top left) and there will be self-interested private investment (bottom right), the area between these two is of particular interest, in terms of blended finance. This involves a range of new instruments and approaches that seek to blend public and private-sector finance, including using public finance to help unlock private sector investment. This can involve early-stage support (e.g., technical assistance or innovation funding, including from incubator or accelerator models) and de-risking investment by offering grants, concessional lending, guarantees or equity. Of course, many of the barriers outlined above will vary with where an adaptation investment sits in this matrix.

This also raises an interesting issue. While it might seem that public finance for adaptation will need to concentrate on public goods, non-market sectors, etc., as the private sector will underinvest in these areas, there is also a need for public finance to support blended finance solutions and to support more innovative adaptation (including transformational adaptation). This raises a question of how best to use available public finance.

FIGURE 3 TYPOLOGY OF ADAPTATION FINANCING

		Who delivers the adaptation?	
		Public	**Private**
Who finances the adaptation?	**Public**	Public funded project delivered by public agency, *e.g. flood defence funded through public budget, local charges or taxes, or public financial institution*	Procurement of private company to deliver public adaptation, *e.g. coastal defence project funded from public budget uses private contractor.*
	Blended	Co-financing between public (or public financial institution) and private investors or financial markets, *e.g. PFI, potentially co-financed with private investors.*	Public finance used to de-risk private adaptation, *e.g. technical assistance, innovation grants, concessional loans, equities, guarantees.* Public private partnership (PPP) arrangements.
	Private	Private finance to provide funding, *e.g. loan from private financial institution, or green bond, or crowdfunding (including public crowdfunding).*	Private company delivering and funding own adaptation *e.g. flood protection of assets.* Private company develops new adaptation goods and services, *e.g. new insurance products* Private company raises finance from financial institution or investor, *e.g. debt, shares, equity*

Source: (Watkiss, 2022)

There are two additional issues that are raised in relation to adaptation financing, and that are important for the CCC to consider.

1 **Who pays?** There is large adaptation finance gap and adaptation costs (needs) are much larger than current finance flows. This gap cannot be bridged by the public sector alone. However, the potential for private finance to fill some of the gap raises the question of *who pays?* While it might be possible to raise finance (e.g., bonds or loans) from the financial markets to fund local government adaptation, repayment to investors will need to come from government budgets, avoided costs or increased revenues. Similarly, regulated companies may invest and finance adaptation, but this is passed through to household customers through increased charges. This leads to the second, related, issue.

2 **Distributional issues and justice**. While CCRA3 and other studies have looked at the inequalities associated with climate risks, there has been less attention on these issues for adaptation. Adaptation involves issue of 'justice', as raised strongly in the IPCC AR6 WGII

report, and these will apply to finance. As set out above, the ease of financing will make adaptation investment 'lumpy', especially for private finance that is likely to gravitate towards low- and no-regret actions in market sectors. Left to the market, adaptation finance is unlikely to have positive distributional aspects or target the most vulnerable. There may therefore be inequalities around access to adaptation finance (and funding).

Financing barriers by type, sector, risk and group. The barriers to financing will also depend on the risk and sector, the sources of finance, the organisations involved, and the financial instruments. The review explored these issues through a number of case studies.

The multi-lateral development banks (MDBs) have programmed some of the largest volumes of adaptation finance to date globally. They have developed typologies for categorising adaptation investment projects and adaptation finance. These differentiate investments into i) where adaptation is the primary objective, e.g., adaptation projects that are targeted at reducing climate risks, and ii) where adaptation is a secondary objective, often associated with climate proofing, i.e., making planned investments climate resilient. These involve different implications for financing, e.g., for climate proofing, there will be an existing financial structure and the level of adaptation finance will be small when compared to the core investment. The focus is thus on mainstreaming adaptation into an existing financial model and instruments. For an adaptation project, the reduction in climate risk (or other benefits) has to deliver the revenues and cash flow for the project. These delineations are also important in terms of adaptation finance tracking, noting adaptation projects are often labelled as 100% adaptation while climate proofing projects are not (e.g. see the EU Taxonomy and the forthcoming UK version).

There is also the potential for private finance to be a complement to public finance for coastal and river flooding projects. The literature reviewed for this study found some potential for additional finance (or blended finance solutions), the additional flows were modest and also highly site and context specific, and accessing non-public funding required considerable time and resources. Further, it was found that the additional revenues generated were often not associated with climate risk reduction, but were co-benefits, for example carbon sequestration or tourism revenues. While this can be positive, it may also make projects more complex, due to competing objectives, as well as multiple beneficiaries. Overall, the study found it was difficult to convince project developers to move away from conventional public funding sources for adaptation, and reinforces the findings above on low returns and preparing investment ready projects (bankability) being key barriers.

The CCC Advice report (2021) presented the economic benefits of a number of early adaptation measures, showing the high benefit to cost ratios for a selection of interventions (mostly low- or no-regret options). This case study expanded this analysis to investigate the potential financial attractiveness of these options. The overall finding is that the financial return of most of the options is much lower than the economic return. They are either focused on public goods (e.g., heat alerts) or the economic return is driven by environmental benefits, rather than their financial return (e.g., climate smart agriculture). This reinforces the barrier findings above, on the importance of revenues and financial returns.

The literature also explores barriers in terms of how they might differ by sector and risk. This highlights the financing barriers related to the nature of the sector, and the public-private focus. It undertook a deep dive on a particular risk (heatwaves) and the potential financing of adaptation options for this risk. This identified clear differences in financing potential according to the specific risk and adaptation objective, rather than the hazard per se, and thus in the barriers faced. To illustrate, there are major differences in barriers for financing overheating and public health risks versus overheating and comfort in homes. A key insight of this case study is that financing barriers and solutions even for a specific risk (hazard) will vary with the

adaptation intervention and objective, and even within a risk area, there is likely to need to be a portfolio of financing solutions to deliver effective adaptation.

2.1 SUMMARY

Based on the overall literature review, the barriers which have been identified as the most important to the financing of adaptation are:

- **Revenues and return:** Many adaptation measures do not create revenue streams (either positive revenues or cost savings), so finding revenue to repay finance is challenging. This is driven partly by the nature of adaptation, e.g., its focus on public goods, in non-market or in public dominated sectors. It is also driven by the challenges in generating revenues from climate risk reduction, even in market sectors. Where revenues are generated, the rate of return is generally low. While it is possible to look at alternative revenue streams (e.g., co-benefits from carbon credits, tourism revenue) this dilutes the adaptation focus, and makes projects complicated.
- **Discounting:** There are a range of barriers related to the timing of the investments. As highlighted above, investments designed to prevent costs in the future (anticipatory adaptation) are harder to finance. Adaptation projects often take time to develop, or to establish benefits streams, which make financing more difficult even when adaptation is reactive.
- **Information gaps, uncertainty and risk appetite:** There are barriers to investing in adaptation because of the information gaps (information failures) around future climate risks, including uncertainty, and thus benefits of anticipatory adaptation. However, more importantly, there are also information gaps around the effectiveness and benefits even for no-regret adaptation. It is clearly more difficult to finance projects when benefits are uncertain, and this may mean investors seek a high rate of return, or else requires public de-risking (blended finance).
- **Project structuring, coordination, and preparation:** A general barrier is that adaptation projects tend to take more time and resources to develop. The issues of information and uncertainty above are compounded by the site and context specific nature of adaptation, and there are often additional legislative and due diligence issues. This is further exacerbated by the fact that adaptation often involves numerous stakeholders, or many diffuse actors, complicating financial structuring. This means there is low transferability and generally more detailed financial assessment, risk analysis and due diligence is needed. All of these increase project financing costs, and disincentivise project developers and financiers. It is more difficult to develop investment ready projects (bankable projects) as well as more difficult to subsequently get them financed.
- **Regulation:** Investing in adaptation, especially in innovative areas, sometimes requires changes in regulatory frameworks or permissions. There can also be issues about the governance around mandated responsibilities for risks and the risk reduction, that may prevent new entrants. These regulatory issues can be a significant barrier to project developers, but also act as a barrier to investors until they are resolved.
- **Perception and willingness to pay:** Scaling up adaptation finance will involve persuading households and business to pay to reduce risks or realise savings associated with climate change. Adaptation is usually an extension of an existing climate problem (variability and extremes) and in many areas, society is currently used to government funding risk reduction. In such cases, there may be barriers in persuading people to pay for services previously provided by the state, or people's willingness to pay may be too low to justify investment. In some cases, there may be a willingness to pay through tax revenues (i.e households and business are happy for the government to invest in adaptation using tax revenues), but the incentives are not strong enough for them to want to invest directly. This willingness

to pay will be impacted significantly on the level of awareness, understanding and engagement with adaptation issues.

3 CASE STUDIES OF ADAPTATION FINANCING AND ITS BARRIERS

3.1 INTRODUCTION

The case studies build on the learnings from the literature review. The aim of these case studies is to understand the barriers each of the adaptation projects faced in terms of financing and to understand the projects' effectiveness.

The case studies are the result of desk research, and discussion with stakeholders. Based on the literature review and discussions with a core group of stakeholders, including members of the Adaptation Committee, over 30 stakeholders were contacted as possible sources for case studies. Possible case studies were discussed with over 20 of these stakeholders to generate a long-listing of possible case studies.

To move from the long list to a short list of case studies the strength of the available evidence for each case study was balanced with the overall aim to create a diverse set of case studies across the following dimensions:

- **Large focus on the UK, but with regional diversity** – given the focus on UK policy recommendations, attention was given to drawing on a set of case studies from around the UK. Some non-UK evidence was included where deemed relevant to the UK.
- **Mixed set of investment types** - large focus on the private sector in the UK, however given the importance of blended finance in the climate change adaptation space, public sector case studies were also explored.
- **Types of risk** – case studies were prioritised on the basis of ensuring that the risks the adaptation projects were addressing came from a range of sectors (housing, infrastructure, natural environment).
- Where possible, cases studies with **innovative funding** models have been selected.

The short-list of case studies were developed in-depth. At the same time, the work revealed a number of other interesting examples which are used to supplement the detailed cases studies but are not explored in as much depth. A detailed overview of the case studies is provided in the annex to this report. This section provides an overview and focuses on drawing out the themes across the case studies in order to support subsequent recommendations.

3.2 SUMMARY OF CASE STUDIES

This section provides a high-level summary of each case study. Each summary provides a brief overview of the case and then draws out the key learnings and themes both within and across case studies.

3.2.1 GLASGOW TENEMENTS – FINANCING ADDED ADAPTATION MEASURES WHILE RENOVATING PUBLIC HOUSING

A single tenement building consisting of eight housing association flats in Niddrie Road, Glasgow was renovated between February 2020 and November 2021. The renovation project received blended finance, comprised of public grant funding and private financing through tenant rents, in order to both reduce greenhouse gas emissions and also some risks from ongoing climate change.

The project faced financial, regulatory and informational barriers. These included:

- Lack of financing for adaptation measures even though they would be lower cost to install at the same time as other renovations were taking place
- Difficulty getting regulatory approval for changes to aspects of the building structure despite their help in reducing climate risks (and approval being available in other circumstances)

An important characteristic of this project was that it was carried out on the whole building. In contrast, it is more common to renovate flats one at a time (as they are vacated or change ownership). Southside Housing Association, and other housing associations, may only rarely have entire buildings free of tenants, although it may occur more frequently in private owned buildings where owners can coordinate tenant leases more readily. It could also be planned to occur in housing associations, who may aim to roll property stock such that whole buildings can be vacant for reforms at the same time potentially through the use of temporary housing. So some of the lessons learned may be more applicable to private buildings. However, even when individual flats are renovated, this case study illustrated the ability for public finance to unlock additional adaptation measures (where the private finance may focus on renovation for other purposes) shows how public sector financing can create additionality to privately financed projects to add adaptation measures into projects. In this case, incremental public finance allowed the renovations to include adaptation measures designed to future proof the tenement against extreme weather, as well as measures to improve the building's energy efficiency.

Emerging themes and learnings

Key learnings from the Glasgow tenements case study include the importance of undertaking retrofitting on multiple homes to achieve scale and reduce the retrofitting cost per home, where possible. Therefore findings ways to facilitate whole building transformation on other retrofitting projects will be crucial for scalability.

Secondly, this project illustrates the role that public funding can play by ensuring adaptation measures are added to the planned mitigation measures that were privately financed. It also indicates that the existence of mitigation benefits can often pay for adaptation benefits in projects. Although this may result in a slightly lower return, and longer time horizons, the case study shows that encouraging investment in adaptation alongside mitigation can be facilitated through revenue flow of mitigation over time.

Third, the project illustrates how regulatory barriers to the project often exist regardless of the finance providing, suggesting that scalability often depends on regulatory approval for many measures.

3.2.2 INSPIRED VILLAGES – FINANCING SUPPORTED HOUSING FIT FOR THE FUTURE

Inspired Villages own and operate retirement villages across England which support independent and assisted living for those of retirement age. Inspired Villages are financially backed by a joint venture between two social impact investors: Legal & General, and NatWest Group Pension Fund. They have spotted a market opportunity from customers who are willing to pay for thermal comfort and for lower bills that are available at operationally Net Zero retirement villages with energy efficient features.

However, the financing of these new homes depends on project developers and buyers having a longer-planning horizon (around 50 years) than typical housing developments. These longer time horizons ensure that the houses are being built with future climate change scenarios in mind, instead of the short term guarantees of a few years normally built into new build open stock housing. That may be a barrier to

scalability as not all developers have an incentive to have such longer term planning horizons. Whilst the focus of the villages is on achieving net zero, adaptation measures considered in the planning and design included ventilation measures and designs to reduce overheating.

Emerging themes and learnings

Key learnings from the Inspired Villages case studies include the willingness of some customers to pay the extra money required to obtain comfort from properties which can offset extreme weather. This is combined with Inspired Villages' business model under which the properties are provided leasehold and are eventually returned which helps to provide incentives to the operator to consider the longevity of the properties and their resilience against extreme weather.

3.2.3 PLATFORMS – BRINGING TOGETHER DEMAND FOR AND SUPPLY OF ADAPTATION MEASURES

Platforms can facilitate the matching of buyers and sellers of projects with adaptation benefits, including projects such as landscape management and nature-based solutions. These projects are typically characterised by a focus on operating expenditure, or opex, rather than capital expenditure, or capex. The platforms typically bring together buyers and enable the alignment of common incentives. In addition, the platforms can enable the stacking and aggregation of environmental products. Buyers may participate for regulatory reasons, such as housing developers buying environmental credits to meet biodiversity net gain regulation. On the other hand, buyers may participate to meet self-imposed objectives, such as food manufacturers who wish to minimise the risk of the flooding of their buildings.

EnTrade and LENs are similar because both platforms support catchment areas which produce a range of environmental outcomes. However, the platforms are different because EnTrade focuses on environmental outcomes which are sufficiently fungible to be turned into a credit and traded, whereas LENs supports environmental outcomes that don't have to be turned into credits. The three outcomes which EnTrade currently focus on are carbon, Biodiversity Net Gain and nutrient reduction. LENs offers these outcomes as well as additional outcomes which aren't currently credited, such as a resilient supply of crops. Therefore, LENs currently offers a wider range of environmental outcomes as it offers both credited and non-credited outcomes, whereas EnTrade only offer credited outcomes. As a result, there are a wider range of buyers within LENs' platform compared to EnTrade.

ENTRADE

EnTrade is a trading platform which creates and operates online markets for nature-based solutions. EnTrade currently focuses on two-sided catchment markets, which are markets containing multiple buyers and multiple sellers within the market. Sellers of nature-based solutions are typically farmers or landowners, and buyers can include housing developers. Housing developers participate to buy environmental credits, and this enables them to meet regulation requiring developments to have a net gain in terms of biodiversity. EnTrade's main catchment market is Somerset, with auctions matching buyers with funding to suppliers of adaptation and related services.

Challenges for EnTrade include long term monitoring of outcomes and the costs of verification. The difficulty monitoring outcomes is linked to uncertainty around the exact outcomes of catchment market projects. In terms of scalability, these types of projects can occur across the country. This would be helped if investor rules allowed the aggregation of different environmental services and benefits in a single product, which is also known as stacking. If stacking is permitted by the Department for Environment, Food and Rural Affairs, blended finance may support catchment markets in a financially sustainable manner. Some trades

could support outcomes which provide social and private value (e.g. flood risk mitigation), and private financing could support outcomes which provide primarily private value (e.g. financing in return for environmental credits). Adaptation measures supported by projects within two sided catchment markets include improved water quality and flood mitigation.

Emerging themes and learnings

Key learnings from the EnTrade case study include how informational barriers about future outcomes can deter buyers and regulators, as well as the importance of future rules (e.g. around stacking). Overcoming these barriers is critical to the scalability of platforms. The uncertainty is also a material issue for buyers, as they want suitable certainty regarding whether the purchased solution will work. Some initial investors may be willing to live with considerable uncertainty but attracting large numbers of investors will require greater certainty over the success – and potential returns – of such schemes. That is linked to whether staking is allowed because allowing a portfolio of measures to be brought together would be one way to reduce the riskiness of investing.

LENS

LENs facilitates the buying and selling of nature based solutions which deliver adaptation outcomes relating to water quality management, flood risk management, and soil health. LENs' business model aggregates demand for landscape management (e.g. food manufacturers, water companies) to facilitate supply side solutions (e.g. from action by farmers). Buyers, such as food manufacturers, participate to support projects which manage natural flooding to limit the risk of their factories flooding. LENs receives a management fee for facilitating transactions in the platform market. Barriers to financing LENs include lack of awareness of these landscape problems and the need to convince a range of authorities responsible for the different elements of the landscape to bring together their requirements. Other barriers to finance include a lack of an institutional framework, including co-ordination failure. The LENs model can be applied to many types of landscape wherever sufficient incentives exist, but scalability will also depend on the future institutional framework and how regulation evolves.

Emerging themes and learnings

In similar vein to EnTrade, future regulatory developments will be critical for trading platforms such as LENs given their nascency. The nascency of platforms facilitating nature-based solutions and landscape solutions, such as LENs, also means that the development of institutional capacity / frameworks will be key to their future scalability and sustainability. Another key factor for the scalability and sustainability of trading platforms is the informational barrier. Actors on the demand side of the market face barriers to investing in these trades, because it is complex to understand how each stakeholders can benefit from the landscape based approach and how to allocate the associated benefit and payments.

3.2.4 WATER SECTOR – ADAPTING THE REGULATORY FRAMEWORK TO IMPROVE RESILIENCE

Climate change could have a major impact on the water sector, for example by damaging water infrastructure, contributing to the overloading of sewers, and increasing the likelihood of droughts which reduce water availability. The water industry is subject to both economic (through Ofwat) and environmental (through the Environment Agency) regulation. Ofwat have made incremental changes to economic regulation in recent years to incorporate measures to improve resilience of the water sector and address climate change adaptation. However, there remain barriers to financing measures including continued bias towards capex projects over opex projects. Barriers to finance also include limitations on water companies collaborating

across sectors where cost effective solutions can be developed with non-water providers. In some cases, raising funds for projects with future benefits is hampered by too much focus on outcomes for current consumers.

Some companies have partially overcome these barriers using green bonds, which can enable water companies to raise financing for adaptation projects with longer term pay-offs. Another potential solution would further shift the regulatory framework towards outcome based environmental regulation. Increased focus on environment outcomes (allowing the companies more freedom to choose the specific actions or inputs they use) would provide water companies with greater flexibility, enabling them to choose solutions that deliver the biggest environmental and social benefits (across a range of dimensions) at the lowest costs, including cross-sector collaboration.

Emerging themes and learnings

Recent regulatory developments have helped to tackle barriers such as a bias towards capex projects over opex projects. A residual bias remains eliminating it would support the ability of water companies to invest in climate adaptation projects. Another key learning is the importance of clearer and coherent rules around what constitutes a green bond. This would help to ensure that green bonds are not seen as greenwashing and will be important for their scalability and sustainability.

3.2.5 CREDO – FINANCING DIGITAL TWINS TO IMPROVE COORDINATED RESPONSES TO CLIMATE THREATS

The Climate Resilience Demonstrator (CReDo) project is part of the UK's National Digital Twin programme. A digital twin (in this case) is a virtual representation of all the infrastructure in a particular area that then allows the simulation of future floods and their impact. The virtual simulation can be used to plan the best adaptation measures and, crucially, who is best placed amongst the various infrastructure providers to act most cost-effectively to prevent disruptions.

CReDO provides a climate change adaptation digital twin project that demonstrates how connected data can improve climate change adaptation and resilience across all infrastructure in an area in relation to flood resilience. The project has identified some key barriers to financing adaptation projects that involve cascading risks, and inter-dependent sectors. These include both informational barriers (that cause co-ordination failures), as well as behavioural barriers (given the issue of free-rider effects where everyone waits for another provider to invest in resilience).

Together these barriers lead to a financial barrier: the difficulty of obtaining funding to create the digital twin, as each infrastructure provider needs to be persuaded that it is in their interest to both fund and share information to allow the twin to be created. This project illustrates the advantages of an independent third-party bringing together multiple asset operators to address adaptation issues.

Emerging themes and learnings

Key learnings from the CReDo digital twin project include the importance of co-ordination and the usefulness of third parties to help stakeholders understand the benefits of such projects. Co-ordination will be a critical success factor for projects that operate across multiple industries.

3.2.6 MANCHESTER NATURAL CAPITAL PLAN AND THE IGNITION PROJECT: IMPLEMENTING SUDS USING BLENDED FINANCE

IGNITION is a research initiative seeking to implement new financing models for sustainable urban drainage systems (SuDS) as one part of the Greater Manchester Natural Capital Plan . SuDS are a nature based approach to managing drainage in the built environment, helping to hold back and slow down water flow. IGNITION used public grant funding to develop a business model for SuDs. The model aims to reduce costs from wastewater management utilities by developing SuDS on public sites, as the land area can be dis-connected from the sewer network, leading to a lower wastewater charge band and offsetting SuDs development costs.

A key barrier to the model was a lack of information on the adaptation benefits of SuDS, i.e., the level of reduced flooding and sewer overloading. Governance and regulation were also important barriers to financing. The regulations and policy affecting water utilities restricted the ability to develop 10 year agreements with confidence. Novel governance structures needed to be improved and defined with greater precision to increase confidence from investors. Project leaders came up against a low appetite or reluctance for risk within the public sector environment, and the uncertainty of the project often became a barrier to active institutional support. There were institutional barriers around the low existing capacity within the public sector and water companies to create a business plan and deliver investment for adaptation.

An effective revenue model is yet to be found for the SuDS project pilot; as current revenues (from reduced charges) are not sufficient to cover costs. This means that the model cannot be sustainable without public funds.

Emerging themes and learnings

The sustainability of projects such as IGNITION depend on the ability to create an effective revenue stream, and this will impact sustainability unless there is additional public finance. The high site-specificity and requirements for local adaptation benefit information may be a barrier by limiting transferability as well the limiting the benefits of economies of scale.

3.2.7 CROWD FUNDING PLATFORMS

The crowdfunding concept typically uses a platform which brings together an investment opportunity (debt or equity based) with individual investors who receive a return. Abundance Investment runs a place-based crowdfunding platform for municipal bonds (debt), currently focused on mitigation (net zero). The approach connects a public authority, with private investors, through a private intermediary. As such these are public projects that raise private finance from private investors, rather than a form of blended finance.

The approach has used a Community Municipal Bond (CMB) structure, where the bond is issued by a local authority directly to the public via a crowdfunding platform. These CMBs provide finance to local authorities at a slightly lower rate than they can typically access conventional public funding sources. In addition, it offers a powerful and innovative way for local Authorities to engage with citizens as investors.

The main financial barrier to transfer this model to adaptation is the lack of a revenue stream for projects to pay back crowdfunding investors. The investment size of bonds to date – even for mitigation - has been low, and has focused on public investors, rather than commercial investors who would typically want larger volumes and higher returns. Information barriers include the time and resources needed by local authorities to develop their project portfolios, as this often requires detailed studies. .

While there is a sustainable model for revenue generating mitigation projects for crowdfunding, it is not clear if a sustainable model exists for adaptation at scale, because of the lack of bankable projects.

Emerging themes and learnings

Crowdfunding offers the potential to link local place-based projects to local investors, thus raising awareness about the need for adaptation at the local level and engaging local citizens. It provides an opportunity for changing perceptions about financing (and who pays) for adaptation. The key barrier is the identification of bankable adaptation projects, to provide revenues. One way around this might be to blend portfolios of revenue and non-revenue projects. Putting such projects together does involve time and resources for local authorities and addressing this barrier will be key for scalability.

3.2.8 RESILIENCE BONDS – FUTURE FINANCING OF ADAPTATION MEASURES

The previous case studies have focused on UK examples. It is informative to also look at an example from overseas, especially where these involve additional climate hazards, in this case the adaptation benefits of wildfire risk reduction. The Forest Resilience Bond (FRB) was designed to support the funding of a US$4 million restoration project to mitigate wildfire risk in Tahoe National Forest, California. It was developed in 2018 by Blue Forest Conservation (BFC) in partnership with the World Resources Institute (WRI). The FRB harnesses upfront investment provided by a combination of private commercial and concessionary investors to cover the initial costs of restoration, with public beneficiaries such as the Forest Service, state agencies and utilities sharing the costs to repay investors over time based on revenue streams from forest products and charges for use of community forest areas.

The informational barriers to financing included quantifying and measuring avoided fire suppression costs, and thus to performance-linked payments. Additional barriers to financing included a lack of awareness of successful projects, coupled with the risk of being first to market.

Emerging themes and learnings

Overcoming informational barriers around measuring outcomes were key for the sustainability of the project. Definitional clarity may also hinder future scalability and investor interest, as it was a barrier in pitch and financing. The scalability and sustainability of future projects will depend on reducing investor uncertainty, which may be a challenge given the market's nascency and limited number of successful projects to date.

3.2.9 KENT DOWNS - TARGETING FUNDING AT THE RIGHT GEOGRAPHY

Kent Downs is a nature-based solution that consists of projects around the River Darent catchment. The main adaptation co-benefit is flood management, in addition to enhanced biodiversity. EU funding through programmes such as Interreg has been core to the projects activities, crowding in other funding (including the National Lottery Heritage Fund). Public funding has been critical to the project, there exists no incentive for private financing given no revenue stream exists. The removal of EU funding has created uncertainty for the future of the project, and barriers for future projects of a similar type.

The new funding scheme to replace EU funding, the UK Shared Prosperity Fund, would require Kent Downs to apply to more than ten authorities to receive funding – a process which could be complex, and resource intensive. Ensuring funding is available at the right geographical level and for the necessary time horizon is needed to support the project over the longer term.

Emerging themes and learnings

The absence of a revenue stream deters private financing and leads to reliance on public funding. The sustainability of the project is subject to changes in that funding. Uncertainty around funding sustainability leads to uncertainty around project sustainability. In addition, the new funding scheme, the UK Shared Prosperity Fund, may be resource intensive for applicants due to the number of applications required to local authorities, highlighting that funding is required at the right level of geographical aggregation, and for a suitable time horizon. This is likely to be context specific, which means that it differs from project to project.

3.3 THEMES: SUCCESSES AND BARRIERS

The case studies highlight that a number of common barriers to financing adaptation projects.

Information barriers were one of the most commonly identified barriers across the case studies. Information barriers include an underestimation of importance of adaptation measures, which affected stakeholders in the Glasgow tenements retrofit project. Information barriers also arise when there is a lack of data on precise outcomes or impacts of projects which contain adaptation co-benefits. This was present with both online trading platforms, EnTrade and LENs, where such uncertainty may deter buyers. Uncertainty around outcomes may also have a financial impact, as seen in the resilience bonds case study where payments are linked to performance. There also exists uncertainty around the exact costs and benefits of each project, often caused by a lack of precedent. Even if there has been a precedent, given projects (especially NBS such as Kent Downs or SUDS) can be very context or site specific, costs and benefits from one project can not necessarily be translated to another.

Another crucial barrier to the scalability and sustainability of adaptation projects, present in many of the case studies, is **the lack of a revenue stream**. The lack of a revenue stream can act as a major barrier to private financing, and this is particularly common with projects involving nature-based solutions. In the Kent Downs natural flood management project, the lack of a revenue stream resulted in a reliance on public funding, linking the survival of the project subject to changes in that funding. This reliance on public funding was also evident in the IGNITION project, where an effective revenue stream has not been realised thus far. The lack of a revenue stream may also limit the ability of some more innovative financial instruments to focus on adaptation projects, as seen with the crowd funding platform Abundance.

Another common theme across the case studies is the fact that many of the markets and funding streams are relatively new (**nascent markets)** and there is an associated **lack of market capacity / regulation.** This can hinder growth and scalability of solutions. Given the lack of precedent in adaptation projects, they are often seen as experimental in nature, raising the risk perception. This was evidenced in the Glasgow tenement retrofit project where there was initially reticence to invest in the adaptation measures. The lack of a stable, recognised institutional framework makes investing in nature-based solutions more risky. The IGNITION project highlighted how an unclear governance structure could decrease investor confidence, and a lack of public sector capacity made it more difficult for business plans to be created and delivered. The funding platforms (EnTrade and LENs) are still establishing a track record that would allow them to attract opportunities and investors at scale.

Regulatory barriers are another type of barrier that have been identified across different case studies. Typically, regulatory barriers are more common in industries which are either heavily regulated or are subject to long-standing regulation. In the Glasgow tenements retrofit project, a lack of precedence hindered approval of certain parts of the project. Long-standing regulation failed to easily address the more novel

parts of the retrofit. In the water sector, regulation needs to weigh up multiple trade-offs, such as different types of projects (capex vs opex), different groups of consumers (current vs future), and flexibility for water companies against the requirement for specific actions to be completed. Regulators are still in the process of establishing how they will deal with novel adaptation projects.

Regulatory barriers can also lead to multiplicative complexity when regulations aren't aligned and create friction with each other. This was exemplified by the Glasgow tenements retrofit project, where different regulations slowed down the project and made it expensive. Each of the regulations presented a new barrier, and led to multiplicative complexity in making sure the retrofit fit all the regulations for construction.

Co-ordination failures are a type of barrier that are linked to both information barriers and markets which are nascent and have a limited amount of regulation. With regards to the LENs platform, co-ordination failure resulted from insufficient communication within industries that could benefit from the landscape based approaches that LENs offers. CReDo had to invest considerable time into trying to overcome coordination failures between the various infrastructure providers to allow asset operators from different industries to work together (eg share sensitive information, each realise part of the benefit).

Learning effects are a common theme, and source of success, across all the case studies. In some cases such effects may lead to lower costs in the future (e.g. for digital twins, some housing renovations, operating investment platforms). Prioritising those adaptation projects and their financing that can generate large learning effects would help to push forward those where lower future costs are likely to increase take-up.

Finally, multiple case studies have indicated that the existence of blended funding facilitated success. It has frequently been the case that **public sector funding crowded in private financing** or allowed for marginal changes in the project that allowed adaptation measures to be added in projects that were initially more focused on mitigation. In the case of CreDo public financing helped to catalyse resources from the private sector, public financing meant adaptation measures were added to Glasgow tenements and helped establish and run IGNITION. However, in some markets (such as those served by Inspired Villages) private financing alone is sufficient.

4 RECOMMENDATIONS

The case studies illustrate many successful efforts to establish adaptation measures in areas ranging from housing to the natural environment. The case studies suggest a large number of elements within the current framework that work well. For example:

- **Effective communication** helped to overcome informational barriers in multiple case studies. In the Glasgow tenements renovation case study, active communication across stakeholders helped to disseminate information, and to enable the presentation of the merits of certain adaptation measures. In addition, using precedence from other settings to present the full benefit of some adaptation measures. The LENs case study highlights how communication could overcome the informational barrier, as communication with stakeholders helped to shift mindsets in relation to landscape management and its benefits and in CReDO the communication supported by the central team has been crucial to developing the prototype.

- **A local approach** is also important to success. By focusing on a specific geography, defining desired outcomes locally and working with local stakeholders the projects have all moved forward. The trading platforms began as local initiatives that have subsequently been taken forward, nature based solutions and infrastructure projects (like CReDO) had to be embedded in local communities and service providers to succeed.

- **Flexibility** can also support effective adaptation projects. The Forest Resilience Bond was enabled through the use of tailored contracting and agreements between the project stakeholders to motivate them to be part of the project. Blue Forest Conservation (BFC) worked through a cooperative process to set up contracts with individual stakeholders, allowing each beneficiary to codify the terms of its contract or agreements. This allowed BFC to structure agreements with project partners based on the specific benefits which they would receive, which were diverse across the project.

- **Learning effects** are a common theme across all the case studies. In some cases such effects may lead to lower costs in the future. The Glasgow tenements project, CReDO and the trading platforms have all learned lessons that would result in lower costs for future projects, and in some cases is explicitly built into the current projects (e.g. for the trading platforms).

- Multiple case studies have indicated that the existence of blended approaches to funding and financing facilitated success. **Public sector finance often de-risked or crowded in private financing** or allowed for marginal changes in the project that allowed adaptation measures to be added in projects that were initially more focused on mitigation.

- The benefit of **involving multiple stakeholders** is also apparent in many of the case studies. While some are explicitly set up to do so (eg CReDO) others could have taken a different approach (e.g. Glasgow, platforms, Inspired Villages) but involving local communities in their projects has helped with success and widening the benefits from the projects.

Alongside the areas that have worked well, the case studies also illustrate some important barriers that need to be overcome if finance for adaptation is to be scaled up to levels that will be needed to ensure resilience against climate change. The barriers identified from these case studies, along with the barriers identified in

the literature review, have been used to draw up these recommendations. We have grouped the barriers into four categories:

1. **Market (including revenues)**. In order for adaptation projects to be scalable and sustainable, a necessary condition is that revenue streams can be identified, unless they can be supported by public funding. T**he lack of a revenue stream** was consistently mentioned as a challenge across the case studies, and the private sector cannot invest if such a stream cannot be identified. This issue is widespread across many sectors for adaptation, though it a particular challenge in some areas, e.g., with projects involving nature-based solutions.

