# FINANCIAL INSTRUMENTS FOR RESILIENT INFRASTRUCTURE

## TECHNICAL REPORT

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Funded by

# FOREWORD

**Disasters cause poverty**. A recent study by the World Bank estimated that disasters force some 26 million people into poverty whilst causing $60bn of economic losses annually. More than 200 million people per year are affected by events such as earthquakes, cyclones and flooding in developing countries. The poorest people suffer disproportionately due to their higher vulnerability and exposure, and this can have long-term impacts on their development prospects. Climate change will further increase the intensity of weather-extremes, and increase pressure on systems, exacerbating these impacts.

**Disasters also cause significant fiscal and economic shocks to vulnerable countries**. For the highest risk countries, the costs of disasters can overwhelm the capacity of governments to respond, and this can amplify the impacts on the lives and livelihoods of people significantly. In Dominica in 2017 for example, more than 200% of GDP was wiped out overnight. For these reasons, building resilience to disasters is prioritised within several of the Sustainable Development Goals, which are at the heart of DFID's work.

**Resilient infrastructure is a key to reducing the impacts of disasters**. Infrastructure that can perform during or shortly after a crisis can not only reduce impacts on people's lives and livelihoods but can be of substantial national economic and social benefit. However, there are a number of barriers to building resilient infrastructure or retrofitting existing infrastructure, including upfront costs and local capacity. These challenges can be prohibitive for the world's poorest and most vulnerable nations, leading to poor quality infrastructure that does not perform well during crises. The result is that shocks place greater stress on economies and social systems, and the continued spiral of poverty.

**The Centre for Global Disaster Protection draws upon UK and global expertise in risk, finance and insurance to provide impartial advice, innovation and cutting-edge science.** The Centre is DFID's flagship Disaster Risk Finance technical assistance programme, aiming to help developing countries strengthen their pre-disaster planning and financial arrangements so they can respond more rapidly and effectively when a disaster strikes.
As part of its work on innovative risk financing, the Centre ran an innovation lab earlier this year. By bringing together knowledge and expertise, the lab developed new ways of realising a resilience dividend by balancing the upfront costs of resilience (e.g. retrofitting) with the associated reductions in insurance premiums (due to lower Annual Average Losses). Although further work is needed, this report presents some initial analysis, including worked examples, to illustrate the potential of the products.

**Rachel Turner**
Chair of the Board, Centre for Global Disaster Protection
Director, Economic Development, Department for International Development

# FOREWORD

Almost one and a half million people have died in natural disasters over the past 20 years. This is a waste of life; a waste of potential.

Natural disasters also have a massive economic impact. Our models suggest natural catastrophes cost the world's poorest countries almost $30bn a year on average. Hard-won development gains are regularly wiped out – and it is the poor and the vulnerable who are most impacted.

In case anyone had forgotten the crippling impacts of natural disasters, 2017 served a painful reminder. Somalia, Ethiopia and Kenya struggled with drought. Floods and landslides wrecked lives and livelihoods in Sri Lanka and Bangladesh. Several Caribbean islands were devastated by a very active hurricane season. Whenever and wherever catastrophe strikes, our thoughts are with those so profoundly affected.

We did not, however, need last summer's tropical cyclones to understand that something is not working. We did not need hurricanes Irma and Maria to learn that investments in resilience reduce losses from natural disasters. And we did not need the events of 2017 to know that incentives are too often insufficient to drive action in the most vulnerable regions.

These truths are at the heart of the Centre for Global Disaster Protection. Innovation is required to solve such complex humanitarian, political and economic problems. The impacts of recent disasters – and the need to finance reconstruction – have heightened the innovation imperative. They provide an opportunity to deploy instruments which catalyse investments in resilience; which enable vulnerable communities to recover faster.

RMS too knows that it is possible to stop manufacturing natural disasters. And RMS knows that financial mechanisms could in theory securitise – and therefore incentivise – the potential 'resilience dividends' from investments in disaster risk reduction.

Yet equally well understood is the fact that financial structures which incentivise resilience are difficult to implement in practice – in developed and in developing countries. To move from theory to practice; to redirect capital at the required scale, ideas need to be fleshed out, structures need to be robustly designed and cashflows need to be tested. Any new financial mechanisms must pass muster with all stakeholders, lest the intended benefits evaporate.

Since 1988, RMS' mission has remained constant: to make communities and economies more resilient to shocks through a deeper understanding of catastrophes. Now, with the Centre's help, experts from the finance, humanitarian and development communities have for the first time come together to refine financial instruments, address practical challenges and provide the interdisciplinary buy-in which mobilises action.

In this collaborative environment, innovation has happened. This report is a product of that innovation.

The four new financial mechanisms examined in the report can help monetise the resilience dividend, thereby incentivising both resilient building practices and risk financing. The outcome: less physical damage, fewer lives lost and faster economic recovery whenever nature proves too much.

More is needed, of course. Policymakers and donors have a crucial role to play, not least in sponsoring pilots, funding the quantification of resilience, promoting risk-based pricing, supporting risk finance and advocating duties of care around life, livelihood and shelter.

Thankfully the significant public benefits of resilience justify the investment. And now we have four new financial instruments for donors and the market to pilot in real-world situations.

**Daniel Stander**
Global Managing Director, RMS

# EXECUTIVE SUMMARY

**The world faces a huge demand for infrastructure investment.** Global infrastructure needs are large and growing: the 2017 Global Infrastructure Outlook estimates infrastructure investment needs of $94 trillion by 2040. However, financing infrastructure is a difficult task, especially in developing countries, driven by challenges such as low user purchasing power, high country risk and weak institutional set ups. These challenges help to explain why, if current trends persist, there is expected to be a 20% infrastructure investment shortfall by 2040.

**Without further intervention, a large proportion of this infrastructure is expected to be non-resilient, particularly in developing countries, increasing the exposure to disasters.** This lack of resilience helps to explain why the impact of disasters are most acutely felt in developing countries. Last year’s hurricane season left Dominica – a small island state with a GDP per capita 8 times lower than the US – suffering losses of 224% of GDP. Low-income, high-exposed countries such as Bangladesh can suffer losses of approximately 3-5% of GDP every 5-10 years from recurring disasters while direct economic losses (as a % of GDP) from disasters are 14 times higher in low-income countries than high-income countries. These challenges will be exacerbated by climate change.

**Investments in resilience make economic sense but are difficult to realise.** Studies suggest that investing in and maintaining infrastructure so that it is resilient can often lead to benefits that are four times higher than the additional costs. This gives rise to the concept of a ‘resilience dividend’. However, this dividend is often not sufficient to ensure resilience, particularly in developing countries for a number of reasons. Resilience typically requires additional upfront costs but only delivers long-run economic benefits that can be perceived as uncertain by those taking decisions. Making such decisions is inherently challenging given short-term focused political structures, and can be exacerbated by the lack of fiscal space in many developing countries and difficulties in accessing private finance. Moral hazard may also deter investment in resilience if there is an expectation for foreign aid disbursements in the event of a disaster. In a similar vein, misaligned political incentives can distort incentives as governments may be politically rewarded for responding to disasters and not for prevention.

**Insurance can play an important role in supporting resilience.** After a disaster, structured and well governed payments can flow quickly from insurers to the centres of need, aiding faster recovery. Insurance also has an important role to play in incentivising preplanning. Finally, and crucially, by providing risk-based pricing incentives, insurance provides a vehicle through which (some) aspects of the resilience dividend can be monetised, and hence used to provide stronger financial incentives for resilience.

**This project seeks to provide an outline design of a series of financial instruments that, through a combination of insurance and other means, seek to monetise the resilience dividend so as to provide stronger incentives for resilient infrastructure construction.**

**To help support the design of these instruments, an 'Innovation Lab' brought together experts from a range of sectors.** The 'Innovation Lab' convened experts from the finance, insurance, engineering, humanitarian, and development communities to help create initial 'strawman solutions', identify the main challenges to implementation and discuss ways to overcome these challenges. The Lab built upon a detailed literature review of the state of infrastructure finance and analysis of existing financial instruments, directly and indirectly related to resilience. Experts worked on specific real-world case studies providing background information and modelled examples of the resilience benefits in each case.

**The lab emphasised a number of key themes to inform the design of the products.** These include the need to focus on the services provided by infrastructure asset, rather than the physical characteristics of the asset itself; the importance of recognising the wide-range of benefits brought about by resilience investments and not just the expected reduction in asset damage; and the need for solution to build upon current practices and leverage the expertise of existing stakeholders and financiers on the ground rather than exist in isolation.

**Four potential financial instruments emerged from the lab discussions, ranging from repurposed existing structures that can be brought to the market quickly to ones further from current practice but with great potential.** These instruments were:

1. ***Insurance-linked Loan Package (ILLP) –*** *an infrastructure loan which has a built-in insurance component. Insurance savings through risk reduction offset loan interest repayments.*

2. ***Resilience Impact Bond (RIB) –*** *a pay-for-performance contract in which an investor is remunerated based on how well they implement resilience measures according to pre-defined performance indices.*

3. ***Resilience Bond –*** *a risk transfer instrument, in which risk reduction is reflected in a reduced premium paid by the insured across the term of the bond.*

4. ***Resilience Service Company (ReSCo) –*** *a company who bears the initial costs of resilience and is repaid on an annual basis using savings on insurance premium.*

**Two were chosen for cash flow modelling – the ILLP and RIB – to help illustrate the viability of promoting resilience as well as the vital role that insurance has to play.**

**Resilience Impact Bond**

- Applicable where the outcomes funder (e.g. donor) wishes to transfer some of the operational risk of implementing the resilience project, and also benefits from a transparent assessment of how well the project performs against its objectives.
- Strongly aligns the incentives of the outcomes funder with the investor – delivery of different elements of resilience provides substantial upside to the investor but failure to deliver this resilience can result in low or negative returns
- Can be structured to explicitly promote individual elements of resilience, e.g. structural, operational, and financial resilience, offering a targeted approach to building resilient systems.

**Insurance-linked Loan Package**

- A simple and potentially efficient means of monetising the resilience dividend generated through insurance savings within one product structure which is achievable in the near-term.
- The repayment term, and the size of the risk reduction, largely determine how much the accrued insurance savings can contribute to the overall additional cost of resilience.
- Flexibility within the product structure allows for the resilience dividend to contribute to the costs of resilience, loan repayments, or insurance premium payments, as is appropriate to the use case.

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# INTRODUCTION

## *i. Project Objectives and Structure*

**The Centre for Global Disaster Protection brings together partners including DFID, the World Bank, civil society and the private sector with the shared goal of enhancing the financial resilience of developing countries to climate change and disasters.** The Centre was launched by UK Prime Minister, Theresa May, in July 2017. It will work with governments to strengthen pre-disaster planning and catalyse innovative finance for resilience to ensure more cost-effective, timely and reliable response to and recovery from disasters.

**The purpose of this project – the first of the new Centre for Global Disaster Protection in collaboration with Lloyd's of London – is to design financial risk transfer instruments that provide incentives for resilient infrastructure and building back better (BBB) post disasters.** In recent years, various financial structures have been proposed to create positive incentives for investment in resilience. These include multi-year insurance, resilience bonds and resilient reinstatement. In practice, there are several challenges to existing models, especially when applied to developing countries. These include high upfront costs, uncertain benefits, competing budgetary priorities, poor data availability, and misaligned incentives between owners of the asset and those benefitting from the service it provides. This project develops a series of solutions that can overcome these challenges to encourage socially beneficial resilience building both pre and post disaster. It focuses on identifying solutions that allow the benefits from resilience investments to be monetised and thus offset the additional upfront costs of resilience investment.

**The project was a collaborative undertaking.** An 'Innovation Lab' convened experts from the finance, insurance, engineering, humanitarian and development communities to help create initial 'strawman solutions', identify the main challenges to implementation and discuss ways to overcome these challenges. The Lab built upon a detailed literature review of the state of infrastructure finance and analysis of existing financial instruments, directly and indirectly related to resilience. Experts worked on specific real-world case studies providing background information and modelled examples of the resilience benefits in each case.

**The strawmen outputs from the lab were developed into four product solutions with further input from experts.** The product solutions describe the features, key stakeholders, risks and challenges to implementation. Two of these solutions have been developed more fully with risk modelling and cashflow analysis. The other two solutions are innovative ideas that would benefit from further research and development and can be implemented over the longer run and for which risk-modelling and cash-flow modelling have not been undertaken.

## *ii. The Building Blocks of a Successful Solution*

**The innovative financial solutions described in this report aim to support the financing of resilient infrastructure and/or building back better, while facilitating the efficient transfer of catastrophe risk.**

**Solutions need to consider the key challenges in infrastructure financing. Infrastructure financing even without resilience is a difficult task.** The infrastructure financing gap that already exists is likely to become wider in the future as demand increases, placing greater stress on developing countries. The challenge of addressing this gap in the developing world is exacerbated by issues such as poor institutional design and limited data availability.