2. **Information.** One of the most commonly identified and include a lack of information on adaptation effectiveness and benefits, as well as on potential co-benefits. Related to this, adaptation is usually site and context specific, thus information is not easily transferable, and this also affects project preparation and development. Future investment is also dependent on this willingness to pay, which is affected strongly by the level of awareness, understanding and engagement with adaptation issues.

3. **Bankability.** Another common theme across the case studies is the fact that many of the markets and funding streams are relatively new (**nascent markets)** and there is an associated **lack of market capacity.** This can hinder growth and scalability of solutions. In addition, given the lack of precedent in adaptation projects, they are often seen as experimental in nature, raising the risk perception. **Co-ordination failures** arise where sectors are fragmented and many parties are involved in adaptation actions: these are quite common for adaptation given cross-cutting themes, and multiple actors and institutions.

4. **Regulatory.** Regulatory barriers are more common in industries which are either heavily regulated or are subject to long-standing regulation. A lack of precedence can hinder approval of certain parts of the project. In other cases, economic regulation needs to weigh up multiple trade-offs, such as projects that might mix capital and operating costs differently, different groups of consumers (current vs future), and flexibility for water companies against the requirement for specific actions to be completed. Regulators are still in the process of establishing how they will deal with novel adaptation projects.

THE EVIDENCE FROM THE LITERATURE AND THE CASE STUDIES SUGGESTS A SERIES OF RECOMMENDATIONS TO HELP OVERCOME THE BARRIERS IDENTIFIED

The four barriers to financing adaptation measures suggest recommendations that could help to address each one. We discuss each barrier in turn and associated recommendations. Draft recommendations were shared before finalising the report. In discussions, opinions for and against particular recommendations have been expressed. We have chosen not to include an indication of how widely particular recommendations were supported. We have not included previous draft recommendations that received no support. Where there has been debate we have used our judgment and experience, along with the evidence from the case studies and literature review, to decide whether and how to frame recommendations.

These are not intended to be a comprehensive list of recommendations needed to solve adaptation financing. The CCC may want to add further recommendations based on its thinking and review of areas beyond the scope of this work (e.g. areas of significant existing funding such as flood defence or the UK's role in funding adaptation efforts overseas).

Markets and revenue

Understanding benefits and revenue streams from adaptation and building up an inventory of business models. It is extremely difficult to derive outcome based indicators and metrics for adaptation, and any approaches have to vary with risk and sector context. To date, the investigation of this area has focused on physical and economic benefits, not financial benefits. **Work should be undertaken, by the CCC and Defra, to identify the financial benefits and revenue streams from adaptation measures, by sector and risk**, aligned to the priorities in the NAP. This work should allow **the next NAP to extend beyond its historic list of actions and owners to also consider the funding of those actions**. This could also extend to see how to use Government incentives (such as regulation) to help create revenue streams. This may be supported by an emerging set of adaptation business models (see case studies and literature review in this report) being developed, in the UK and internationally. It would be useful to compile these and build up an inventory of examples, to help scale-up and transfer promising new approaches, especially private and blended solutions.

Improved estimates of adaptation financing needs are required. Adaptation will require investment in a range of interventions, including processes and plans. There will be a need for increasing volumes of adaptation finance for climate-proofing planned investments and for scaling-up the delivery of targeted adaptation investments. CCRA3 did not estimate the costs of adaptation for England or the UK, and there are no estimates of associated finance needs for adaptation. While it is important to note that finance is a means rather than an end (the availability of funds does not guarantee that they will be used efficiently and effectively), it would be useful to build up a more comprehensive picture of likely adaptation investment needs, separated by sector/risk and by public/private sector. This should encourage government departments to support this process on adaptation financing needs as part of NAP activities, and going forward could use the adaptation reporting powers to help compile this information from other organisations. The information gathered can then be used to assess the sources, instruments and solutions that are needed to help deliver this finance. **Defra should request each Department estimate its funding requirements for adaptation measures as part of the NAP process**.

Separately, in order to cover private sector provision and help understand the financing gaps, **Defra should update the Adaptation Reporting Powers** (ARP) **to ask reporting firms to set out information on adaptation costs and financing**.

The fourth Climate Change Risk Assessment (CCRA4) should use the revised ARP submissions, and other information (see further recommendations below), to more systematically report on the aggregate financing needs and the gap. The **terms of reference for CCRA4 should include explicit reference to the improving understanding of the financing gap**, drawing on this and related evidence.

Understanding benefits and revenue streams from adaptation and building up an inventory of business models. It is extremely difficult to derive outcome based indicators and metrics for adaptation, and any approaches have to vary with risk and sector context. To date, the investigation of this area has focused on physical and economic benefits, not financial benefits. **Work should be undertaken, by the CCC and Defra, to identify the financial benefits and revenue streams from adaptation measures, by sector and risk**, aligned to the priorities in the NAP. This work should allow **the next NAP to extend beyond its historic list of actions and owners to also consider the funding of those actions**. This could also extend to see how to use Government incentives (such as regulation) to help create revenue streams. This may be supported by an emerging set of adaptation business models (see case studies and literature review in this report) being developed, in the UK and internationally. It would be useful to compile these and build up an inventory of examples, to help scale-up and transfer promising new approaches, especially private and blended solutions.

Use of public finance for de-risking and blending. The case studies reveal that it is important to encourage public organisations (e.g. local authorities) to seek opportunities to use public funds or assets to support public-private sector partnerships or unlock investment from the private sector for adaptation. This can be particularly useful in cases where the economic benefits of adaptation are larger than the private financial benefits (positive externalities), or to help in de-risking of private sector adaptation. There is also a role for public financial institutions to help bring down the initial costs of adaptation investment and de-risk new investors, through tools such as market competitive or concessionary finance, equity and guarantees. **The CCC should identify public bodies (notably local authorities) that are well placed to de-risk projects through co-financing and the extent to which they are constrained through existing regulations, rules or other barriers from doing so.**

Information and support

Adaptation projects are time and resource intensive to develop to investment readiness. In response to this challenge, internationally there is now a focus on project preparation facilities and adaptation incubators or accelerators to make it easier for the private sector to develop new adaptation models. For the public sector, such facilities could help public sector organisations to develop projects, for subsequent public or private financing, as well as helping to share lessons and business models. It could also help in supporting the emerging market for adaptation goods and services in the private sector. This can provide a range of technical assistance support (e.g., on climate risks and benefits, business model development, staff training and skills, legal services, etc.,), supporting marking information (market research, investor forums) as well as innovation grants or de-risking.

Defra should identify, and then implement and champion, the best institutional mechanism to deliver adaptation project and financing support. There are a number of examples to draw upon, for example: support and funding provided by UK Research and Innovation through Catapults and Challenge Funds, the models developed by What Works Centres, more bespoke teams within departments (e.g. BEIS support for hydrogen investments, BEIS/DfT support through the Office for Zero Emission Vehicles). These provide options that could be drawn upon to provide more focused support for adaptation projects and their financing.

One element of that support could be to clarify for investors – particularly smaller, non-institutional investors – which opportunities are likely to be good quality options for investment. This is particularly true of the trading platforms seeking to bring together new financing with new adaptation project opportunities. A **kite-mark or similar scheme should be set up to certify trading platforms** and similar activities that support new investment opportunities. The scheme should allow new institutions to demonstrate appropriate governance and financial measures are in place to demonstrate to potential participants the good standing of the organisation.

Aligning UK public investment portfolios. Public sector funding for new investments needs to assess the need for adaptation measures (alongside mitigation measures) as part of the business case. Despite some existing guidance (e.g. in the HM Treasury Green Book and from the Bank of England), the case studies revealed this is often not happening (e.g. projects like public housing, funding of nature). There are also opportunities to include greater consideration of climate risks, and adaptation requirements, in public private partnerships. Similarly, there are opportunities for regional and local government to do more to formally consider the need for adaptation within their local project planning. In the first instance, **the CCC should undertake a stock-take of whether the main public sector lenders and funders (e.g. HM Treasury,**

UK Infrastructure Bank, British Business Bank, local authorities) are properly incorporating climate risk management into their review of business cases and funding decisions. Based on the findings of that stocktake, informed by international best practice, recommendations should be made about how to improve consideration of climate issues in public funding.

Bankability

Sharing sensitive information has emerged as important in many of the case studies, although particularly those linked to infrastructure. Such sharing is important for coordination but also to help generate projects that can be financed. **The Cabinet Office should clarify and codify how sensitive information can be shared between infrastructure providers** for the purpose of resilience. This could be by certifying independent third parties to hold and aggregate such information or through other means.

Business case guidance and best practice in Defra and elsewhere in the public sector, should proactively look for opportunities to stimulate adaptation financing in emerging government policies. As an example, the new Environmental Land Management schemes could create revenue streams for adaptation by including relevant actions in the schemes, and rewarding land managers for delivering adaptation as a public good (e.g., adaptation for ecosystem services). . Policy development in other areas across government should seek to include the potential for adaptation financing as part of broader adaptation integration.

The public and businesses will increasingly have to pay for adaptation (or bear the risks), whether this is through taxation, direct charges, or new adaptation goods and services. The latter will require a shift in perception, and a recognition of the need to pay for adaptation. There is a need to start raising awareness of this likely shift, and help to create the conditions for the adaptation economy. One of Defra's duties is to communicate climate risks to the public. As part of that duty, **Defra should develop a specific communications strategy (potentially informed by public surveys and other engagement) for how to discuss the financial consequences of climate risks and measures that will be required to address them.** Such a strategy should give particular consideration to the distribution of the risks (and costs) to ensure it is appropriately focused on those most vulnerable.

Regulation

Adaptation can be encouraged by addressing the relevant legal and regulatory frameworks for regulated industries, but also more broadly, to create the enabling environment for adaptation.

Infrastructure regulators (e.g. Ofwat, Ofgem, Ofcom) **should move more quickly towards a fully outcome-based approach to regulation** such that there is equal certainty over returns from capital and revenue expenditure and it is easier to move revenue across sectors based on who is best placed to address the risk in question. This is particularly important in the context of adaptation, as demonstrated in the water sector case study, where the decision about the right approach should be based on adaptation outcomes rather than differences created by the regulatory treatment of different expenditures.

A **systematic review of building regulations** — including guidelines for planning and related consents — **should be undertaken by the Department for Levelling Up, Housing and Communities to identify measures that are inconsistent between different types of buildings or not consistent with proper preparation for climate change**. The Government published a new edition of the Manual to the Building Regulations on 15th June 2022. This was largely in response to the important Independent Review of Building Regulations and Fire Safety led by Dame Judith Hackitt following the tragedy of the Grenfell fire. Further

work is needed to also consider how best to facilitate financing of adaptation measures that are needed in buildings.

Together implementing these recommendations will improve the changes that suitable adaptation projects are developed, approved and financed. The case studies, and the wider literature, illustrate a number of important successes for adaptation financing. The scale of the climate challenge will require a proliferation of projects on a much larger scale. The development of such a large number of projects will require these, and likely other, steps to be taken.

ANNEX 1: BARRIERS TO INVESTMENT BY THE PRIVATE AND PUBLIC SECTOR IN UK CLIMATE CHANGE ADAPTATION

To improve the evidence on adaptation finance, the Climate Change Committee (CCC) commissioned a study on the 'Barriers to Financing Adaptation Actions in the UK'. The work was done by Frontier Economics and Paul Watkiss Associates.

This annex presents the full findings of the first part of this work: a rapid literature review to identify barriers to investment from the private and public sector in UK climate change adaptation.

A.1.1 - DEFINITION OF FINANCE

This study includes all sources of funding and financing for adaptation from the public, private and third sector, and all financial instruments including grant, debt, equity and other. This follows the convention in the adaptation finance literature (see CPI, 2021) and uses 'finance' as a broad term to represent all investment in adaptation. However, it is noted that financing and funding are sometimes defined differently. Funding is sometime defined as money (especially grants) that is provided by government / public sector. Finance is often defined as capital raised from financial institutions or other lenders (such as debt) which requires repayment. However, these definitions might be confusing here, for example, public funding of adaptation can be through debt that has to be repaid. We use the generic term of 'finance' for all investment in adaptation but note the differences between public and private sources and various instruments.

A.1.2 - BARRIERS AND CONSTRAINTS TO ADAPTATION

There is a recognition that there are barriers or constraints that make it difficult for individuals, businesses and governments to plan and implement adaptation actions (Cimato and Mullan, 2010; Moser et al., 2010; Klein et al., 2014). These various barriers can make it difficult to make decisions or take action, even when it is clear that action is needed (Cimato et al., 2017). Addressing these challenges is therefore key for successful adaptation. Addressing such barriers is therefore key to supporting investment in adaptation, even before considering different financing models.

The IPCC Fourth Assessment Report (Adger et al., 2007) identified five types of barriers or constraints to adaptation (See table 1). The Fifth Assessment Report (Klein et al., 2014) updated this and identified that a range of biophysical, institutional, financial, social, and cultural factors constrain the planning and implementation of adaptation options and potentially reduce their effectiveness, see below.

FIGURE 4 BARRIERS AND CONSTRAINTS TO ADAPTATION

IPCC FOURTH ASSESSMENT REPORT	THE FIFTH ASSESSMENT REPORT DEVELOPED
▪ Physical and ecological limits; ▪ Technological limits; ▪ Financial barriers; ▪ Information and cognitive barriers; and ▪ Social and cultural barriers.	▪ Knowledge, Awareness, and Technology Constraints; ▪ Physical Constraints; ▪ Biological Constraints; ▪ Economic Constraints;

	▪ Financial Constraints; ▪ Human Resource Constraints; ▪ Social and Cultural Constraints; ▪ Governance and Institutional Constraints.

Source: Adger et al., 2007; Klein et al., 2014

The AR5 had a stronger focus on the limits to adaptation. These are the point at which an actor's objectives or system's needs cannot be secured from intolerable risks through adaptive actions. These include hard limits, where no adaptive actions are possible to avoid intolerable risks, and soft limits, where options are currently not available to avoid intolerable risks through adaptive action, but which might be available in the future.

The recently published IPCC 6th Assessment Report does not have a separate chapter on constraints or barriers and has a greater focus on the limits of adaptation (Chapter 16: Key Risks Across Sectors and Regions, O'Neill., 2022). It reports that that the most significant determinants of soft limits to adaptation are financial, governance, institutional and policy constraints, with high confidence. The ability of actors to overcome such constraints largely influences whether additional adaptation can be implemented and can prevent soft limits from becoming hard. It highlights financial constraints are important determinants of limits to adaptation, although more so in low-to-middle income countries. For Europe, it identifies key constraints as technical, biophysical, economic and social, though we (the authors of this paper) believe this judgement underestimates the importance of finance barriers.

There is also a much wider literature that often presents barriers in a different way. As an example, Oberlack and Eisenack (2014) present five ways in which barriers may impede the adaptation process:

- By constraining the available means for adaptation;
- By hampering the use of available means;
- By increasing the cost of adaptation, including transaction costs;
- By reducing the incentives for adaptation; and
- By increasing the incentives for maladaptation.

Some of these could be considered hurdles, rather than barriers, but the important thing is they act to make adaptation more difficult to plan and to finance, and thus we consider a broader definition that includes these hurdles is also useful here.

There are different framings in the literature on understanding and cataloguing barriers and constraints.

For example, it is possible to use economic (welfare) theory and its underlying normative principles as a reference framework for adaptation and thus adaptation barriers and financing. In this case, barriers are constraints that prevent the appropriate level of adaptation from a societal perspective, and broadly correspond to market failures. Under this framing, successful adaptation actions are those that minimise the combined total of residual damages and costs of adaptation (see Fankhauser et al. 1999; Cimato and Mullan, 2010), with adjustment where appropriate for distributional weighting across time and space, and barriers are those factors that hamper cost minimisation. This economic approach was adopted in the UK under the Economics of Climate Resilience Study (HMG, 2013. Frontier et al., 2013) and the more recent Defra funded 'Economic Case for Climate Change Adaptation' (Frontier and PWA, 2022). These studies look at

barriers and market failures first, and then identify the economic case and the justification for public intervention to support adaptation.

Alternatively, some consider that the normative framework underpinning standard welfare economic theory may not fully capture real-world decision-making and underplays several factors affecting adaptation. Other perspectives are therefore used in the literature to describe barriers to adaptation. For example, some of the literature adopts a social framing and argues that some barriers are socially constructed, subjective and mutable, as they depend on the underlying goals and values of different decision-makers across different scales and agencies (Adger et al., 2009). The factors and events that are considered a barrier are determined by how actors interpret and value past events, which depends on value and interest, and so what might be considered a barrier to one actor could be an opportunity to another. Importantly, this literature highlights that the importance and severity of each barrier varies between actors and context and are likely to change over time (Adger et al., 2013). These additional perspectives are useful, as they can identify barriers to real world adaptation financing, that might be overlooked from a focus on the economic and financial literature alone.

Finally, there is also an emerging literature on the practical barriers to adaptation financing. This includes a strong reference to the economic literature above on market failures (e.g., UNEP, 2016) but extends to consider the financing and investment around adaptation. There is relatively little on this is in the academic literature (although Bisaro and Hinkel, 2018, is a notable exception though only focuses on coastal adaptation, and Boston et al., 2020 looks at funding for coastal relocation). Much of the information is in the grey literature (e.g., UNEP FI, 2019; Mortimer et al., 2020) or is focused on global adaptation finance (e.g., Stoll et al., 2021) but it has relevance for the UK. There is also some literature on barriers to financing nature-based solution which has relevance for adaptation (e.g., FUKR, 2022).

For this synthesis, we have tried to combine these three perspectives and typologies, i.e., using the economic framing, the more practical literature on adaption finance and investment, and considering additional social and behavioural barriers. We have identified five broad barriers that are likely to be relevant for adaptation financing:

- Information;
- Economic;
- Financial;
- Policy, regulatory and governance;
- Social and cultural.

Each of these will have a number of sub-categories of barriers. These have been explored to identify a long list of barriers, and understand the potential importance of each of these, as identified by the literature. The five areas are discussed below.

It is stressed that these barriers and constraints to adaptation will vary with the type of adaptation and also with the risk and sector (discussed in later sections). Barriers also vary with the actor, given adaptation decisions even for a single risk may be taken by different groups, e.g., by government (national, regional and local), individuals, businesses, planners, developers, corporations, etc. This initial discussion is therefore generic to adaptation, and later sections provide analysis of how they may differ with context.

INFORMATION BARRIERS

One of the most common barriers to adaptation cited in the literature is around information gaps and uncertainty around climate change impacts, and the costs and benefits of different adaptation measures (Cimato and Mullan, 2010; Frontier et al., 2013; HMG, 2013; UNEP, 2016; UNEP FI 2019; Cimato et al., 2017; Khosla and Watkiss, 2020; Stoll et al. (2021)). The presence of these gaps means there is imperfect information, which is a market failure (HMT, 2020). This acts as a barrier to the adaptation of both public authorities and the private sector (individuals and firms).

Well-functioning markets require buyers and sellers to both have perfect information about what is on offer, including quality and price. When public or private actors have inaccurate, incomplete or uncertain information they are unable to make the most appropriate decisions, or in some cases, any decision at all, on adaptation.

These information gaps are endemic across the entire adaptation cycle, from identification of risks, analysis of options and through to implementation. The information on future climate risks is often partial, especially at the project level, both in physical impacts and financial/economic impacts. This makes it challenging to understand local impacts and the potential benefits of adaptation. However, even when risks are well characterised, there is a lack of empirical evidence on adaptation effectiveness and so physical, economic and financial benefits (UNEP, 2021). This lack of information on quantitative benefits also makes it difficult to know how much adaptation to do, and thus also the costs and financing needs.

Imperfect information is clearly a barrier to financing of adaptation investments. For example, organisations (firms, investors or financial institutions) may not know or have the necessary information about the level of future flood risks (physical, economic, financial impacts), the range of different options to reduce damage from flooding (whether soft or hard measures), and the costs, effectiveness and benefits in reducing economic or financial costs, of different adaptive strategies or measures. This disincentivises investment.

The information gaps are exacerbated for future climate change because of uncertainty. This prevents action or encourages prevarication. While uncertainty is inherent in all decisions, there is deep uncertainty associated with climate change impacts (Wilby and Dessai, 2010), where it is not possible to understand risks as a function of severity or probability. It is also clear that this uncertainty will not be reduced any time soon, as it is not yet clear whether the world is on pathway towards a global temperature rise of 2˚C or 4˚C by end of century, relative to pre-industrial levels. However, even if future scenarios were known, there is still large uncertainty around the climate model projections. Different models, or even multiple ensemble runs of the same model, lead to different impacts of climate change, leading to for example, wetter or drier projections. This uncertainty is captured in the UKCP18 projections (Lowe et al., 2018). In the medium-term (to 2050), model uncertainty is generally larger than scenario uncertainty. This leads to a large possible range of outcomes, making proactive and planned adaptation difficult in practice, since it requires decision-making under conditions of uncertainty (DMUU) and changes the options and costs compared to analyses of adaptation for a single, precisely defined single future. This uncertainty makes it harder to select the type and level of adaptation, and it also reduces the benefits of adaptation, as a particular action may under or over-estimate the level of adaptation required, and thus the economic and financial benefits it delivers over time. From a financial point of view, the information gaps around the benefits of adaptation and uncertainty affect the timing of returns to investment in adaptation.

Some of the literature also highlights the potential risks of asymmetric information and moral hazard (Cimato and Mullan, 2010; HMG, 2013). Asymmetric information arises when (superior) information is known by some actors but not others, and can lead to opportunism, but also inertia (though with adaptation, there

is insufficient knowledge generally on all sides). Moral hazard can arise when there is a belief that someone else will deal with potential impacts and has been identified as a barrier in some studies (e.g., UNEP FI, 2019).

Information barriers are important for public projects, but especially important for blended and private sector projects because of the uncertainty around financial returns, for example, EBRD (2015) report information barriers as a common hindrance to private sector adaptation finance.

The presence of imperfect information and associated market failures highlights the potential role for government intervention (Cimato and Mullan, 2010; Frontier et al., 2013; HMG, 2013; UNEP, 2016; Frontier and PWA, 2022. The more academic literature highlights information provision as a public good, while the more practical literature highlights the role of technical assistance to help in project preparation (public, private and blended), including in project preparation facilities and adaptation accelerators, as well as support to help de-risk projects because of these uncertainties (see discussion below).

ECONOMIC BARRIERS (MARKET FAILURES)

There are economic barriers to adaptation which in a social welfare economic framework are centred on market failures (HMT, 2020). These are very commonly raised in the literature as a key barrier to public and especially private sector financing of adaptation (Cimato and Mullan, 2010; Frontier et al., 2013; HMG, 2013: UNEP, 2016; LSE, 2016 UNEP FI, 2019; Stoll et al., 2021; Frontier and PWA, 2022). These factors prevent the market from delivering the socially efficient level of adaptation.

Some of the largest economic barriers to adaptation are in relation to the presence of public goods, non-market sectors and positive externalities (Cimato and Mullan, 2010; Bisaro and Hinkel, 2018; Mortimer et al., 2020; Stoll et al., 2021). Individual and firms will act in their own interest and take adaptation decisions based on private costs and benefits. However, many adaptation actions have the nature of public or quasi-public goods for which no market exists and/or they result in high environmental or societal benefits, but no or low financial returns for investors, in the same way that for example a renewable energy projects would do.

These are often reported as positive externalities (UNEP, 2016). In such case, the economic net benefit of a project (the economic net present value or economic internal rate of return) is higher than the financial or private benefit (financial net present value of financial internal rate of return). As such there is little incentive for the private sector to invest if the private financial benefits are not high enough to make an investment viable, as they do not benefit from the additional social benefits. Positive externalities might also appear in the form of spill-overs, when a project generates lessons that will be helpful for other actors (technology or other) but do not provide additional revenues to the investor (UNEP, 2016).

Public goods are non-excludable in supply and once provided, are non-rivalrous in demand. These features make it difficult or impossible to supply such goods on a commercial basis (HMT, 2020). There are many aspects of adaptation that have public good characteristics that make them unattractive for the private sector, e.g., large-scale flood defences (Cimato and Mullan, 2010).

There is also a need to deliver adaptation in non-market sectors, e.g., in relation to the risks to public health, to natural ecosystems, etc. Non-market sectors are obviously a low priority for the private sector, unless they are specifically incentivised to act in these areas by government. For example, ecosystem-based adaptation is very attractive from a social welfare (public) perspective, because of the large environmental benefits, given the positive externalities (e.g., GHG emission reductions, benefits to well-being). However, such adaptation investment is less attractive financially from a private sector point of view (ECONADAPT,

2017). It is the role of government to address externalities, and so there is a role to create the enabling environment for the private sector to support adaptation investment whenever the private sector is best placed to do so. Nonetheless, this is often challenging to achieve in practice.

All of these factors mean that many adaptation actions have economic benefits that are higher than their private benefits. These lead to a difference between how adaptation is viewed from the perspective of social value (public value) as compared to the private perspective. This highlights that there is an important difference between the public (economic) and private (financial) approach to financing.

An economic perspective, focused on social or public value is based on the principles and ideas of welfare economics and overall social welfare efficiency, and includes all significant costs and benefits that affect the welfare and wellbeing of the population, such as environmental, cultural, health, social care, justice and security effects (HMT, 2020). An economic perspective will look at costs and benefits for the economy, but also those that do not involve market prices. This allows for consideration of the public good and non-market aspects that many adaptation interventions deliver.

However, a financial or private sector perspective will largely ignore these non-market benefits. In this case, the benefits of adaptation are viewed from the perspective of the investor and consider the incremental cash flows (revenues and costs) generated, to assess the ability of the project to recover the initial investment and generate a return.

This difference is very important. The lower financial return leads to underinvestment by the private sector. To put this another way, by acting rationally in their own interest, companies will base their adaptation decisions on private costs and benefits, not those that are best from a societal perspective, and may even lead to maladaptation by transferring or increasing – through their adaptation - risks to others.

The attractiveness of adaptation investment therefore is different for the public sector as compared to the private sector (see also later CCC case study on no-regret adaptation).

There are also potential economic barriers around misaligned incentives, where the costs of adaptation fall on certain individuals, while the benefits accrue to others. As an example, the costs of passive ventilation for houses is borne by the developer, but the benefits of this in reducing cooling costs (the avoided need for electricity use in air conditioning) will accrue to the occupiers or tenants (Watkiss et al., 2015). In theory, the developer might be able to recoup these additional costs, if consumers recognise them and are willing to pay, but this is more difficult when proactive adaptation is involved.

The market structures in place, including market power distribution, can represent a further market failure. The market structures in which businesses operate (monopoly, oligopoly or perfect competition) shape the incentives and affect the investment decisions on climate change adaptation. Generally, market distortions occur when market signals (e.g., prices) are distorted, and can result due to a lack of action, or from government involvement in a market through monetary or fiscal policies. As described by Fankhauser et al. (1999), when market signals are distorted, people may under- or over-adapt. For example, fixed allocations of water resources may hinder incentives to adapt, or similarly, prices set by utility companies, when they do not reflect the full economic costs of provision, could undermine adaptation (Cimato and Mullan, 2010).

In terms of the financial markets, UNEP (2016) highlight additional market failures around market imperfections. They identify imperfect capital markets as a market barrier, when financial markets are unable to efficiently allocate capital or transfer risk. They highlight that many financial markets are characterised by a shortage of longer-term credit, which inhibits the ability/willingness to finance

investments to cope with longer-term climate impacts. Stoll et al., (2021) focus in the same area and identify incomplete financial markets.

Overall, these various economic barriers above are particularly acute for private investment, and act as a significant constraint, though they even pose challenges for public investment. Further, these challenges are greater when adaptation benefits are weighted towards the future (OECD, 2015). Proactive (planned) adaptation for future climate change is less attractive because of the concept of time preference – that generally people prefer to receive goods and services now rather than later (HMT, 2020). This is formalised in public decisions on adaptation through the use of discount rates in economic appraisal[1], and the lower benefits of future adaptation in present value terms[2]. For the private sector, this is even more acute, and feeds through to the financial international rate of return (FIRR)[3] / pay-back period / weighted average cost of capital (WACC). The problem of future benefits is further compounded by the high uncertainty around risks, and thus of adaptation benefits.

The fact that these market failures exist again provides a strong case for government intervention (Cimato and Mullan, 2010; Frontier et al., 2013; HMG, 2013; UNEP, 2016; Frontier and PWA, 2022). So for example, the fact that a project economic internal rate of return is higher than the financial internal rate of return, might justify some level of concessionary finance or a blended finance model, involving public and private sector finance.

Stoll et al. (2021) albeit looking at private sector projects in the Green Climate Fund portfolio, found that addressing market failures had a positive and statistically significant effect on private sector engagement in the GCF's adaptation portfolio. They report very high confidence that addressing the barriers of positive externalities, information gaps, and incomplete financial markets, increases private sector engagement.

FINANCE BARRIERS

The availability of finance is an obvious and important constraint to adaptation (e.g., Klein et al., 2014; O'Neill, 2022). According to the CPI Global Landscape of Climate Finance 2021 (CPI, 2021), global climate finance flows – including public and private flows of both domestic and international origin for mitigation and adaptation – were tracked at US$632 billion per year for 2019–2020. The vast majority (US$571 billion) of this tracked finance flowed to mitigation, with US$46 billion for adaptation and US$15 billion to cross-cutting themes that include both mitigation and adaptation. Almost all of the tracked adaptation finance came from public sources (in contrast to mitigation, where the split is closer to 50:50 public: private).

There are no tracked numbers on adaptation finance flows in the UK, but the broad trends (low adaptation finance, predominantly public) are likely to be the same. This leads to the question of why adaptation is

[1] The use of discount rates when calculating the social cost of carbon, or the costs and benefits of mitigation policy, has been very contentious. This is because of issues around inter-generational wealth transfers (see HMT supplementary guidance on Intergenerational wealth transfers and social discounting, HMT, 2013). However, most adaptation is associated with shorter-term interventions and thus uses existing discounting approaches. It is noted that the use of such rates might need to be re-considered when looking at larger scale risks and transformational adaptation. Further discussion was included on this issue in the CCRA3 method report (Watkiss and Betts, 2021).

[2] The Present Value is the sum of future values (in real prices) that have been discounted to bring them to today's value (HMT, 2020). The PV of benefits and PV of costs can be estimated and compared to derive the total present value (PB benefit- PV costs) or a benefit to cost ratio (PV benefit/PV costs).

[3] A financial analysis only uses market prices – it excludes environmental or social benefits (and note there are some other differences as well, for example consideration of taxes and charges). The financial attractiveness of a project is usually expressed in terms of an Internal rate of return (IRR), the annual return that makes the net present value equal to zero.

more difficult to finance, and whether it is the availability of finance that is the problem, or rather the attractiveness of investing in adaptation.

There is an emerging literature on the barriers to financing adaptation, centred on more practical project preparation and what is often termed the 'bankability'. There are different definitions, but bankable projects are those that can attract investors, or are investment ready, having undertaken feasibility studies, having a financial model with adequate cash flows, and having consideration of risk and safeguards, etc., (IRENA, 2018). This area is more dominated by grey literature, especially when discussing financing barriers for private sector adaptation (e.g., UNEP, 2016: UNEP FI, 2019; Mortimer et al., 2021; Khosla and Watkiss, 2020).

A useful starting point to frame the challenges for financing adaptation is by comparing with mitigation, where finance flows including private sector flows are much higher.

Greenhouse gas emissions mostly arise from existing activities, goods and services, and mostly involve fossil fuel combustion. Mitigation therefore is primarily technical in nature, and typically involves fuel switching or energy efficiency. It also normally acts in areas where there are already functioning markets. Mitigation tends to involve a substitution of technology for existing goods or services, which means there are existing revenue streams for financing. For example, investment in a new offshore wind farm, or the household retrofit of more efficient boilers or even heat pumps. Many mitigation options also can be implemented at scale, whether this is in the form of large, consistent markets (electric cars) or large investment size (a large offshore windfarm). This allows for easy replicability, economies of scale, and involves low transaction costs. Investments that support mitigation to climate change can be easily packaged up for investors to attract finance.

In contrast adaptation often involves taking action to reduce rising climate risks over time, i.e., spending more to keep things the same. This means it is often a defensive expenditure and provides benefits relative to a future counter factual. It does not generate additional material outcomes or tangible benefits, as such, rather an absence of impact, and so its benefits may not be recognised as "real". Furthermore, it often involves investment in public goods or non-market sectors, where there are no or low revenues streams, and thus low financial returns. Furthermore, a consideration of a list of national adaptation priorities (e.g., the National Adaptation Plan 2, Defra, 2018) also shows that adaptation is much less a set of technical solutions, but rather a mix of plans, policy interventions and incentives. Further, the site and context specific nature of adaptation means there is less replicability, and there is more need to focus on specific impacts and benefits (noting that for mitigation, the focus is only on reducing a non-specific burden, a tCO_2e). There are also complex temporal dimensions, as adaptation has to address risks that vary dynamically and non-linearly over time.