**Enhancing resilience is economically attractive in the long-term but it brings its own complexities including higher upfront costs and that benefits are often spread across many agents.** A range of studies suggest that, on average, the benefits of resilience (broadly defined) outweigh the costs fourfold (UNISDR 2007; OECD 2015a; UK Government Office for Science 2012). Resilience investments can generate a 'resilience dividend'. However, developing infrastructure which is resilient to climate change and disasters comes with new challenges. These include high upfront cost, uncertain long-term benefits, and differences between the agents who are responsible for managing the risk and those who benefit from resilience. In other words, the positive externalities of resilience may not be appropriately considered, leading to socially inefficient decisions.

**This project seeks to incentivise resilience by creating financial instruments that monetise the resilience dividend and provide it upfront or transfer it to agents who have the capacity and willingness to wait for it.** Monetising the dividend helps to ensure that the agent who is responsible for the asset directly benefits from implementing resilience. One way to capture the resilience dividend, for example, is through reduced insurance premiums in response to lower risk once a measure is implemented. If it is possible to realise the resilience dividend upfront the proceeds can be used to fund this resilience measure. Alternatively, rather than bringing the resilience dividend upfront, a product may transfer it to a 'patient' counterparty with longer term objectives.

**The solutions also seek to transfer disaster risks effectively.** Risk transfer instruments, such as insurance, can help stakeholders identify, understand, and assess disaster risks. Once assessed, many risks can be managed more effectively through insurance-linked products and structures. Insurance can provide prompt and effective finance after a disaster, dealing with issues of commitment, responsibility, and institutional failure. Given the complicated nature of infrastructure projects and multiple stakeholders involved, insurance schemes can distribute funds faster and more effectively than alternatives, thus ensuring greater continuity of service in the wake of a disaster. As discussed further below, in theory at least, insurance can play a role before a disaster strikes in catalysing resilience though price incentives.

**The solutions are also intended to be implementable.** They consider the challenges and barriers to building resilient infrastructure in the developing context. Their design is built on the existing financing and risk transfer practices available on the ground and are mindful of institutional and financial constraints.

**Building on these ideas, the analysis makes use of eight success criteria to provide a structured way to address the issue.** These comprise of both ex-ante criteria and ex-post criteria. The ex-ante criteria are intended to allow an assessment of existing financial instruments and select their useful features in light of the key objectives of this project - incentivising resilient infrastructure and efficient risk transfer. These features are then extracted and used in the design of potential innovative solutions. The proposed solutions can then be tested against the ex-post criteria to test their practical viability. Figure 1 summarises these criteria:

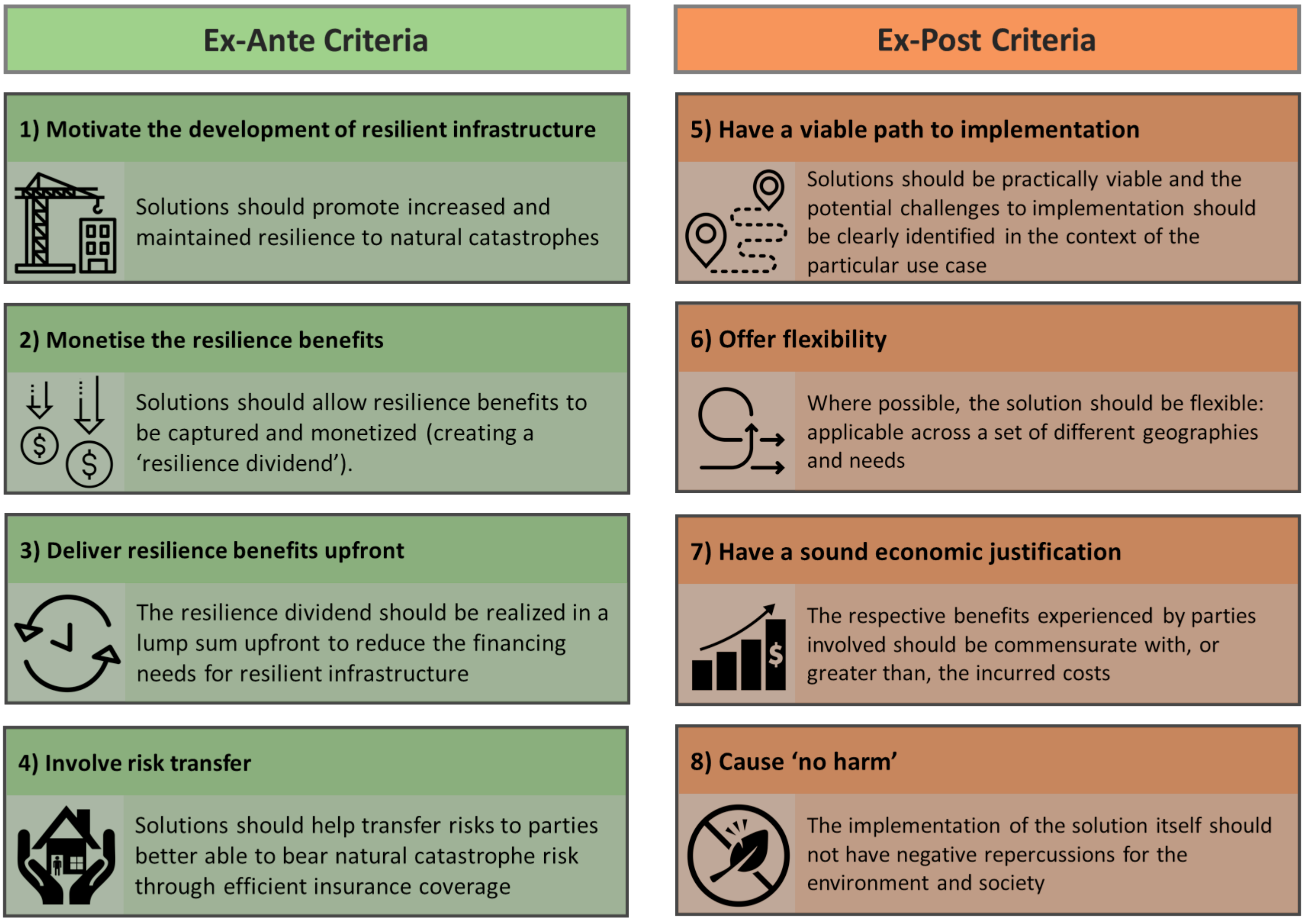



**FIGURE 1** THERE ARE EIGHT SUCCESS CRITERIA IN TOTAL THAT SHOULD BE MET.

# *iii. Structure of the Report*

**The report is organised into four sections** – a detailed literature review of infrastructure financing and risk transfer instruments, a summary of the outcomes and findings from the Innovation Lab, a section developing product solutions and a set of recommendations for next steps (Figure 2).

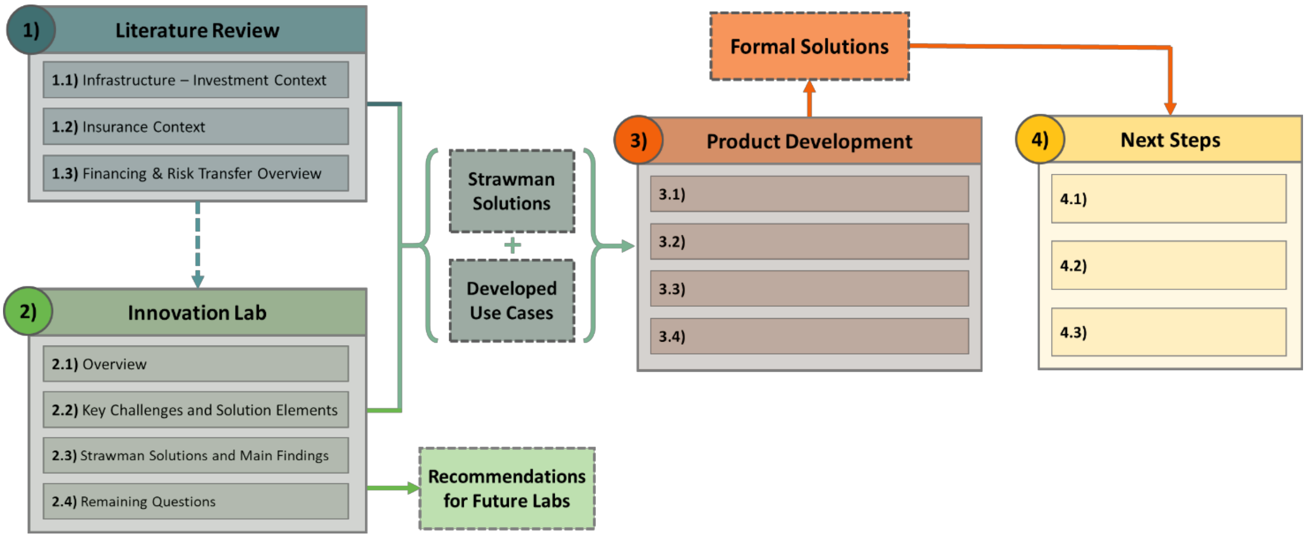



**FIGURE 2** THE REPORT HAS FOUR SECTIONS, MOVING FROM A BACKGROUND LITERATURE REVIEW, THROUGH OUR INNOVATION LAB AND AN ANALYSIS OF SOLUTIONS, THROUGH TO POTENTIAL NEXT STEPS.

**The literature review helped identify potential building blocks from the existing space of financial instruments.** It covers the state of infrastructure investment, the barriers to resilient building, the role of insurance in developing resilience and an overview of existing relevant instruments. It was compiled through desk review as well as interviews with insurance sector and other experts.

**The findings from the literature review supported the discussion in the Innovation Lab to help create initial 'strawman' solutions.** A pre-lab session brought experts together to discuss and refine possible case studies for the main Innovation Lab session. The Lab was interactive. After some context setting presentations, working groups concentrated on designing innovative financial products to address the challenges of each case study.

**The strawmen from the labs were then developed and tested through further outreach to relevant experts, economic cash flow analysis and risk modelling simulations.** This process helped refine the mechanics of the potential products, provide solid economic justification for its use and stress test their usability with risk model simulations to understand how the instrument may perform under different scenarios.

# 1. LITERATURE REVIEW

This section provides a brief overview of three critical areas:

- **The (resilient) infrastructure investment context**, including financing needs, sources and challenges to building resilience.
- **The role played by the insurance industry**, focusing on transferring risks related to infrastructure and supporting resilience.
- **The financial instruments for (resilient) infrastructure**, including a review of the range of existing funding and risk transfer instruments that can be combined or built upon to address the challenges of funding resilient infrastructure.

This review draws on a broad set of sources spanning academia, press, public and private sector publications, as well as interviews with industry experts.

**Key findings:**

- Infrastructure investment needs are large and under-funded, particularly in the developing world.
- Building resiliently, and ensuring effective maintenance so that resilience persists, adds further complexity, due to the high upfront costs and/or uncertain benefits realized over long time horizons.
- In theory, insurance against disasters can play a critical role in incentivizing resilience. In practice this is challenging due to the short-term nature of insurance contracts, low penetration and limited use of risk-based pricing in a highly competitive industry.
- No single existing instrument fulfils the ambitious goals of this project: 1) to incentivise resilience through monetising the resilience dividend and allowing it to be captured before or at the time of infrastructure construction; 2) to involve risk transfer to ensure effective risk management post disaster.
- There are, a range of potential financial instruments, including risk transfer and pure funding instruments. These were suggested as useful building blocks of a solution during the Innovation Lab.

## *1.1. The Infrastructure Investment Context*

### *1.1.1. Infrastructure investment needs are large and growing*

**The 2017 Global Infrastructure Outlook[1] estimates infrastructure investment needs of $94 trillion by 2040.** If current trends persist, there is likely to be a 20% investment shortfall (The World Bank 2017c). The largest needs are expected to be in the transport and power sectors with 60% of this new infrastructure investment being required in emerging economies, as shown in Figure 3. China alone accounts for nearly 30%, India and other emerging Asia for 13%, Latin America 6% and Africa 2%.

[1] The Global Infrastructure Outlook focuses on the infrastructure needs of 7 sectors: air transport, road transport, ports, rail, energy, telecommunications and water. It covers 50 countries across 5 regions: https://outlook.gihub.org/. Estimates of future infrastructure needs vary widely by source, depending on sector coverage, geographic coverage and ambition.

**There are further costs associated with making this infrastructure more resilient to extreme weather, other catastrophes and long-term changes in climate.** The World Bank estimate that annual climate adaptation needs for infrastructure in developing countries could be between $13 and $28 billion until 2050, with a further $43-$48 billion needed in coastal zones and for water supply and flood protection. While these figures are small in the context of the trillions needed for infrastructure investment, the costs, relative to GDP, fall disproportionately on the lowest income countries (The World Bank 2010).

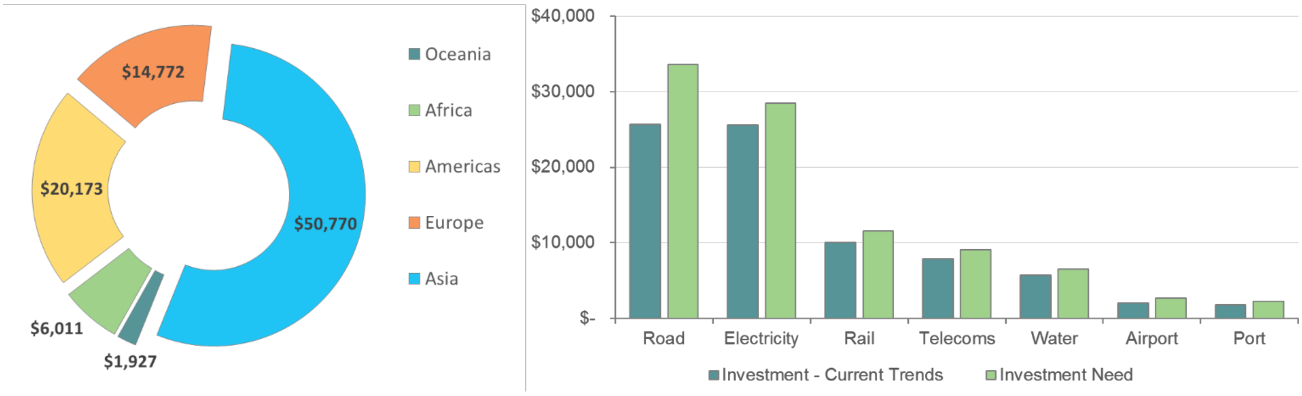



**FIGURE 3** GLOBAL INFRASTRUCTURE NEEDS TO 2040 IN BILLION USD BY GEOGRAPHY AND BY SECTOR (SOURCE: *GLOBAL INFRASTRUCTURE HUB 2017*).

## *1.1.2. Financing infrastructure is no easy task*

**Past spending in infrastructure has not been enough to meet today's requirements and if current rates are maintained, the gap will continue to grow.** This highlights the pressing need for innovative financing solutions and substantial reallocation of capital. However, scaling up infrastructure investment faces a number of challenges (OECD 2015c):

- **Capital intensity:** large upfront investments, lack of liquidity and a delayed return period lead to substantial financing requirements that may exceed the capital available from conventional sources.

- **Economies of scale:** the profitability of infrastructure investment assets depends on achieving critical levels of demand, which is uncertain ex-ante and, for private investors, increases required returns.

- **Externalities:** infrastructure assets often produce non-monetizable benefits that do not lead to direct payoffs for an investor or are difficult to measure for a policymaker.

- **Heterogeneity:** complexity, number of stakeholders: different infrastructure assets have different characteristics and all infrastructure typically affects a wide range of stakeholders. This reduces information for investors and increases the complexity of legal arrangements to manage risks and incentives between stakeholders.

- **A lack of bankable pipelines:** the difficulties and political economy challenges of project preparation (e.g. acquiring permits and consents) means that there are insufficient bankable projects (Ehlers 2014).

- **Financing regulations and policies:** Basel III and Solvency II regulations could reduce the capital that might be allocated to infrastructure at the global level (Bielenberg et al. 2016).

**Many of these challenges are exacerbated in developing countries, widening the infrastructure financing gap that already exists:**

- **Lower users purchasing power:** reduced ability of users to pay for infrastructure asset services exacerbates the financing gap. Foster & Yepes (2006) estimate that roughly a third of developing countries in the two lowest per capita income groups did not attempt cost recovery for electricity assets. The challenge is even more severe in the water sector, where only around 10% of the poorest countries attempt to recover any operating or capital costs.

- **Country risk:** existing studies suggest infrastructure investment, especially that financed by the private sector is highly sensitive to sovereign risks. Araya et al. (2013) show that a difference of one standard deviation in a country's sovereign risk score decreases the probability of having private participation in infrastructure by nearly a third and reduces private investment in dollar terms by around 40%. Similarly, Moszoro et al. (2015) show that higher levels of corruption (measured by the Corruption Perceptions Index) correspond to lower levels of private investment participation in infrastructure. The perception that these risks are higher in lower-income countries may unfairly stigmatize investment in infrastructure generally, without due consideration for the characteristics of a specific project (The World Bank 2017b; OECD and World Bank 2015).

- **Institutional and regulatory set up:** weak institutions, regulatory frameworks and enforcement issues have negative impacts on infrastructure investment (OECD and World Bank 2015). 40% of surveyed investors in developing countries mentioned that they experienced financial losses through adverse regulatory changes, and 34% through breach of contract (MIGA 2013).

- **Data availability:** the lack of adequate data on the volume and performance of private capital mobilized for infrastructure investments in developing countries reduces the appeal of such projects for investors.

- **Public communication and engagement issues:** in several low income countries, private sector infrastructure projects have failed due to strong end-user opposition (OECD and World Bank 2015), highlighting the need for effective communication with regards to critical infrastructure.

**Finally, the need to ensure that infrastructure is resilient to climate change and disasters brings its own challenges:**

- **Additional cost, uncertain benefits:** building resiliently often requires higher upfront costs, while bringing potentially uncertain, heavily-discounted long-term economic benefits. This is particularly challenging in developing countries often dealing with lack of fiscal space and difficulties in accessing private finance. Furthermore, there is significant uncertainty over the cost of future technology. Future resilient infrastructures could be enhanced and cheaper, creating a temptation to wait rather than invest now (Fay et al. 2010).

- **Externalities - the broader resilience dividends:** typical cost-benefit analysis may adopt a limiting view of the benefits of resilience, making such investments appear unattractive. Cost-benefit analysis may focus only on the lens of avoided physical asset damages. However, investing in resilient infrastructure can yield a 'triple dividend': in addition to 1) avoiding losses when disasters strike, it can 2) unlock development potential by stimulating innovation and bolstering economic growth; and 3) generate social, environment and economic co-benefits of resilient investments even if a disaster does not happen for many years (Kryspin-Watson 2017). These broader benefits may be difficult to estimate and incorporate for public asset owners. They may be irrelevant to private ones.

- **Information Asymmetries:** even when there is a desire to capture the broader benefits of resilience measures, this may not be possible as they are not well known by all parties involved. Lack of awareness of the benefits of resilience or the associated risks among policy makers, investors and the general public is due to a number of reasons: 1) there is no effective or common way to measure resilience or its wide-reaching benefits (ClimateWise 2016); 2) infrastructure owners rarely share information on vulnerabilities due to security concerns (Kunreuther et al., 2016b); 3) most infrastructure managers have sparse experience with disasters (Chang et al. 2014); 4) the broader risks to a highly interdependent system are complex and may be unknown.

- **Commitment and ownership of risk issues:** identifying key stakeholders and interests in resilient infrastructure on the ground is difficult. Given the wide-ranging benefits and interdependencies of resilient infrastructure, the stakeholders responsible for limiting physical asset damages may not be the same as the beneficiaries of a continuous service.

- **Moral Hazard:** post event public support may discourage investment in resilience (Kunreuther et al., 2016b). Aid and government recovery programs can deter private investment in resilience as there is an expectation of being bailed out in the case of disaster (Neumayer et al. 2014). This is further exacerbated by the low perceived urgency to act due to the infrequency of catastrophic events (Kunreuther et al. 2016).

- **Misaligned political incentives:** Similarly, governments are politically rewarded for responding to disasters, not for preventing them. This can deter investment in resilient infrastructure and incentivise spending on recovery and emergency response measures (Neumayer et al. 2014). Moreover, making complex, long-term policy commitments to resilience is inherently challenging given short-term focused political structures (UK government 2011).

- **Institutional, technical and enforcement capacity:** resilience requires additional technical capacity and an enabling environment to enforce resilience measures, which may be lacking in some of the countries most exposed to catastrophe risks. For example, building hurricane-resilient housing requires technical capacity, adequate building codes as well as the ability to enforce building to code via the appropriate institutional set up.

- **Maintenance:** related to the previous point, resilience is not just delivered at the point of construction. It requires ongoing maintenance. This brings a host of further funding and misalignment of incentives issues. Despite high economic rates of return, maintenance of infrastructure is generally neglected in both developed and developing countries. This may be due to differences in funding sources, particularly in developing countries: international institutions and donors may be more willing to provide loans (potentially at concessional low rates) or grants for the construction of new infrastructure than for maintenance. This means that, once the infrastructure is built, the government must raise the maintenance cost from its general revenue sources. Given competing spending priorities and low visibility, this often results in maintenance being deprioritised (Rioja 2013).

### *1.1.3. Sources of infrastructure finance are diverse*

**Traditionally, especially in developing countries, infrastructure investments have been financed with public funds.** While public funding finances around 40% of infrastructure spending in developed countries, this increases to 60-65% in developing countries (OECD 2017b). Indeed, data from the World Bank suggests that private participation in infrastructure financing in developing economies has seen minimal growth since 2007 and has actually fallen in the latest data (The World Bank 2016a). Developing countries can struggle to attract the required levels of private financing given the economic, political and institutional issues discussed above. There are, however, significant differences between countries – for instance, in India the share of private investment has been steadily increasing to nearly 40% in 2013 and is even higher today, while in China almost all infrastructure financing is from the public sector (Chong & Poole 2014).

**Where the private sector is involved in infrastructure finance, it is normally through corporate actors.** Globally, 65-75% of private finance in infrastructure comes from corporate actors, with the rest from institutional investors (Bielenberg et al. 2016). Public-Private Partnerships (PPPs) are growing as a source of infrastructure financing, but typically make up only about 5 to 10% of overall infrastructure investment, even in leading PPP use countries (Woetzel et al. 2016).

**Support from development partners to infrastructure in 2013 was estimated at around $60 billion per year and represented a small but significant share of infrastructure financing in developing countries (6-7%)** (OECD 2015d). The basic split of financing in developing countries in 2013 for four key infrastructure sectors is shown in Figure 4. In these countries, development partner funding accounts for, on average, around 6-7% of infrastructure investment, although it is markedly lower in the communications sector where strong demand has made the sector ripe for private investment. Development partner funding[2] is concentrated in low income and low middle-income countries due to reduced capacity to mobilize domestic and external private finance (see Figure 5). From 2007-2016, almost 77% of official development assistance (ODA) for infrastructure sectors was directed towards low income countries[3], while the total volume of ODA funding for infrastructure increased at 8% per annum.

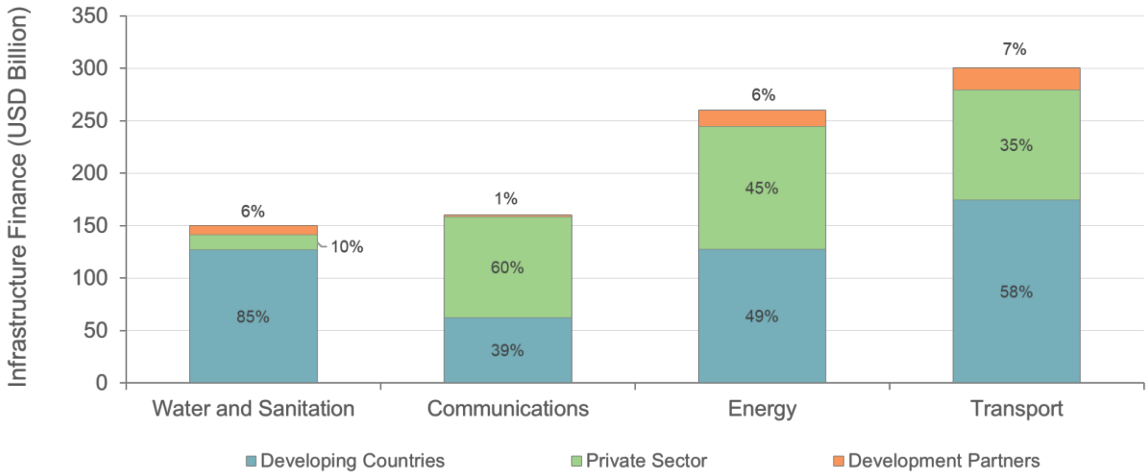



**FIGURE 4** DEVELOPMENT FINANCING PLAYS A SMALL BUT SIGNIFICANT ROLE IN INFRASTRUCTURE FINANCING. SOURCE (*OECD & WORLD BANK, 2015*).