FIGURE 5 EXAMPLE OF THE COMPARISON OF MITIGATION AND ADAPTATION FINANCING

Barrier	Mitigation - wind farm	Adaptation – building overheating
Description	Investment in new offshore wind farm	Investment in passive cooling for new homes
Objective	Mitigation is the primary objective	Adaptation is a secondary objective, associated with climate proofing of new homes (building new homes is the primary objective) (see A.1.8))
Information barriers	Low information barriers -Observed data on wind speed. -Off-the-shelf technical solution	High information barriers -Low information on over-heating risks for individual buildings and locations (current and future) - Very heterogenous building stock and technical options, costs and effectiveness varies

	High investor knowledge, as established market	-Medium awareness among developers -Low awareness of households
Economic barriers	Market sector, providing known good (electricity)	Non-market sector, associated with health impacts or effects on well-being to occupiers
Finance barriers		
Revenue potential	High GWh of electricity produced generates revenue/cash flow Existing market High confidence in return	Low No obvious revenue/cash flow In theory, willingness to pay of homeowners for increased comfort, and/or potential avoided counterfactual to air conditioning (cost of electricity)
Rate of return	High Commercial IRR	Low As captured through customer willingness to pay for higher cost in new build or discounted future cooling from AC avoided
Replicability	High Standard technology and financing	Low Highly heterogenous technology because of housing stock, unclear financial model
Transaction /financing arrangement costs	Low -Large capital investment, one off due diligence study, etc. -Small number of actors (developer, financer)	High -Large number of small additional investments -Very large number of individual actors - thousands of developers / households, with high heterogeneity
Policy barriers	Low Existing developed market with appropriate incentives	High Lack of requirement in building codes (under review)
Behavioural barriers	Low	High Incentives for developers low, as bear cost/risk but household enjoy benefits

Source: Watkiss, 2022

Following on from the discussion above, much of the literature highlights that the greatest barrier to financing for adaptation is the lack of revenues or low revenues (Bisaro and Hinkel, 2018; Mortimer et al., 2020; Khosla and Watkiss, 2020). This is critical for private sector investment in adaptation. In practice, it is often difficult to monetise climate risk reductions (value capture) and there are few investment-ready (bankable) private sector adaptation projects.

As an example, Mortimer et al., (2020), as part of a Climate-KIC initiative in Australia, looked at the potential for developing the first adaptation bond in Australia, based on a portfolio of private sector adaptation. This worked with the banking, finance and insurance sectors, and government, with the aim to develop project investment criteria, assess potential projects and facilitate an investment strategy. However, this initiative was unsuccessful (Mortimer, 2021). The project found no investment-ready adaptation projects existed in Australia, as adaptation projects were designed to access funding, and not private finance. The key barrier was revenue streams were unclear and arose due to the fact many adaptation projects were public goods (with disperse beneficiaries). The project also reported that that no amount of modification (of the criteria or supplementing data) could create an investable business case. This was due to the mismatch between the finance system with its focus on individual items of infrastructure (single assets), and the adaptation challenge for which a system of inter-related future impacts requires a system of inter-related interventions. The authors went as far as to suggest that 'the traditional model of assessing needs, developing a business case and accessing funding, cannot work'.

Because of the challenges around monetising climate risk reduction, adaptation projects often rely on co-benefits for revenues (Adaptation Scotland, 2022), for example, associated with carbon sequestration and carbon credits, or tourism revenue. While this can aid financing and can help with integration and synergies (e.g., mitigation and adaptation, adaptation and nature based solutions) it means that projects will be more

complex, as it has multiple objectives and multiple beneficiaries. Further, there can often be trade-off and conflicts between competing objectives (Adaptation Scotland, 2022).

Further, if adaptation is a minor objective of a project, there is a danger that adaptation is not designed properly, and projects just do what they would have done anyway. There are some lessons from the international global adaptation finance here. Pauw et al. (2016) report that in around half of cases, private sector adaptation projects 'accidentally' contributed to adaptation rather than deliberately aiming at adaptation, as evidenced by whether they had an explicit climate rationale and consider climate impacts. Projects that claim to be delivering adaptation that are not considering future climate risks run a significant risk of maladaptation, but the incentives to consider and design adaptation in depth will be less for a project when such action produces no revenues.

A further example of the general low bankability of adaptation projects is provided by IGCC (2017). This undertook a multi-stakeholder climate adaptation finance consultation process. Working with potential investors, this identified the following gaps as major barriers to adaptation investment:

- A clearly defined project scope where the adaptation component is made explicit;
- A credible project proponent or counterparty;
- A revenue stream and commercial investment return;
- Adequate project scale;
- An accepted framework for allocating financial benefit (value add);
- Effective coordination across different levels of government.

Similarly, UNEP FI (2019) looked at the barriers to financial system governance bodies and financial actors and align on adaptation and identified twelve barriers arranged in five key themes:

- Inadequate support for action on adaptation investment;
- Policy and practice in the financial industry;
- Market barriers, including perceived lack of profitable investments and low commercial readiness;
- Nascent application of climate risk management practices;
- Low capacity for climate risk management, including in financial governance bodies and with financial actors.

A number of other studies highlight challenges in developing bankable projects. EBRD (2015) reviewed 26 private sector projects across the MDBs and found that adaptation projects take longer to prepare than other projects and thus may lose out to other fasting moving investment opportunities. They conclude technical assistance (TA) is an important facilitator of private sector adaptation finance. Mortimer et al., (2020) report that most adaptation projects are context specific, and their value is often distributed among multiple stakeholders. Several studies highlight legal hurdles or barriers (discussed in subsequent policy and regulation section). Bisaro and Hinkel (2018) identify that project preparation costs (for coastal adaptation projects) are very high.

There are some relevant lessons on barriers from nature-based solution financing. For example, the financing UK nature recovery initiative (FUKR, 2022) identifies the current approaches to regulation and public funding for the environment present substantial barriers to environmental market development and identifies the following specific barriers to private investment in nature recovery in the UK as:

- Limited sources of revenue from nature to fund investment at the scale required;
- Lack of a coherent framework for ensuring market integrity;
- Mis-aligned economic and environmental regulation;

- Financial disincentives to investment;
- Limited expertise and capacity within supply chains for nature-based projects.

They highlight that these barriers mean that there is insufficient certainty for most investors to price and manage the risk of investing in nature over the long term, and thus risks outweigh returns.

In response to these challenges, a number of adaptation accelerators has been set up to provide the support to bankable projects, particularly private sector projects[4]. These often provide technical assistance and advice to help in project preparation. This can range with business model development support, legal, technical, etc. As highlighted later, it also has led to a focus on blended finance, to help de-risk private projects.

POLICY, INSTITUTIONAL AND GOVERNANCE BARRIERS

There are also a set of policy, institutional and governance barriers to adaptation (Klein et al, 2014: Oberlack and Eisenack, 2014: Brown et al., 2017), and these may be among the most frequent types of barriers encountered (Ekstrom and Moser, 2014). There are considered some of the most important constraints for European adaptation by the IPCC AR6 (O'Neill, 2022).

Policy failures or constraints may arise when regulation or policy creates a barrier to effective adaptation, noting this may be due to a constraint at the national level (in terms of mandated authority), as well as sector or local levels (Cimato and Mullan, 2010). Frontier et al. (2013) identify policy failures can arise from a lack of understanding of policy trade-offs, conflicting policy objectives or missed opportunities to integrate climate change into policy can lead to maladaptation (e.g., retrofitting housing for emissions mitigation without accounting for adaptation) or lack of clarity. HMG (2013) describe policy failures as cases when the framework of regulation and policy incentives creates barriers to effective adaptation. Similar to the concept of market failures, this prevents an efficient market solution, though they add this concept must not be interpreted as a failure of policy, but as a systemic characteristic which prevents an efficient policy solution.

Several studies highlight regulatory frameworks can be a barrier to adaptation (e.g., EBRD, 2015; UNEP, 2016) or similarly that weak legal and regulatory frameworks and guidance constrain adaptation (UNEP FI, 2019).

As adaptation is a relatively new theme in policy decision-making, adaptation planning is influenced by the existing legal and institutional context set by national governments, and this can constrain the development and implementation. For example, many adaptation responses, i.e., flood and land use, are legally mandated responsibilities of the government, which acts as a barrier to other organisations acting (Bisaro and Hinkel, 2018; Mortimer et al., 2020). In the UK, policy and regulatory responsibility flows from the UK Climate Act, and through the mandated lead responsibility of Defra (for England) for adaptation but adopts a mainstreaming approach so that mandate is passed to the relevant departmental leads with respect to sectors and risks (Watkiss et al., 2019). However, the existing structure and regulatory policy framework are not yet aligned to adaptation objectives and there is little cross-comparable. The 25 YEP does not have a

[4] For example:

https://www.climatefinancelab.org/

https://brigaid.eu/the-climate-innovation-window/

https://www.laudesfoundation.org/

https://lightsmithgp.com/asap/

clear framework or indicators on adaptation, and the objectives and outcome metrics for adaptation are not well developed (see also Watkiss et al., 2019).

Frontier et al. (2013) and HMG (2013) also identify governance barriers (also called institutional barriers). These can arise from diversity in responsibility, or where institutional decision-making processes create barriers to effective adaptation. These can constrain action, creating challenges or slow planning and implementation. These are identified in the literature. For example, institutional barriers can arise from a lack of a clear mandate and responsibility, insufficient leadership or champions, a lack of coordination or cooperation between relevant public organisations (or these organisations and other relevant actors (Lehman et al., 2012; Oberlack and Eisenack, 2014) as well as competition (sometimes internal) for resources and policy control (Lonsdale et al., 2015) that act to make adaptation harder to deliver.

Frontier et al. (2013) and HMG (2013) also identify the potential for co-ordination failures where sectors are fragmented and many parties are involved in adaptation actions. It is noted that adaptation frequently involves cross-cutting themes, and thus multiple actors and institutions with different objectives, jurisdictional authority and levels of power and resources, making it more difficult to align governance and get agreement (Watkiss et al., 2015).

Policy barriers or failures can also arise when there are conflicting or competing policy objectives – or a lack of clarity. These can arise from a need to address short-term priorities (rather than long-term climate risks), inherent in political and indeed medium-term policy. However, it can also involve other long-term issues. As an example, the UK's Net Zero commitment will require transformational shifts and it is creating major policy challenges for delivery teams in government, as well as for private sector actors. There are some indications that Net Zero is crowding out adaptation actions, an example of which is the UK Government's Ten Point Plan for a green industrial revolution (HMG, 2020), which effectively omitted adaptation, and the recent Build Back Greener (2021) report, which focuses more on the international dimensions of adaptation, and does not integrate national adaptation (climate risks are only discussed in the annex). These policy barriers will exist for each individual sector.

It is also highlighted that England's local authorities have limited fiscal powers and this can constrain options for revenue capture.

The importance of these barriers will vary by risk and sector, but also on the level of ambition. For example, Bisaro and Hinkel (2018) identify that the political economy is important for coastal adaptation, due to existing real estate values (which adaptation might affect), while Zografos et al. (2020) found that power politics and interests (the political economic) are a key barrier to adaptation to more transformational change.

SOCIAL AND CULTURAL BARRIERS

Finally, there are a set of social, behavioural and cultural barriers to adaptation. The general literature identifies that these can include psychological, cognitive, emotional, cultural and social factors that shape individual and societal norms and rules, risk perception, management and thus affect adaptation action (Klein et al., 2014). These may also influence perceptions of risk that may determine adaptation responses because of preferences or norms from a social context.

Behavioural barriers shape decision makers' or relevant actors' perception of risk and their decisions on adaptation - be they public decision makers or individuals. These social and behavioural barriers will also apply to potential adaptation financiers, be they organisations or individuals.

These barriers affect the way individuals and the general public think of adaptation. When people make choices, their current reference point matters, and past experience, rather than anticipated future climate impacts, are often a driver of private adaptation. These factors can explain why individuals sometimes do not act, or at least do not act rationally (in what would be their best interest). People generally find it more difficult to make decisions when there is ambiguity or uncertainty, and to consider trade-offs across time and between options with uncertain benefits. This is a problem given the complexity of climate change and adaptation. This can lead to inertia or procrastination, and result in an inefficient or ineffective level of adaptation (Cimato et al., 2017). These barriers may be higher for certain vulnerable groups (Frontier et al, 2013).

Further, preferences are formed in a social context that influence decision-making. Many of the areas where adaptation is needed are in areas where the public sector currently is the main supplier (e.g., flood risk protection, public health provision). This may lead to an expectation from the public that government will continue to provide adaptation in these sectors. In the context of adaptation financing, public perception of climate risks can be low (Bisaro and Hinkel, 2018), hence the rewards for government for making investments in adaptation may also be low (Mortimer et al., 2020), and similarly, there may not be sufficient willingness to pay by the public to generate viable private sector investment.

SYNERGISTIC ADAPTATION AND MITIGATION BARRIERS

There is literature that looks at the potential linkages between mitigation and adaptation. These linkages can be summarised as (OECD, 2017):

- Mitigation strategies or options that are beneficial for adaptation;
- Adaptation strategies or options that are beneficial for mitigation;
- Mitigation strategies or options that make adaptation more difficult (e.g., urban densification for reducing emissions increasing urban heat island effects);
- Adaptation strategies or options that make mitigation more difficult (i.e., increased use of air conditioning or pumped irrigation increase energy use and GHGs);

The first two involve win-win or synergistic linkages: the second two potential conflict. Some literature is relatively optimistic that a mix of mitigation and adaptation options implemented in a participatory and integrated manner can enable rapid, systemic transitions, notably the IPCC 1.5˚C report (IPCC, 2018). Other literature is less positive (GIZ, 2019), and finds most links are minor, and there are just as many linkages that are negative or involve trade-offs, as positive. The latter study also found that there are policy, technical, market, financial and governance barriers that act to reduce the integration of mitigation and adaptation. This includes:

- Mitigation and adaptation involve different entry points in policy (stand-alone and centralized for mitigation, mainstreaming for adaptation;
- Mitigation and adaptation are often taken forward by different sectors and actors; mitigation focuses on the major emitters, while adaptation focuses on the most climate sensitive;
- There are potential market failures that act to prevent integration or synergies;
- There are information and technical complexities associated with synergistic interventions;
- There are financial and economic barriers to integration.

The important issue is that while there can be positive elements, there are barriers to synergistic mitigation-adaptation projects and financing, and win-win solutions may not need to address additional hurdles. These issues are important given the primary focus in policy on Net Zero in the UK.

A.1.3 - TYPOLOGY OF ADAPTATION FINANCE BARRIERS

The sections above are brought together in the table below. This sets out the main barriers and constraints. The individual barriers are ranked later, based on the strength of evidence and importance in the literature, as well as from information from the case studies.

Given the low evidence base, this analysis should not be considered exhaustive. It is also stressed that the importance of individual barriers will vary with public and private project and with sector and risk. Indeed, barriers will vary for most adaptation projects, due to the type of adaptation, finance sources, organisations, etc.

FIGURE 6 BARRIERS TO ADAPTATION FINANCING

Barrier	Evidence in the Literature
Information barriers	
Insufficient information on risks / high uncertainty (market failures and information asymmetry)	Cimato and Mullan (2010), Frontier et al., (2013), HMG (2013), EBRD (2015), UNEP (2016), Stoll et al. (2021), UNEP FI (2019)
Information gaps on adaptation effectiveness and benefits (physical and financial) (note include site and context specificity and variation)	Frontier et al., (2013), Mortimer et al., (2020), Khosla and Watkiss (2020); Stoll et al. (2021)
Investor understanding of adaptation	
Market failures*	
Public good characteristics or non-market sectors	Cimato and Mullan (2010), Bisaro and Hinkel, 2018, Khosla and Watkiss (2020), Mortimer et al., (2020)
Positive externalities (economic BCR>financial BCR)	UNEP (2016), Mortimer et al., (2020), Khosla and Watkiss (2020); Stoll et al. (2021)
Under-developed markets for adaptation (imperfect capital markets)	UNEP (2016); Stoll et al. (2021)
Misaligned incentives (adaptation costs, vs who benefits accrue to)	Cimato and Mullan (2010)
Financial barriers / bankability	
Low or no revenues from climate risk reduction	IGCC (2017), Mortimer et al., (2020), Khosla and Watkiss (2020), FUKR, 2022), UNEP FI (2019), Bisaro and Hinkel, 2018
Low economic or financial internal rate of return / long payback (timing of benefits)	Cimato and Mullan (2010), UNEP FI (2019)
Low replicability (site and context variability)	Mortimer et al., (2020)
Low investment size (£)	IGCC (2017)
Large number of actors (beneficiaries/organizations) and benefits to different beneficiaries	Mortimer et al., (2020)
Project complexity (time and resources) (long lead-times)	Frontier et al., (2013), EBRD (2015), Bisaro and Hinkel, 2018
Low capacity among developers / financial institutions)	Frontier et al., (2013), UNEP FI (2019).
Policy & governance	
Regulation (or lack of) (policy failures)	Cimato and Mullan (2010), Mortimer et al., (2020), Bisaro and Hinkel (2018), FUKR (2022), UNEP FI (2019)
Conflicting or competing policy objectives (inc. Net Zero) (coordination failures)	Frontier et al., (2013), HMG (2013)
Lack of coordination and cooperation (inc. cross-sector) (coordination failures, governance failures)	Frontier et al., (2013), HMG (2013), IGCC (2017)
Political economy, challenge of altering status quo	Bisaro and Hinkel (2018) Zografos et al. (2020),
Behavioural barriers	
Social, behavioural and cultural barriers	Cimato and Mullan (2010)
Perceived urgency of adaptation/ lack of awareness (inertia, moral hazard)	Cimato and Mullan (2010), Frontier et al., (2013), HMG (2013), Mortimer et al., (2020), Bisaro and Hinkel (2018)

Low willingness to pay for adaptation / current reference	Khosla and Watkiss (2020)

Source: Watkiss, 2022

Note: Some market failures are captured in other areas, such as information failures and coordination failures

A.1.4 - TYPOLOGIES OF ADAPTATION AND BARRIERS TO FINANCE

In general terms, it is useful to set out how the barriers above vary with adaptation. To do this, it is useful to define the types of adaptation and consider how the barriers affect these.

The starting point is to define adaptation. The IPCC, AR5 definitions were:

Adaptation - The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Incremental adaptation. Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation - Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

The IPCC AR6 (IPCC, 2022a) has updated as follows:

Adaptation. In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

Resilience. The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure.

The AR6 also reports that resilience is an entry point commonly used, although under a wide spectrum of meanings.

The Climate Change Risk Assessment 3 Method (CCRA3) (Watkiss and Betts, 2021) also included additional definitions for adaptation, as follows:

Reactive adaptation - Adaptation in response to experienced climate and its effects.

Pro-active planned (anticipatory) adaptation - Planned adaptation to expected climate effects. Note this can be taken by both public and private actors.

There is also the term **autonomous adaptation**, which is adaptation that happens without explicitly or consciously focusing on addressing climate change. We do not use this term, as it is often incorrectly used to include private sector adaptation (when in reality, private action can be planned). The term autonomous adaptation should really be limited to action that happens automatically (i.e. reductions in thermostat

controlled household winter heating demand). Autonomous adaptation is much less relevant for financing, because this action happens unconsciously and thus does not involve an actor seeking finance (although it does involve a cost or benefit).

The type of adaptation, as set out by these definitions above, has a major influence on their financing potential. This is due to the timing of when the benefits of adaptation arise, and the degree of uncertainty. Essentially reactive adaptation is addressing an existing impact, and thus provides benefits now, while planned adaptation is future orientated, and so has to address the lower present value of benefits in future years, as well as the issue of uncertainty.

In terms of types of adaptation, it is also useful to use the CCRA3 typology (Watkiss and Betts, 2021), developed from previous CCC frameworks (CCC, 2013: 2018) and CCRA2 (Warren et al., 2018). This set out three types of early adaptation priorities that can help address risks and opportunities within the next five-years:

- To address any current adaptation gap by implementing 'no-regret' or 'low-regret' actions that reduce risks associated with current climate variability, as well as building future climate resilience.
- To intervene early to ensure that adaptation is considered in near-term decisions that have long lifetimes and therefore reduce the risk of 'lock-in', such as for major infrastructure or land-use change.
- To fast-track early adaptive management activities, especially for decisions that have long lead times or involve major future change. This can enhance learning and allows the use of evidence in forthcoming future decisions.

These three priorities are not mutually exclusive, and a combination of all three is often needed as part of a portfolio at the national level.

Linked to the barriers section above, the barriers to adaptation are likely to be low for no and low-regret adaptation. There is some evidence to back this up. EBRD (2015) found that the MDB private sector adaptation finance portfolio (from a review of 26 projects) was dominated by 'no regret' adaptation activities.

Recent work (Watkiss, 2022) has outlined how the barriers to adaptation vary with the type of adaptation, and thus affect the ease of financing. This is presented below. This shows that definitions are important, because the type of adaptation involves different challenges for finance.

In general, it is more difficult to finance adaptation as one moves from left to right. This will be the case for public finance but will be especially the case for the private finance, which is likely to gravitate more towards the left. For example, it is easier to fund reactive adaptation and no-regret adaptation, as compared to proactive adaptation, as the latter involves more challenges due to uncertainty and lower rates of return / present values from future benefits. Similarly, it is easier to fund incremental rather than transformational adaptation, because the latter involves system level and often governance change (or to put another way, sectors or investments that require more anticipatory adaptation will potentially involve greater financing challenges). Note while these are shown as discrete boxes, in many cases they are a spectrum of change.

This ease of financing will also influence the financial instruments needed for adaptation, and it is likely that a larger proportion of grant finance will be needed to deliver adaptation for the centre and right.

It is highlighted that this does raise some challenges on the accepted need for adaptation. For example, the message from the CCC in the CCRA3 advice report (CCC, 2021) was that as well as no-regret adaptation, there is a need to act now to avoid much higher costs in the future. The figure below does not contradict

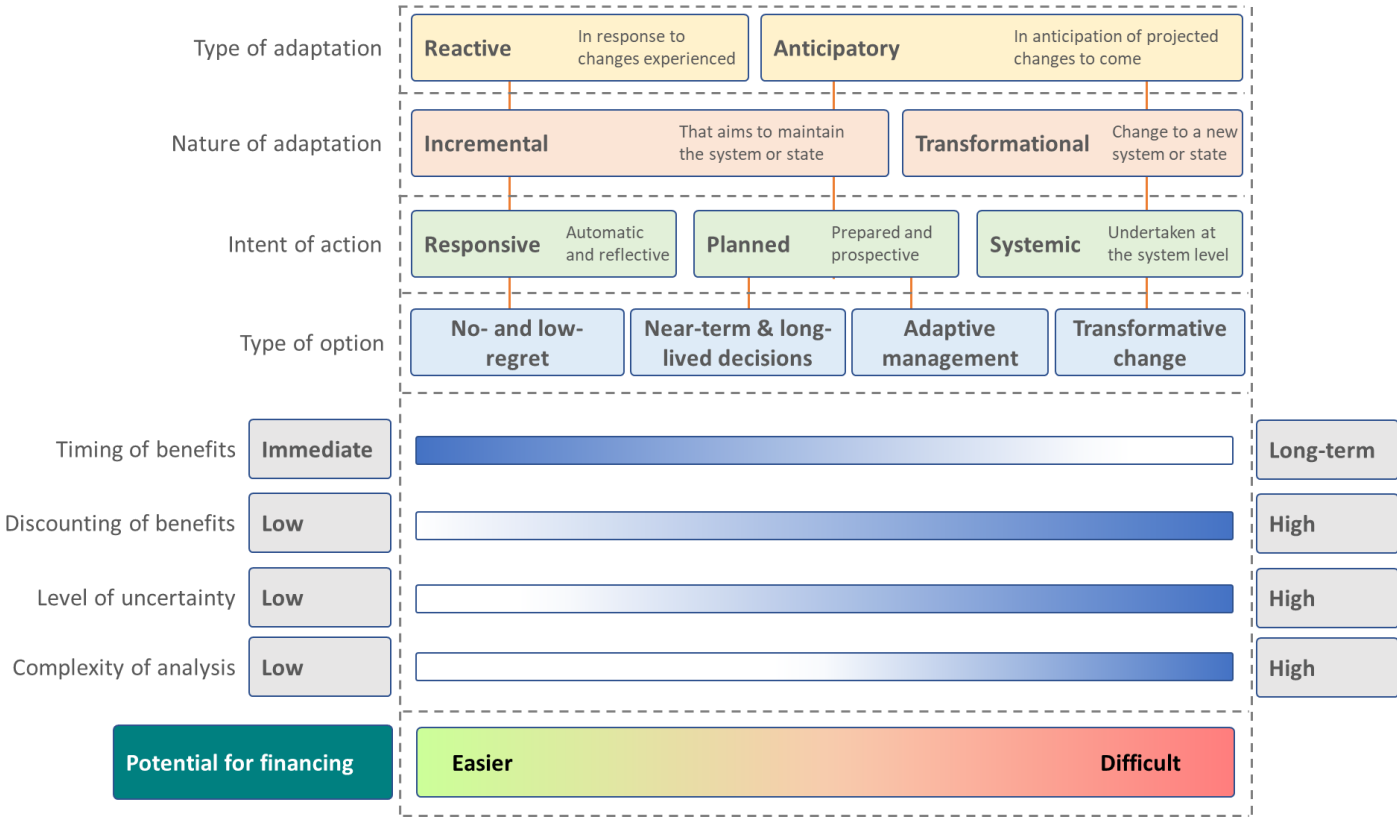
this message, but it does highlight that such future orientated actions are likely to be more difficult to finance, and this is likely to be especially the case for private sector adaptation.

FIGURE 7 TYPOLOGY OF ADAPTATION, KEY BARRIERS AND FINANCING CHALLENGES

	Adaptation Typology and Ease of Financing			
Type of adaptation	**Reactive**	**Concurrent**	**Anticipatory**	
Nature of adaptation	**Incremental**			**Transformational**
Intent of action	**Responsive**		**Planned**	**Systemic**
Type of option	**No and low regret**	**Near-term & long-lived**	**Long lead-time/major change**	
Timing of benefits	*Immediate to short-term*		*Long-term*	
Discounting of benefits	*Low*		*Medium*	*High*
Level of uncertainty	*Low*		*High*	*Very high*
Complexity of analysis	*Low*	*Medium*	*High*	*Very high*
Potential for Financing	*Easiest*	*Medium*	*Most difficult*	

Source: Watkiss, 2022

FIGURE 8 TYPOLOGY OF ADAPTATION, KEY BARRIERS AND FINANCING CHALLENGES



Source: Watkiss, 2022

A.1.6 - ADAPTATION FINANCE SOURCES AND FINANCIAL INSTRUMENTS

The next typology classification relates to the roles of public and private sectors, and public and private finance, for adaptation, and the financial instruments that can be used. The starting point is to map the various actors that could be involved in adaptation financing. This can include organisations that provide funding for delivering adaptation as well as organisations that provide finance for others to deliver. The existing literature includes several classifications on finance sources, with some examples presented in the table below. Most studies (e.g., CPI, 2021; UNEP, 2021; UNEP FI, 2019; Khosla and Watkiss, 2020) have a fairly standard high-level classification, that includes public money (government budgets), public financial institutions, private money (companies), private money (households), private financial institutions and intermediaries (including institutional investors), and third sector (foundations, charities). The sources of finance will depend on the type of adaptation project and the actor delivering the adaptation, i.e., it will be different for public and private projects. Interestingly, Bryson et al. (2018) include a wider set of finance sources and funding inputs, that include noon-monetised inputs (e.g., volunteer time, expertise and leadership, access or use of property or equipment, etc., that may be particularly relevant for alternative financial models, especially locally based.

FIGURE 9 EXAMPLES OF SOURCES OF FINANCE FOR ADAPTATION

Study	CPI (2021) – global adaptation finance	Khosla and Watkiss (2020) – UK adaptation finance
Source of finance	Public Government Bilateral DFI Export Credit Agency (ECA) Multilateral Climate Funds Multilateral DFI National DFI Public Fund SOE State-owned FI Private Commercial FI Corporation Funds Households/Individuals Institutional Investors	Public UK Government and DAs Government Agencies Regional & Local Authorities Public Financial institutions Private Micro, small and medium enterprises Large enterprises & multinationals Venture capital investors Commercial banks Institutional investors Pension funds Asset management firms Investment banks Utilities Insurers Re-insurers Third sector Foundations / Philanthropic NGOs Charities and Trusts Impact investors Retail investors Angel investors Households Households direct Households through utilities Households through insurance

Source: Watkiss 2022

A similar analysis is made on the potential financial instruments that can be used for financing adaptation. Again, there is a broad alignment around a set of financial instruments that includes grants, debt (concessionary loans, market rate loans, bond), equity, guarantees, and then the additional of other forms of finance or arrangements (public-private partnerships, insurance, etc.)

FIGURE 10 EXAMPLES OF TYPOLOGIES OF FINANCIAL INSTRUMENTS FOR ADAPTATION

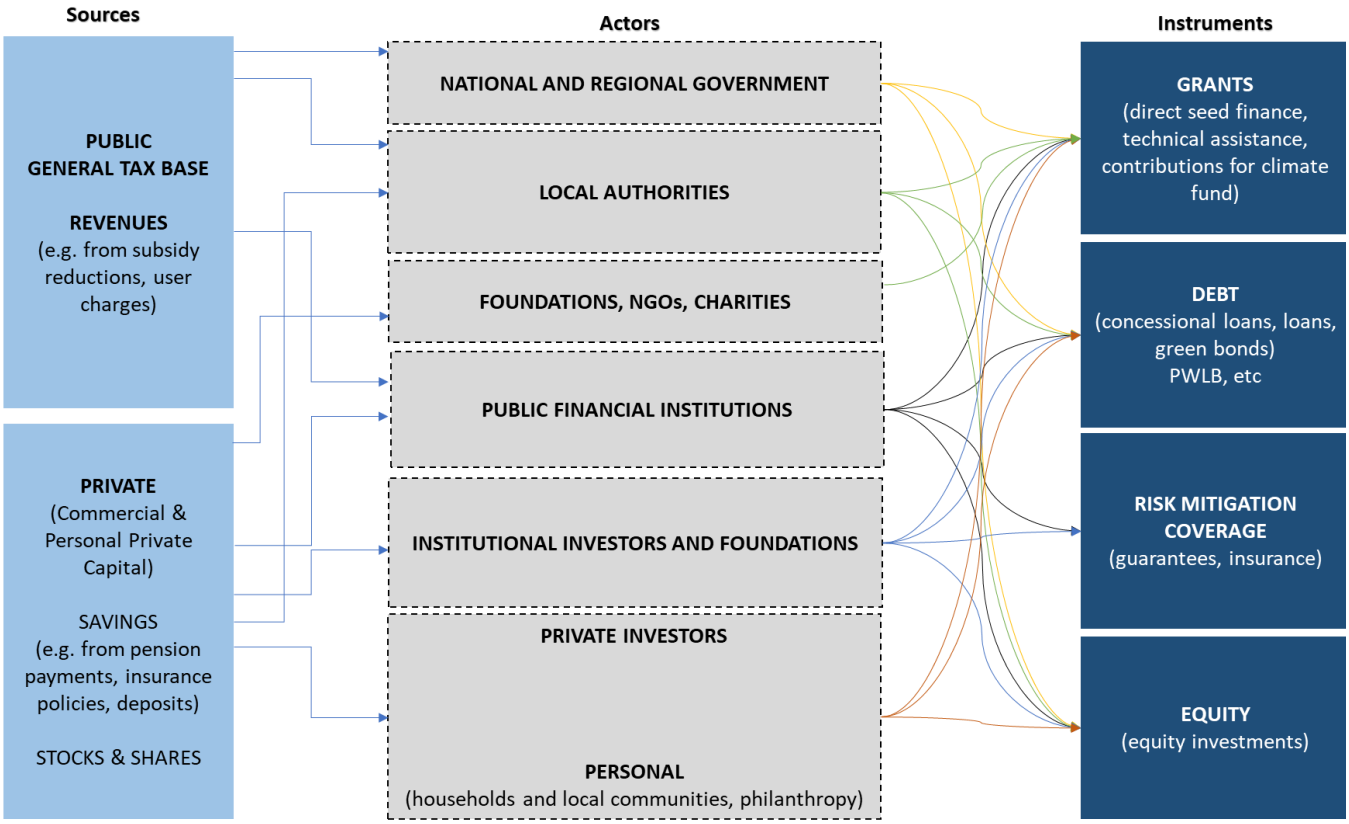
Study	CPI (2021)	UNEP (2016) (focus private sector)	Khosla and Watkiss (2020)	GCF (2022)
Financial instruments	Grants Low project debt Project level market rate debt Project level equity Debt	Debt Bank loans (incl. project finance, corporate lending) Leasing Microfinance	Grants (seed finance, technical assistance, project funding) Debit	Grants, including: -project grants -revolving grants -technical assistance grants

	Balance sheet financing Equity	Bonds (corporate bonds, thematic bonds) Mezzanine <u>Equity</u> Private equity / venture capital Stocks	(concessional loans, loans, green bonds), PWLB, Nature Climate Bond, etc.) Risk Mitigation Coverage (guarantees, insurance) Equity (equity investments)	-project preparation and pipeline grants -results based grants Loans (including concessionary) Guarantees Equity Bonds Insurance and climate risk finance Public-private partnerships

Source: CPI (2021), UNEP (2016), Khosla and Watkiss (2020), GCF (2022)

The actors and financial instruments can also be aligned, i.e., to better understand which organisations provide which types of instruments, to which actors. An example is shown below from Khosla and Watkiss (2020). There is also the increasing consideration of blended finance for adaptation, where public or philanthropic actors provide some form of concessionary finance to support or de-risk private sector investment. This can, for example, include technical assistance funds (grants) to help strengthen financial viability or provide support on key areas, the use of concessionary finance to lower the cost of capital or provide additional protection to private investors, to provide guarantees or insurance (on below market terms), or to provide design or preparation grants.

FIGURE 11 MAPPING OF EXISTING SOURCES OF ADAPTATION FUNDING AND FINANCE



Source: Khosla and Watkiss, 2020

This mapping of sources of finance and financial instruments can also be explored through two questions:

- Who delivers the adaptation? This can be through public or private actors?
- Who finances the adaptation? This can be public, private, or a combination (blended finance).

A typology for this is shown below.

FIGURE 12 MATRIX OF WHO FINANCES AND WHO DELIVERS ADAPTATION

		Who delivers the adaptation?	
		Public	**Private**
Who finances the adaptation?	**Public**	Public funded project delivered by public agency *e.g. flood defence funded through public budget or public financial institution (or through local taxes or charges).* *e.g. loan to sovereign or city authority for adaptation from public financial institution.* *(can also include third sector funders)*	Procurement of private company to deliver public adaptation *e.g. coastal defence project funded from public budget uses private contractor.*

	Blended	Co-financing between public (or public financial institution) and financial markets *e.g. PFI, potentially co-financed with private investors.*	Public finance used to de-risk private adaptation *e.g. technical assistance, innovation grants, concessional loans, , equities, guarantees.* Private delivery or public services or investment e.g. *Public private partnership (PPP) arrangements.*
	Private	Private finance to provide funding, *e.g. loan from private financial institution* *e.g. Bond issue.* *e.g. crowdfunding (including public crowdfunding).*	Private company delivering and funding own adaptation *e.g. flood protection of assets.* Private company develops new adaptation goods and services (Adaptation economy), *e.g. new insurance products, household adaptation goods.* Private company borrowing from commercial institution (e.g. debt, bonds) or raising finance from investors/market (e.g. shares, equity) or using mezzanine financing (hybrid).

Source: Watkiss, 2022

Looking at the top row, from left to right, public financed adaptation can be delivered by the public or private sector. This could involve conventional public expenditure and delivery, or through the procurement for this delivery by the private sector.

As highlighted above, most adaptation finance flows to date (CPI, 2021) involves sources (financing) by the public sector (top left). This can be from government budgets (e.g., from general taxation). There are examples of adaptation funding through local financing approaches using taxes or charges, e.g., Copenhagen Cloudburst (2012) plan and its use of water charges for the public to raise finance. Finance can also be raised from a public financial institution, e.g., a loan from the European Investment Bank to a regional or municipal authority. In all these cases, the dominant perspective is an economic one, i.e., centred on HMT Green book and welfare economics, or economic based lending from a PFI (which use the economic internal rate of return for loan approval).

There is also the potential for other investors to be involved in this space, i.e., in what might be considered generally public type projects. This can involve third sector investors (e.g., foundations) as well as also impact investors (who may seek a lower rate of return), for financing public projects. This can also include innovative ways of raising finance from individual investors (who are still private investors) such as through the use of crowd funding platforms.

Moving to the bottom left, there is the potential for raising finance from the financial markets and private investors for public adaptation. This can be from public financial banks, private commercial banks or from financial markets, for example through the use of a bond. There is high demand for green bonds and, while these have focused on mitigation to date, there is growing interest and early examples for adaptation. For example, the European Bank for Reconstruction and Development (2019) issued a bond dedicated to climate resilience in late 2019, which raised US$ 700 million to finance existing and new climate resilience projects. Bonds are a debt instrument: the value of the bond is paid by investors to the issuing entity in exchange for guaranteed repayments. However, this requires avoided costs or increased revenues from bond-financed activities, meaning that appropriate targeting is critical. For mitigation based green bonds, this can come from, e.g., the revenues generated by a low carbon investment. For adaptation, this may need to come from

government budgets over time (e.g., as with a municipal bond). In short, Bonds can raise finance, but it is the bond issuer (and adaptation recipients) that have to pay.

Between these two, there is the potential to blend public and private finance, e.g., to raise larger volumes using co-financing arrangements and to help spread the risks of projects between borrowers.

Moving to the bottom right, there are a number of reasons why the private sector may want to invest in adaptation for its own benefit.

These might relate to a desire for a company to address physical climate risks because of the potential impacts on company performance (Romain et al., 2018; de Bruin et al., 2019). This is linked to the current focus in the Task Force on Climate Related Financial Disclosures (TCFD) and especially the component on physical climate risks. While these are likely to be focused on the balance sheet and profitability, they could also include reputational risk, as well as cascading through to the cost of capital.

There is an emerging interest in the adaptation economy i.e., the potential market for new adaptation goods and services. CCC (2014) estimated sales of adaptation goods and services by UK companies in 2011/12 were £2.1 billion, of which £0.3 billion were exports. There has been more recent analysis on the market for adaptation goods and services (KMatrix (2016, updated 2020), Acclimatise (2016) and Bonaventura (2018), which identify opportunities for particular adaptation goods and services, especially in climate modelling, professional services including architecture and engineering, and finance and insurance products. In these cases, companies would invest in adaptation because of the potential for new markets.

Therefore, it is possible to identify a number of reasons for private sector investment and financing of adaptation, which includes.

- Defensive expenditures to protect revenues or assets, e.g., investing in flood protection at company sites, ensuring risk mitigation in supply chains.
- To reduce costs, e.g., to reduce water use in drought risk area with water efficiency, reduce risks to lower insurance costs.
- To add value to existing activities, e.g., as an add onto existing services such as new insurance products.
- Delivering adaptation benefits as a co-benefit of other activities or goods or services.
- To generate new revenues from new adaptation services or goods, e.g., developing and selling new household flood resilience options.

These investments, whether in defensive expenditure or towards new goods and services, would potentially seek debt from commercial lenders and capital markets or seek investment through equity (e.g., directly through shares or through equity investors, venture capital, etc). It is also possible, indeed likely, that such investments will be increasingly sought out by investors, because of their alignment with sustainable finance taxonomies and thus in ESG and green funds.

There are also mezzanine instruments (or capital) which provide a hybrid of debt and equity (e.g., subordinated debt, preferred stock, project-specific arrangements, risk-oriented yield, or conversion options (UNEP, 2016).

Complementing the list above, the private sector can also be incentivised to act through regulation or through economic or financial incentives.

The space between these public and private domains centres on blended finance.

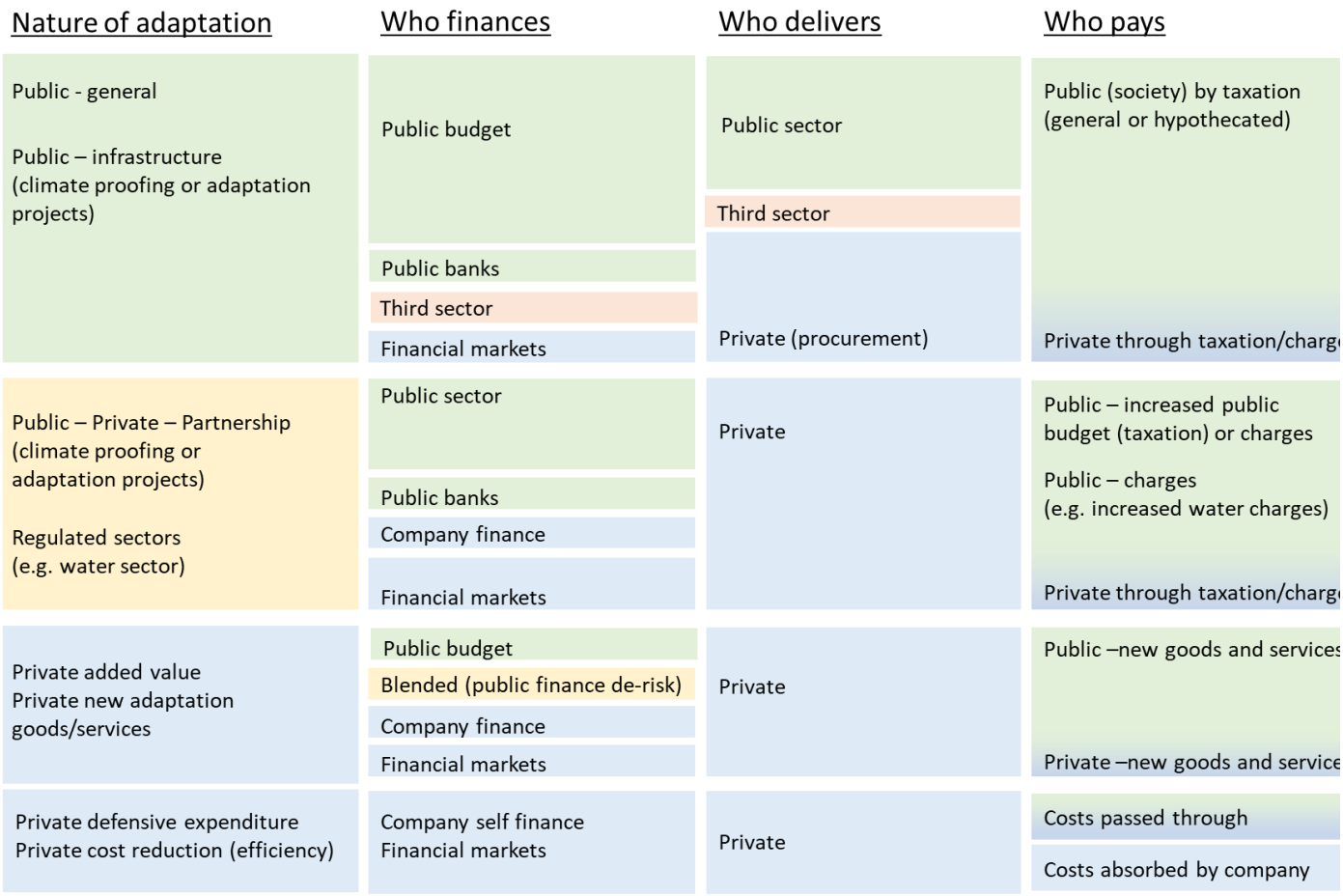
There is growing private-sector involvement in financing and delivering adaptation, with a range of new instruments and approaches developed to encourage this. These seek to combine public and private-sector finance, normally using public sources to address barriers to help unlock investment from the private sector. This can help with the development of bankable ideas or attracting private investment at early stages (with technical assistance, project preparation or business model support, challenge funds or seed funding, including incubator funding or accelerator funding and support) and help to de-risk investment by offering concessional lending, guarantees or even equity.

There is a growing number of examples in this space. There has been a greater focus on encouraging private-sector investment in adaptation by multilateral funds, such as the initiatives from Stoll et al., (2021). There are also a number of innovative mechanisms and approaches, such as the Climate Resilience and Adaptation Finance and Technology Transfer Facility (CRAFT), a commercial investment vehicle that uses blended finance to expand the availability of technologies and solutions for climate adaptation by investing in companies with an accompanying technical assistance facility. As highlighted earlier, there are also a number of international adaptation accelerators which provide various forms of support (business support, project preparation grants, etc. such as Brigaid, and similar models runs by Lightsmith group and the Laudes foundation.

There is also the potential for PPPs (Public Private Partnership), which have been used in the UK. PPPs involve everything from operating facilities and providing services on behalf of the public, to flexible methods of financing these services. They have been used in the health sector for public services projects. In such cases, partnership with the private sector delivers efficient, cost-effective and measurable public services within modern facilities whilst minimising the financial risk (DHSC, 2013). This can also relate to PFIs (Private Finance Initiative), which are a method of financing capital investment which requires that the private sector design, build, finance and operate specific facilities. Climate change does pose some risks for standard PPPs, but it is also possible that climate adaptation could be included in public–private partnerships (for example, Frisari *et al.* 2020) or in PPP adaptation investments.

This means that the overall adaptation financing landscape is now becoming quite complex, but also that there are considerable opportunities for different sources of finance, instruments and models. As an example, this review has sketched out an example of the landscape. An important consideration, however, is not to lose sight of who pays. It may be possible to raise large volumes of finance from investors for adaptation, but this will need to be repaid, whether through public taxation, hypothecated charges, or revenue streams.

FIGURE 13 ILLUSTRATIVE SKETCH OF THE EMERGING ADAPTATION FINANCE LANDSCAPE



Source: Watkiss, 2022

Clearly the source of finance and the financial instruments will depend on the type of adaptation, the sector and risks, and the organisations involved. Linked to above, conventional public funding and finance will be needed for delivering core adaptation actions, but it will also be needed for blended finance, and especially for piloting more innovative actions (e.g., transformational). This raises the question (Khosla and Watkiss, 2020) or where to best use available public finance for adaptation – and that it might be more impact can be achieved by moving the public sector to a more commercial mindset (for adaptation) and using available public finance for blended finance and innovation spaces.

A.1.7 - WHO PAYS FOR ADAPTATION (AND JUSTICE)?

There are two additional issues that are raised in relation to the financial sources and instruments above.

The first issue is around who pays for adaptation. There is a recognition that there is a large adaptation finance gap (UNEP, 2021), i.e., adaptation finance needs are much larger than current finance flows, and further, that this gap cannot be bridged by the public sector alone (although it is not yet tested if this applies to the UK). However, an underlying question is around who pays for this adaptation, rather than who finances it.

It is possible to raise private sector finance for public sector adaptation. However, such finance (e.g., bonds or loans) requires repayment to investors, which will need to come from government budgets, avoided costs or increased revenues.

Similarly, regulated companies may be allowed to invest and finance additional adaptation, but this will be passed through to household customers through increased charges.

Alternatively, the public sector could also step back from some areas where public funding currently dominates and try and encourage new markets, which moves adaptation funding from general taxation through to direct payment (by households and companies). However, private-sector finance is likely to gravitate to opportunities where revenues are highest and risks are lowest, even with public finance de-risking or blending, and as highlighted above, is less likely to be able to develop proactive and especially transformational adaptation.

Given the large scale-up in adaptation finance needed, the question of who pays for adaptation is important, as it involves some potentially major shifts in public perception on risk reduction and whether taxation is used, there is hypothecation through taxes and charges, or whether the market is expected to deliver, in which case households and businesses will pay directly or live with the (higher) risks.

The second issues flows from this and is around distributional issues and justice. Justice was a key theme in the IPCC AR6 (SPM, IPCC, 2022b). The term climate justice, while used in different ways in different contexts by different communities, was reported by the AR6 with respect to three principles: distributive justice which refers to the allocation of burdens and benefits among individuals, nations and generations; procedural justice which refers to who decides and participates in decision-making; and recognition which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives.

While CCRA3 and other studies have looked at the inequalities associated with climate risks, there has been less attention on these issues for adaptation. For adaptation finance, distributive justice is particularly important. Or in conventional economic terms, there are important distributional issues around the financing of adaptation, in terms of who pays and who benefits. There are potential inequalities around access to finance and thus adaptation, i.e., the private sector is likely to prioritise those that are able or most willing to pay, potentially creating adaptation finance gaps for low-income households. Left to the market, adaptation finance is unlikely to have positive distributional aspects or target the most vulnerable. Further, there is an issue of the equity around who pays, for example, if financial markets are lending money (and generating profits from lending) to cities for adaptation, and this is passed through in local taxes or charges, then there could be seen to be distributive inequalities. There is some work on the development of criteria for adaptation finance that includes such elements (e.g., for finance Mortimer et al., 2020: and for funding Boston et al., 2021), but further investigation of these issues will be important for this area going forward.

A.1.8 - HOW ADAPTATION FINANCE DIFFERS BY SECTOR AND RISK

The discussion above considers the nature of adaptation, and how this influences the barriers and the potential for financing. However, these barriers will differ for sectors and risks. There is relatively little in the literature that provides information on the differences in barriers and thus the approaches for financing (with the exception of coastal adaptation, Bisaro and Hinkel, 2018).

Each sector will have an existing and established framework for financing, and in many cases, this will already include financing to address (some) current weather and climate related hazards. There will also be differences in the willingness to pay for adaptation in different sectors, which will be influenced by existing financial mechanisms and current practice. This will further vary with the type of option, and how it is

perceived by public and private actors. This leads to a complex mapping that combines the various typologies above and then applies to the specific sector or risk context.

To explore this area, this section has undertaken a number of case studies. These are then used to provide some insights on how barriers may differ for sectors and risks.

CASE STUDY ADAPTATION FINANCE TRACKING AND TAXONOMIES FROM THE MDBS

One of the largest volumes of adaptation finance programmed to date has been through the multi-lateral development banks (MDBs), with US$16 billion of flows in 2020 (MDB, 2021). These flows have focused on investment projects where the MDBs provide finance, primarily as loans, occasionally as grants, and mostly to countries (sovereigns) but also to the private sector.

The MDBs have developed finance typologies for looking at adaptation investment projects. These are important because these recognise that adaptation can be differentiated in different ways to the classic definitions in the literature (as above). The type of adaptation investment for which finance is needed are split between (ADB, 2020):

- **Climate resilience (climate-proofing) of projects**. This involves the integration of adaptation in investments. In this case, adaptation is a secondary objective. An example is the integration of adaptation measures in a planned road project.
- **Adaptation projects**. The targeted investment in projects to address climate risks and deliver adaptation. An example is a new coastal protection scheme to manage rising sea levels, although it could also be a large capacity building project for adaptation. In this case adaptation is the primary or principal objective of the project.
    - A variation of this is where a project has strong adaptation co-benefits, i.e. where there are multiple objectives, one of which is adaptation.

Looking at climate proofing first, climate change can affect the financial and economic performance of investments. It can have an important influence on key financial parameters, including asset values (capital), current expenditures (operating and maintenance costs), and revenues (ADB 2020). These changes in turn will affect:

- Economic returns delivered by the investment—whether the total economic and social benefits generated by the asset are sufficient to justify the costs.
- The cash flows (cost and revenues) and hence financial returns delivered by the project—and, in some cases, whether cash flows generated by the asset are sufficient to meet the return requirements of investors.

Correspondingly, these changes will have important implications for how projects are financed, delivered, and managed. ADB (2021) identifies four separate channels:

- The direct damage from extreme weather events that either require additional rehabilitation spending or lead to a deterioration in the performance and/or value of the asset and services it provides;
- The increase in operating costs that may result from climate change impacts;
- The possibility that climate change will reduce the function or services provided by the assets, and their revenue generation potential or the socioeconomic benefits that they are expected to produce;
- The increased variability of asset performance and hence the greater uncertainty in the financial returns that an asset will provide.

This means projects need to assess the impacts of climate change on assets, costs, benefits (revenue) and cash flows, and costs and benefits of marginal adaptation, and then consider how to finance any additional adaptation spend to cover these risks, noting this should consider the costs and benefits of such action.

In contrast, for an adaptation project, the reduction in climate risk has to deliver the overall benefits of the project (the revenues and positive cash flow). This means adaptation has to deliver the core financial benefits.

These differences affect how finance is tailored and structured. For climate proofing projects, adaptation finance is marginal to the overall investment and financing, and so adaptation financing is ideally integrated in the core project financing structure. For an adaptation project, the adaptation finance has to cover the total investment and deliver the core financial benefits. These differences are shown below.

FIGURE 14 COMPARISON OF CLIMATE PROOFING VERSUS ADAPTATION PROJECTS

	Adaptation investment		
	Climate proofing projects	**Integrated projects**	**Adaptation projects**
Objective of investment	Adaptation is a secondary objective	Adaptation one of number of objectives / co-benefit	Adaptation is the primary objective
Example of investment	Climate resilience in a new road project	Urban green development project	New coastal defence for rising sea levels
Investment in adaptation	Marginal investment	Medium investment	All of investment
Adaptation tracking level	<100%	<100%	100%
Financing structure	Integrated and aligned to core investment project	Integrated and aligned to core investment project	Stand-alone and new

Source: Watkiss, 2022

The delineations are also important in terms of adaptation finance tracking, for both public organisations and increasingly for private organisations.

International public bilateral and multilateral finance flows for mitigation and adaptation are tracked and reported by the Development Assistance Committee (DAC) database of the Organisation for Economic Co-operation and Development (OECD, 2016). The OECD distinguishes between climate protection- and adaptation-related expenditures, as well as between expenditures that pursue these goals as a primary or a significant objective, i.e. expenditures that contribute to adaptation but have another primary objective. In the early reporting, organisations often used a simple approach for tracking with expenditures with adaptation being a secondary goal counting for 40% as adaptation costs and those with a primary goal counting for 100%. More recently, the UK (for International Climate Finance) and the Multilateral development banks, have used more specific bottom-up accounting to track the level of adaptation finance in a project. For example, MDBs track and report data on their climate-related contributions following their own Climate Components methodology (European Bank for Reconstruction and Development 2019). Based on this approach, MDBs determine the specific components of a transaction that directly contribute to mitigation, adaptation or both simultaneously.

There are a number of significant challenges in tracking adaptation finance, including definitions, accounting issues, confidentiality restrictions and a lack of universally accepted impact metrics (CPI, 2021). The attribution of financial levels for adaptation is often subjective because it relies on judgement. The definition of adaptation used leaves room for interpretation and the accounting methods differ.

The reason adaptation finance tracking is relevant is because this is also being developed to track levels for green finance. This has been advanced most notably with the EU Technical Expert Group on Sustainable Finance (2020) Taxonomy. This aims to support sustainable investment by making it clearer which economic activities most contribute to meeting the EU's environmental objectives. The EU Taxonomy is a tool to help investors, companies, issuers and project promoters navigate the transition to a low-carbon, resilient and resource-efficient economy. The Taxonomy sets performance thresholds (referred to as 'technical screening criteria') for economic activities which:

- make a substantive contribution to one of six environmental objectives (Figure 1);
- do no significant harm (DNSH) to the other five, where relevant;
- meet minimum safeguards (e.g., OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights).

The performance thresholds will help companies, project promoters and issuers access green financing to improve their environmental performance, as well as helping to identify which activities are already environmentally friendly. In doing so, it will help to grow low-carbon sectors and decarbonise high-carbon ones. One of the six objectives is climate change adaptation. For each environmental objective, the Taxonomy Regulation (TR) recognises two distinct types of substantial contribution that can be considered Taxonomy-aligned:

- Economic activities that make a substantial contribution based on their own performance: For example, an economic activity being performed in a way that is environmentally sustainable, e.g. low carbon energy production.
- Enabling activities: Economic activities that, by provision of their products or services, enable a substantial contribution to be made in other activities. For example, an economic activity that manufactures a component that improves the environmental performance of another activity.

An economic activity shall be considered to contribute substantially to one or more of the environmental objectives by directly enabling other activities to make a substantial contribution to one or more of those objectives, and where that activity:

a does not lead to a lock-in in assets that undermine long-term environmental goals, considering the economic lifetime of those assets;

b has a substantial positive environmental impact on the basis of life-cycle considerations.

These concepts have been applied to mitigation, and while this involves challenges, this is workable. The same concepts are much more difficult to apply to adaptation, because of the nature of adaptation as a process, and the site and context specificity, as well as uncertainty.

There is some consideration of how this might work, set out below.

These issues are important because of Environmental, Social and Governance (ESG) Investing and also the potential for green finance. The physical risks of climate change are increasingly recognized as a financial

risk (Task Force on Climate-related Financial Disclosures 2017; Network for Greening the Financial System 2019). This is leading to increased private-sector interest in managing potential climate risks. It is also generating interest from the financial sector on the potential for investing in adaptation.

FIGURE 15 EU TAXONOMY ON ADAPTATION

	Do no significant harm: adaptation	Substantial contribution to adaptation
Own performance Adapted activity	The economic activity must reduce all material physical climate risks to the activity to the extent possible (to the extent economically rationale) and on a best effort basis. For example, incorporating sustainable drainage systems in urban areas.	The economic activity includes adaptation solutions that either: ■ Substantially reduce the risk of adverse impact; or, ■ Substantially reduces the adverse impact of the current and expected future climate on that economic activity itself. For example, an urban flood risk management programme.
Enabling adaptation	The economic activity and its adaptation measures do not increase the risks of an adverse climate impact on other people, nature and assets or hamper adaptation elsewhere. For example, incorporating green infrastructure into urban spaces.	The economic activity provides adaptation solutions that: ■ Contribute substantially to preventing or reducing the risk of adverse impact; or, ■ Substantially reduces the adverse impact of the current and expected future climate on other people, nature or assets. For example, investment in the development of an Earth observation satellite.

Source: Adapted from the EU Technical Expert Group on Sustainable Finance (2020) Taxonomy Report: Technical Annex

CASE STUDY: PRIVATE ADAPTATION FINANCE

A further case study is reported. This involved work for Adaptation Scotland looking at private and blended financial solutions for adaptation projects. This focused on at two projects:

- Nature based solution, focused on a managed retreat on a coastal estuary, converting an existing farmland site to a wildlife area.
- Standard flood protection, with a barrier for a river flooding, but with the potential to develop surrounding land as part of a community project.

These might have typically been funded by standard public funding. The study considered the potential options for using private or other finance solutions as an alternative.

FIGURE 16 CONSIDERATION OF ADDITIONAL SOURCE OF FINANCE FOR ADAPTATION

		Managed realignment	Protection Scheme
1.	Mitigation revenue streams from carbon sequestration.	High	High
2.	Payment for ecosystem services	Low	Low
3.	Tourism revenues	High	High
4.	Crowdfunding platform	High	Low
5.	Biodiversity habitat bank/biodiversity credits	Medium	Medium
6.	Government grant funds	High	High
7.	Philanthropic based grant funds	Medium	Medium
8.	Equity financing	Low/Medium	Low/Medium
9.	Flood insurance based on a risk pool model	N/A	N/A
10.	Parametric insurance	N/A	N/A
11.	Resilience bonds	N/A	Low
12.	Land-use development option/ Green infrastructure finance	Medium	Medium
13.	Household or local business charges	N/A	Medium
14.	Renewable energy revenues	Low/Medium	Medium
15.	Landowner investment	Low/Medium	N/A

Source: (Adaptation Scotland, 2022)

Some relevant lessons of the study for this barriers review are summarized below.

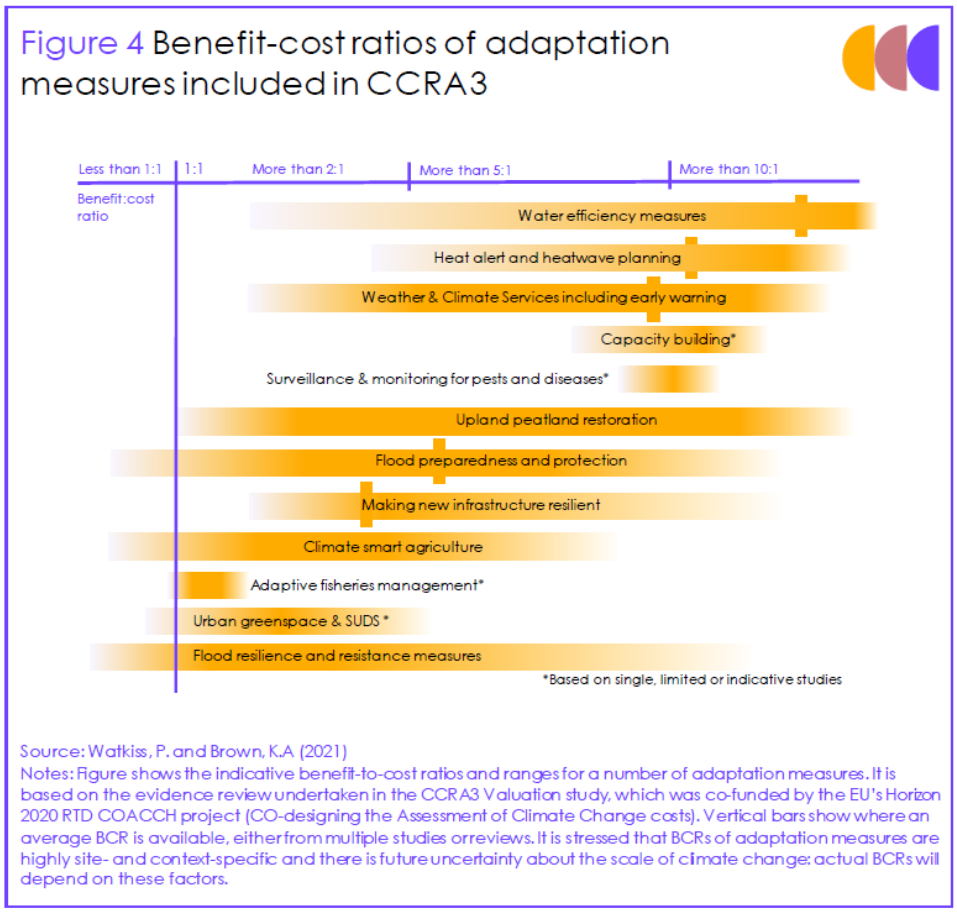
- One size does not fit all projects. The analysis found that for all the projects, there is some potential for additional finance (beyond traditional public grant finance), however, different instruments were relevant to different case studies.
- The pay-off between effort and reward (revenue) do not always match up. Delivering additional revenue streams involves extra activities and take considerable time and resources - they would be unlikely to happen on their own. Project developers could struggle with lack of time and expertise to assess and follow-though on some of the more innovative financing options.
- In most cases, the additional revenues were the result of wider project benefits, i.e. co-benefits, rather than from the adaptation (reduction in risk), for example carbon sequestration or tourism revenue. This is important, because to deliver these, projects will have to deliver adaptation and other benefits at the same time. This may involve changes to scheme design or additional activities to maximize these co-benefits, and it might even lead to trade-offs with adaptation.
- It is also likely that the size of the additional finance will be modest for the projects, and would therefore provide additional finance, rather than covering the scheme costs entirely.
- Dedicated effort and expertise are needed for resource mobilization. The list of financing options emphasizes the need for specialized knowledge on the development of financing and subsequent proposals or business cases. There is also a need for knowledge brokers who can help projects develop these new solutions, because they involve a new skill set that is not often/always present in public organizations.
- Earlier is better. Finance needs to be considered at the project concept stage. Evaluation of financing options and related innovation for adaptation needs to be integrated within the first stages of project development. This approach could also save some funds in the long run by e.g. taking advantage of project development funding, building in necessary climate adaptation components and co-activities to project design and building of essential (financing) partnerships.
- Knowledge products and capacity building is required. Whilst encouraging project proponents to be bolder and explore alternative financing options, it should also be recognized that the provision of some

basic knowledge and expertise building would accelerate both the learning and the impetus to try new approaches to financing adaptation.

CASE STUDY: CCC ADVICE REPORT – DOES PRIVATE FINANCE LINE UP?

The CCC (2021) reported the analysis from Watkiss and Brown (2021) which provided the economic benefits of a number of early adaptation measures. A key question is therefore to consider these from a financing perspective and explore if economic attractiveness would convert through to financial attractiveness.

FIGURE 17 BENEFIT COST RATIOS FOR ADAPTATION



Source: (Watkiss and Brown, 2021) in (CCC, 2021)

It is stressed that these options were picked because they were primarily low or no-regret adaptation, and thus they fall into the more finance ready areas (reactive adaptation, providing immediate benefits, with lower levels of uncertainty). Even so, an analysis of this list shows that there are financing challenges for many of these. As examples:

- Water efficiency measures are private no-regret, and the financial returns are potentially high, because they deliver immediate economic benefits. However, in order for these to be realizable as financial benefits, it requires appropriate water charging (e.g., metered reductions). In such cases these can deliver high financial returns (See CCC funded studies).

- Heat alert and heatwave information are public goods. They provide information to trigger heat wave plans in the health and social care sector (as well as for the public more generally) and reduce down public health impacts, which are non-market benefits. There are no cash flows generated.
- These also apply to upstream investment in weather and climate services. There are some potential private sector value chains in this area (e.g., information for airports, increasingly service for a range of sectors) and there is opportunity for some private finance and innovation, although this is predicated on upstream public investment, and in the UK still tends to involve public blended finance (the US is a little different, with a greater private sector in weather and climate services).
- Capacity building is also a public good. Economic benefits are generated by the improvement in efficiency and value of information (for better decisions). In most areas capacity building is seen as a public good and enabling activity that should be provided by Government. It is possible that private actors might invest, but there are no obvious revenue streams.
- Monitoring and surveillance of pests and diseases is another public good, with again, little obvious revenues. There has been some discussion about the role of the private sector in providing some of these services, but this would likely still be public funded.
- Upland pest restoration has high economic benefits, but these are based on non-market benefits (carbon sequestration) and regulating ecosystem services (e.g., water management, biodiversity). Most of these have little revenue potential, though the exception is the carbon sequestration through the peatland code.
- Climate smart agriculture is a low regret economic option, but the economic return is much higher than the financial return (Posthumus et al., 2015). This is because it involves non-market benefits (on GHG sequestration, environmental benefits including ecosystem services). It also often involves upfront costs and time for measures to become established. These factors explain the lack of uptake by farmers.

An important thing that emerges from this is that the areas where we might anticipate positive early adaptation actions are not the areas that the private sector is likely to invest in. There is therefore a disconnect between adaptation priorities and private adaptation financing attractiveness.

CASE STUDY: ADAPTATION FINANCING FOR A SPECIFIC RISK

The final case study has looked at a particular risk (heat-waves) and looked at the potential financing options for adaptation to this risk. This identifies clear differences in financing potential based on the specific risk and adaptation objective. The public health risks (fatalities and morbidity) sit within the public dominated health and health care system, although there is a large private sector in terms of private health care, and of particular relevance, private social care (for the elderly, the most vulnerable group). As this moves to the broader issue of over-heating in buildings, it then moves to private households, public buildings, and private buildings. This indicates that barriers differ even within a risk area, depending on the end-user targeted.

FIGURE 18 POTENTIAL ADAPTATION FINANCING FOR HEAT, PUBLIC HEALTH AND OVERHEATING

Risk/adaptation	Adaptation type	Recipient	Benefit stream	Revenue	Who pays	Possible finance
Heatwaves and health						
Heat-Health Watch System	Reactive (no-regret)	Health sector General Public	Avoided fatalities and illness	WTP for reduced risk	Society through taxation	Public, grant
Awareness raising, training, capacity	Reactive and concurrent	As above	Avoided fatalities and illness	WTP for reduced risk	Society through taxation	Public, grant

Occupational (clothing, hours)			Avoided heat stress Labour productivity	Reduced health costs (3) Improved labour productivity	Society (public) Private (private health)	
Air conditioning (retrofit or new)	Reactive and concurrent	Households	Reduced health risk Comfort (welfare)	WTP for reduced risk and cooling	Household	Private households
		Hospitals	Reduced health risk Labour productivity	Reduced health costs (3) Improved labour productivity	Public budget	Public PPP PFI
		Private social care	As above	As above	Private owner	
Built environment						
Passive cooling design	Planned	Households				
		Business				
Urban green space	Planned		Ambient cooling Co-benefits	Carbon Recreation		
Innovation actions						
Private HHWS	Reactive	Private sector (health and general)	Improved labour productivity	Cost savings	Private companies	Private, new service

Source: Watkiss 2022

Such an analysis could be built up for all the major investment areas for adaptation, but is likely to reveal similar findings, i.e., there will be a need for a mix of public and private investment in each risk area.