[2] The following figures are based on the data from the OECD-DAC database which collates ODF from around 50 major development partners – this is not a complete representation of all the support available but offers a reasonable sub-sample.
[3] Defined as those with incomes per capita under $3,955 (OECD and World Bank 2015).

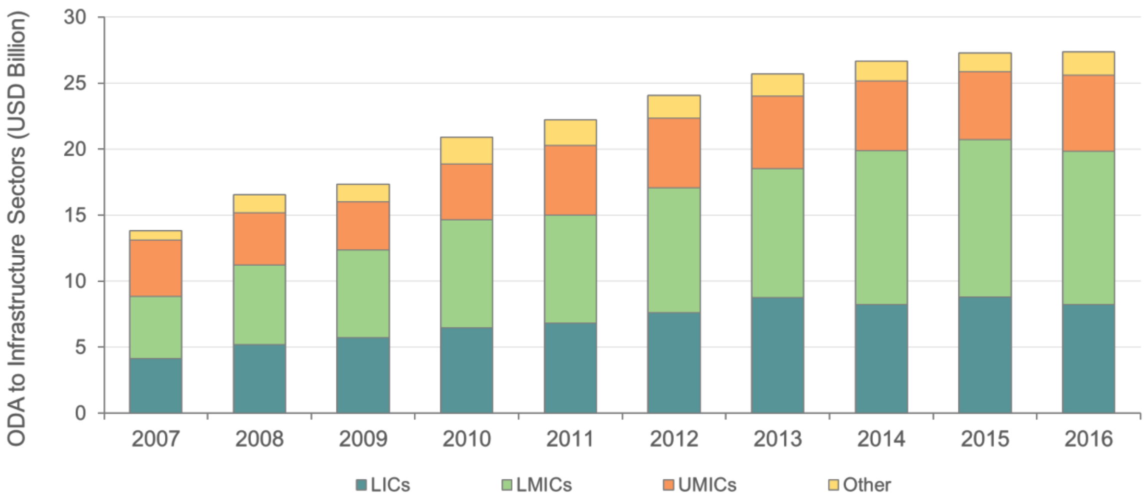



**FIGURE 5** ODA FOR INFRASTRUCTURE SECTORS IS MORE CONCENTRATED IN LOWER INCOME AND LOWER-MIDDLE INCOME COUNTRIES[4]. SOURCE (*OECD, 2017C*).

**The recent rise in ODA for infrastructure financing has been driven by greater contributions from multilateral agencies, increasing at a rate of 5.7% per annum from 2007-2016** (OECD 2017c). This trend is evident in Figure 6. DAC country donor funding make up 53% of the total ODA financing that was reported to the OECD in 2016, with multilateral agencies accounting for 42%[5]. However, the role of multilateral agencies has been growing in recent years with their share of total ODA rising from 31% in 2007 to a peak of 45% in 2014. This has been associated with an increased role for loans rather than grants: indeed, of the increase in ODA from multilateral agencies since 2007, 85% was due to a rise in lending (see Figure 7).

**Multilaterals are particularly prominent in financing infrastructure in low-income countries.** Multilateral agencies account for between 50 and 70% of the infrastructure ODA in low-income countries. This makes multilateral agencies particularly important in these countries; by contrast multilaterals only account for around 30-40% of infrastructure ODA in middle income countries.

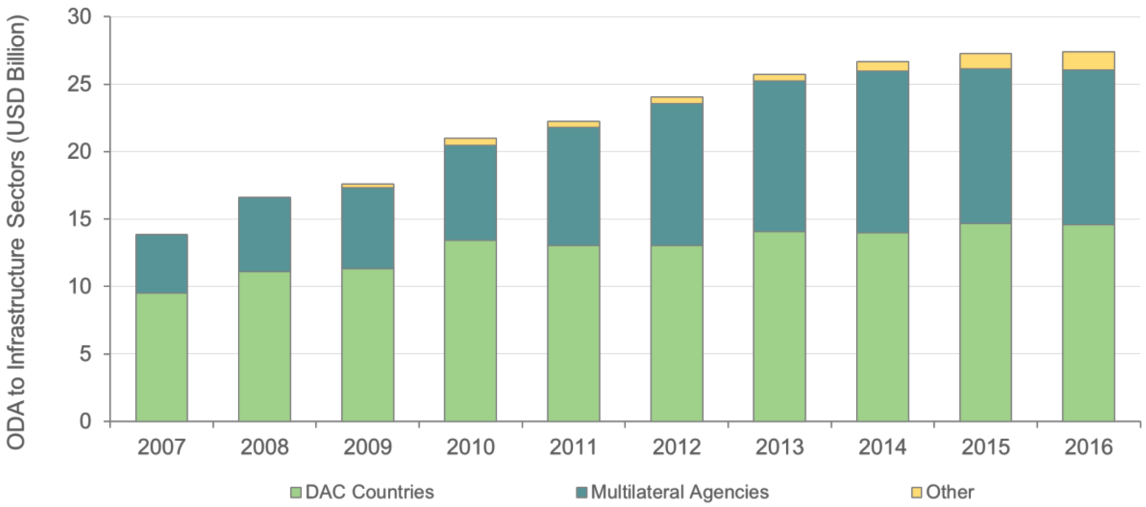



**FIGURE 6** THERE HAVE BEEN STRONG INCREASES IN ODA FROM MULTILATERAL AGENCIES IN RECENT YEARS[6]. SOURCE (*OECD, 2017C*).

[4] ODA data comes from the OECD's DAC database which collates ODF data from major development partners but is not complete – hence the total value of ODA aid in Figure 5 is lower than the level of development partner infrastructure finance implied in Figure 4.
[5] The following figures are based on the data from the OECD-DAC database which collates ODF from around 50 major development partners – this is not a complete representation of all the support available but offers a reasonable sub-sample.
[6] ODA data comes from the OECD's aid flow database which collates data from a large number of aid agencies but is not complete – it represents an underestimate of true aid flows

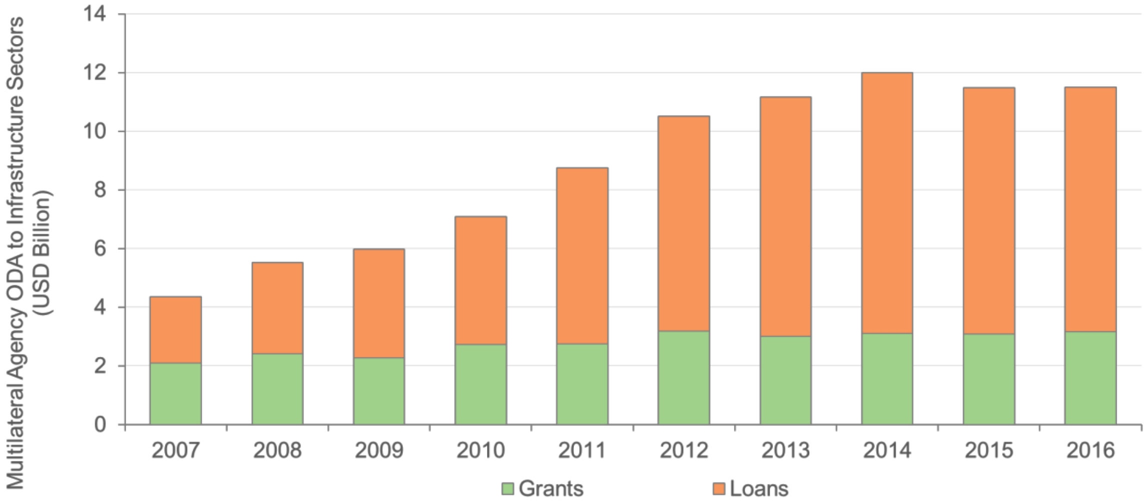



**FIGURE 7** GREATER ISSUANCE OF LOANS RATHER THAN GRANTS APPEARS TO HAVE THE DRIVER OF RECENT GROWTH IN ODA FROM MULTILATERAL AGENCIES[7]. SOURCE (*OECD, 2017C*).

**Development partners can also support the private sector in mobilizing financial resources for infrastructure projects.** (OECD 2015d) (OECD and World Bank 2015). This support tends to be provided by Development Finance Institutions (DFIs) and International Finance Institutions (IFIs), who have experience in working with the private sector, rather than bilateral donors. Total disbursements for infrastructure from DFIs and IFIs to the private sector amounted to $5.9 billion in 2013, of which IFIs contributed around 71%. Beyond financing, there is also a key role played by a range of development partners to promote best practices in the design and implementation of infrastructure projects, which can lead to efficiency gains of to 40% of project costs (Global Green Growth Institute & G-24 2015).

**Beyond these aggregate-level trends, comprehensive data and analysis on infrastructure financing remains elusive.** The OECD is currently undertaking an important study - ‘Breaking Silos: Actions to develop infrastructure as an asset class and address the information gap’ - to map the gaps in data on infrastructure financing spend and how they might be filled (OECD 2017a).

## *1.2. The Risk Transfer Context*

**Investment in infrastructure involves large capital outlays and is exposed to a range of concentrated risks including legal, political and environmental ones.** Insurance and insurance-related instruments can be used as a means of transferring these risks to agents better equipped to manage and hold them. These can include (re)insurance companies, risk pools, public agents and the capital market. This section summarises the current role insurance plays in transferring disaster risks related to critical infrastructure projects and explores the role of insurance in building resiliently.

### *1.2.1. In the context of infrastructure, insurance practices vary*

**The decision on whether to use risk transfer mechanisms largely depends on the sponsorship of the infrastructure project.** Privately financed infrastructure projects tend to make use of insurance, predominantly during the construction phase. Experience is more mixed for public projects.

**Where the project involves private investors, insurance is typically taken out during the construction phase, and more rarely, during the operational phase, to protect investor’s cashflows.** Project insurance, typically held by engineering companies, serves to protect investors’ cashflows against a range of possible perils. During the construction phase, these include business interruption, property damage, late delivery, public liability, third party liability, political risk (depending on location), environmental risk and contract works (Baarts

[7] ODA data comes from the OECD's aid flow database which collates data from a large number of aid agencies but is not complete – it represents an underestimate of true aid flows.

& Longley 2003). Contracts can provide cover over multiple years, given the long-term nature of the construction phase, and tend to extend for one to two years after completion to cover potential defects. The £15.9bn Crossrail project broke new ground in terms of insurance contract duration with the first nine-year policy without a break clause in the UK (Lloyd's of London 2014). Upon completion, a smaller subset of operational risks can also be covered by insurance, typically on an annual contract basis. These can include business interruption, third party liability, terrorism and property damage among others.

**Catastrophe risk can be insured separately, bundled with other traditional types of insurance, or covered under "all hazards" policy.** The contracts differ on the extent of cover offered, indemnity limits, and whether the policies are compulsory, bundled or voluntary (IPCC, 2012). Depending on the exposure, insurance companies might impose higher deductibles or limits for catastrophe risk. In many instances, insurance companies have been reluctant to offer country-wide policies for hazards because of the systemic nature of these risks, as well as problems of moral hazard and adverse selection.

**Where extreme catastrophe risks cannot be insured efficiently by the insurance market, the government can step in as an insurer of last resort.** In some highly exposed countries, such as the Netherlands, insurance for flood doesn't exist and government relief is provided instead (IPCC, 2012). For London's £4.2bn Thames Tideway Tunnel project, which is largely financed by private investors and lenders, the infrastructure firm in charge, Bazalgette, procured a set of standard commercial insurance policies (Tideway 2017). The residual risk was covered by the UK government through a contingent financial support package, which mitigated certain extreme risks beyond the commercial insurance limits, in order to ensure the project was attractive to private investors. (National Audit Office 2017).

**In the case of publicly owned assets, policy and practice on insurance varies significantly between countries.** In Sweden, disaster risk insurance for public assets is illegal (IPCC, 2012). At the other extreme, disaster risk insurance of public assets is compulsory by law in four APEC economies and Colombia (The World Bank 2017b). In some cases, the law requires public asset owners to evaluate available disaster risk management options to determine the most appropriate one. This is the practiced in Australia and New Zealand, where states and government agencies must assess available insurance options on a cost-benefit basis. Finally, some economies leave financial risk management of public assets to the respective managers, who decide whether to protect them with disaster insurance. This approach is taken in Canada, Taiwan, and the United States (U.S.) (The World Bank 2017b). In the U.S alone, there is considerable variation: transit organizations generally seek private insurance for catastrophe risks (Kunreuther et al. 2016), while the New York's Metropolitan Transit Authority (MTA) has its own captive insurance company. Both New York's Metropolitan Transit Authority (MTA) and Amtrak now use catastrophe bonds to offer protection from disasters (Kunreuther et al. 2016), providing diversification of capital and rapid pay-outs in complement to their traditional (re)insurance programs. The majority of states, however, often carry cover of catastrophe for their public assets (IPCC, 2012).