For example, Bisaro and Hinkel (2018) looked at possible finance solutions for coastal adaptation, focusing on arrangements that align public actor and private investor interest. They identified that private provisioning, public–private partnerships, and public debt arrangements could be promising, but found varying attractive for these in practice based on empirical examples. This indicates that there will be a need for an applied focus in identifying financing by sector, which will be highly context specific.

A.1.9 - DISCUSSION

The study findings on barriers to adaptation finance are summarised in the table below. The evidence from the literature review, the case studies in this report, and also the Task 2 case studies, are brought together to provide a score for each barrier, in terms of importance (magnitude). The scoring is somewhat ad hoc (using expert opinion) but is based on the literature review findings (the number of studies highlighting the barrier) and from the number of case studies that identified the barriers.

Given the low evidence base, the ranking should only be considered indicative. It is also noted that while an importance (magnitude) is given, it is not clear how frequently each barrier arises. The importance of individual barriers will vary with public and private projects, for example, to raise private finance for adaptation, a revenue stream is likely to be a key condition. They will also vary with sector and risk, and for each adaptation project, due to the type of adaptation, finance sources, organisations, etc.

FIGURE 19 EVIDENCE ON BARRIERS TO ADAPTATION FINANCE AND INDICATIVE IMPORTANCE (STUDY SCORE) BASED ON LITERATURE REVIEW AND CASE STUDY FINDINGS

Barrier	Literature	Case studies	Score
Information barriers			
Insufficient information on risks / high uncertainty (market failures and information asymmetry)	Cimato and Mullan (2010), Frontier et al., (2013), HMG (2013), EBRD (2015), UNEP (2016), Stoll et al. (2021), UNEP FI (2019)	CReDO (digital twin pilot to reduce cascading risks)	3
Information gaps on adaptation effectiveness and benefits (physical and financial) (note include site and context specificity and variation)	Frontier et al., (2013), Mortimer et al., (2020), Khosla and Watkiss (2020); Stoll et al. (2021)	Manchester SuDS California Forest Resilience Bond Glasgow Niddrie Road tenements retrofitting (housing association flats) EnTrade (trading platform for nature based solutions) LENs ((trading platform for nature based solutions)	4
Investor understanding of adaptation		Evidence from some interviews (organisations not named)	1
Market failures*			
Public good characteristics or non-market sectors	Bisaro and Hinkel (2018), Cimato and Mullan (2010), Mortimer et al., (2020), Khosla and Watkiss (2020)	Manchester SuDS EnTrade LENs CReDO Kent Downs (payments for landscape conservation measures) Analysis of CCC (2021)	4
Positive externalities (economic BCR>financial BCR)	UNEP (2016), Mortimer et al., (2020), Khosla and Watkiss (2020); Stoll et al. (2021)	Manchester SuDS EnTrade LENs CReDO Kent Downs Analysis of CCC (2021)	4
Under-developed markets for adaptation (imperfect capital markets)	UNEP (2016); Stoll et al. (2021)	Manchester SuDS Glasgow Niddrie Road tenements retrofitting (housing association flats) CReDO Kent Downs	2
Misaligned incentives (adaptation costs, vs who benefits accrue to)	Cimato and Mullan (2010)	UK Water Sector (Ofwat) Kent Downs	
Financial barriers / bankability			
Low or no revenues from climate risk reduction	IGCC (2017), Bisaro and Hinkel (2018), Mortimer et al., (2020), Khosla and Watkiss (2020), FUKR, 2022), UNEP FI (2019)	Manchester SuDS Abundance Investment Adaptation Scotland (2022) Glasgow Niddrie Road Kent Downs)	4
Low economic or financial internal rate of return / long payback (timing of benefits)	Cimato and Mullan (2010), UNEP FI (2019)	Manchester SuDS Abundance Investment Adaptation Scotland (2022) UK Water Sector (Ofwat)	4
Low replicability (site and context variability)	Mortimer et al., (2020)	Manchester SuDS Glasgow Niddrie Road	2
Low investment size (£)	IGCC (2017)	Manchester SuDS Abundance Investment	2
Large number of actors (beneficiaries/organizations) and benefits to different beneficiaries	Mortimer et al., (2020)	Manchester SuDS CReDO	2

Project complexity (time and resources) (long lead-times)	Frontier et al., (2013), EBRD (2015), Bisaro and Hinkel (2018)	Manchester SuDS Adaptation Scotland (2022) EnTrade CReDO	3
Low capacity among developers / financial institutions)	Frontier et al., (2013), UNEP FI (2019).	Adaptation Scotland (2022)	2
Policy & governance			
Regulation (or lack of) (policy failures)	Cimato and Mullan (2010), Mortimer et al., (2020), Bisaro and Hinkel (2018), FUKR (2022, UNEP FI (2019)	Manchester SuDS Glasgow Niddrie Road EnTrade LENs CReDO	4
Conflicting or competing policy objectives (inc. Net Zero) (coordination failures)	Frontier et al., (2013), HMG (2013)	UK Water Sector (Ofwat)	2
Lack of coordination and cooperation (inc. cross-sector) (coordination failures, governance failures)	Frontier et al., (2013), HMG (2013), IGCC (2017)	LENs UK Water Sector (Ofwat) CReDO Kent Downs	3
Political economy, challenge of altering status quo	Zografos et al. (2020)	UK Water Sector (Ofwat) CReDO	1
Behavioural barriers			
Social, behavioural and cultural barriers	Cimato and Mullan (2010)	Adaptation Scotland (2022)	1
Perceived urgency of adaptation/ lack of awareness (inertia, moral hazard)	Cimato and Mullan (2010), Frontier et al., (2013), HMG (2013),Bisaro and Hinkel (2018), Mortimer et al., (2020)		2
Low willingness to pay for adaptation / current reference	Khosla and Watkiss (2020)	Khosla and Watkiss (2020) Adaptation Scotland (2022) UK Water Sector (Ofwat)	3

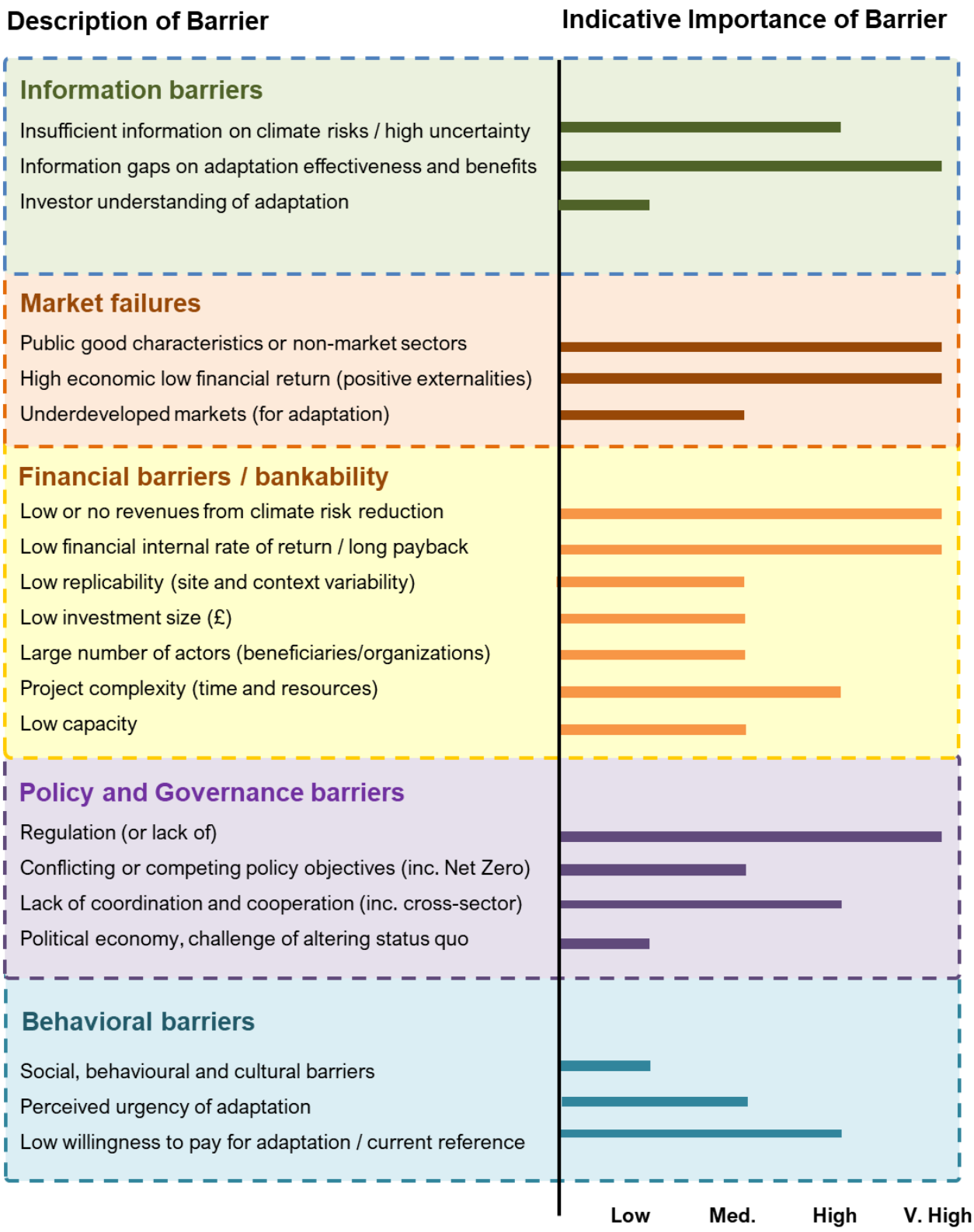
Source: Watkiss, 2022

Note: Score key: 1 equals low, 2 equals medium, 3 equals high, 4 equals very high.

Note: Some market failures are captured in other areas, such as information failures and coordination failures.

The results are summarised in the figure below.

FIGURE 20 BARRIERS TO ADAPTATION FINANCE AND INDICATIVE IMPORTANCE BASED ON LITERATURE REVIEW AND CASE STUDY FINDINGS.



Source: Watkiss, 2022

Based on the overall literature review, the most important barriers to financing adaptation are:

- **Information barriers (gaps, uncertainty and risk appetite):** There are barriers to investing in adaptation because of the information gaps (information failures) around future climate risks, including uncertainty, and thus benefits of anticipatory adaptation. However, more importantly, there are also information gaps around the effectiveness and benefits even for no-regret adaptation. It is clearly more difficult to finance projects when benefits are uncertainty, and this may mean investors seek a high rate of return, or else requires public de-risking (blended finance).
- **Market failures, including revenues and return:** Many adaptation measures do not create revenue streams (either positive revenues or cost savings), so finding revenue to repay finance is challenging. This is driven partly by the nature of adaptation, e.g., its focus on public goods, in non-market or in public dominated sectors. It is also driven by the challenges in generating revenues from climate risk reduction, even in market sectors. Where revenues are generated, the rate of return is generally low. While it is possible to look at alternative revenue streams (e.g., co-benefits from carbon credits, tourism revenue) this dilutes the adaptation focus, and makes projects more complicated to finance.
- **Discounting:** There are a range of barriers related to the timing of the investments. As highlighted above, investments designed to prevent costs in the future (anticipatory adaptation) are harder to finance, due to the discounting in public project appraisal, or the expected rate of return for private sector projects. Adaptation projects often take time to develop, or to establish benefits streams, which make financing more difficult even when adaptation is reactive.
- **Financial barriers and bankability (project structuring, preparation, risk levels, and co-ordination):** A general barrier is that adaptation projects tend to take more time and resources to develop. The issues of information and uncertainty above are compounded by the site and context specific nature of adaptation, and there are often additional legislative and due diligence issues. This is further exacerbated by the fact that adaptation often involves numerous stakeholders, or many diffuse actors, complicating financial structuring. This means there is low transferability and generally more detailed financial assessment, risk analysis and due diligence is needed. All of these increase project financing costs, and disincentivise project developers and financiers. There is also an issue of the low capacity and skills, among developers and financiers, for adaptation. Overall, these factors make it is more difficult to develop investment ready projects (bankable projects) as well as more difficult to subsequently get these financed.
- **Regulatory barriers:** Investing in adaptation, especially in innovative areas, sometimes requires changes in regulatory frameworks or permissions. There can also be issues on the governance around mandated responsibilities for risks and the risk reduction, that may prevent new entrants. These regulatory issues can be a significant barrier to project developers, but also act as a barrier to investors until they are resolved.
- **Perception and willingness to pay:** Scaling up adaptation finance will involve persuading households and business to pay to reduce risks or realise savings associated with climate change. Adaptation is usually an extension of an existing climate problem (variability and extremes) and in many areas, society is currently used to government funding risk reduction. In some cases, households or customers may be willing to pay more for resilience, e.g., there is some anecdotal

evidence from the water sector on this. However, in other cases, there may be barriers in persuading people to pay for services previously provided by the state, or people's willingness to pay may be too low to justify investment. In some cases, there may be a willingness to pay through tax revenues (i.e households and business are happy for the government to invest in adaptation using tax revenues), but the incentives are not strong enough for them to want to invest directly. The less awareness, or understanding of adaptation there is, the more the willingness to pay for these projects will be weakened.

ANNEX 2: ADAPTATION PROJECT CASE STUDIES

One of the main focuses of this piece of work was to take the learnings from the literature review, and apply them to a set of case studies. The aim of these case studies was to understand not only what the barriers each of these adaptation projects faced in terms of financing, but also to understand how effective the adaptation projects were. These case studies primarily focus on the private sector in the UK, however public sector are also explored, as well as non-UK case studies where deemed relevant to the UK.

A.2.1 - GLASGOW TENEMENTS

Sector	Housing sector
Climate risk	Changing weather conditions resulting in extreme hot and cold temperatures, and increased rainfall
Why pays?	Blended finance: Public grant and private traditional debt finance
Synopsis:	*Retrofitting of eight flats within a tenement building to include Net Zero and adaptation measures, whilst maintaining the exterior features of the sandstone (cultural heritage).*

Tenements are a common type of large residential building which contain multiple apartments[5] in Scotland, and in Glasgow in particular. There are more than 75,000 pre-1919 sandstone tenement buildings located in Glasgow (Collaborative Centre for Housing Evidence, 2021). Flats within tenement buildings make up around 20% of Glasgow's homes (Collaborative Centre for Housing Evidence, 2021).

It has been estimated that up to 80% of the Scottish homes that will exist 2045 have already been built (Collaborative Centre for Housing Evidence, 2021). Therefore, even if all new builds were constructed with adaptation features, the majority of the stock of Scottish homes are unlikely to contain adaptation features. As a result, retrofitting homes is a key solution to ensuring homes can be adapted to withstand extreme weather events that are expected to occur due to climate change.

The renovation of the eight flats within a single tenement building at 107 Niddrie Road began in February 2020, and finished in November 2021 (Collaborative Centre for Housing Evidence, 2021; Scottish Housing News, 2021). The eight flats are owned by Southside Housing Association (SHA), who undertook the project with John Gilbert Architects and CCG Construction Ltd.

[5] Under Scottish law they are defined as "Two or more related but separate flats divided from each other horizontally. The definition is framed broadly in order to include not only traditional tenement properties, but also four-in-a-block houses and larger houses which have been subdivided". Source: Tenements (Scotland) Act 2004. Available at: https://www.legislation.gov.uk/asp/2004/11/pdfs/asp_20040011_en.pdf [Accessed 6th May 2022]

FINANCING AND BARRIERS

The Niddrie Road renovation project was supported through blended finance, and the public funding was crucial to unlock higher levels of additional funding that enabled the investment in the additional adaptation measures (McGrath and Morgan, 2022).

The overall capital cost of the project at funding was £1.091 million. The final project cost was around £1.295 million (Higney, 2022). Funding included (Higney, 2022):

- £448,000 from the Glasgow City Council.
- £129,000 from the Scottish Government's Social Housing Net Zero Fund Costs to provide air source heat pumps for half of the properties (Scottish Housing News, 2021).
- The balance was funded by private finance from Southside Housing Association. The main revenue stream from the project is the future rental payments on the property paid by the future social housing tenants.

The total cost of the renovation was £88,000 per unit. This consists of (Higney, 2022):

- £44,000 for the basic refurbishment of the vacant properties.
- £32,000 for the initial cost of the EnerPHit retrofit, including the adaptation measures.
- £12,000 for contingencies.
- The cost per unit increased after the project started due to unanticipated problems, such as the poor condition of the plasterwork requiring additional work.

In addition, the approximate cost of fitting a unit to EnerPHit standard beyond traditional energy efficiency retrofit standards is approximately £32,000 a unit if fitting occurs at scale, whereas the costs are likely to be more if fitting does not occur at scale (McGrath and Morgan, 2022).

The project faced three main barriers:

Informational barriers. During the project, some stakeholders in the project were not supportive of the additional adaptation measures partially due to their high cost but also due to a lack of information around the benefits of the measures. This barrier resulted in insufficient value being placed on the adaptation measures. Future renovation projects with multiple stakeholders similar to this project will also likely have informational barriers that must be overcome for adaptation measures (which are often costly) to be included in projects.

Financial barriers. There is no well-established funding route for projects of this kind that blend finance for extensive renovation projects. Whilst there are funding routes for general repairs to housing association buildings, there is not a clear path to financing renovations for housing association buildings, either through government funding or other sources.

Regulatory barriers. During the project, there were multiple barriers to receive approval for certain parts of the renovation, due to a lack of precedence regarding what could be approved. These regulatory barriers would harm the ability to fund similar projects with private finance, due to the uncertainty in terms of the likelihood of regulatory approval. For example, there was no policy regarding approval for locating heat pumps on the outside of buildings, which slowed down the project.

Approval for planning in a residential setting could be more difficult compared to a commercial setting in the same building because planning policy can often lag behind or hinder agreed public policy objectives. For example, a commercial property owner seeking a fast food licence and permission to put up large metal flumes has a clear and tested planning approval route and is likely to be successful despite the outcome being questionable in terms of public health priorities and possible neighbour nuisance. However, an affordable housing project seeking to carefully reduce carbon emissions and reduce the level of fuel poverty can be subject to planning conventions that don't necessarily align with public policy objectives. In addition, planning rules can be susceptible to a reasonable level of subjective interpretation by planning officials.

There were a variety of measures taken as part of the project in order to reduce these articulated barriers, including:

- Active communication across stakeholders to disseminate information, and to enable the presentation of the merits of certain adaptation measures.
- Using precedence from other settings to present the merit of certain adaptation measures, reducing informational barriers. In order to facilitate the acceptance of the external wall insulation plans (which were initially rejected), a visit to another building with the same insulation was organised to display the merits.
- Gaining the support of the local council through multiple discussions was central to overcoming some of the barriers to financing, by opening up the ability to obtain public funding that "unlocked" the investment in adaptation measures.

This project was made possible by the vacancy of all eight flats at the same to the Southside Housing Association, the occurrence of which is almost unprecedented. This enabled a total building renovation to occur, without the need for displacing of tenants during the disruptive work. This would likely constitute a barrier to the project occurring in any further housing association flats.

The retrofit adhered to EnerPHit standards, with EnerPHit standards being the Passivhaus equivalent for retrofitting existing buildings (Collaborative Centre for Housing Evidence, 2021). Passivhaus standards refer to buildings that are designed such that a residence can almost maintain a constant temperature (Energy Saving Trust, 2021).

ADAPTATION DETAILS

Two of the aims of the project were to improve the energy efficiency of the building, and to make the building more resilient in case of future extreme weather events.

Climate change adaptation measures built into the design included:

- Using breathable (permeable) materials, such as vapour permeable wood fibre internal wall insulation, as internal wall insulation will magnify the effect of wetter conditions caused by climate change
- Re-designing to take timber joists out of the walls to prevent rotting during periods of heavy rainfall, preventing water entering the building as stone wall moisture and causing the timber joist to rot.
- Increasing the size of outdoor gutters to be able to withstand higher future expected levels of rainfall.
- Adding lead soakers under gutters to stop any rainfall from soaking into the building stone.

Several measures within the project were anticipatory and transformational adaptations.

- Increasing the size of outdoor gutters is anticipatory as it will "*protect the client in the future*" by accounting for expected increased levels of rainfall as a result of climate change.
- The retrofit project as a whole was transformational, as it involved measures which "*have never [been] done or [they] haven't done them in the same way*". This includes using lime plaster as an air tightness layer, and the internal wall insulation, which was re-designed to ensure no contact with timber joists, as this could cause rotting.

Overheating is one of the climate risks addressed by the adaptation features of the project. An evaluation of 26 new Scottish residential buildings found that more than half of the homes exhibited overheating (Morgan et al., 2017). In addition, with the UK aiming to build approximately 300,000 homes each year, there is a risk of lock-in[6] if without urgent immediate action, with the potential for new and exisitng homes to become uninhabitable due to rising temperatures (CCC, 2021). Discussions with representatives of John Gilbert Architects suggests that overheating can occur in residential buildings in Scotland, despite the country's northerly latitude, because building design can be a greater determinant of overheating than geography or latitude.

Increased levels of rainfall is another climate risk addressed by the adaptation features of the project (McGrath and Morgan, 2022). Adaptation features addressing the expected increase in rainfall included larger outdoor gutters, and adding leak soakers under the gutters. Finally, the stonework of the building was altered so that all stone work on the front of the building was re-pointed[7] in line in order to stop moisture from getting sealed into the stone and saturating during wet periods.

Energy efficiency was an important aim from both a Net Zero and fuel poverty perspective. 40% of heat loss (and thus energy bills) occurs through draughts (Collaborative Centre for Housing Evidence, 2021), and so the project had an ambitious target of a 70-90% reduction in energy use, without compromising the comfort and health of the residents (Scottish Housing News, 2021). Energy efficiency measures included a combination of internal wall and external wall insulation (EWI), utilising natural and vapour-open materials for internal wall insulation (IWI), mechanical ventilation and heat recovery, and triple glazed windows and doors (Scottish Housing News, 2021).

SCALABILITY AND SUMMARY

Whilst the project is scalable from a technical perspective to all tenements of similar types in Scotland, the financial model for the adaptation is less scalable due to the high cost per flat. Furthermore, "*the only way to make financial sense of it [the project] is to do it at scale*" (McGrath and Morgan, 2022). If the total package of retrofit measures were to be performed on a large scale there would be economies of scale, but this is unlikely given that it is not possible to complete multiple housing association retrofits at the same time. It is likely that some level of public funding would still be needed for a project at a larger scale, despite the cost efficiencies that would be achieved from the economies of scale (McGrath and Morgan, 2022).

Despite these challenges to scalability, the Niddrie Road project has presented successful multiple adaptation measures that future projects can learn from. So whilst the entire package of reforms is unlikely

[6] Lock in refers to decisions which are either delayed or not taken with the long-term future in mind leading to irreversible changes, increased climate change damages, or higher costs due to action needed in the future (CCC, 2021).

[7] Repointing is the process of taking out and replacing the mortar ('pointing') from the face of a masonry joint. When executed correctly, re-pointing helps to exclude the weather and delay deterioration of the wall (SPAB, 2022).

to be financially viable for projects, future renovations by housing associations or private investors could focus on "cherry-picking" the retrofit measures that would be most appropriate to the project in question.

The Niddrie Road renovation project contained multiple adaptation measures to 'future proof' the building against potentially extreme future weather. Public funding was a key factor in enabling the additional adaptation measures for the project, in addition to the private financing that would have supported some of the energy efficiency measures. The project faced multiple barriers, with information barriers leading to an underestimation of some adaptation measures, and financial barriers including the lack of a clear financing route for the retrofit of housing association buildings. Whilst the Niddrie Road renovation occurred on eight flats simultaneously, other retrofits are likely to not occur in such numbers, leading to a higher cost per unit through diseconomies of scale, and potentially limiting the extent of the work that can be undertaken due to disruption.

A.2.2 - INSPIRED VILLAGES

Sector	Housing sector
Climate risk	Extreme cold and extreme heat due to changing weather conditions
Why pays?	Private finance
Synopsis:	*A retirement village operator which builds Net Zero homes, which also include adaptative features in the case of extreme weather.*

Inspired Villages own and operate six retirement villages across England. These villages support independent and assisted living for those of retirement age. Inspired Villages have another fourteen retirement villages either under construction, soon to start construction, or at the planning stage (Inspired Villages, 2021). The company began to invest in building Net Zero energy retirement villages from 2021.

FINANCING AND ADAPTATION DETAILS

Inspired Villages are financially backed by a joint venture between two social impact investors: Legal & General, and NatWest Group Pension Fund. The fifteen year joint venture partnership commenced in August 2021, with £500 million of equity funding being used to build new retirement villages (Legal and General, 2021).

From 2030, Inspired Villages plans build all future villages to Net Zero (Inspired Villages, 2021). The new Net Zero retirement homes are primarily designed from a Net Zero perspective, and conform to the following building regulations[8]:

- Conservation of fuel and power
- Onsite generation of electricity

[8] The Building Regulations 2010

Whilst the focus of these measures is on achieving Net Zero, and therefore more focused towards climate change mitigation, adaptation measures have been considered in the planning and design. The key theme behind the following adaptation measures is thermal comfort, given the vulnerabilities and concerns of the elderly. The value of this thermal comfort is expected to increase as the effects of climate change occur, and make temperatures more extreme. Adaptation measures on the homes include:

- Ventilation measures
- Overheating mitigation

New build homes have multiple options to mitigate against overheating. Inspired Villages utilise a range of options, including:

- A "fabric first approach" – designing the home with the future in mind:
  - The amount of window glazing[9] can be appropriately chosen to limit solar gains.
  - The type of window glazing can be changed if an area is expected to have a lot of solar gains.
  - Considering the minimum free area in the design – the ratio of glazing to flooring - can help to reduce overheating in hot weather.
- Measures after the home has been built:
  - Adding internal and external shading to the home after overheating issues are identified.
  - Increasing the mechanical ventilation of the MVHR system.

Mechanical Ventilation Heat Recovery (MVHR) systems are installed in all Inspired Villages homes to support ventilation. A MVHR system is an air pump which extracts hot air in cold conditions, and conversely extracts cold air in warm conditions and can change the air temperature by 2-3 degrees. This incremental change can significantly improve the wellbeing of the population which reside in Inspired Villages homes (Bunce, 2022), especially given they are elderly: "*older populations are more vulnerable to climate-induced effects as they are more likely to have underlying chronic health complications, making them more vulnerable to heat stress*" (Oikonomou et al., 2020).

SCALABILITY AND SUSTAINABILITY

Inspired Villages take a long term view to their sites as they are the operator and not the developer. Inspired Villages have a planned maintenance view to 2072, a horizon of over 50 years. This is considerably beyond what is required by regulation, with planned prevention maintenance[10] programmes typically covering 5-10 year maintenance periods (Royal Institute of Chartered Surveyors, 2022).

As the operator of these homes, Inspired Villages have a strong interest in the longevity of the asset, by ensuring that homes are well prepared for potential future extreme weather. Commercial housing developers however are unlikely to go above and beyond what is required by regulation, as they are less interested in the longevity of the asset given that they will be selling it after construction to the open market.

Inspired Villages, and Legal & General and NatWest Group Pension Fund, have spotted a market opportunity from customers who are willing to pay for thermal comfort and for lower bills that are available at

[9] The appropriate amount of window glazing also depends on the location of the home, and the orientation of the largest glazed façade.

[10] Planned prevention maintenance is the maintenance that is performed purposely and regularly to keep the structure and fabric, facilities, plant and equipment of a building in satisfactory operating condition (Royal Institute of Chartered Surveyors, 2022).

operationally Net Zero retirement villages with energy efficient features. Since the pandemic, "*there has been a sea change in people's approach to climate change*", as well as a "*growing change in customer expectations*" (Bunce, 2022).

However, the financing of these new homes depends on project developers and buyers having a longer-planning horizon (around 50 years) than typical housing developments. That may be a barrier to scalability as not all developers have an incentive to have such longer term planning horizons. A solution could be a signal to those who will buy and operate properties (disclosure of Energy Performance Certificates before the purchase, for example) those which will be more expensive to operate in the future. This mechanism would thus signal to developers the importance of longer time horizons.

COMPARISON TO GLASGOW TENEMENTS

In comparison to the Glasgow tenements renovation project, there appear to be less barriers to the private financing of adaptation measures for Inspired Villages and potentially other new builds. Customers are generally willing to pay the additional cost resulting from adaptation measures as these measures help to protect the value of the asset, and make them more comfortable for a future with more extreme temperatures. This ability to take a long term view (as an operator), coupled with the change in customer demands (and ability to pay for them) presented far less barriers to investing in adaptation for the new build villages than was faced by Glasgow for their renovation project. Inspired Villages and Niddrie Road serve different markets, with Inspired Villages targeting households able to pay for tailored retirement living, whilst Niddrie Road is aimed at households who require social housing. These differences will impact the quantity of finance available to fund adaptation measures.

A.2.3 - PLATFORMS

Sector	Water sector, land use, farming, manufacturing
Climate risk	Flooding, soil degradation, water quality, nutrient degradation.
Why pays?	Private finance, Public finance
Synopsis:	*Two different nature-based solution operators have generated platforms to facilitate trades for nature outcomes (including some relating to climate change adaptation). They bring together supply side operators (e.g farmers) and demand side operators (e.g utility companies or manufacturers).*

This case study considers the barriers to the financing of adaption actions in the context of online platforms. The two platforms which are discussed are EnTrade and LENS, who both facilitate the matching of buyers (e.g. housing developers or food manufacturers) and sellers (e.g. landowners such as farmers).

To date, platforms which match buyers and sellers of nature-based solutions and landscape management, such as EnTrade and LENs, haven't focused on adaptation as their primary objective. For example, one of the key aims of the LENs Cumbria trading community is to strengthen the resilience of Nestle's diary supply. However, there is future potential for the platforms to focus more on adaptation goals if the complexities of the platforms can be facilitated.

A.2.3.1 - ENTRADE

EnTrade was established by Wessex Water in 2016 as a spin out from the business, but now operates independently from Wessex Water. EnTrade is a trading platform which creates and operates platform markets for nature based solutions, that bring together demand side actors (such as water companies) and supply side actors (such as farmers) to facilitate trades.

EnTrade's first platform solution centred in Poole Harbour, Dorset. A successfully negotiation with the Environment Agency and Natural England resulted in an agreement to offset 40 tonnes of nitrogen from entering Poole Harbour by working with farmers to reduce their run-off of nitrogen from fertilisers. This solution was approved against the counterfactual of building an additional capex asset at Dorchester sewage treatment works. The Poole Harbour project first ran as a pilot in 2016, with subsequent auctions occurring twice a year (EnTrade, 2020; EnTrade, 2021). EnTrade has since moved its focus for future projects to a two-sided catchment market model, which has multiple buyers and sellers, away from the reverse auctions model, which has one buyer and multiple sellers.

BUSINESS MODEL AND BARRIERS

EnTrade operate auctions where the surplus is shared between buyers (such as housing developers) and sellers (such as farmers), and the cost of running the market is retrieved from the auction. The Poole Harbour was a reverse auction, which means that there is one buyer and multiple sellers, and the sellers compete by bidding the prices at which they are prepared to sell their services. EnTrade now operate auctions for two-sided catchment markets. Two-sided catchment markets have multiple buyers and multiple sellers who come together to trade environmental credits, with the online platform ensuring that both buyers and sellers are happy with the price (EnTrade, 2020). Environmental credits refer to a known quantity of environmental benefits, such as water quality and biodiversity, that are generated from the nature-based projects (EnTrade, 2020).

EnTrade incur three costs to run an auction on their online platform:

- The cost of running the auction, which is the most significant cost.
- The upfront cost of engaging farmers in the auction process.
- The cost of developing the project so that it can be accredited.

Due to the sensitivity of EnTrade's business model, exact costs are not possible to provide.

The three main barriers to financing and running the platforms are **informational**, **financial** and **regulatory**:

Informational barriers exist due to the uncertainty of the catchment markets, in terms of the expected impact on the environmental goals. Catchment markets can have less certain outcomes. For example, at Poole Harbour treating the water at a treatment plant would have had a more precise impact than reducing nitrogen releases into the catchment area, due to the nature of the chemicals used, and the experience of the water company in doing these nutrient balances. In comparison, EnTrade's catchment market solutions involve a multitude of actors on the supply side, each with a differing land holding, which creates more uncertainty as to the exact impact on the nitrogen levels.

This uncertainty around the impact of a catchment markets approach, versus the certainty of a treatment plant, creates a risk to the Environment Agency as they are unable to fully estimate the expected impact with certainty. This therefore creates a strong informational barrier for the regulator, as the Environment Agency

are required to achieve measurable outcomes (Peacock, 2022). The same uncertainty of the underlying impact of the adaptation exists for EnTrade's projects relating to flooding risk: catchment markets containing nature-based projects reduce, but do not eliminate, the risk of flooding. Whereas, a flood barrier has the capacity to eliminate the risk.

Additionally, in catchment markets it is difficult to precisely measure the allocation of environmental benefits, such as credits, of the projects to the different buyers. This is not an issue in projects such as Poole Harbour, as there was only one buyer. However in catchment markets there are multiple buyers who are seeking environmental credits from different aspects of the catchment area. Therefore, accurately measuring the allocation of credits to the different buyers is an important factor for potential buyers to commit to the project.

Financial barriers to EnTrade's projects are primarily created by the long term monitoring and verification costs of the catchment area, in addition to the uncertainty of outcomes referred to above in the informational barriers making these projects less investable for the demand side operators due to the risk of the outcomes not being achieved.

Outcomes from the catchment markets need to be measured for several decades after the markets are set up for regulatory and legal purposes. For example, nutrient neutrality, meaning that the nutrients from all surface water runoff and wastewater generated by a development must be less than or equal to the nutrients generated by the existing land use (Water Environment, 2022), is required by the Habitat Regulations to be measured in perpetuity, which is defined as 80-125 years (Natural England, 2022). The net gain to biodiversity from the projects needs to be measured for 30 years (Environment Act, 2021). The considerable horizon over which outcomes need to be measured could be offset if the monitoring costs were low. However, depending on the project, monitoring costs can be prohibitive. For example, phosphorus is particularly expensive to monitor.

Regulatory barriers exist for EnTrade, due to the fact that each component of catchment markets have siloed regulation. Therefore, catchment markets with multiple outcomes – nutrient neutrality, biodiversity net gain and carbon soil sequestration, for example – leads to multiplicative regulatory complexity. Increased regulative complexity could be resource intensive for buyers, which may lead to lower demand for projects within catchment markets.

An example of siloed regulation relates to the requirements for nutrient neutrality. Nutrient neutrality is required as part of housing developments to compensate for their impact, and this can be done through the creation of wetlands woodlands and meadows. This requirement is driven by The Conservation of Habitats and Species Regulations 2017, which have strict requirements as to what constitutes 'compensation' in terms of timing, certainty and other requirements. EnTrade are simultaneously delivering the same outcomes and measures for water companies, as required by the Water Framework Directive. However, the directive has a different and incompatible set of requirements for showing nutrient reduction. Therefore, EnTrade can't currently manage the outcome as a single market, even though it ideally would do so.

PROJECTS AND ADAPTATION MEASURES

In the Tone & Parrett catchment in Somerset, EnTrade has worked with the Environment Agency and Natural England on a pilot project to develop a catchment market that will begin operating later this year:

- **Aim**: The four aims of the Somerset catchment market include nutrient (e.g. phosphorus) reduction, carbon storage, biodiversity net gain, and natural flood risk reduction (Somerset Catchment Market, 2022).
- **Supply side**: Farmers and other land managers (Somerset Catchment Market, 2022).
- **Demand side**: Housing developers are the main market participants, and they will be buying environmental credits for environmental services provided by the projects supplied by farmers and landowners (Somerset Catchment Market, 2022).

Adaptation measures supported by the projects supported by EnTrade (both the reverse auction, and two-sided catchment market) include improved water quality and flood mitigation:

- **Poole Harbour:** The main adaptation benefit from the Poole Harbour project was water quality improvement, which was achieved reduced nitrogen releases into the water, as opposed to being removed from a local treatment plant. This adaptation was transformative, as the land use was changed by farmers in order to achieve the aim.
- **Somerset:** The main adaptation benefits from the Somerset Catchment Market are improved nutrient reduction (i.e. improved water quality), and natural flood risk reduction. These adaption benefits will be achieved through projects including temporary arable reversion, buffer strips, cover crops, water course fencing, and the supply of wetland and woodland (Somerset Catchment Market, 2022).

SCALABILITY AND SUMMARY

In terms of scalability, these types of projects can occur across the country. This would be helped if investor rules allowed the aggregation of different environmental services and benefits (stacking) to deliver a service, and thus a return to investors in a project. Stacking would make catchment markets more attractive for:

- Supply side operators, who could offer a wide set of services to potential buyers.
- Demand side operators, who would be able to buy the precise services they want from a catchment area, versus paying for excess services that they do not value.

Stacking can currently occur with carbon, biodiversity net gain and nutrient reduction credits, as these outcomes are all sufficiently fungible to be turned into a credit.

If EnTrade's pilots are successful, and stacking is permitted by the Department for Environment, Food and Rural Affairs, then catchment markets and similar types of platform projects are anticipated to increase. They could be "*common practice within two to three years*" (Peacock, 2022). Without the enabling of stacking of services and thus revenue streams however, the potential scalability of these projects will be limited. However if stacking is allowed then blended finance is likely to be the most common type of financing. In some trades, public funding could support outcomes which provide social and private value (e.g. flood risk mitigation), and private financing could support outcomes which provide primarily private value (e.g. financing in return for environmental credits). However, there may be trades where public benefits have brand value for companies, particularly if the company providing investment is situated in the same location as the risk.

EnTrade projects are complex, with many stakeholders participating and projects within catchment markets not necessarily producing precise outcomes. In addition, current regulation isn't supportive for projects of this complexity. Therefore, funding these projects is a difficult choice for both the demand side operators and for regulators to support. Some initial investors may be willing to live with considerable uncertainty but attracting large numbers of investors will require greater certainty over the success – and potential returns

– of such schemes. That is linked to whether staking is allowed because allowing a portfolio of measures to be brought together would be one way to reduce the riskiness of investing.

A.2.3.2 - LENS

LENs is a platform which facilitates the buying and selling of nature-based solutions. LENs create and manage a regional trading system of collaborative value chains, with each chain driving specific landscape outcomes for different groupings of businesses (3Keel, 2019). Previous LENs projects have included a wide range of outcomes relating to climate change adaptation: improved water quality, reduced flood risk, and resilience of crop supply. LENs was founded by 3Keel, a social purpose business which advises on sustainability issues relating to food systems, supply chains and landscapes.

BUSINESS MODEL AND BARRIERS

LENs' business model aggregates demand for landscape management (eg food manufacturers, water companies) to facilitate supply side solutions (e.g. from action by farmers). LENS receives a management fee for facilitating transactions in the platform market. Whilst the LENs platform itself does not attract (or need to attract) financing, the platform works to create revenue streams for landscape management which involves adaptation. LENs groups businesses with common interests on the demand side (such as those operations with at risk from changes to the local landscape), to farmers on the supply side and facilitates their trades.

The three main barriers to financing and running the platforms were **informational**, **lack of institutional capacity,** and **regulatory**:

Informational barriers. Actors on the demand side of the market face barriers to investing in these trades, because it is complex to understand how the stakeholders can benefit from the landscape based approach. Discussions with representatives from LENS suggest that a "*shift in the way of thinking*" has been required in order to bring demand side stakeholders in to the projects, to help them see the merit in alternative solutions to their problems (Curtis, 2022).

Lack of institutional capacity. The nature based solutions provided by platforms such as LENs currently exist within a context of limited regulation. This makes investing in these solutions more risky for the demand and supply side stakeholders. The lack of an institutional framework results in insufficient communication within industries that could benefit from the landscape based approaches such that LENs offers, resulting in a co-ordination failure.

Regulatory barriers. In the **longer term**, there is a risk that regulation may evolve to compartmentalise landscape areas into separately regulated components, each requiring separate solutions. Given that LENs aggregates buyers around common interests and helps to align their incentives, compartmentalisation may limit the ability of LENs to effectively aggregate buyers around common interests, thus hindering the sustainability of the model.

The three barriers can be viewed as sequential:

- The informational barrier is the *initial* barrier to the financing of projects.
- This barrier can be overcome through effective communication with stakeholders to shift mindsets in relation to landscape management.

- The second barrier, a lack of institutional capacity, can jeopardise the success of projects if the projects cannot be de-risked through effective understanding of the project.

And whilst the potential future risk from regulation compartmentalising is not a current risk, if regulation was to change to this it would create a final barrier to investing these sort of approaches. Thus limiting the impacts these projects could have in terms of adaptation co-benefits.

PROJECTS AND ADAPTATION DETAILS

TABLE 2 ACTIVE LENS PLATFORMS IN THE UK

	CUMBRIA	EAST ANGLIA
Aim:	Soil and nutrient management in local landscape. Focus on reducing phosphorus in water courses, flood management and creating bounded habitats.	Resilient agricultural supply chains supported by the local landscape. These include the following measures: flood risk mitigation, water quality improvements, increase in agricultural land managed in a more 'regenerative' way.
Supply side actors:	Farmers from Eden Rivers Trust and First Milk, and National Trust, who are land owners and operators in Cumbria.	Local farmers and land managers.
Demand side actors:	Nestlé, United Utilities, Environment Agency, and Eden District Council.	Affinity Water, Anglian Water, Cargill, Cereal Partners UK, Essex and Suffolk Water, Nestlé Purina and West Northamptonshire Council
Traded activity:	Peatland restoration and delivery of green infrastructure (United Utilities, 2021).	Cover crops, reduced cultivations, crops in rotation, hedge planting (Nestlé, 2022).
Adaptation co-benefits	More than 35,000 properties are at risk from flooding in Cumbria, and flood mitigation can be tackled via hard infrastructure, improved community resilience and planning, and natural flood management (e.g. habitat creation) (LENS, 2018).	Increase in the quality of soil health, and an increase in water quality (Nestlé, 2022).
Trades flows to date:	The trading platform in Cumbria has grown from an initial unilateral trade between United Utilities and local land holders into a larger community with multiple stakeholders (LENS, 2022a). The first large scale trade was valued at approximately £700k, with Nestlé and United Utilities co-funding a nature based solution, which was co-ordinated by First Milk.	The first set of annual trading occurred in East Anglia in 2021, with trading valued at over £1m (LENs, 2022b). Trading in 2022 in East Anglia had a similar value, at £980k (Nestlé, 2022).

Source: Frontier analysis

Climate change adaptation co-benefits resulting from theses nature based solutions vary from project to project. However, as the above table shows, co-benefits relating to flood-management and soil health are the focus of these platforms to date.

The adaptation co-benefits from the nature-based solutions are reactive, because the co-benefits are designed to tackle issues that are already occurring as a result of climate change. For example, United Utilities costs of £13.8 million in 2015 and £19.5 million in 2016 due to flooding in Cumbria (LENS, 2018a). In East Anglia, soil moisture content is an ongoing risk to the supply of crops, which can require factories to be re-tooled, resulting in a large cost to the farmers (Curtis, 2022).

SCALABILITY AND SUMMARY

The nature based solutions facilitated by LENs can be applied to a wide range of types of landscapes. The ability of the LENs approach to scale will also depend on the evolution of institutional capacity and how regulation of nature based solutions and landscape management develops. The government could facilitate nature based solutions and landscape management through a formal accreditation scheme which would help to create a common set of standards and statutory requirements.

Projects facilitated within LENs trading communities have several adaptation co-benefits, including lower natural flooding risk, improved water quality, and improved soil health. There are multiple real and potential barriers. Information barriers mean that relevant actors, such as buyers and sellers, underestimate the benefits of the projects, and the nascency of the market means that there is a lack of institutional capacity to support the development of these types of projects. In addition, future regulation may hinder LENs' ability to aggregator actors around common interests. However, LENs projects have previously involved a wider set of actors on the demand side, including some with less regulatory requirements to those in EnTrade.

A.2.4 - WATER SECTOR

Sector	Water sector
Climate risk	Droughts and flooding
Why pays?	Private finance
Synopsis:	*Climate change is expected to have a major impact on the water sector and regulation has developed (to some extent) to account for resilience and adaptation. There remains barriers to financing adaptation measures,*

Climate change is expected to have a major impact on the water sector. The UK is expected to experience warmer, wetter winters and hotter, drier summers as the climate changes (UK Climate Risk, 2021). Within the water sector, climate change could lead to the following consequences (UK Climate Risk, 2021):

- Damage to water infrastructure such as reservoirs, dams, and water and sewage treatment plants, as a result of increased flooding.
- Damage to buried infrastructure, such as water pipelines, which can be caused by flooding and subsidence.
- Reduced water quality if more frequent flooding affects water treatment facilities.

- More intense rainfall contributing to the overloading of sewers leading to environmental damage and flooding of property.

The water industry is subject to both economic and environmental regulation. Ofwat regulates the water industry in England and Wales from an economic perspective. Ofwat allow investment by water companies through 5-year revenue allowances and the setting of outcomes that water companies are required to deliver. The Environment Agency (EA) regulates the water industry in England from an environmental perspective. The EA designs and sets thousands of individual outputs that water companies are obliged to deliver.

Ofwat have made incremental changes to economic regulation in recent years to incorporate measures to improve resilience of the water sector and address climate change adaptation:

- In 2014, the Government placed a new resilience duty on Ofwat in the Water Act 2014, which requires Ofwat to secure the long-term resilience of water companies' supply systems and sewerage companies' sewerage systems (Water Act, 2014). This new duty opened up the possibility of including some longer term investment that relates to climate change adaptation, with greater cost allowances and enhanced incentives for companies to invest in resilience (see Wessex Water case study for more details).
- Until the 2014 price review, Ofwat performed a granular evaluation of the opex and capex plans of each water company. However, from 2014, their methodology changed to a total expenditure (or 'totex') approach, meaning companies had more flexibility in how the cost of investment would be recovered from current and future customers (Department for Environment, Food, & Rural Affairs, 2016).

The EA has also been making incremental changes to their regulation to consider climate change adaptation:

- The Water Industry National Environment Programme (WINEP) is a key plan in the water industry with regards to environmental investment. The WINEP is a set of actions that the EA require all water companies to complete between 2020 and 2025, including many requirements for each water company to meet (phosphorus and nitrate removal, chemical investigations and removal, water quality investigations etc.)

There are many initiatives to support adaptation and resilience in the water sector. Some of these initiatives are outlined in the box below.

- The **National Framework for Water Resources** was released in 2020 (Environment Agency, 2020). The framework explores England's long-term water needs, setting out the scale of action needed to ensure resilient water supplies are available to meet the needs of all users in the future, as well as the greater ambition needs to protect the environment that is the source of water supply.
- The **Regulator's Alliance for Progressing Infrastructure Development (RAPID)** is a partnership between Ofwat, Environment Agency and the Drinking Water Inspectorate (Ofwat, 2022b). The aim of RAPID is to help accelerate the development of new water infrastructure and design future regulatory frameworks.
- **Drainage and Waste Water Management Plans (DWMPs)** have been commissioned by Water UK in collaboration with many organisations, including Defra, Ofwat and the Environment Agency (Water UK, 2021). DWMPs will set out how wastewater systems and drainage networks are to be extended, improved and maintained to ensure they are resilient to future pressures.

BARRIERS TO FINANCING ADAPTATION

There are two main barriers to the financing of adaptation projects within the water sector:

1. **A continuing bias towards capex projects over opex projects** remains, although the move to a 'totex' approach under the 2014 price review has reduced the magnitude of this bias.
2. Cost effective solutions are often **cross-sectoral**, however water companies are currently limited in their ability to collaborate across sectors due to the granular requirements of outputs, making cross-sectoral partnerships unnecessary.

1. A bias towards capex intensive projects over opex intensive projects

Under Ofwat's existing allowed investment regulation for the water industry, there remains an incentive for water companies to invest in large capex projects over projects that have long running opex costs. Water companies are more likely to invest in capex rather than opex intensive projects due to the five-year regulatory cycle for the following reasons:

- Investment in a capex investment, such as a water treatment plant, depreciates and has decreasing opex over time if efficiencies are present.
- Given the cost of the capex investment will occur in only once five-year regulatory period (but will be depreciated in set amounts in subsequent years), the cost of the investment is "locked in" and certain.
- However, for an opex intensive project, the cost will occur over several regulatory periods, and may differ in each of the period, leading to uncertainty as to whether the cost will be funded in full.
- There is therefore an incentive for the water company to invest in capex, over a more opex intensive investment - such as a catchment market – due to the way in which investment is allowed in the price control periods.

This emphasis on capex solutions was identified in stakeholder calls with Wessex Water as being a key barrier to investing in adaptation projects, that often have high ongoing opex costs (for example, nature-based solutions). Projects that have a long-term horizon for benefits, also have a long-term horizon for costs and are not incentivised by the current regulation that only has a five-year horizon. As adaptation projects have inherently long-term horizons - the higher benefit will be gained by future customers than current – these projects are not incentivised by the current regulation.

Ahead of the next price review in 2024, Ofwat are considering the introduction of long-term adaptive planning in economic regulation to address issues of long-term incentives over multiple price controls (Ofwat, 2021). Water companies should set out 25 year strategic plans which set out interventions which can also be translated into deliverable solutions. Ofwat expects companies to prioritise and stagger schemes across multiple price review periods, depending on the scale, complexity and required lead times for planning.

2. Cross-sectoral barriers to investing in adaptation

There is currently limited scope for the water sector to form cross-sector partnerships to tackle climate change adaptation challenges. Water companies must follow their WINEP, which is primarily a prescriptive list of outputs that the water sector must deliver. This reduces the opportunities for innovation and working across sectors to deliver the best value solutions (which take into account cost as well as environmental and social benefits).

For example, the EA may oblige water companies to improve river water quality via investing in a carbon-intensive asset, which improves water quality whilst emitting more carbon in the process. Instead, water companies could deliver the same improvements in river water quality via paying farmers to develop a

wetland, or a local authority to invest in sustainable drainage. These cross-sector solutions would improve river water quality but also reduce carbon emissions, reduce flood risk and boost biodiversity.

Last year, the EA, Defra and Ofwat led a taskforce to consider how nature-based and outcomes-based solutions could be reflected in the WINEP (Environment Agency, 2022). The taskforce proposed redesigning the WINEP via a three-tiered approach to include some limited scope for environmental improvement to be linked to a high-level outcome[11]. This is a step towards outcome-based regulation for the water sector, however it is expected that many actions will in practice be closer to outputs than outcomes[12].

There have been a small number of innovative, collaborative approaches to climate change adaptation issues that the water sector has been involved in. Approaches can be based on grants and social funding, for example working with landowners to gain funding through the Environment Land Management Scheme (ELMS), or market-based, such as the projects below:

- **EnTrade** – project where farmers to reduce nutrient run-off to local water sources rather than pursuing a capex infrastructure solution. *(see Platforms case study for more detail)*
- **CReDO** – project where Anglian Water was involved in a cross-sectoral pilot project mapping out inter-dependent risks from flooding. *(see CREDO case study)*

These projects have however mostly been at a pilot stage, and there has been considerable cost involved in facilitating discussions. For example, for EnTrade the engagement with the EA has resulted in notable transaction costs. The vast majority of the current WINEP is therefore delivered by the water companies themselves, by working on their own assets.

3. Other barriers

Raising funds for projects with future benefits can be hampered in some cases by too much focus on outcomes for current consumers.

Ofwat enable 'allowed expenses' to water companies as part of the five-year regulatory cycle, and water companies' adaptation investment projects are therefore ultimately financed by higher bills for their customers. For example, if a water company needs to invest in a flood defence project within its allowed expense, water bills for customers are likely to increase to pay for the project. The cost of the project would therefore be paid by current customers, whereas the benefits may not occur for many years as the project is designed to protect against expected future extreme weather caused by climate change. This means that the benefits would be received by future customers, despite the cost being liable to current customers.

Customers may be unwilling to pay for adaptation that they may not benefit from, or benefit less from than future customers. This is supported by engagement with water consumers, which found that, in the context of severe drought measures, consumers believed that the likelihood of severe drought was "*very low*", and this would be caused by extreme weather which consumers "*could not conceive of in the UK*" (Ofwat, 2022a).

[11] Tier 1 refers to high-level outcomes, tier 2 refers to objectives, and tier 3 refers to outputs (in line with the current WINEP) (Environment Agency, 2022).

[12] For 2025 to 2030, tier 1 and tier 2 proposals will only be appropriate for "*some, rather than all, drivers*". The taskforce also notes that the EA "*may – at its discretion – allow actions to be included in the WINEP where the actions are not linked to a specific tier 3 output and are instead set as a tier 2 goal or a tier 1 outcome (for non-permitted actions)*" (Environment Agency, 2022). This suggests that in practice most actions will still likely be linked to a tier 3 output, including water quality.

This can hinder the ability of water companies to invest in long term projects, such as adaptation projects, because investment plans can be rejected by customer scrutiny groups and Ofwat alike.

THESE BARRIERS ARE BEING ADDRESSED TO A CERTAIN EXTENT THROUGH ACTIVITIES, BUT FURTHER REGULATORY DEVELOPMENTS ARE NEEDED

Two developments which may help to address these barriers are green bonds and outcome based environmental regulation (OBER).

Outcome based Environmental Regulation (OBER)

OBER involves setting outcomes-based targets that allow companies to choose solutions that deliver the biggest environmental and social benefits (across a range of dimensions) at the lowest costs. OBER would require a switch from the current output based environmental regulatory requirements to outcome based environmental regulation. Outcomes are higher-level objectives that company actions, activities and achievements are intended to help deliver (Ofwat, 2015a). Outputs are the observable and measurable activities, actions or achievements that a company needs to deliver to bring about the outcomes that customers and broader society value (Ofwat, 2015a). Given that outcomes are higher level than outputs, the switch to outcome focused regulation would provide greater flexibility to water companies to innovate and form partnerships (cross sector, if necessary) to achieve the required outcomes.

OBER may help to solve current issues in the water sector by supporting efficiency and innovation as companies would have greater flexibility. Companies would be able to use their enhanced flexibility to choose solutions that deliver the biggest environmental and social benefits (across a range of dimensions) at the lowest costs. OBER would also facilitate more collaboration with entities from other sectors in comparison to current regulation.

There are multiple issues with the current approach to environmental regulation in water catchments (Frontier Economics, 2021):

1. **Fragmented**: Different sectors that impact the water environment are subject to different types of environmental regulation, and they face very different incentives.
2. **Prescriptive outputs**: Historically, water companies must deliver a prescriptive list of outputs, reducing opportunities for innovation and working across sectors to deliver the best value solutions.
3. **Output not outcome focused**: The list of outputs that water companies must deliver doesn't consider the most efficient method of achieving the favoured outcome.

OBER in the water sector would represent a material change from the current regulatory approach. Water companies are currently required to deliver thousands of outputs, as defined by the Environment Agency, to improve the environment. Under OBER companies would be able to deliver required outcomes (high-level objectives), and companies would not need to specify the exact method they would use to achieve the outcome. As discussed above, the EA, Defra and Ofwat led a taskforce on how to reflect outcomes-based solutions in the WINEP (Environment Agency, 2022). Whilst the suggestion of a three-tiered approach to outcomes is a step in right direction, it is expected that many actions will in practice be closer to outputs than outcomes.

Green bonds

A green bond is similar to a traditional bond, however it is specifically targeted to support climate-related or environmental projects. A benefit of green bonds is that they can improve the efficiency of accessing capital at scale for adaptation investments. In other words, multiple investments can be grouped into a larger transaction which can considerably reduce the transaction costs of sourcing capital, instead of trying to finance all of the investments separately.

A green bond, such as the Anglian Water Green Bond, can appropriately balance the costs and benefits between current and future customers as it allows capital to be raised outside of Ofwat's allowed expense. The Anglian Water Green Bond is discussed below.

In 2017, Anglian Water became the first utility company to offer a green bond. The £250 million, eight-year bond will mature in August 2025 with a return to investors of 1.625 per cent (Anglian Water, 2020). Anglian Water have since raised a further £627 million of Green Bonds from investors in the UK and United States (Anglian Water, 2020).

The Anglian Water Green Bond has five environmental objectives, one of which is climate change adaptation (Anglian Water, 2020). Discussions with representatives from Anglian Water suggest that around 25% of the Green Bond is used in some way to support adaptation projects (Pass, 2022). In 2020, there has been a total of £876 million funding for Green Bond projects, and this has enabled around 850 projects.

The capital is not raised for specific projects, and investing in multiple projects is beneficial as it allows the risk to be spread across the projects, rather than the risk sitting with one project. In addition, the green bond status applies to all capital investment. The Water Industry National Environment Programme (WINEP) has green bond status, for example.

An example of the Anglian Water Green Bond supporting adaptation is the protection of 14 homes in Sutton-on-Sea, Lincolnshire, from flooding (Anglian Water, 2020). Flooding has been triggered by increasingly frequent heavy rainfall and storms overwhelming the current sewer system. The scheme cost £612,700 and saw two multi-property Offline Pumping Station chambers installed to protect nine properties, and five additional properties have been protected through the installation of two high-capacity non-return valve chambers (Anglian Water, 2020). Valve chambers consist of a concrete sealed manhole and a pump and are used in the management of water, oils and chemicals (FP McCann, 2022).

SUMMARY

Regulatory and policy developments in recent years have allowed water companies to further consider climate change adaptation and resilience. However, these developments have not fully addressed the barriers to investing in climate change adaptation in the sector. Current regulation incentivises water companies to favour current consumers over future consumers, with limited incentive for companies to invest in adaptation projects, and cross-sectoral approaches are difficult to enact. Further changes to regulation, such as a move to OBER, could support water companies in tackling some of these barriers to financing climate change adaption projects.

A.2.5 - FLOOD RESILIENCE – CLIMATE RESILIENCE DEMONSTRATOR (CREDO)

Sector	Digital
Climate risk	Flooding risk to infrastructure (energy, water, telecoms)
Why pays?	Private finance
Synopsis:	*CReDO provides a climate change adaptation digital twin project that demonstrates how connected data can improve climate change adaptation and resilience across all infrastructure in an area in relation to flood resilience.*

Flooding is not only an existing risk to UK households, it is an increasing risk that is expected to grow due to climate change in the future. The expected annual damages from damage to residential and non-residential properties, in addition to the associated indirect damages are projected to increase from £2bn today to between £2.7bn and £3.9bn (depending on associated population growth, and 2C vs 4C future) (Sayers, et al., 2020).

The importance of the risk from flooding was presented in CCRA3 (Betts & Brown, 2021) where 11 of the 61 of the risks and opportunities to the UK from climate change identified related to flooding. One of the risks identified as having a 'more action needed' urgency score in CCRA3 related to cascading risks across the UK infrastructure network[13].

Cascading risks are inherently very difficult to model as they require data from multiple infrastructure operators, each with a different risk profile. Electricity, water and telecoms assets are owned and operated separately, but they form an interconnected system that is interdependent. Failure of one asset, for example in the event of a flood, can cascade and cause assets of other operators to fail. For example:

- Electricity substations provide power to water and wastewater pumping stations and telephone exchanges (cooling water systems can be used to remove waste heat from telephone exchanges); and telephone lines are installed at electricity substations where a mobile telephone signal cannot be received

The CReDO project is part of the National Twin programme (NDTp), which is run by the Centre for Digital Built Britain[14], a partnership between the University of Cambridge and the Department for Business, Energy and Industrial Strategy (BEIS). A digital twin is a virtual representation of all the infrastructure in a particular area that then allows the simulation of future floods and their impact. The virtual simulation can be used to plan the best adaptation measures and, crucially, who is best placed amongst the various infrastructure providers to act most cost-effectively to prevent disruptions. The CReDO project focused on a specific geography (East Anglia), but did not specify location in order to maintain data confidentiality for the pilot project.

[13] I1: Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures

[14] With effect from 1 April 2022, the Digital Twins (DT) Hub will transition from its current home at the Centre for Digital Built Britain (CDBB) to an Industry/Catapult partnership housed at Connected Places Catapult (CPC).

In addition to collaboration across these organisations, the project necessitated involvement from utility infrastructure providers –telecoms (BT), water (Anglian Water) and energy (UK Power Networks)[15].

FINANCING AND BARRIERS

CReDO was grant funded, after gaining a year of funding from the UK Research Innovation (UKRI). The Centre for Digital Built Britain was interested in a pilot project to show proof of concept for the application of information sharing in a digital twin context.

The funding provided by the grant was not to fund the asset owners themselves to run the project, but instead to fund a collaboration of third parties to produce the pilot such as innovators, academics and researchers.

The three main barriers to the project were behavioural, informational and financial:

Behavioural - CReDo faced significant difficulty in signing up asset owners to provide their data, due to confidentiality concerns. This barrier was significant, but a solution was found using information sharing. CReDo currently have the confidential asset data (which is held securely at DAFNI[16]), but this cannot be shared with the public due to security concerns. Therefore to make the publicly facing model, synthetic data was used to represent the relationships seen in the real data.

Informational – CReDo faced informational barriers, linked to those behavioural barriers. In terms of the risk that CReDo defends against, there is a distinct lack of understanding by asset owners and investors as to the true extent of the risk their assets risk. Generally, interdependent risks are particularly not understood well, and true risk level is often underestimated. (Dawson, 2015) state that looking at the risk of flooding from a linear regression (or solo operator) perspective captures only 17% of the variance in risk, whilst analysis of the first order sensitivity indices provides only 29% of the variance — highlighting the importance of variable interactions (as would occur between operators) in determining risk.

The value of the Digital Twin, and the subsequent reduced risk in areas with the infrastructure mapping are not fully understood by the private asset operators. One of the aims of the project as a proof of concept, was to in fact reduce some of these barriers by showing asset owners the benefit from sharing information.

Financial – CReDO is not yet at the point at which asset owners will be privately financing the work, or subsequent work. This implies a financial barrier A connected barrier to those mentioned previously, is the large investment in time (and therefore cost) by the asset owners to be involved in a project like CReDo – particularly if it was too scale up.

These barriers are largely connected to a coordination failure across the asset operators. CREDO indicated that *"we are not quite yet at the stage at which asset owners are willing to put their hands into their pockets"*, but that the CREDO project itself facilitated getting the operators to work together – overcoming the first hurdle to success in a cascading risk adaptation project such as this.

If a regulatory framework existed to support asset owners, it may be easier to let asset owners see the benefit to working together to provide information surrounding climate change risks. The existence of a an

[15] CReDo does not currently consider the transport sector, but this sector (and others) could be included in a full scale model.

[16] Data and Analytics Facility for National Infrastructure

independent third party assisted overcome this informational barrier in this project, but if the project was to scale up there would need to be a strong institutional framework to support the asset operators.

CReDO was created with the aim to show at a pilot scale, how a full system digital twin could help operators avoid cascading failure caused by extreme flooding events. There were two concrete aims to demonstrate:

- The benefits of using connected digital twins to increase resilience and enable climate change adaptation and mitigation.
- How principled information management enables digital twins and datasets to be connected in a scalable way as part of the development of the Information Management Framework (IMF).

CReDO focused on using a systems-based solution to improve information flows looking at the interdependency between the assets of those involved in the project by avoiding asset silos.

The expected cost of the CReDo project in total is £5 million. This estimate includes the cost already incurred to build the current version of CReDo and the cost of further developing CReDo over the next three years. This estimate excludes costs to asset operators.

EFFECTIVENESS

CReDO was effective in bringing together asset operators from across a geographic location (East Anglia), to provide their data for the purpose of improving climate resilience. The project was successful in achieving the aims of the project but has not, at this stage, resulted in the asset operators taking the project forward using their private finance.

Whilst the project has been very effective in achieving its aims, until the informational and co-ordination barriers can be overcome with further investment into supporting asset operators there will be a limit to the impact that CReDO can make in reducing the risks for asset operators from future climate change. This is due to the fact that at this stage the data currently within CReDO for display purposes is simulated data, rather than actual.

The below table, produced as part of an impact report from CReDO gives an indication of the simulated expected social benefits for the roll out of CReDO to East Anglia, but also to the entirety of the UK. These results are based on a simulation, but give an indication of how large an impact a project like this could create, and incentivise investment into future work on the model.

TABLE 3 ESTIMATED (SIMULATED) IMPACT OF CREDO

SCOPE	LOWER SIMULATION (PROBABILITY OF OCCURRENCE OF FLOOD: 0.5% TO 1%)	CENTRAL SIMULATION (PROBABILITY OF OCCURRENCE OF FLOOD: 1% CONSTANT)	UPPER SIMULATION (PROBABILITY OF OCCURRENCE OF FLOOD: 1% TO 2%)
East Anglia	£6m	£8m	£13m
UK	£81m	£117m	£186m

Source: (Frontier Economics, 2022)

By focusing on a specific geography (East Anglia), CReDO was able to get the involvement of the infrastructure operators, as they were only providing a small amount of their data. One of the aims of the project was to show how a "full scale digital twin" could look. The project aimed to show scalability, by using the information management framework. However, there are limitations – at present – to the scalability of the project.

SCALABILITY, SUSTAINABILITY, AND SUMMARY

In terms of the sustainability of the financing, CReDo did not generate a model for the continuation of the project (outside of grant funding) as part of the project. Further work in the area to develop CReDo further, or increase its geographic scope would likely need public funding to kick-start private activity again.

In terms of the scale of investment required, it is expected this number would be large but not extremely so. Whilst it has not been possible at this time to estimate the total cost to rolling CReDO out nationally, there would be significant economies of scale to doing so, as indicated by the stakeholders -*"If you clean the data once, you can reuse it many times".*

As discussed in the discussion of the barriers the project faced, for the project to scale strong institutional framework to support the asset operators to successfully work together to share their data would be required.

However, if these barriers can be overcome a future, more comprehensive version of CReDo could not only map out infrastructure providers, but also include additional factors that influence the flood resilience of critical services, residential and business properties.

CReDO provides an example of how pilot projects can identify potential barriers in complex inter-dependent adaptation issues and help to identify how to overcome them. Informational, and co-ordination issues limit the success of such projects and will involve strong investment in institutional frameworks to overcome these.

A.2.6 - TRAFALGAR FISHERIES INPUT

Wiltshire-based trout rearing specialist Trafalgar Fisheries has doubled their production following a £1.5million investment in sustainable technology to combat rising river temperatures, with funding from Lloyds Bank.

In the last few years, increasing water temperatures in the River Avon has resulted in an increase in fish mortality rates caused by exposure to infectious diseases (Business Leader, 2020). The new technology utilises borehole water and drainage pipes to create a stable environment for the fish, improving their health and welfare. The recirculation unit has been operational for 12 months.

The financing from Lloyds was a £1.5 million loan. The financing was provided by Lloyds Bank's Clean Growth Finance Initiative, which delivers discounted funding to help businesses transition to a lower carbon, more sustainable future (Business Leader, 2020).