**Despite varying practices, catastrophe perils, including for infrastructure assets, remain largely uninsured even in developed countries. Coverage is low globally.** On average, only approximately 30-40% of catastrophe losses have been covered by insurance over the past 10 years (Czajkowski et al. 2017). While there is no systematic data indicating the degree to which critical infrastructure is insured against catastrophic risk, there appears to be low insurance of assets even in mature insurance markets such as the U.S (Czajkowski et al. 2017). Lloyd's (Edwards & David 2012) estimates that although the U.S. has a relatively high insurance penetration rate from a global perspective, 57%of losses from disasters during 2004 to 2011 were uninsured. Our research suggests that, while typical project-specific insurance packages are common during the construction phase of UK-based projects, catastrophe insurance is uncommon thereafter.

**In many developing countries, with a few exceptions, there is little insurance for disaster risks in the case of both public and private infrastructure projects.** The market is underdeveloped, particularly because there is often limited risk assessment information, limited scope for risk pooling and little or no supply of insurance instruments (IPCC, 2012). Data issues are a critical barrier: data on exposure is often poor and model coverage is limited. Even when infrastructure is financed by development bank loans, this insurance typically only covers catastrophe risks during the construction phase and potentially the first couple of years after completion. A key example where catastrophe insurance is linked to infrastructure is FONDEN, Mexico's natural disaster fund, which has been transferring catastrophe risk to the (re)insurance and capital markets since 2004, targeting the funding of both emergency relief costs and infrastructure reconstruction. The Caribbean Catastrophe Risk Insurance Facility and the Pacific Catastrophe Risk Insurance Pilot both supply insurance against emergency losses to member sovereign nations. Underinsurance is still common in the developing world. RMS analysis shows that average annual asset losses from catastrophe events in these countries is around $29.1 billion, of which only 3% are insured. While there is no equivalent data specifically for infrastructure assets in developing countries, stakeholder discussions suggest that insurance penetration for these assets is likely to be similar or lower.

### *1.2.2. Insurance can play a key role*

**Where insurance is in place for infrastructure assets, it can be a fast and cost-effective solution in the event of disaster.** Insurance can provide prompt and effective immediate response, dealing with issues of commitment, responsibility and institutional failure. Given the complicated nature of infrastructure projects and multiple stakeholders involved, insurance schemes can distribute funds quickly and effectively, thus ensuring greater continuity of service in the wake of a disaster. Supporting infrastructure systems to become functional again as soon as possible can save lives, prevent ‘cascading failures’ of other urban systems, and minimize potentially devastating social and economic outcomes (Lloyd’s, 2017). Edwards & David (2012) examine five large catastrophes to show that an increase in insurance penetration of 1% would reduce proportion of the total damage borne by the taxpayer by approximately 22% of the total estimated damage.

**As well as directly providing cover, insurance practitioners often play a valuable role ex ante in helping government and other stakeholders understand and “price” the risk exposure of their critical infrastructure.** Disasters are a tail risk that represents a significant contingent liability for the government. It is often associated with large fiscal costs and the contingent liability of the government is generally implicit and not clearly defined by law. The government thus acts as a (re) insurer of last resort, in some cases without knowing with precision its disaster risk exposure (The World Bank & Swiss Confederation 2011). By exploring insurance solutions, governments can better assess, understand, and manage these risks.

### *1.2.3. Insurance can incentivise resilience, at least in theory*

**Several recent papers have argued that insurance and insurance-linked instruments can catalyse resilience through price incentives.** Resilience measures should lead to lower future premium payments in response to risk reduction for the insurer (Lloyd’s, 2017). Thus, insurers can help improve construction standards or developing prevention policies (The Geneva Association & The World Bank 2018). For example, conversations with insurance industry specialists suggest that, although installing sprinklers for schools in the UK was not a legal requirement, many local authorities opted for this measure, incentivised by the large reduction in insurance premium that resulted. Similarly, United Insurance, an insurance company active in the Caribbean, promoted structural mitigation, offering premium discounts of up to 40% for retrofitted commercial properties and 25% for retrofitted domestic properties in the late 1990s. When Hurricane Jose subsequently struck Antigua in 1999, losses were 10% of the total sum insured, but only 4.75% of the sum insured in the case of retrofitted projects (Benson & Clay 2004). Other insurers have offered discounts for clients who implement resilience measures such as hurricane shutters, relocation away from coastlines and retrofits to make structures more hazard-proof (Benson & Clay 2004). In designing such schemes, a number of important factors need to be considered – such as the treatment of assets that already benefit from more resilient measures and the benchmark from which improvements in resilience are recognised – in order to make sure that the mechanism is robust and does not undermine insurance penetration (Risk Management Solutions 2010).

**In general, however, the ability of insurance to provide sufficient economic incentives to build resiliently has been questioned due to the short-term nature of typical contracts and because premiums are not always fully risk-based.** Typical insurance premiums are renegotiated annually and subject to frequent price and cover changes, particularly in the wake of a disaster. The resulting lack of visibility reduces the incentive for the insured to invest in resilience measures. While multi-year contracts could incentivise resilience by offering a long term fixed price for insurance, their implementation in the real world has been limited (Maynard & Ranger 2011) due to the high costs associated with tying up capital for long periods. In addition, premiums rarely reflect the true level of risk. Other supply and demand factors are often more important in price formation. Additional premiums reflecting data or model uncertainty in expected losses also dilutes the impact on premiums of mitigation measures as reflected in the modelled risk. This is particularly true in developing countries exposed to frequent disasters, where the vast majority of risks are transferred to the reinsurance industry. For example, more widespread discriminatory pricing in the Caribbean is discouraged by low retention of risk and blanket-pricing policy practiced by reinsurers who tend to lead pricing (Benson & Clay 2004).

**The industry might also incentivise resilience through reduced cover, pre-conditions for cover or technical assistance and information with regards to existing risks. Incentivizing resilience through pre-conditions for cover can be very effective.** In the late 1990s, catastrophe insurance penetration in Fiji was unusually high for a small island state. This reflected a set of institutional arrangements and aligned incentives between the finance industry, insurance sector and the regulator. Securing a mortgage in Fiji was made conditional on the acquisition of cyclone insurance, which itself could only be obtained on the presentation of a certificate confirming compliance with the 1985 National Building Code (Benson & Clay 2004). Requesting information and limiting insurance cover could also lead to improving resilience. A recent example of followed the tragic events at London's Grenfell Tower in 2017. Matters related to cladding and to fire safety more generally became a concern for Professional Indemnity Insurers in the case of high-rise buildings. The insurance industry is thus envisaging a number of measures incentivizing risk reduction, such as requesting disclosure, providing further due diligence on the ground, restricting cover where risk is deemed high or applying a higher level of self-insured excess (Willis Towers Watson 2018).

## *1.3. The Financial Instruments Context*

**The previous sections illustrated the various financing needs – and challenges – associated with resilient infrastructure, especially in developing countries, and the potential role for insurance.** Infrastructure financing is a difficult task; the financing gap that already exists is likely to become wider in the future, placing greater stress on developing countries where the challenge of addressing this gap is made more difficult by issues such as poor institutional design and limited data availability. While developing infrastructure which is more resilient to climate change and disasters is societally beneficial, it comes with additional challenges, particularly around ownership of risk and the uncertain realization of benefits that resilience building provides. The insurance industry can also play a potentially important role in managing the catastrophe risks faced by infrastructure, supporting recovery and, in the right circumstances, enhancing resilience.

**The purpose of this section is to explore a range of existing infrastructure financing and risk transfer instruments and the role they can play in relation to the objectives of this work.** The overarching aim of the project is to identify a financing instrument that can meet eight success criteria. These comprise 1) ex-ante criteria – preconditions for success, which allow us to reduce the universe of existing instruments to a set of relevant ones to this project; and 2) ex-post criteria which test a viable path to implementation once a potential solution has been identified:

- **Motivate the development of resilient infrastructure.** Solutions should promote increased and maintained resilience to catastrophes.

- **Monetize resilience benefits through effective insurance and funding mechanisms.** Solutions should allow resilience benefits to be captured and monetized, thus creating a 'resilience dividend'.

- **Deliver resilience benefit upfront.** The resilience dividend should be realized in a lump sum upfront to reduce the financing needs for resilient infrastructure. This reflects that the high upfront costs of resilient infrastructure are one of the biggest barriers to its provision.

- **Involve risk transfer.** Solutions should help transfer risks to parties better able to bear catastrophe risk through effective and efficient insurance coverage.

**The review considers the features of existing instruments across two major categories: risk transfer instruments and pure funding instruments.** The risk transfer instruments can be further grouped into (i) traditional insurance instruments, such as catastrophe insurance and reinsurance, multi-year insurance, (ii) alternative risk transfer instruments and carriers such as sovereign risk pools, catastrophe bonds, resilience bonds. The universe of traditional funding instruments is long, but we have chosen to focus on more recent structures, such as green bonds and impact bonds. Some of these instruments are directly related to disaster risk and resilience while others have been developed for use in other contexts (such as climate mitigation or health) but could conceivably be used to support resilience building. Although this list of instruments considered may not be exhaustive, it provides a broad overview of some of the most important instruments of relevance to this work (see Figure 8).

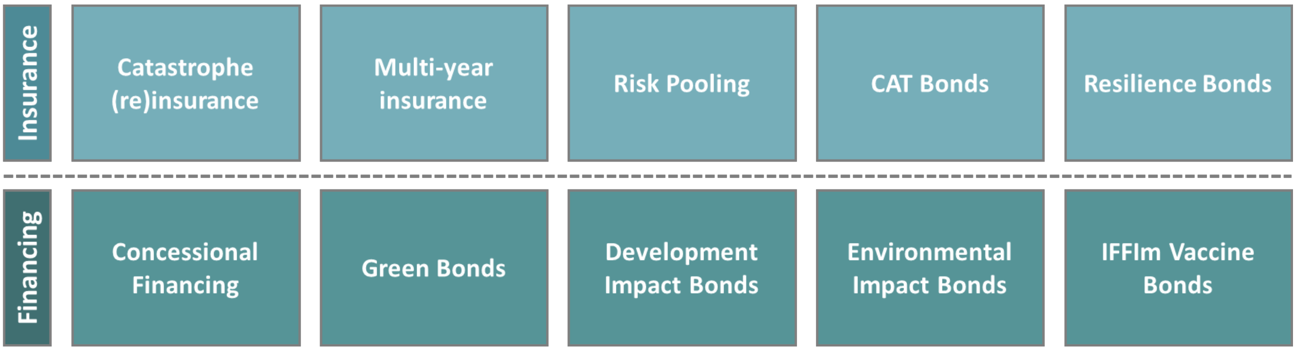



**FIGURE 8** EXISTING INSTRUMENTS EITHER FOCUS ON PROVIDING RISK TRANSFER OR FINANCING. SOURCE (*VIVID ECONOMICS*).

## *1.3.1. The resilience dividend is yet to be monetised by risk transfer instruments*

**Our review of existing risk transfer instruments suggests that there is no single instrument in the market that satisfies the first four ex-ante criteria simultaneously.** Figure 9 summarises the findings: while insurance and insurance-related instruments involve risk transfer, their ability to incentivise resilience through monetizing the associated benefit is questionable. The property most clearly absent from the existing suite of risk transfer instruments is that they do not allow the resilience dividend to be captured and delivered upfront. The Appendix provides more detail about each of the instruments in relation to each of the criteria.

| | Encourage the development of resilient infrastructure | Monetise resilience benefit | Make resilience benefit available upfront | Involve Risk Transfer |
|---|---|---|---|---|
| Catastrophe insurance and reinsurance | × Not directly – insuring against risks over the short term can lead to moral hazard and have the opposite effect | ? Maybe – if pricing is risk-based there can be some monetizable resilience benefit | × No – uncertain future pricing as premiums are renegotiated annually | ✓ Yes – by definition |
| Multi-year insurance (MYI) | ✓ Yes – if accompanied with transparent risk-based pricing | ? Unclear given higher premium and capital requirements than short-term contracts | × No – resilience may lower yearly premiums but there is no lump sum gain upfront | ✓ Yes – by definition |
| Sovereign Risk Pooling (CCRIF, ARC, PCRAFI) | ✓ Yes – depending on design (mandatory resilience plans) | ? Maybe – if pricing is risk-based there can be some monetizable resilience benefit | × No – any benefits realised over the long run through potentially lower premiums | ✓ Yes – by definition |
| Catastrophe bond | × No – has a pre-defined trigger that is independent of resilience measures | × No – instrument has no direct pay-out for any resilience measures | × No – instrument has no direct pay-out for any resilience measures | ✓ Yes – transfer of risk from the sponsor to investors and capital markets |
| Resilience Bond | ✓ Yes - premium payments fall as resilience measures are introduced | ✓ Yes – through lower premiums for bond sponsors | × No lump sum payment – bond delivers a rebate in the form of savings from reduced premium | ✓ Yes – transfer of risk from the sponsor to investors and capital markets |

**FIGURE 9** SUMMARY OF FINDINGS ACCORDING TO OUR SUCCESS CRITERIA. SOURCE (*VIVID ECONOMICS*).

While there is no one risk transfer instrument providing all that is intended for the purposes of this project, a number of ideas may help identify some of the building blocks for a solution:

- **Multi-year insurance contracts capture the resilience benefit through lower insurance premiums.** They demonstrate the significance of long-term relationships in helping to create incentives for resilience building, especially given the long asset lives of many resilience improving investments.

Their implementation however relies on the assumption that 1) insurers are willing to offer multi-year cover for catastrophes and 2) the price of this cover is reflective of actual risks. In practice, these conditions may not be consistently observed in the market, as discussed in section 1.2.3 above.

- **The resilience bond mechanism has a number of attractive features in the context of this work.** In theory, the concept allows the resilience dividend to be monetised through lower insurance premiums. It also brings these savings forward through the rebate mechanism, although they only become available after completion of resilience measures. To date, work is ongoing in converting the concept into a marketable product (re:focus partners 2017).

### *1.3.2. Traditional and innovative funding mechanisms can provide capital upfront*

**Given the limitations of existing insurance-related products in the context of the objectives of this project, a range of funding instrument were also reviewed; these may allow the provision of upfront financing/ dividend delivery.** These financing-focused instruments span both the public and private sector, ranging from basic grants and concessional lending from development agencies, bond-based capital market instruments and more innovative, donor-supported bond issuances such as the IFF's Vaccine Bond program. The Appendix provides more details and some of the key insights from this review include:

- **Multilateral lending for infrastructure by international development institutions can be extended either on concessional or commercial terms.** Concessional loans are loans that are extended on more generous terms than market loans. The concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these. For example, the World Bank's IDA extends concessional lending to the poorest developing countries – it provides credits at little or no interest rate and repayments are stretched over 25 to 40 years, including 5-to 10-year grace period. Multilateral lenders can also provide loans on commercial terms, often offering long-term source of finance (20/30-year loans) critical for infrastructure projects.

- **Green bonds demonstrate the growing investor appetite for financial instruments with strong environmental, social and governance (ESG) credentials.** An established and vibrant market, they provide upfront funding for projects with positive environmental benefits, but do not generate resilience dividend or involve risk transfer.

- **Impact bonds, also known as pay-for-performance contracts, transfer the risk of implementing a project to private investors who receive principal repayment plus a financial return according to the extent to which independently verified performance targets have been achieved.** They are therefore not 'bonds' in the conventional sense as investors stand to lose part or all of their investment if unsuccessful. Impact bonds are typically issued by a government or a donor, funded upfront by private sector investors and executed by private sector service providers. Thus, they are an attractive option in theory as they promote private sector involvement and risk sharing. However, modifying them to resilient infrastructure investment needs careful consideration of outcomes and measurement issues.

- **The International Finance Facility for Immunization's vaccine bonds convert long-term donor pledges into upfront capital for immediate project finance.** IFFIm sells 'vaccine bonds' in capital markets that are effectively backed by the pledges from donors – this secures favorable pricing and provides immediate resources to support immunization programs (Gargasson & Salomé 2010). Though not directly relevant to infrastructure or disaster risk management, the IFFIm concept helps to illustrate how public donor funds can bring forward upfront benefits.

- **The World Bank's Catastrophe Deferred Drawdown Option (CAT DDO) shows the important complementary role that various instrument layers play.** Such layering ensures quick recovery post disaster without jeopardising the long-term resilience goals of a structure (GFDRR 2011). With the CAT DDO, funds of up to $500 million are available immediately once a state of emergency is declared due to a disaster. Countries must have disaster risk management programs in place to be eligible for the CAT DDO, encouraging disaster resilience.

# 2. THE INNOVATION LAB

## 2.1. Overview

**The Innovation Lab brought together experts from finance, insurance, development, engineering and humanitarian sectors to design creative yet realistic financing options to incentivise resilience.** Co-financed by Lloyd's of London and the Centre for Global Disaster Protection, the Lab convened a diverse range of over 50 attendees who contributed to the discussion on the day. A detailed attendee list is available in the appendix of this report.

**The Lab consisted of three sections: context setting, product development on pre-worked case studies, and a discussion on primary challenges.** The first part of the day set the context around the challenges of building resiliently in developing countries and the intense needs that many of them face, with a focus on the Caribbean. Experts gave short presentations and shared knowledge around eight diverse tables to build a comprehensive picture. In the second part of the day, working groups applied their expertise on a specific case studies to design innovative financing solutions that encourage resilience. In the final part of the day, attendees identified the key challenges and lessons learned from the Lab.

**Five representative case studies were developed before the main lab session, describing the country and peril context** (see Appendix iii. for a more detailed description of each and further details on the exact process of the innovation lab):

1. A small, low income country, highly exposed to earthquake risk (e.g. Nepal) – designing innovative financing solutions to support building or retrofitting of schools to 'code+' following the Gorkha earthquake in April 2015.

2. A small island state, highly exposed to hurricane risk (e.g. Dominica) – encouraging resilient and sustainable low-income replacement housing following the hurricane season in 2017.

3. South-East Asia, highly exposed to earthquake and other hazards (e.g. Indonesia or Philippines) – developing a financial product that concentrates on funding protection, effective maintenance, or quick recovery for road network infrastructure after earthquakes.

4. A small island state, large-scale coastal defence – financing coastal defences and preparedness for ports and cruise terminals, which are critical for the continuity of jobs and income following the hurricane season in 2017, incorporating risk transfer product to facilitate rapid recovery of services for future events.

5. Resilience of critical infrastructure services across several small island states – risk transfer product to finance rapid recovery of critical services, such as health, sanitation, power, education, across several states in the immediate aftermath of events.

The literature review (Section 1) informed the eight success criteria that would define a successful solution and identify potential building blocks that could be used from the existing space of financial instruments. The eight criteria that lab participants were asked to contemplate in designing solutions are outlined in Figure 10:

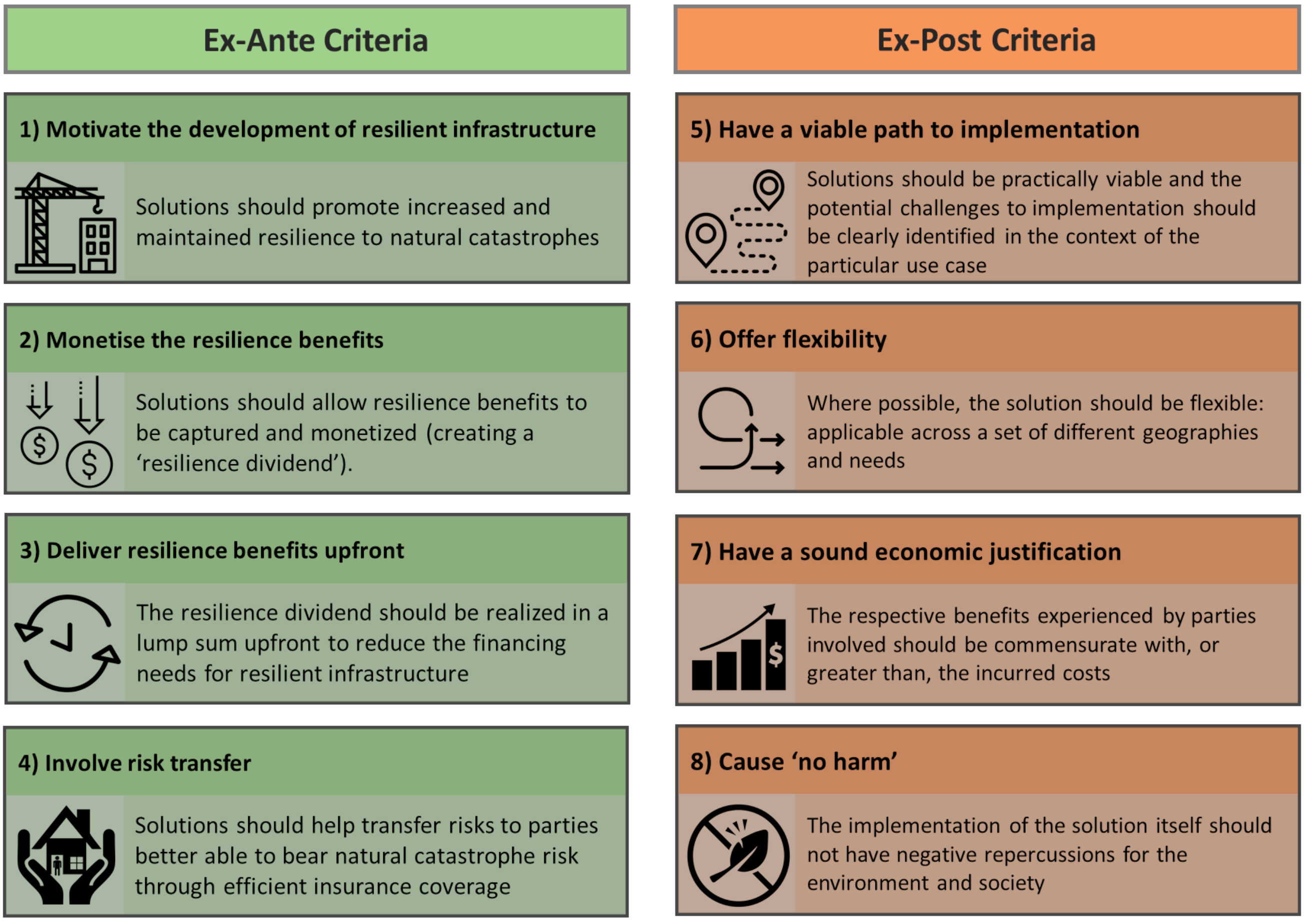



**FIGURE 10** THERE ARE EIGHT SUCCESS CRITERIA IN TOTAL THAT SHOULD BE MET. SOURCE (*VIVID ECONOMICS*).

**The lab was a collaborative and interactive process.** Attendees rotated around different groups throughout the day so there was the opportunity for everyone to be involved in discussions on 2-3 case studies. The Lab facilitated a wide range of rich discussion. Critically, it helped catalyse four ideas for products solutions, as set out in Section 4. In addition, it provided extra context and emphasis on some of the key barriers to greater resilience. It also helped identify several critical issues and contextual factors that need to be taken in designing solutions to enhance resilience.

## 2.2. Key challenges on the ground

**Expert presentations highlighted several practical challenges that are preventing effective resilience measures from being adopted.** These issues create market failures that prevent the socially efficient level of resilience from being implemented (see Figure 11).