This investment in adaptation not only addresses the existing risk to fish health from higher temperatures, but also protects against the future risk arising from climate change. The risk to the River Avon farming operations from rising water temperatures has been increasing over the last 15 years, in addition to lower

flow rates in the river system. Water temperatures have been as high as 22 degrees in the summer months, and at these temperatures trout farming becomes very high risk due to high mortality and disease rates.

There are multiple benefits from the adaptation investment in the recirculation system:

- More controlled water use, which is important given Trafalgar Fisheries farm in an SSSI area so will have increasing pressure to reduce water usage over the long term.
- More controlled temperature, and available oxygen for the fish, which reduced mortality and disease rates. Disease Management is much more controlled within an enclosed unit having control on water temperature.
- The removal of phosphates in the form of fish waste. Traditionally, this would be filtered out through a settlement bed before re-entering the river system, but is now able to be removed and used as fertiliser.

This enables Trafalgar Fisheries to manage their production and have greater control over their costs, including their losses from disease and mortality. Given that the water from the drainage pipes is gravel filtered it is therefore cooler in the summer than the river, but also slightly warmer during colder months. This gives a revenue advantage as the fish grow larger, and more reach the market.

A.2.7 - MANCHESTER NATURAL CAPITAL PLAN AND THE IGNITION PROJECT: IMPLEMENTING SUDS USING BLENDED FINANCE

Sector	Water
Climate risk	Floods; Habitat degradation; Health impacts
Why pays?	Blended
Synopsis:	*Sustainable urban drainage systems (SuDS) are a nature based approach to managing drainage in the built environment, and a pilot scheme was implemented in Manchester as part of the IGNITION project.*

SuDS are a nature based approach to managing drainage in the built environment, helping to hold back and slow down water flow. They can reduce pressure on existing sewage structures, support the natural environment to manage water and help to reduce the risk of flooding. In addition, they deliver wider co-benefits. While they primarily act to reduce localised flooding, they do create the potential for benefits that can be monetised (revenue or savings) (Howard, 2020).

IGNITION has developed business cases for strategic co-investment in SuDS involving different organisations (including investors). This includes organisations who could benefit from the management of urban drainage and improved water quality (beneficiaries), alongside pre-planned grey infrastructure improvements of highways or town centres across Greater Manchester.

The key project partners in the SUDS scheme include 10 councils within the greater Manchester areas, the Water Resilient Cities Project as the project manager, and United Utilities. The SuDS schemes in Manchester are targeted at public sites only, given that they involve a loss of land (and the landowner takes on maintenance) it was easier to work with public organisations on the schemes.

FINANCING AND ADAPTATION DETAILS

IGNITION received £4.6 million grant funding from ERDF through the EU's Urban Innovation Actions (UIA) initiative to continue its operations until April 2022 (Greater Manchester Combined Authority, 2022). This funding was only granted for the cost of developing the model only, the pilot SUDS project required further financing.

The project has developed a blended finance pipeline of 16 sites, the majority of which are schools, requiring a £1.5 million capital investment. It aims to blend public funds with a repayable finance segment of £200k over 10 years.

The adaptation benefits that SuDS schemes provide are fully evidenced in Table 7 (Annex 3) include (IGNITION, 2020a):

- Reduced waste-water pumping/treatment costs.
- Reduced properties at risk from surface water flooding.
- Water quality improvements.
- Increased road safety.
- Improved quality of place for local businesses leading to increased footfall, spend and patronage.

SuDS are form of no- or low-regret adaptation, and are reactive and incremental, in that they are addressing current risks. However, they also have potential under a changing climate. The UK is projected to experience heavier rainfall (intensity and/or frequency), and the need for options such as SuDS will be higher due to the increased frequency of localised surface flooding.

Urban areas are particularly vulnerable to such floods because of the low permeability of the built environment – instead of rainfall soaking into earth, it runs off concrete and into the sewer systems which are not fit for purpose. The SuDS adaptation can therefore reduce economic losses, from material destruction to loss of livelihood and social infrastructure. In addition, there are multiple environmental co-benefits to the projects: carbon benefits, water quality and quantity benefits, and local biodiversity benefits.

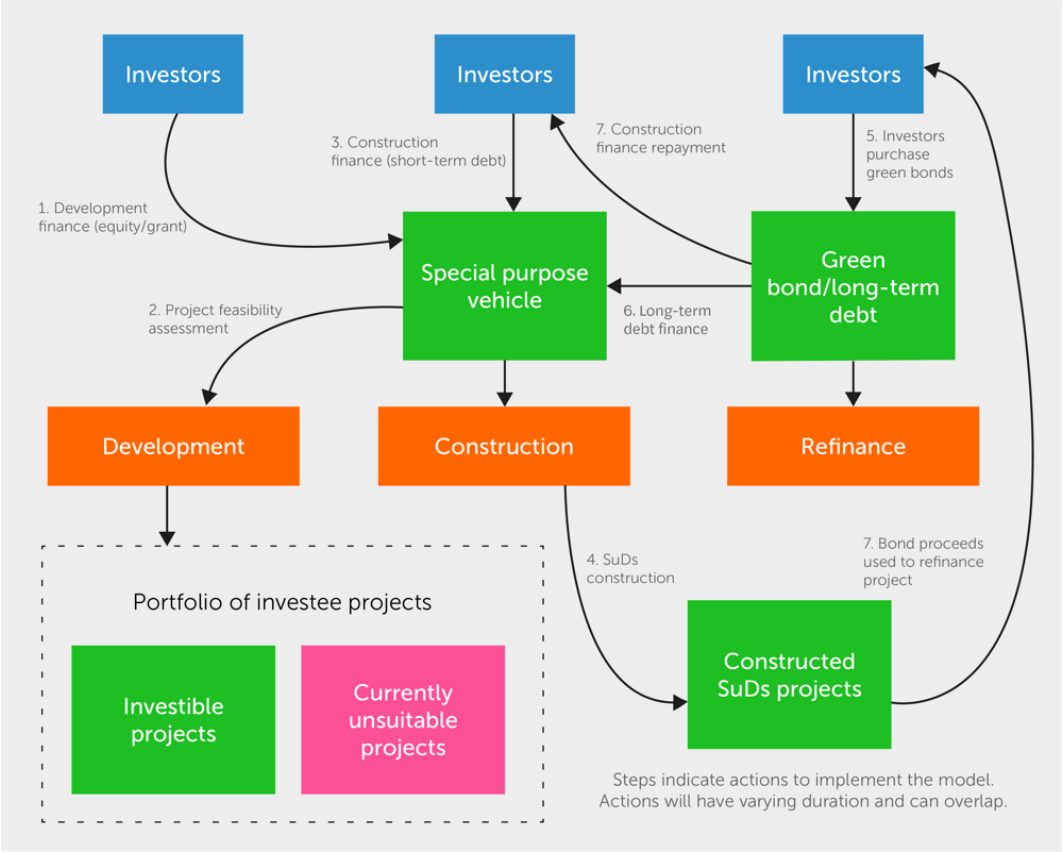
The model developed in Manchester aims to leverage a reduction in cost from wastewater management utilities from the development of SuDS. By implementing a SuDS and so improving the natural ability of the land to manage water flows, the land area can be dis-connected from the sewer network and enjoy a lower charge band, as demonstrated in Figure 1. These lower costs allows the initial investment to be recouped. The model only monetises water quantity, and this value stream is monetised by an avoided future cost in wastewater treatment and is not an actively generated revenue.

FIGURE 21 SUDS BAND CHARGING MODEL

Source: Ignition (2020b)

This financing approach is based around three main phases of SuDS project delivery development, construction and operation which require different forms of capital based on the level of risk. The model proposed to set-up a single Special Purpose Vehicle to raise and deploy the appropriate form of capital for each phase over the project lifetime.

FIGURE 22 SCHEMATIC OF FINANCING FOR SUDS



Source: Khosla and Watkiss, 2020

In the primary model, site owners would pay for the upfront investment of the SuDS by borrowing against the savings anticipated from lower wastewater charges (IGNITION, 2020a). The sites also incur costs from

building, such as loss of revenue during closure in the case of commercial zones, which are not accounted for in the primary SuDS model.

The model blends public and private finance. A pilot would require £1.5 million upfront constituted from repayable and grant finance. The proportion of repayable finance was small; and the project quantified this as £200,000 over 10 years. A SuDS for Schools grant worth £1million from the Department of Education (DoE) would have covered a large section of the upfront grant finance. The pilot would allow a pipeline of SuDS to be created and implemented through a Special Purpose Vehicle (SPV) which would also manage the finance flows, procurement and regulatory permissions considerations.

The risk of infrastructure failure and consequential flood damage lies with the site owner (or insurance companies) but the site owner has no responsibility for wider flood risk management which lies with wider authority and the water utility, so the site owner has limited ability to control or manage their assumed risk. A better balance might be achieved in these projects if the financial risk from a flood was placed on the stakeholder responsible for flood risk management (the utility and local government), and the site owner was actively financially compensated when the assets they paid for made a positive effect within the remit of flood management. This would create a revenue model that generates active income as well as an avoided cost and also would stimulate research into where the most effective locations for SuDS for private deployment could be, with the aim of maximising financial gain from the investment.

BARRIERS

At inception, the IGNITION team believed that financing SuDS would be smooth to develop. In practice however, there were many unforeseen barriers and delays, in addition to known barriers. The project faced four main barriers:

Informational barriers – given the innovative nature of the project, there were multiple informational barriers that arose throughout the project. These can be bucketed into the following groups:

- Low existing capacity within the public sector and water companies to create a business plan and deliver investment:
    - The project required skill-set development (rapidly) to progress ambitious timelines, and there was little funding to support capacity building within the project (Green Manchester Combined Authority, 2019c).
    - There was no existing baseline for the project to be measured against. Therefore, there was a need to build institutional trust and confidence, making investor relations much more complicated, and creating challenges in raising additional finance (Greater Manchester Combined Authority, 2019b).
- Lack of information around identifying the benefits that SuDS would lead to from reduced flooding and sewer overloading:
    - Limited industry standards, or standardised cost information
    - Generating this information would require detailed technical analysis (and modelling) around specific locations, which is costly.
    - Each site requires site specific analysis and design (e.g., a SuDS project is not like a small mitigation project, where there is off-the shelf information and often ease of replicability / transferability).

- The actual financial benefit of disconnecting a particular site from the sewage network (i.e. the actual benefit of the SuDs to the wastewater company) was therefore hard to quantify.

Despite the lack of an institutional standard or common knowledge base on SuDS investments, through the establishment of an evidence base, and the Living Lab, the project did identify evidence (and evidence gaps). A range of resources were also published that are now helping evidence-based investments in Nature Based Solutions (NBS) (IGNITION, 2021).

Economic and Financial barriers -SuDS differ in respect of the economic case (societal) and the financial case (private). A purely public funding scheme could consider the economic case along, but given the model, both the economic and financial case are important.

Economic: A study by (Ossa-Moreno et al., 2017) undertook a societal and private cost-benefit analyses of five catchment-wide SuDS schemes in the Decoy Brook catchment in London, UK. The Benefit of SuDS Tool (BeST) developed by the UK Construction Industry Research and Information Association was used to appraise societal benefits including amenity, air quality enhancements, biodiversity and ecology, and health improvements. The analysis also assessed the potential private benefits derived from avoidance of damage to property and its contents. This analysis shows that the *economic* case for SuDS is significantly higher than the *private* financial case, i.e., the financial BCRs were less than one. This finding is replicated in the outcomes from the IGNITION project.

TABLE 4 NET PRESENT VALUES (NPV) AND BENEFIT-COST RATIOS OF SUDS SCHEMES IN NORTH LONDON

	Private Benefits		Private & Societal benefits	
	NPV	B-C Ratio	NPV	B-C Ratio
SUDS 1	-£363,079	0.32	-£62,737	0.91
SUDS 2	-£169,869	0.66	£10,385	1.06
SUDS 3	-£199,729	0.64	£390,960	1.82
SUDS 4	-£532,948	0.47	£62,741	0.97
SUDS 5	-£369,598	0.65	£401,345	1.46

Source: (Ossa-Moreno et al., 2017)

The Ignition project was facilitated by public funding (EU funding), which allowed the development work to build the business case. Ideally the project would have moved into the pilot phase with a continuation of the EU Grant finance, however it was much more difficult to get continuation funding under the EU programmes (e.g., Horizon 2020 / Europe) and thus there is a funding gap to move the project to implementation.

Without continued funding from the EU, the project has had to cease temporarily. In interviews, possible avenues are being discussed to use the work created during the IGITION project. Without IGNITION facilitating the rest of the project, the stakeholders would need to take the initiative themselves to complete the agreements and financing. This would involve a considerable level of public-private cooperation, and an acceptance of shared or assigned costs for project incubation (estimated at about £200,000 remaining in overheads for project completion).

The project was also affected by the COVID-19 pandemic which had a particularly large impact on schools (which represent over two thirds of the project pipeline). With the disruption and the rapid shift to remote learning, the impetus and available resource to focus on implementing SuDS fell away. This then decreased the available funding for the project from the DoE, and presented an economic barrier to the project.

As is the case with all place-based innovations, the applicability and viability of different sites varies (IGNITION, 2021). This could create competition for good "profitable" sites and this may leave some areas under protected and in need of public grants.

Financial: An effective revenue model is yet to be found for the SuDS project pilot; the outputs were not sufficient to cover costs. Reductions in charges in non-domestic properties were not generally sufficient to repay the upfront capital costs of SuDs installation within a reasonable time frame (IGNITION, 2021).

A financial incentive for schools (price reduction) to engage in the scheme also reduced the margins of the scheme. Further work was carried out by IGNITION and BITC through Water Resilient Cities to refine the model for pilot launch however the project has reached completion in April 2022 with no agreed demonstrations.

Many investors and project partners had difficulty understanding the business model, including the risk and revenues. The revenue, while potentially low risk as involving public authorities and a regulated utility, were actually relatively high risk investment due to lack of confidence in revenue streams over time (over a decade). The return on investment and timeframes were outside most investors' preferences (Greater Manchester Environment Fund, 2021).

The primary model was complicated and quite intensive for the expected benefit, which added extra burden to an already ambitious project. The need to get lots of small SuDS (each costing £60k to £100k) with the cost varying per site, coupled with large fixed due diligence costs (1/5 to ¼ of projects costs) meant the project could not easily unlock economies of scale.

There were some particular barriers around the financing of the schemes, given the large number of partners the project involves. For example, the timelines were important due to the need to fit SuDS during school holidays, and if the SuDS could not be completed in time then the pipeline collapses. It is much easier to monetise when there is only one beneficiary to the project.

Each of the 16 sites in the current pipeline requires a legally binding site reduction agreement for 10 years, which creates a barrier. This was made more complex as the AMP programme does not run over the same period (it is shorter). The cost differential in the agreement was relatively small, about £20,000 for all proposed sites, but the implications of a specialised agreement were more of a barrier as it could create grounds for further negotiation which the water company wanted to avoid.

Efforts to increase the financial benefits of the project are being considered, to increase the target market. Alongside looking at sites that would be able to reduce their wastewater charges, sites are also considered where SuDS would have the most benefit in terms of reducing the risk of flooding incidents in the local areas (IGNITION, 2020a). By widening the beneficiaries to economic beneficiaries as well as financial beneficiaries, there may be better scope to capture climate benefits, as well as including savings to the utility and site owners in reduced cost when the site floods.

There is also a research stream on bundling the adaptation efforts with other Nature Based Solutions for human habitat improvement, such as green roofs and tree lined streets. However, these solutions also offer

little financial opportunity for exploitation and are unlikely to improve the models bankability (IGNITION, 2020a). If the combined projects were funded through public capital, it could be possible to find finance flows through co-benefits, though this is a large uncertainty and predictable, demonstrable and financially viable are benefits which are likely to take several years to materialise.

Further research could also be carried out into mainstreaming SuDS into other non-adaptive development projects such as roads and communication lines which are co-located in vulnerable areas to reduce project costs. Embedding adaptive measures into regular maintenance and development work will leverage cost savings and open routes to finance which are more established and substantial.

Policy and regulatory – water companies have restricted ability to match innovation in their retail offers, due to the regulatory environment. Regulatory shifts can happen in the short term which could have profound, negative impact on the financial viability of the scheme. This was a major barrier to success of the project, especially as the 10 year agreements needed would cross AMP periods.

Without more detailed policies that provide certainty of costs into the future, a savings model is difficult to develop and use with confidence. It is difficult to craft a policy that can provide security whilst also protecting the water company from rising costs associated with the increase in water quantity projected through the wastewater system.

The novelty of the project therefore faced challenges, in that it required a change to the status quo of public governance operations. Governance structures needed to be improved and defined with greater precision to increase confidence from investors. Project leaders kept coming up against a low appetite or reluctance for risk within the public governance environment, and the uncertainty of the project often became a barrier to progressing with active institutional support (Greater Manchester Combined Authority, 2019a). Other projects in the region found this was a critical criterion for success, as in the Forest Resilience Bond which sought to attract investors.

Behavioural - political debates within the project did affect its direction and success. Project leaders found that there was a social and professional resistance to "*putting your head above the parapet*" in both the public and private sectors (Greater Manchester Combined Authority, 2019a). The low number of dedicated actors/champions means the project takes longer and likelihood of success is decreased.

Similar to the structural instability in the cash-flow outlined in the finance barriers, some stakeholders were unwilling to accept a larger proportion of costs and therefore risk when another stakeholder with a smaller investment was thought to have a greater value in co-benefits.

SCALABILITY AND SUMMARY

The SUDS scheme is currently at proof-of-concept stage, although an aim exists to scale to a larger pilot across Greater Manchester. Several private contractors exist to facilitate the implementation of SuDS (SUDS, 2022); however, they are still lacking is a critical mass of projects to create a reliable business investment from SuDS implementation.

While the project has shown positive potential, an effective revenue model is yet to be found for the SuDS project pilot, without which the model cannot be sustainable without public funds. Reductions in charges in non-domestic properties are not generally sufficient to repay the upfront capital costs.

The existing water charging regime in England is subject to change, so reduction in charges cannot be relied upon to repay the upfront capital installation costs and due to this insecurity, the primary model was not bankable.

The benefits that SuDS provide varies significantly depending on the location, including topography and proximity to high-risk flood infrastructure. Reductions in wastewater charges are applied in a blanket way, irrespective of flood risk.

Key stakeholders identified governance as the key barrier and therefore, a key enabler to a project such as this. The work of several key civil servants over several years, from making the case for adaptation investment, to project creation, to finance, to implementation was potentially catalytic. Eventually these leaders created working groups within the teams and the momentum was generated from these key thinkers and managers.

This project has encountered many challenges, and its key strength has been documenting these, to provide lessons for other projects. Below is a list of various lessons learnt by the GMCA to be implemented in future projects:

- Ensure you offer flexible finance; consider offering returns on future raised capital;
- Make the verification methodology for project milestones cheap/inexpensive;
- Involving the financial heavy weights of the region;
- Further involve of the public (community and individual) and charities;
- Leverage the financial viability of real estate by including economic benefit of SuDS in the asset price;
- Evaluation should be at a process level rather than project by project;
- Collaborate with Net zero projects to share the pot;
- Organisational innovation / workforce evolution should be encouraged;
- Link investment drivers to create better business cases;
- Stakeholder communication/convening/collaboration innovation should be encouraged and is necessary in innovative project governance;
- Break down communication siloes in governance;
- Continue to push boundaries;
- Keep the energy;
- Keep it practical and grounded, continue to test and learn.

(Greater Manchester Combined Authority, 2019a) (Greater Manchester Combined Authority, 2019b) (Green Manchester Combined Authority, 2019c) (Greater Manchester Environment Fund, 2021)

Ultimately, there needs to be a proof of concept with a SuDS pilot to gain investor confidence. This will require changes to regulations and public funds. Innovation finance could be used as part of an effort to also alter regulatory frameworks to be more favourable to such projects.

Whilst the project could not continue to full implementation, it did catalyse several positive transformations in research, governance, community engagement and citizen science. Most notably it is a pioneer project in the UK and represents a political will to get people working on solutions for addressing the climate gap, which remains a key barrier to adaptation finance.

The project has been ground-breaking in creating and growing an evidence base for nature based solutions and their role in climate change adaptation. The project has established a broad framework for understanding the existing level of green space across GM. One lesson is that increasing urban green space

is not a simple, linear process and GM are using this data to establish a metric to reflect an increase in functional green space which also builds resilience to climate change rather than just a generic increase in green space alone (IGNITION, 2021). By understanding the co-benefits if NBS with better precision and detail, it should then become easier to build revenue models out of them.

A.2.8 - PLACEMAKING CROWDFUNDED CLIMATE BOND: EXAMPLE OF ABUNDANCE INVESTMENT

Sector	N/A
Climate risk	Not adaptation – focus is on the financing model through decentralised public financing
Why pays?	Private finance (for public bodies)
Synopsis:	*Offer Community Municipal Investment Bonds for councils such as West Berkshire Council. Provides a model against for similar financial offering for adaptation projects.*

Crowd funding is an established financial mechanism for raising capital and is rising in popularity due to its social framing. The crowdfunding concept typically uses a platform which brings together an investment opportunity (such as capital investment for a project or portfolio of projects or early stage companies looking for working capital or funds in order to grow) with individual investors who receive a return. Crowdfunding can be either debt or equity based, depending on the nature of the interventions and use of proceeds, the risk profile of the return and the available financing. The concept is sometimes connected to impact investing, i.e., investments made with the intention to generate measurable social and environmental impact alongside financial return.

This case study focuses on the potential for place-based adaptation, i.e. local, people focused initiatives, and draws on a municipal bond model that has primarily been used for net zero investment. Crowdfunding offers the potential to link local projects to local investors, and thus create a higher motivation for the public to invest in local adaptation.

This case study focuses on how to develop a climate-focused crowdfunding platform to support adaptation projects. It uses a case study of a place-based crowdfunding platform, run by Abundance Investment, which has been used for a series of municipal bonds, albeit currently more focused on mitigation (net zero). These use a Community Municipal Bond or Loan structure, collectively Community Municipal Investments ICMIs), where the debt is raised by a local authority directly from the public via a crowdfunding platform.

These CMIs provide finance to local authorities at a slightly lower rate than they can typically access from conventional public funding sources such as the Public Works Loan Board (PWLB) (part of HMT). In addition, it offers a powerful and innovative way for Local Authorities to engage with citizens as investors. Many local communities do not have clear information or awareness of what councils actually do, and so crowdfunding can help more broadly in bridging the communication and collaboration between communities and local governance on these issues.

The first Community Municipal Investment Bond was launched for West Berkshire Council in June 2020. This provided a return of 1.2% over 5 years for investors. While this return is low, the investment is low risk. The bond was issued directly to the public in partnership with the online crowdfunding platform run by Abundance Investment. Individuals invested from as little as £5 to support projects that align to the Council's green project portfolio. A further 5 municipal investments have been launched and all of them would intend to raise debt from citizens as a way to grow familiarity, increase awareness and keep building up the sense of partnership and the potential to activate citizens' desire to undertake their own carbon reduction initiatives.

TABLE 5 COMMUNITY MUNICIPAL INVESTMENTS

INVESTMENT	FUNDING GOAL	OFFERED RETURNS OF	INVESTMENT TIMEFRAME	NUMBER OF INVESTORS	PAID IN RETURNS (AS OF 2022)
West Berkshire 2025	£1 million	1.22% IRR fixed, capital repaid at maturity	5 years	640	£207.4 k
West Berkshire 2025	£1 million	1.22% IRR fixed, capital repaid at maturity	5 years	640	£207.4 k
Islington Greener Futures 2027	£ 1 million	1.55% fixed, capital repaid at maturity	5 years	661	£2.6 k
Camden Climate Investment 2027	£1 million	1.75% fixed, capital repaid at maturity	5 years	Funding ongoing	Funding ongoing
Cotswold Climate Investment 2027	£1 million	2.1% fixed, amortising	5 years	Funding ongoing	Funding ongoing
Telford & Wrekin Climate Action Investment 2027	£0.5 million	2.1% fixed, amortising	5 years	Funding ongoing	Funding ongoing

Source: (Abundance Investments, 2020a) (Abundance Investments, 2020b) (Abundance Investments, 2022a) (Abundance Investments, 2022b) (Abundance Investments, 2022c)

All these investments have included a portfolio of green projects which contribute to net zero targets/climate emergencies. The West Berkshire project centred on renewable energy (solar panels on public buildings), while Warrington included a new solar storage electricity generation facility. These renewable investments generate a revenue stream from the project to pay back investors although a fundamental

premise of the investment is that the returns to investors are not linked to the performance of the underlying initiatives – this underpins the low risk nature of the investments and therefore the lower level of return.

Some of the investments have also included non- revenue projects (e.g., nature based solutions). Islington's funding is combining clean energy with green public neighbourhoods (which might have some adaptation benefits), to create people-centric neighbourhoods and integrate e-mobility more widely.

ADAPTATION DETAILS AND FINANCING

There is some potential to translate this concept to the adaptation space, but the low revenue potential of many adaptation projects means that greater potential for the crowdfunding concept is to merge mitigation and adaptation projects in a local MCB portfolio (Khosla and Watkiss, 2020), whereby the revenue streams from mitigation are used to generate net positive aggregate revenue streams from the overall portfolio (i.e. mitigation revenues subsidize adaptation). As previously mentioned above, the obligation to repay investors exists irrespective of the revenue performance of what has been funded but bundling revenue generating with non-revenue initiatives is an established part of any finance function.

The concept is already piloted, and Abundance Investment are looking at the potential to develop at scale, given the high replicability for other local authorities.

The concepts align with general public surveys which highlight a growing concern about climate change, and also surveys of crowd investors who do care where their money is invested.

There is no demonstration for adaptation (to our knowledge) in the UK, though there are municipal bonds for adaptation internationally. These tend to pay investors back through the public budget, rather than direct revenue generation.

The main potential is for mixed projects (mitigation and adaptation) given that adaptation projects are more likely to be non-revenue parts of the project portfolio. The co-benefits will depend on the project, but the highest potential for adaptation may be on local adaptation projects with health and well-being benefits, e.g., nature-based solutions.

It is possible to translate the CMI approach to the adaptation domain (Khosla and Watkiss, 2020). Local projects could be developed that seek to reduce local climate risks, provided these fall within the mandate and responsibility of local authorities.

There might be three potential types of adaptation CMIs:

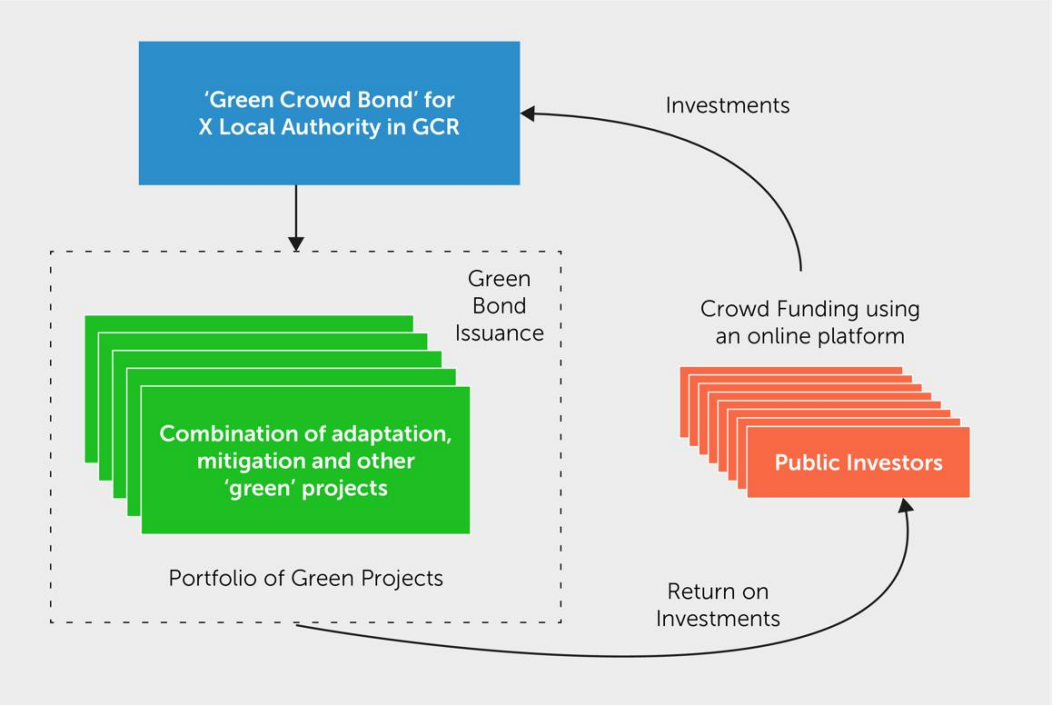
1. Adaptation projects that target public goods or non-market investments, which do not generate revenue. In this case investors would be paid back over time from the annual local authority budget or local taxes or charges. This can raise finance at slightly lower rates than the PWLB, but more importantly may create a greater local sense of adaptation and place-making.
2. Portfolio projects, where adaptation investments are subsidised by revenue generating projects in the portfolio, such as renewable projects.
3. Adaptation projects that directly generate a revenue stream to pay back crowdfunding investors). While ideal, the opportunities for such projects is considered modest.

The greatest potential for direct revenue raising (the final bullet above) is likely to be associated with reactive adaptation, investing in low – or no-regret adaptation. Projects that are more transformational are likely to be funded either from public budgets (grant models).

However, the potential for exploring transformational adaptation using crowdfunding (or potentially a mix of crowdfunding and crowdsourcing) could be extremely valuable, because the place-making concept would connect local adaptation with the local population and could be a route for raising awareness around transformational adaptation (see Khosla and Watkiss, 2020).

The project combines a public authority, with private investors, through a private intermediary. As such they are public projects that raise private finance from private investors, rather than a form of blended finance. To date, the investors has been limited to the general public as investors. In theory, private investors (commercial) could invest, though the volumes of finance are currently quite small.

The financial structure is shown below.



Source: Khosla and Watkiss, 2020

To date, the approach has used bonds. The return on investment is generated by the revenue generated by the mitigation projects. Abundance are also considering moving to a loan based model (rather than bonds).

The returns on finance for investors are presented in the earlier table. Abundance also levies a fee (charging a small fee to investors, and a small amount to the council).

Abundance Investment does perform its own due diligence in packaging the investments, preparing the funding round and keeping up with the project once funding has been secured. The primary function of the due diligence process is to make sure the risks of each investment are carefully considered and to communicate these to investors. The investment can also rely on the structural due diligence systems and

accountability metrics that are often present in local authorities. Municipalities often demonstrate good financial governance and this aids in project creation and management, as well as investment attractiveness.

The CMBs are low risk. This is because projects involve a public authority. To date, the investment themselves and the confidence in revenue generation are also high (e.g. there is low risk with an EV charging station). It is noted that an adaptation project would have higher project risk, because there is typically lower confidence around benefit levels, and revenue models are often indirect or involve co-benefits.

BARRIERS

Information

Significant work has been undertaken by Abundance Investment to reduce the barriers to crowdfunding, through the development of standardized processes and procedures.

However, one barrier that remains is around the time and resources needed by local authorities to develop their project portfolios. This often requires detailed studies. The design and due diligence required for each project is usually specific (bespoke) and dependant on the project management team.

These barriers are likely to be greater for adaptation because adaptation projects will be more site and context specific, and will require more detailed studies, and in turn, more bespoke solutions. To illustrate, while some technical studies are needed to site and implement an EV charging station, this uses an existing off-the-shelf technology. Developing an adaptation project (e.g., a local nature-based solution) would require detailed climate risk assessment and modelling work, detailed site monitoring and analysis, more safeguard and due diligence checks, and would require bespoke analysis for the design. This will involve more time and costs for the LA and project development will be a greater barrier than a mitigation project.

Economic

The usual challenges of the public nature of many adaptation investments, and the temporal pattern of benefits (smaller in the short-term, larger in the future), mean that the economic and financial internal rates of return from adaptation projects are likely to be much lower than mitigation projects, and thus offer lower investment return for crowdfunding investors.

Financial

As above, the main challenge will be finding revenue streams for adaptation to pay back crowdfunding investors, i.e., finding a pipeline of bankable projects. The investment size of CMB projects to date – even for mitigation - has been low. This constrains the funding potential to public investors, rather than commercial investors who would typically want higher returns. However, the crowdfunding approach has a number of solutions to common adaptation financing barriers, and these are worth highlighting notably that it lowers the transaction costs of involving large number of investors.

There are also some barriers to scale within the tax regulations relating to investing in bonds that affect investment returns. In discussion with Abundance Investment, it was reported that addressing the concerns below will have the highest impact:

Adding local authority bonds into the eligibility for IFISA, Innovative Finance ISAs, so that returns can be tax free. At the moment local authority loans qualify but not bonds.

Removing withholding tax from investment-based crowdfunding debt securities so they are aligned with P2P loans. Currently, if one invests in a bond the issuer is required to hold back 20% of interest to pay taxation. This creates a disincentive to invest for lower earners who might not have to pay any tax if they are below the income threshold (you have to complete a form to claim the tax back).

Policy and regulatory

The existing policy and regulatory regime may limit the types of projects that can be financed, at least for local authorities. For example, LAs have some responsibility for local flooding, but this is limited. This may mean that investments are focused on local authority land or buildings, or in areas where there is a strong regulatory mandate for LA action.

Behaviour

While the local focus has high potential to increase interest in adaptation finance from the public, there will be a question of whether the public are willing to pay (through investment) for local adaptation, especially if to date this has been provided by government.

More positively, there is the potential to use the crowdfunding concept to 'wake-up' the public to the fact that public budgets along are not sufficient to fund all adaptation, and there will need to be greater contribution from local communities and businesses. Viewed from this perspective, crowdfunding has extremely important potential to start changing public perceptions of the costs of adaptation and the delivery of adaptation finance.