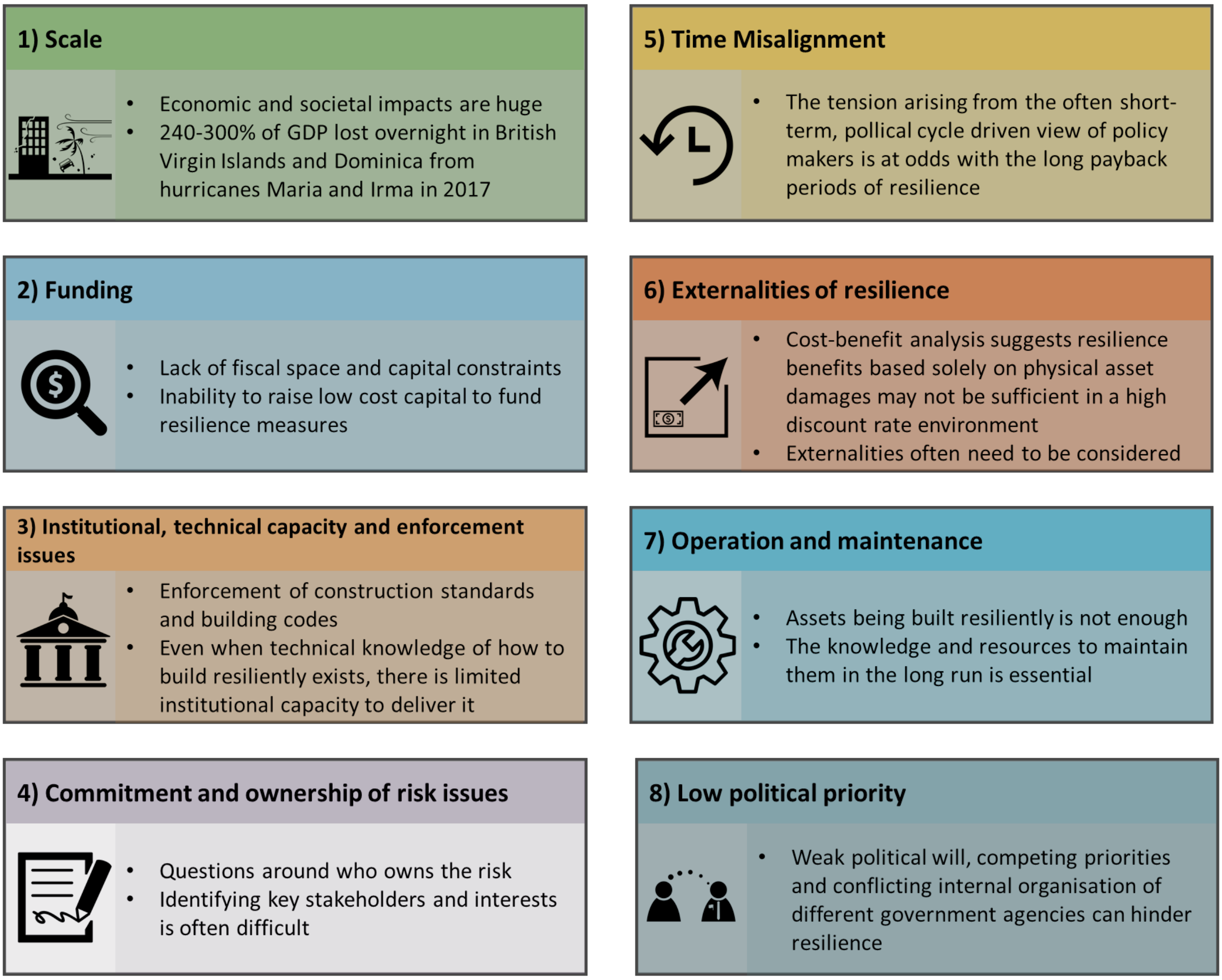



**FIGURE 11** SUMMARY OF PRACTICAL CHALLENGES TO RESILIENT INFRASTRUCTURE AND POST DISASTER RECOVERY. SOURCE (*VIVID ECONOMICS*).

1. **Scale:** disasters can have large economic and societal impacts, which exacerbate existing financing difficulties. Hurricane Maria, for example, resulted in damages and losses equivalent to 226% of Dominica's GDP in 2016, and large parts of the country remained without power several months on (Government of the Commonwealth of Dominica 2017). This aggravates restricted budgets in many of the Caribbean islands and on-going difficulties raising low cost capital to fund resilience measures.

2. **Institutional, technical capacity and enforcement issues:** application and enforcement of construction standards and building codes is key. However, even when technical know-how of how to build resiliently exists, there is often limited institutional capacity to deliver it on the ground.

3. **Commitment and ownership of risk issues:** identifying key stakeholders on the ground can be challenging: those who benefit from the continuity of a resilient service often differ from those who service the asset financially.

4. **Misalignment between short political cycle and long-term impacts of investment in resilience:** different time scales should be considered in proposed product solutions to ensure a viable path to implementation.

5. **The limitations of simple cost-benefit analysis:** typical cost-benefit analysis may be limited to the benefits of resilience on a physical asset damage only basis. These are not sufficient in a high discount rate environment and a solution must be mindful of the broader "triple dividend" of resilience.

6. **Operation and maintenance** along with the required knowledge and resources to facilitate this will play a large part in determining the success of any resilience building scheme.

7. **Political economy:** addressing resilience building can often be overlooked due to poor allocation of responsibilities in government agencies and weak political will.

## 2.3. *Lessons learned from the Innovation Lab*

**Several underlying themes emerged from the discussions around the tables that should be understood and considered when designing and implementing a financial solution.** These themes are summarised in Figure 12 and elaborated on below.

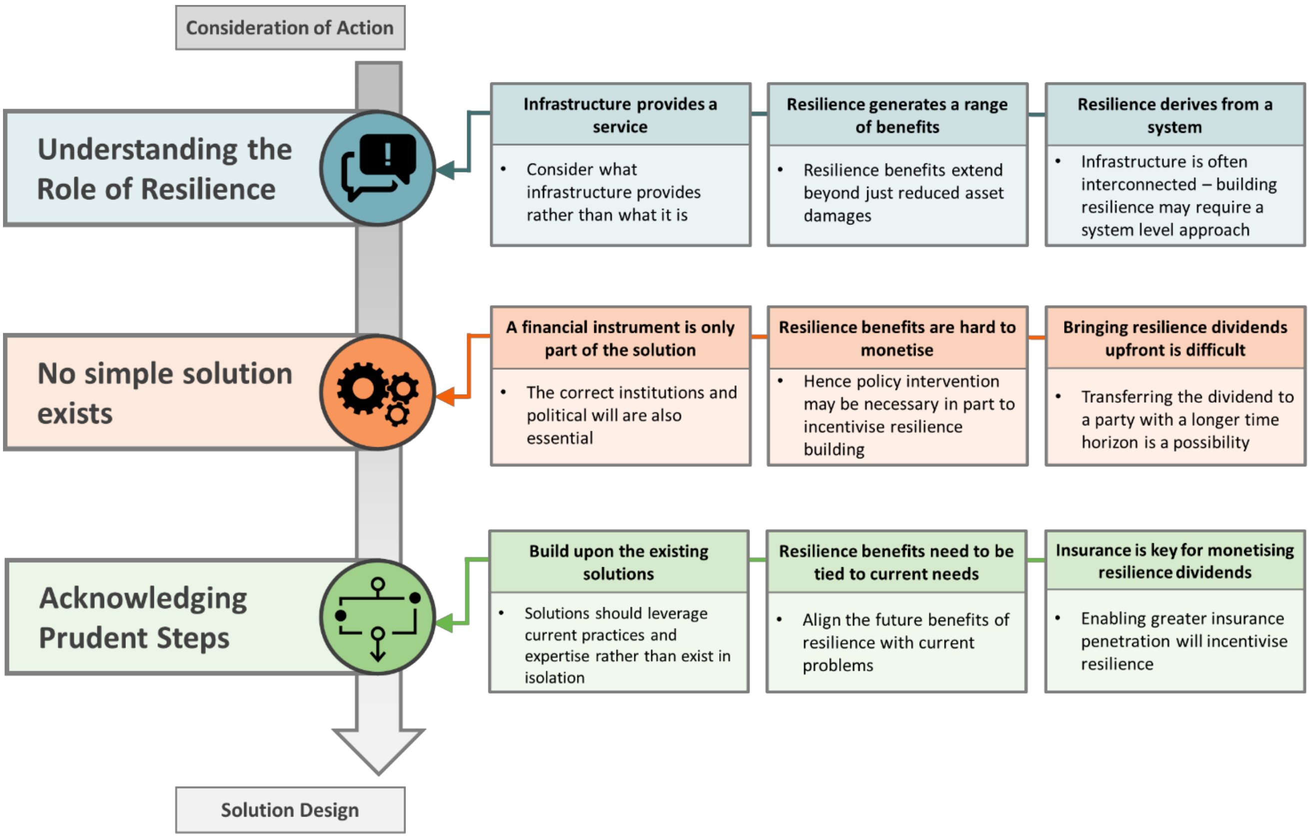



**FIGURE 12** THREE KEY THEMES SHOULD BE CONSIDERED WHEN DESIGNING A SOLUTION. SOURCE (VIVID ECONOMICS).

**1) Understanding the role and importance of resilience**

- **Resilient infrastructure is not just about the asset, it is predominantly about the resilient service this asset provides.** Rather than thinking about what the infrastructure is, one should think about what it does (e.g. protection, provision of essential services, connection).
- **The resilience dividend contains a range of benefits, not only reduction in asset damage.** One example of this broader range is the “triple resilience dividend” which considers benefits that accrue even in the absence of disaster. This include the reduction of future losses from disaster, increased economic potential in lower risk environments, and the co-benefits of resilience investments (such as schools used as community shelters, roads used as coastal defences, resilient buildings used for solar power generation).
- **As well as building resilience at an individual asset level, resilience solutions should consider systems-based approaches.** Incorporating interconnectedness and interdependency of different types of infrastructure is essential in understanding and valuating its resilience dividend.

**2) A robust solution is not simple to devise**

- **A financial instrument is only a part of the solution**. While an important vehicle to channel funds and incentivise stakeholders, it cannot succeed without important structures and political will in place. Broader policy enabling environment and institutional set up to enforce building to code is therefore key.
- **Many of the benefits from resilience measures are hard to monetise (and sometimes quantify**). A range of public policy interventions may be needed to encourage behaviour that supports the delivery of these benefits.
- **Bringing the resilience dividend forward is difficult.** Instead, transferring this dividend to parties more willing to wait for it may be a more realistic and easier to implement approach.

**3) Some common prudent steps should be acknowledged in designing a solution**

- **Where possible, build upon what already exists.** Solutions should build upon current practices and leverage the expertise of existing stakeholders and financiers on the ground rather than exist in isolation. Solutions should utilise local skills and build local technical expertise.

- **Future resilience dividend needs to be tied to current immediate needs.** It is easier to talk about future benefits when they are aligned with current problems

- **Insurance and insurance related mechanisms are critical in allowing to monetise the resilience benefit.** An enabling environment for increasing insurance penetration and greater risk-based pricing is key.

# 3. RESILIENCE DIVIDEND

## 3.1. Quantifying and Capturing the Resilience Dividend

The motivation for development of resilience-linked financial instruments is based on two principles:

- There are benefits associated with the development of more resilient buildings and infrastructure.
- The benefits can be quantified, captured, and monetised using innovative financial structures.

The captured benefit described within these principles is defined as the 'resilience dividend'. Quantification of the resilience dividend is fundamental to the development of effective product options. In some cases, once measured, the resilience dividend can be transferrable into up-front capital. This capital can financially motivate resilience building activities offsetting the initial additional costs of developing resilient infrastructure.

### *The Benefits of Resilience*

Total disaster costs are a function of both the direct and longer-term downstream impacts of a disaster event:

1. **Direct impact (physical)** - damage and loss that occurs during a disaster event as a direct result of the severity of hazard that is experienced, including:
   - Structural asset damage
   - Injury and loss of life

   The financial impact of these components of disaster losses can be covered using standard insurance policies. Catastrophe models are ideally placed to quantify the risk of direct losses.

2. **Downstream impact (operational, societal, environmental, and economic)** – contingent losses that result from direct damages, including:
   - Disaster response costs
   - Service disruption
   - Impact on health and livelihood
   - Impact on economic and developmental potential

   The magnitude of downstream impacts can be multiples of the direct losses. The systemic nature of contingent impacts means that they are more difficult to quantify and may not be as comprehensively captured under standard insurance coverages, although certain contingent losses such as service disruption are strongly correlated to direct damage and hence can be explicitly quantified using catastrophe models. With reasonable assumptions it is also possible to quantify other downstream impacts, though the model uncertainty increases as the complexity of the system increases.

The benefits of increasing the resilience of physical infrastructure therefore extend well beyond the reduction in direct damage and loss. The objective of this process is to develop innovative financing products that capture and monetise the benefits of risk reduction into a realized resilience dividend. Effectively, the product aims to capitalize on the future event savings that are expected to result from more resilient infrastructure.

### *The Role for Insurance*

Insurance exists to transfer the unmanageable volatile risk of large future losses into manageable annual insurance premium payments. Premium payments are a function of the underlying risk: if the risk of loss is reduced using resilience measures, then it is expected that the annual insurance premium payments will also fall. Insurance may therefore be a useful means of monetising the benefits of risk reduction measures.

All elements of disaster losses, direct and downstream, are technically insurable, though those responsible for the losses range from asset owners, to government, to the international development community. Despite the reality that all parties benefit from more resilient infrastructure, typically only one will be responsible for the risk of structural asset damage and loss, and therefore for insurance premium payment.

The simplest approach to capturing a resilience dividend to use towards resilient infrastructure is therefore to use the saving on asset insurance premium, for which ownership is less ambiguous than for other types of disaster losses associated with the infrastructure.