Abundance have created a process for users that does not need investment experience or prior knowledge of finance and investing so as to further remove barriers to investment.

SCALABILITY AND SUMMARY

The undoubted success of the place-based crowdfunding model is to connect local people with local issues. The model has been enabled by Abundance by developing standardized processes and procedures. The underlying model itself has been made possible by earlier changes in financial regulation, to allow the crowdfunding model and CMBs.

In the context of mitigation, it is assumed GHG emission reductions are tracked and reported as part of the net zero commitments of the LAs involved, as similar tracking of adaptation effectiveness would be likely to sit with LAs. The model has already been replicated multiple times (see earlier table).

There is a large potential market for crowdfunding and CMBs. For investors, there is the potential to include these investments in ISAs and thus provide additional tax benefits (ISA eligibility was approved for crowd-funding debt-based finance in 2016).

While there is a sustainable model for revenue generating mitigation projects for crowdfunding and CMBs, it is not clear if a sustainable model exists for adaptation, because of the availability of bankable projects.

However, the model has considerable potential for raising awareness about the need for adaptation at the local level and engaging local citizens both with local authorities and local issues and on adaptation. As such, place-based adaptation crowdfunding can be considered an opportunity for changing perceptions on financing (and who pays) for adaptation.

It is noted that in the international adaptation area (Watkiss et al., 2021), public finance is often used to develop project pipelines of investable projects (e.g., through preparation grants, or project preparation facilities, including as part of adaptation accelerators). It is possible that government funding or investment in similar activities could help local authorities unlock project portfolios by addressing these adaptation preparation costs.

A.2.9 - RESILIENCE BONDS

Sector	Forestry
Climate risk	Wildfires
Why pays?	Public
Synopsis:	*The Forest Resilience Bond supports the funding of a $4.6 million restoration project to mitigate wildfire risk in Tahoe National Forest, California.*

Californian forests are increasing being affected by extreme wildfires. This is due to a combination of historic forest management (fire suppression policy) and rising temperatures and dry conditions. Forest areas have become too dense with dry or dead material that would have otherwise been cleared by small burns. While there is awareness of this risk, the Forest Service does not have available funds to address at the scale needed, not least because budgets are stretched from tackling severe wildfires.

Blue Forest Conservation – originally a team of students at UC Berkeley – won the Kellogg-Morgan Stanley Sustainable Investment Challenge in 2015, a competition for innovative finance vehicles that seek positive environmental or social impact and competitive financial returns. Recognizing the economic costs of forest fires, BFC sought developed an innovative financial model that could mobilize additional sources of finance from multiple beneficiaries to fund forest restoration activities, with the aim of reducing the severity and frequency of wildfires and so structured the Forest Resilience Bond.

The project primary objective is reduced wildfire risk, but the project also generates co-benefits from protecting water quality, increasing water quantity for electricity generation, and building on the existing carbon sink and job creation.

The Forest Resilience Bond (FRB) was designed to support the funding of a US$4 million restoration project to mitigate wildfire risk in Tahoe National Forest, California. It was developed in 2018 by Blue Forest Conservation (BFC) in partnership with the World Resources Institute (WRI). The Yuba Project is a 14,545-acre project in Sierra County, CA that encompasses Tahoe National Forest system lands within the Yuba River Watershed. The FRB harnesses upfront investment provided by private investors to cover the initial costs of restoration, with public beneficiaries such as the Forest Service, state agencies and utilities sharing the costs to repay investors over time. The YUBA FRB is the pilot of BFC's operations, and they have plans to expand to other watersheds in California and the wider USA (BFC, 2022a).

Project Partners

- Blue Forest Conservation – Project owner, a non-profit.

- The National Forest Foundation (NFF) – Implementation partner. As the congressionally chartered philanthropic partner of the Forest Service, NFF brought capacity and implementation expertise. The Forest Service decided to not partake as a project payer.
- Yuba Water Agency (YWA) – cost-sharing partner. A water utility provider based in Yuba County, California. As a beneficiary of a healthy watershed, YWA recognized the significant benefits that the FRB could bring to protecting and enhancing water supplies. The partnership that BFC had with the WRI had an important impact here as the research demonstrated the business case to YWA of investing in ecosystem benefits.
- FRB Yuba Project I LLC - Special Purpose Vehicle (SPV). Incorporated as an LLC and a wholly owned subsidiary of BFC. The SPV has entered into a joint loan agreement with lenders and passes loan proceeds along to NFF in the form of both 0% interest rate loans and grants. There will be an LLC for each project.

(Convergence, 2020) (Knight, 2019) (BFC, 2022b) (BFC, 2022c)

The first FRB for the Yuba project was a pilot. The pilot bond focused on a project that had already been identified, costed and completed in the planning stage, i.e., all permitting and contracting was complete, but which had the problem of (public) financing constraints. The lack of finance elongated the project timeline, potentially nullifying the expected benefits (Wobbrock, 2020). This was because the event horizon for a catastrophic fire (extremely high risk) was shorter than the project completion on the existing budget. The FRB allowed for the Tahoe to accelerate work and complete projects in just four years instead of the projected 10 to 12 years (BFC, 2020). With the success of the pilot, BFC are continuing to structure and make available further bonds for other areas (BFC, 2022d).

Value flows – there are a number of ecosystems services being captured and measured and paid for within the project (Knight, 2019):

- Water (the bedrock is solid so avoided flooding, avoided sedimentation, enhanced water quality, and quantity);
- Carbon –credits cannot be generated on public (federal) land but payments can be made on avoided carbon emissions through reduced fire;
- People hours – increased jobs and careers from the project.

These value flows are a mix of mitigation and adaptation, with the main adaptation benefits being decreased risk of hazard (and economic losses) from reduced fire as well as an enhancement in quality of resources. The project is incremental, in that it is aiming to maintain existing assets and resources.

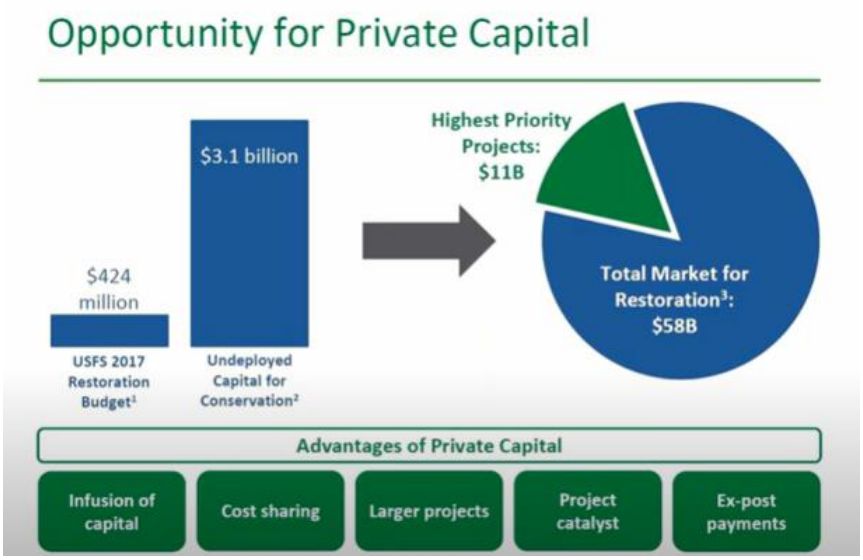
FINANCING

Financing for the Yuba FRB came from three main sources:

- **Investors:** The Yuba FRB raised $4 million USD from four lenders. There were two types of investors in the bond which had different investment packages tailored to the investment mission. All lenders rank *pari passu*, and receive principal and interest on a quarterly basis (Convergence, 2020; Wobbrock, 2019).
- **Concessional investors** ($2 million USD) : Rockefeller Foundation and Gordon and Betty Moore foundation – 1% ROI project bundle;
- **Commercial investors** ($2 million USD) : AAA insurance and Calvert impact capital – 4% ROI + 50 basis point commitment fee.

Both investor groups are debt investors, so there is no ongoing influence from the investors as there would be if they were equity investors. On average the rate of return is about 2.5%. The project is expected to reach financial stability by 2023-2024 (BFC, 2020).

The following diagram outlines the opportunity for private capital in the project:



AAA insurance and Calvert Impact Capital (CIC) required a better return than the concessional investors. BFC saw it as a credible proof of concept to offer higher ROI's to CIC due to their global reputation as well respected leaders in the impact investment market (Westley, 2018). AAA insurance were interested, as they had not invested in environmental projects before, due to low confidence in viable returns. However, with the risk of increased severity of wildfires affecting the likelihood of insurance pay-outs to their customers and hence affecting their balance sheet, coupled with the tax benefits given on ESG investments, "*it made commercial sense to invest in the Forest Resilience Bond"* (Madiera & Woolworth, 2019).

The concessional investors are impact investors with very large portfolios under management and could therefore invest at a much lower ROI.

Cash flows

Each beneficiary individually negotiated their financial contributions to the FRB, with source of funds outlined below:

- Yuba Water Agency: $1.5 million fee for services contract over 5 years;
- California Fire: $2.598 million grant (over 3 years) all reimbursable after work is completed;
- Sierra Nevada Conservancy (SNC) grant: up to $0.25 million (over 3 years;)
- Forest Service: in-kind and cash contributions and the value of merchantable timber that arises from the restoration work.

(Convergence, 2020)

Concessions

The FRB benefited greatly from free or concessional finance and services supplied to this project, and it is highly unlikely this would have been able to be avoided or supplemented by market rate capital. Sources

come from both public and private sector, with a brief overview below (Knight, 2016) (Knight, 2019) (Madiera & Woolworth, 2019):

- Pro bono law firms provided services to the avoided cost of 1.5 million USD;
- "Free" labour from forest service was not accounted for in project overheads;
- Existing revenues from timber capital supplemented the overheads in project conception;
- Grants upfront, with 0% loan repayments;
- The LLC did not take a fee to structure the instrument (but will in the future);
- Program related investments (PRI) provided a tax benefit of 1.5 million USD;
- Joint Fire Science and various other institutions funded research papers on the project which added informational capital and will likely improve the inevitability of the following FRB's.

Within the USA there is policy to support charitable organisations. Foundations can count program investments as part of the 5% giving allotment and pay it back only if the investment works. This regulation helped most in the testing phase.

Philanthropic seed capital was critical for two reasons (Knight, 2019; Wobbrock, 2016 & 2019):

1) Attaining a government grant was unlikely without proof of concept partnerships.
2) Presence of soft capital created a good environment (time and flexibility) to find, choose and present the best project for the pilot. There was not a time pressure to get the project operational and making returns as quickly as possible.

Key insights from BFC for private adaptation projects was to really understand and strategize finding certain types of funding at the most opportune time. Grant finance is critical to project initiation and needs to be plentiful and easy to access, which is where public funding can have a great impact. Social investors are most valuable in the proof of concept and planning stage as they place higher value on the impact assessment scores and can accept below market rate returns. Only once the proof of concept is demonstrated robustly, all agreements and licenses are secured and the project is ready to launch should any private project go to the institutional financiers (Knight, 2019).

ADAPTATION DETAILS

The Forest Service budget going to fighting fires has risen from 16% to 67% since 1995 and his costs tens of millions of dollars (Wobbrock, 2019). By returning to a less dense forest environment, the risk of a naturally occurring wildfire spreading to become uncontrollable is lower. By clearing the majority of sapling trees and dense undergrowth the project removes 'ladder fire', and reduces heat intensity of any fire.

While the project is primarily reactive, looking at current risks and the already experienced increase in wildfires in CA, climate change is projected to increase forest fire frequency in the future (Abrams, 2020)

Activities include strategic tree planting, bringing woodland into management, opening up woods for visitors, building and maintaining visitor facilities (e.g. footpaths, cycleways) and educational and community initiatives. Revenue streams can be generated primarily from forest products / charges for use of community forest areas by the local populations and tourists (recreation, health and well-being benefits). If recreational activities and associated infrastructure are provided within the forested areas e.g. rock-climbing facilities, restaurants etc, user charges could be set. Funds from the user charges could be used to develop and deliver verifiable pre-agreed activities for investors and communities – for example, planting and maintenance of woodlots.

BFC identified several private beneficiaries in the water value flow whose profit model was dependant on the ecosystem being in good health.

Beneficiaries in the water-based value flow were identified (WestFAST, 2021; Wobbrock, 2019) as:

- Water utilities;
- Hydroelectric (1/3 of California's hydroelectric generation was dependant on Yuba watershed);
- Insurance companies;
- Public security;
- Mine and metal refinement.

BARRIERS

Information

There are challenges with quantifying and measuring avoided fire suppression costs, and thus to performance-linked payments. In the initial business model, beneficiaries make fixed payments. BFC identified it would reduce performance risk to use performance based contract for beneficiaries, but there were no existing performance indicators that were appropriate for the projects and which specified a quantifiable impact in fire suppression which could directly link to the project activities. Contracting was carried out with the inclusion of a term to record the options for performance indicators in lieu of confirmed definition (Convergence, 2020) (Knight, 2019).

Definitional clarity was also a barrier in pitch and financing (Knight, 2019; Wobbrock, 2019). The term 'resilience' in relation to the climate does not have a widely accepted definition and can often be used to describe less technical solutions; it is not a precise phrase. Yet it is a term that is expected in all pitch and funding conversations. The absence of a clear definition meant the investors and that stage of pitching was complicated.

Economic

The market for investment in climate resilient is nascent and as such, there are not many established managers of projects (WestFAST, 2021). The lack of awareness of successful projects, coupled with the risk of being first to market makes investment uncertain. It also creates a bottle neck on the investor side. BFC identified a $3.1 billion pot of capital from distributed sources (Knight, 2016) that had been earmarked for environmental resilience projects but had not been deployed due to limited supply of bankable projects. A priority is to generate a healthy pipeline of projects.

There is a general economic barrier around the positive externalities of adaptation, in this case the public good characteristics of wildfire risk reduction. Using distributed revenue streams (entrance fees, timber capital, etc.) was used to mitigate this barrier. However, a question remains whether communities that usually expect access to publicly managed areas to be a free right, are prepared to pay for this. Reliance on private entities as the source of revenue through fees was a less complex approach.

Financial

There are not many examples of proof of concept for adaptation, those that exist do not have an attractive risk-return profile. This reduces the availability of a compatible investor, limiting searches to financiers with direct links into impact and climate resilience investments.

This project was able to hit the ground running, as the Forest Service had completed all necessary studies, permits and budgets to complete the work, which would have been necessary to provide substance to a new investment proposition (Forest Service, 2020; Abrams, 2019). This meant that BFC could go to market (Knight, 2019). For projects without all permitting completed, the project implementers would need seed finance to get the investment proposal ready, which is where most projects fail. In a traditional model (raising through a dedicated fund) the finance round would take too long. This also compounds working capital and cash flow (Wobbrock, 2019).

The BFC were wary of capital investment size – due to it being a pilot project it was important to understand bandwidth and capacity and keep investments small, yet balancing the need for attractive returns for investors (Madiera and Woolworth, 2019). The pilot had to cap investment size, despite an appetite to invest more than $1 million from some investors, because of economies of scale in due diligence costs.

Policy and regulatory

The ability to deploy capital from public sources is complicated. Initially, BFC approached the Forest Service about being the principle investor in the FRB, however regulatory restraints prevented this – federal agencies in the USA are largely funded by single year appropriations from Congress and are therefore restricted in providing the multi-year reimbursements required for investors over the life of the FRB (Convergence, 2020). Bureaucratic uncertainty from the public partners compounded the inflexibility from public departments, creating complications and delays.

Planning activities to control (ecological) environmental impacts takes a very long time and a lot of resource due to the due diligence and permitting structure present in the USA and in many other countries around the world (Madiera and Woolwoth, 2019). These regulatory structures were created and cemented in a time when conservation looked different to the needs of today – conservation was much more passive and followed the idea that nature should be left untouched. Therefore, any project that takes and active modification approach to adaptation on public goods is likely to face institutional delays.

Behaviour

Co-operation between public and private interests is usually a heavily contracted and well-defined process. Initially, there was a barrier of trust between stakeholders of the project and managers (contractors) (Knight, 2019). There were questions on the quality of work done vs impact of benefits promised. BFC mitigated this on the investor side by introducing performance based contracting to the FRR, however, that lead to informational barriers (Knight, 2019).

EFFECTIVENESS

The FRB was a success in funding and the project is also being implemented. Despite an unprecedented wildfire season during 2020 and the coronavirus pandemic, all of the work is on track to achieve the 2022 goals on schedule. With FRB financing and the modest revenue reinvested from timber sales, the partners on the ground were able to work with fewer interruptions. Funding from private loans reduced the uncertainty of finance flows during the pandemic (BFC, 2020).

The approach of BFC was to look for a project that needed funding and then find the methodology, rather than theorise a methodology and then apply it to a pilot. This meant that the project timelines were shorter, as the forest service had already completed the necessary research and development, and costing for the project as well as all the permissions and audits (Wobbrock, 2019; Knight, 2019).

This project has balanced opportunity-risk axis among the project stakeholders. Risk was assumed by the forest agency, as was their remit and by nature of the organisation. BFC intentionally rebalanced the economic benefit for the agency by working closely with them to set up the research partner relationship as a long term economic benefit – the agency had control over the research material and approach. BFC is the equity investor of the LLC and structured the LLC to only pay out dividends once all loans are honoured. (Knight, 2019; Madeira and Woolworth, 2019)

A major strength of this project was using tailored contracting and agreements between the project stakeholders to motivate them to be part of the project. BFC worked through a cooperative process to set up contracts with individual stakeholders, allowing each beneficiary to codify the terms of its contract or agreements. This allowed BFC to structure agreements with project partners based on the specific benefits which they would receive, which were diverse across the project. This flexibility removed regulatory difficulty, created financial attractiveness tailored to the needs of the investor and aided in negotiation. (Wobbrock, 2019; Knight, 2019; Convergence, 2020). The partnership between BFC and the NFF was critical to successful investment (Madeira and Woolworth, 2019).

There were some issues in cash flow between the different stakeholders –as the revenues are staggered, dependant on the contractor/contracting party chain. This means that a contractor on the project could end up experiencing up to a lag six-month lag from work completed to full payment, because the contracting party cannot pay until they themselves have been paid. (Wobbrock, 2019; Knight, 2019). This makes is very difficult for contractors to engage in a scaling of supply with inconsistent payment schedules.

Monitoring

One of the challenges and uncertainties of this project was that monitoring was underfunded within the state agencies. Beneficiaries were asked to identify success indicators/metrics to ensure they were attributable to impact.

Blue Forest use the SDG's to measure impact of the project, displayed below:

Yuba FRB Impact 2020						
SDG Target	Project Outcome	Unit	2019	2020	Total Planned	% Completed
6	**Clean Water & Sanitation**					
	Water supply protected/made resilient	Acre-feet	7,398	13,662	50,035	27%
7	**Affordable & Clean Energy**					
	Biomass Utilization	Tons	13,750	42,581	54,164	79%
	Renewable Energy Generated by Biomass	MWh	3,998	--	15,750	25%
	Hydropower Protected	MWh	10,254	18,935	69,348	27%
8	**Decent Work & Economic Growth**					
	Direct & Indirect Jobs Created	#	17	25	79	32%
	Total Funds Invested in Ecosystem Restoration	$	$875,000	$1,275,000	$4,000,000	32%
11	**Sustainable Cities & Communities**					
	Road Reconstruction	Miles	4	4	5	80%
	Fire Control Lines	Miles	25	25	25	100%
	Communities Involved	#	4	4	4	100%
13	**Climate Action**					
	Avoided Wildfire Carbon Emissions	MT CO2e	7,312	13,503 *(+85%)*	49,453	27%
15	**Life on Land**					
	Fuels Reduction	Acres	625	1,078	1,630	66%
	Prescribed Fire	Acres	0	0	2,510	
	Aspen Regeneration	Acres	92	206	225	91%
	Meadow Restoration	Acres	0	0	395	
	Invasive Plant Treatments	Acres	0	40	89	45%
	Terrestrial Ecosystems Restored	Acres	717	1,324	4,849	27%
	Terrestrial Ecosystems Protected	Acres	2,151	3,971	14,545	27%
17	**Partnerships for the Goals**					
	Formal Blue Forest FRB Partners	#	18	18	18	100%
				Cumulative % Complete		**49%**

SCALABILITY AND SUMMARY

The FRB model is scaling-up in the Tahoe National Forest and beyond. After working with 18+ national forests to scope need and opportunity, multiple opportunities have been identified in California, Oregon, and Washington. Blue Forest has a pipeline consisting of $100M worth of projects across 1 million acres. These expansion opportunities demonstrate the large potential for FRB scaling as well as the need for financial instruments that extend infrastructure finance to forests and watersheds. In addition to expanding in acreage, the FRB can also expand in scope to consider the holistic benefits of forest resilience with various co-benefits such as salmon habitats, public health, and local economies (BFC, 2020).

In the long term, the FRB model could be applicable for 58 million acres in the USA, in theory a market of $41 billion USD (Knight, 2016). Sites can be chosen on criteria including 'set-to-scale' – this allows the bond to be re-issued to the same beneficiaries once the original bonds have paid out to continue adaptation and restoration work (Madeira and Woolworth, 2019).

However, scalability is limited by the overheads of the project, which do not have an economy of scale because most of the overheads of these projects are people and capacity (Wobbrock, 2020). The opportunity to overcome this would be to use citizen science in a more formal or integrated way.

A.2.10 - NATURE-BASED SOLUTIONS

Sector	Nature-based solution
Climate risk	Biodiversity loss and habitat destruction, Carbon sequestration. Flooding.
Why pays?	Kent Downs - public, Wyre - blended
Synopsis:	*Two nature-based solutions which provide natural flood management solutions. Kent Downs entails a transitional shift away from a farming landscape, and Wyre entails a market which offers multiple ecosystem services using a social enterprise model.*

Nature-based solutions are "*actions that involve the protection, restoration or management of natural and semi-natural ecosystems; the sustainable management of aquatic systems and working lands such as croplands or timberlands; or the creation of novel ecosystems in and around cities*" (Nature-based Solutions Initiative, 2022). These utilise natural and modified ecosystems to address societal challenges such as climate change, disaster risk reduction, food and water security, and health (International Union for Conservation of Nature, 2022).

Nature-based solutions can support both climate change mitigation and adaptation (World Wildlife Fund, 2020). Adaptation that can be supported by nature-based solutions include:

- **Forest creation** protect against soil erosion, flooding and landslides.
- **Greener cities,** for example green roofs and rain gardens, can minimise damaging runoff by absorbing rainwater, reducing flood risks and safeguarding freshwater ecosystems.
- **Wetlands and peatlands** which can reduce flooding and droughts

A.2.10.1 - KENT DOWNS

Kent Downs is a nature-based solution that consists of projects around the River Darent catchment. The location of the project is in the Kent Downs, an area classified as an Area of Outstanding National Beauty (AONB):

- The River Darent has been at significant risk from climate change due to its growing local urban population. The river suffered heavily in the 1970's and 1980's from drought, with the river drying up entirely along certain stretches (Kent Downs, 2022).
- Recent extreme weather events have resulted in flooding occurring more regularly, and this has impacted the local population (Kent Downs, 2022). 2000 was the wettest year for over 200 years, with severe flooding in the upper Darent caused by three successive extreme rainfall events (Kent County Council, 2017). The winter of 2002/03 saw the worst flooding since 1968, with 50 properties flooded. And the winter of 2013/14 was the second wettest winter in Kent since 1910, with record water levels experienced on the Darent (Kent County Council, 2017).

The Kent Downs project, begun in early 2000s, entails farmers receiving funding to undertake landscape conversation measures. The landscape led approach can include farmers transitioning farmland into natural

habitats such as farmland meadows and wetlands. The aim of these natural habitats is to reduce the risk of flooding occurring in the local area.

ADAPTATION DETAILS AND FINANCING

The primary adaptation measure from project is a reduction in flood risk, however a notable co-benefit to the project is an improvement in the local biodiversity. The landscape based approach which underpins the project was taken in multiple locations, including Preston Farm, where a floodplain meadow was created (Kent Wildlife Trust, 2019). Key aims of the proposed flood plain at Preston Farm include (Kent Wildlife Trust, 2019):

- To lessen the impact of periods of drought on the River Darent, and the cumulative effects this has on associated low flows in the river.
- To provide for landscape scale flood mitigation in the area between the village of Otford, which lies on the Darent, and the Thames, of which the Darent is a tributary.
- To create conservation and landscape benefits as a material supporting feature. Material conservation and landscape benefits include:
    - An enhanced habitat for biodiversity via the wetland and floodplain meadow.
    - An objective to manage the area extensively with a target condition of neutral grassland, wetland and floodplain meadow habitat will also help mitigate for diffuse pollution levels in the river environment.

Specific measures within the Preston farm proposals to create a floodplain include (Kent Wildlife Trust, 2020):

- Reinstating historic river meadow drains;
- Create an off-stream pond from a historic gravel dig; and
- The installation of a channel habitat restriction structure using natural materials.

EU funding has been the key enabler for the project at Kent Downs. EU funding came from four different schemes, including Interreg (Bayne, 2022). Interreg is an instrument designed to fund solutions to cross-border issues in fields such as the environment, and it is funded by the European Regional Development Fund (Interreg, 2022). The EU funding also helped to attract additional funding from the National Lottery Heritage Fund.

An additional advantage to the Interreg funding was the ability of information sharing from other recipients. The sharing experiences and knowledge across borders, via similar projects, allowed the natural flood management investment undertaken at Kent Downs to be informed by similar projects in Belgium and Holland (Bayne, 2022). This helped to reduce some of the barriers to completing the projects, as will be discussed further.

The public funding has been critical for the nature-based solution at Kent Downs given there are no revenue streams. This lack of revenue stream results in no incentive for private sector organisations to support the project with financing.

Interreg funding for the nature based solution at Kent Downs will end in March 2023, and the UK government has set up a replacement fund called the UK Shared Prosperity Fund (SPF). The UK SPF is at a district and borough level of granularity, in comparison to Interreg which was at a European sub-regional level. Kent Downs would need to submit bids to 11 different districts and boroughs if they want to obtain funding from

the UK SPF to continue the project. This is likely to take a material time and effort for organisations such as Kent Downs, and would entail substantial cost.

BARRIERS

Barriers to the Kent Downs project are **financial** and **informational**.

Financial barriers to the project continuing include a lack of stable public funding, with future funding schemes requiring resource consuming bids. EU funding has been a critical enabler of the project, not only by providing funding but also crowding in funding from the National Lottery Heritage Fund. The funding will end in March 2023, which will uncertainty over the future of the project. As discussed above, a key **future financial barrier** is likely to be the large resource requirement to apply for the UK SPF.

Informational barriers to the project include a co-ordination failure and risk considerations. Grants are currently provided on a farm-by-farm basis, however to minimise the risk of flooding the catchment area must be considered as a whole. This requires significant co-ordination across farmers, and sophisticated modelling to determine which farms can achieve the greatest reduction in water flow. In addition, a barrier to farmer involvement, is that some farms have lower incentives to be involved as they are not at risk of flooding (or underestimate their risk of flooding). For example, a failure in flood management upstream will only lead to the flooding of a downstream farm, not those further upstream. Farmers upstream therefore need to be incentivised, using funding and information dissemination, to be involved in the project.

SUMMARY

The Kent Downs nature-based solution was enabled by long-term EU funding which provided stability and certainty for the project. The end of the funding in March 2023 has created uncertainty for the future of the project, given the high resource load and uncertainty of application success for the UK SPF. It is therefore key for funding to be available at the right level of aggregation and for the necessary time horizon to enable projects such as Kent Downs to have a sustainable and certain future.

A.2.10.2 - WYRE CATCHMENT NATURAL FLOOD MANAGEMENT

The River Wyre, Lancashire, was selected to receive grant funding to support environmental projects such as a natural flood management scheme. The communities local to the Wyre catchment have experienced a 1 in 50 year flood four times between 2000 and 2020 (The Rivers Trust, 2020a). The economic cost to insurers of a 1 in 50 year flood is £1.96m (The Rivers Trust, 2020a).

As part of the project, over 70 hectares of natural flood management interventions have been installed, including:

- Ponds;
- Hedges; and
- Leaky dams.

These interventions store 600,000 cubic metres of water in the catchment area. In addition, co-benefits from the project include the creation of new wildlife habitat, and climate change mitigation as greenhouse gases are stored in the newly created landscape, such as peatlands and wetlands (The Rivers Trust, 2020b).

Investors include the Woodland Trust, who provided a grant of £600,000. More than 10 farmers and landowners provide land which is used to create ecosystem services, with the Wyre Rivers Trust supporting

the delivery of the project. Five buyers from the public and private sector, including United Utilities, Wyre Council, FloodRE, Environment Agency, NW Regional Flood and Coastal Committee, are collectively paying £220,000 per annum for nine years (The Rivers Trust, 2020a). At the end of the nine year period, the contracts with the buyers will be renewed, at which point all the upfront capital will be paid off and the 'revenue' payments will decrease significantly. New investment will not be required.

To bring together the multiple project stakeholders, a not-for-profit special purpose vehicle (SPV) was created – the Wyre Catchment Community Interest Company. The SPV receives payment from buyers of ecosystem services and benefits, such as the 283 off-site biodiversity credits that are created as part of the project (The Rivers Trust, 2020a). The SPV also receives grants from impact investors. The SPV then repays capital and interest to the impact investors, as well was lease agreement payments to farmers and landowners, and payment to local suppliers to deliver interventions. The interest repayment to investors is financed by the revenue generated from a performance payment linked to flood management.

Barriers to the project are informational and financial.

Informational barriers refer to the uncertainty around how exisitng schemes would interact with private schemes given the current agricultural transition. **Financial barriers** refer to the challenge of external factors in the catchment affecting performance based payments relating to flood risk reduction. In addition, many buyers were accustomed to short term funding cycles, such as three years, whereas this project has a nine year cycle.

A key enabler of the project is Social Investment Tax Relief (SITR). Working with Triodos Bank, the project successfully unlocked SITR, although it took considerable time and effort. This project was the first time it has been used for environmental purposes, and the project will need an extension of this relief beyond its March 2023 expiry date. SITR could be a useful tool to attract private investment into smaller scale nature-based investment projects.

The primary ecosystem service is natural flood management, and payment is performance based on a 'peak flow reduction' performance metric. Buyers are involved for different reasons, such as financial (i.e. avoid future costs) and strategic reasons.

Biodiversity has been monetised through a 'impact adjusted' finance mechanism with the institutional investor, in which, if biodiversity gain is demonstrated based on a simple metric, the investors will reduce their interest rates. This occurred at a time when Biodiversity Net Gain was not possible. Through the Woodland Trust grant the project also monetised carbon through the woodland carbon code and selling the carbon through the peatland work.

COMPARISON

Kent Downs received full public funding which was critical to the project, as the absence of a revenue stream limited incentives for private financing. The Wyre catchment project however uses a blended finance model, with the project providing ecosystem services such as biodiversity credits to beneficiaries, including private entities.

The Wyre project is an example of how the demand side (e.g. buyers of environmental credits) and the supply side (e.g. such as landowners) can efficiently be brought together in the context of blended finance. In comparison to the Kent Downs project, the Wyre catchment project receives financing from a wider range of organisations, making its sustainability less reliant on a single source of financing.

ANNEX 3: BENEFITS OF SUDS ASSESSED BY IGNITION IN THE LIVING LAB

TABLE 6 BENEFITS OF SUDS ASSESSED BY IGNITION IN THE LIVING LAB

BENEFIT	# OF STUDIES	PHYSICAL FLOW	COMMENTS
Air quality	0	Pollution removal	*There is no data for this at present, although data could potentially be taken from green spaces database where appropriate.*
Carbon	15	Annual carbon sequestered	*Only strong data on SuDS carbon storage focusses on detention ponds, it would not be appropriate to generalise this across SuDS due to the difference in hydrology influence. Outlying data reporting 17kg m2 yr sequestration was not included.*
		Carbon storage	
Water quantity	26	Peak flow reduction	*An abundance of research is available for this benefit, covering many measurable units, the three included here were found to be most common. Less data on infiltration SUDS.*
		Peak flow delay	
		Runoff reduction	
Water quality	26	Total nitrate removal	*All but one study report nitrate removal. (One reports increased oxidisable nitrate in effluent in an infiltration SUD).*
		Total suspended solids removal	*All studies found reported removal.*
		Total phosphate removal	*All but one study reports phosphate removal. (One reports increase in phosphate in filter strip & swale SuDS).*
Temperatur e	4	Reduction in air temperature	*Qualitative data with differing units requiring interpretation. Definitive studies need to be found.*
Energy use	0	Energy consumption for cooling	*There are potential energy reductions from decreased requirements to treat waste water.*
		Total energy consumption	
		Energy consumption for warming	
		Thermal resistance	
	0	Attention	

BENEFIT	# OF STUDIES	PHYSICAL FLOW	COMMENTS
Health and wellbeing		Memory and recall	*There is no data for this at present, although data could potentially be taken from green spaces database where appropriate.*
Noise	0	Reduction in noise levels	*There is no data at present and unsure if this would show any positive benefit.*
Land and property	4	% house price premium	*Data listed in summary based on 3 studies that make reference to generic "blue space", other data in database on varying measurable aspects exists. 1 study concludes that in the absence of green and blue spaces, property prices in Great Britain would be £4,813 lower and this reflects the value of services provided by green and blue spaces.*
		% property premium close to water	
Amenity	2	No consistent physical flow data	*Summary figure based on 2 studies, other studies available in database with differing measuring units.*
Biodiversity	12	No consistent physical flow data	*Multiple qualitative data entries, mostly UK based.*
Local economic growth	0	Staff turnover	
		Sick leave	
		Productivity	

Source: (Greater Manchester Combined Authority, 2022)

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