### *Risk Reduction*

A hypothetical example is used to demonstrate how retrofit measures can reduce the risk of direct damage and loss to a portfolio of school buildings in Dominica[8], and how this benefit might be captured as a resilience dividend through savings on insurance premiums. Sensitivity analyses are also included to demonstrate how risk-reduction can be represented in insurance premium, and how discount rates influence the total resilience dividend that can be accrued over time.

The example compares how the vulnerability of a standard ('base') school construction compares against a retrofitted ('resilient') alternative at an additional cost of 5.5% of building value. As expected, the structural vulnerability of the school buildings decreases following installation of wind retrofit measures, though the magnitude of reduction varies across a range of wind speeds. Figure 13 displays this difference between the vulnerability of the base and resilient examples.

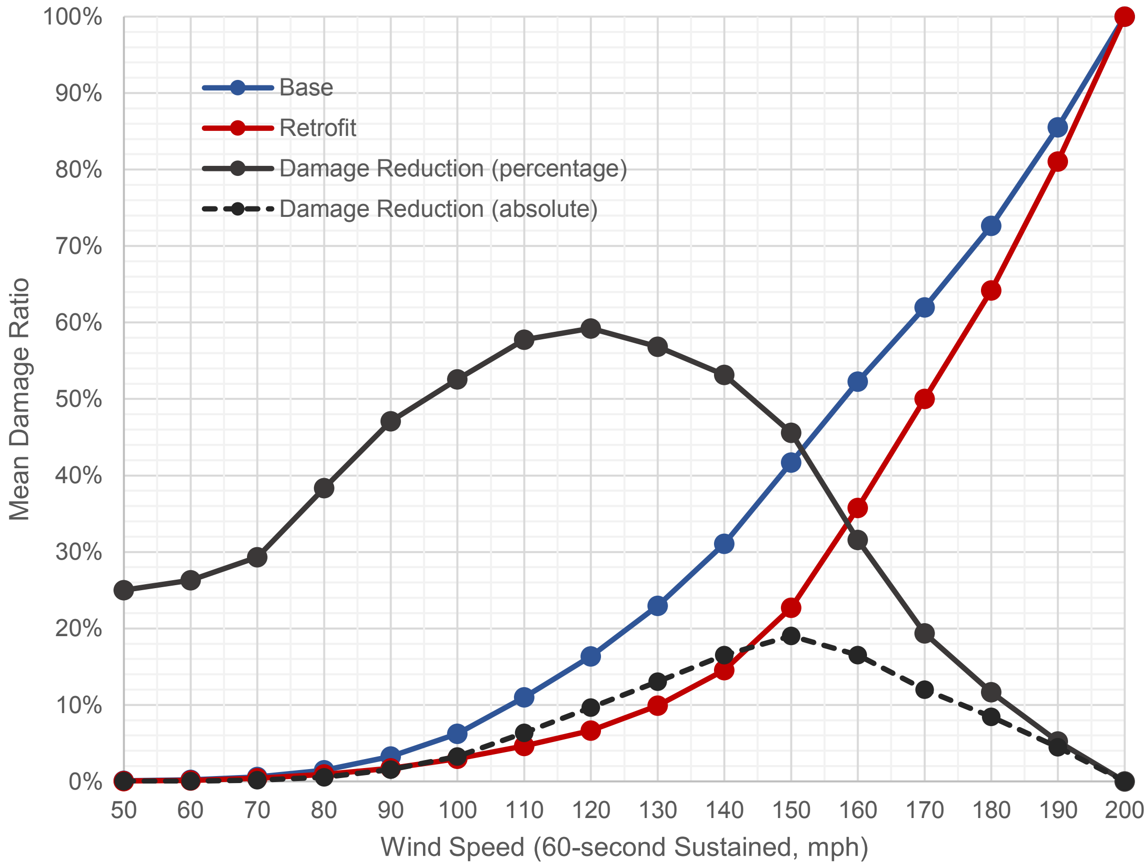



**FIGURE 13** VULNERABILITY CURVES FOR BASE SCHOOL CONSTRUCTION AND SCHOOLS WITH RETROFIT MEASURES. BLACK CURVES SHOW DAMAGE REDUCTION AS A PERCENTAGE, AND IN ABSOLUTE TERMS.

[8] This example also supports the applied use case analysis for the Resilience Impact Bond contained in the following section, which contains further information on the specific details of this use case.

There are several key observations for this example, which affect the cost-benefit of retrofit for events of different magnitudes:

- At lower wind speeds, the percentage reduction in damage is at least 25%, but the absolute savings may be small since the events do not cause extensive damage.
- Retrofitting creates the greatest proportional savings, up to 60% reduction, at a wind speed of 120 mph.
- The greatest absolute damage reduction occurs at wind speeds of 150 mph and the absolute damage reduction equals or exceed the additional cost of the retrofit for a portion of the curve. At wind speeds greater than 150mph the relative value of retrofitting decreases – this occurs as the vulnerability curves for the base and retrofit cases converge at higher wind speeds.
- For extremely severe events (200 mph) the damage ratios are approximately 100% for both the base and resilient cases. However, the probability of these types of event occurring is very low.
- The loss you would expect to experience on average in one year, the average annual loss (AAL), is reduced by 46%, reflecting the complete distribution of event severity and frequency.

This example demonstrates that the benefit of investment in retrofit for an individual event depends on its wind severity. For low loss causing events, the total saving may not be as great as the cost of resilience, the same is true at very high wind speeds. Figure 14 displays the wind hazard profile of the ten school locations across Dominica. The hazard occurrence exceedance probability (OEP) curves show the probabilities of exceeding a range of wind speed thresholds at the locations of the schools (including minimum, maximum, and mean ranges to show the variability in wind hazard across the island).

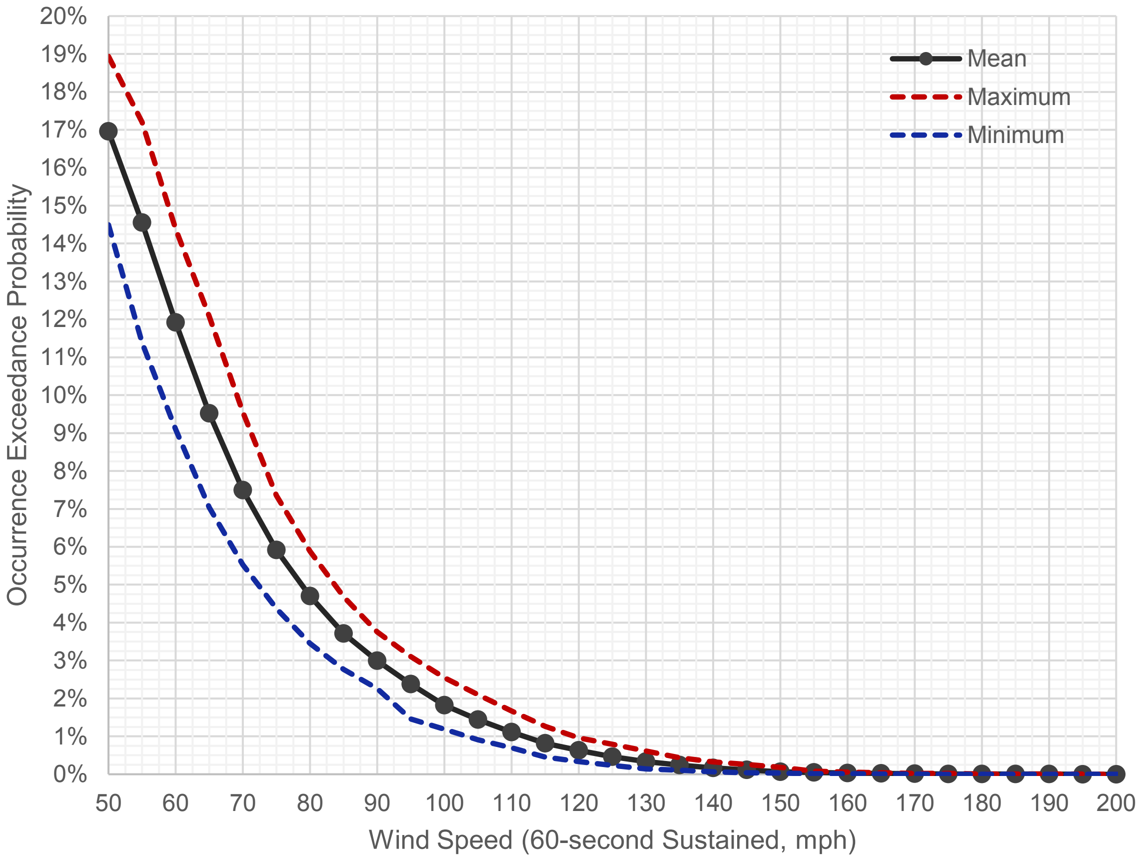



**FIGURE 14** DOMINICA WIND SPEED HAZARD OCCURRENCE EXCEEDANCE PROBABILITY CURVE.

It is the combination of vulnerability, and hazard frequency and severity that determines the AAL. AAL, or pure premium, is a measure of the annual expected loss that can be expected to occur within a year, on a long-term average. Among other factors, this forms the basis for calculation of insurance premiums – a reduction in AAL should generally yield a reduction in insurance premium. The magnitude of AAL reduction as a portion of the additional cost of resilience is a good indicator of whether a resilience investment yields a good cost-benefit ratio ('Resilience Ratio').

$$Resilience\ Ratio = \frac{Cost\ of\ Resilience\ (\$)}{\Delta AAL\ (\$)}$$

As would be expected, the resilience dividend (ΔAAL in this case) should be large in relation to the cost of resilience in order to produce good benefit-cost ratios. Note that ΔAAL is a metric that describes the average annual risk reduction, some years may experience no losses (and no Δloss) and the resilience dividend may be accrued over many years. As a general guide:

- Average annual losses vary significantly based on vulnerability, combined with the frequency and severity distribution of the hazard (as described above). Loss cost is a measure of the AAL as a proportion of the value of the asset under consideration[9]. When combined with reasonable risk reduction measures, high loss costs represent scenarios where there is a good potential resilience dividend. A loss cost of 10 would imply that AAL is 1% of the total value of the asset, this is a very high loss cost (in the context of catastrophe risk), which could represent a worst case for residential or commercial type exposures. For additional context:

    - In general, the major influence of loss costs is the frequency of the peril at any given location.
        - Climate perils (e.g. hurricane, flood) typically have higher loss costs than earthquakes. This is largely due to the difference in frequency (climate impacts are much more frequent than earthquake impacts).
        - Extreme loss costs (10-50) are possible where high frequency is combined with low vulnerability. For example, slab-on-grade single family dwellings in some low-lying areas of lower Mississippi basin can have loss costs exceeding 30 for flood risk. This would be considered extremely high risk.

- Additional costs of resilience can be very small compared to the total value of the base structure. For example, smaller retrofit measures, such as roof anchors or opening protection may cost as little as 1% of the total cost of base construction.

- More substantial resilience measures, such as seismic damping or heavy protection measures, can incur high costs.

- For certain resilience measures, risk reduction can be of the order of 90% of AAL. The schools example demonstrates a case where the risk reduction in terms of AAL is 46%.

- The resilience ratios can therefore vary significantly between use cases. However, it is likely that the resilience dividend will need to be accrued across several years for it to contribute meaningfully to the additional cost of resilience.

The resilience ratio is indicative of the number of years it would take for the annual reduction in insurance premiums to pay entirely for the additional cost of resilience (its 'payback period'), if changes in insurance premiums are assumed to fully mirror changes in AAL. In reality, insurance costs are likely to be influenced by additional factors, and the true payback period is a function of the actual cost of insurance premium which can be achieved, and the discount rate which is used to calculate the present value of future annual savings. These factors are explored further in the following sensitivity analysis and in Section 1.5.

[9] $Loss\ Cost = \frac{AAL*1000}{Total\ Value}$

### *Scale*

The costs and values of insurance and resilience investments vary according to the scale of the underlying infrastructure or resilience project. Scale refers here to the number, value, and spatial distribution of the underlying exposure[10]. Scale is important for a number of reasons:

- The relative frictional costs of setting up innovative financing mechanisms decrease with increasing scale.
- Larger portfolios of assets are more attractive to insurers. Administrative costs and volatility in loss decrease with increasing scale.
- The modelling uncertainty in the benefit of resilience measures decreases as the number of assets increases. Risk reduction measures deployed at scale are therefore more likely to be recognised in reduced insurance premiums.
- The total magnitude of risk, and potential risk reduction benefits, is a key factor in determining whether there is a great enough resilience dividend available to be worth capturing.
- Building resilience at scale, across many pieces of infrastructure, has inherent benefits to the overall resilience of the system over targeting individual assets. The operational resilience of services is dependent on how well the system as a whole is able to manage disasters.

The types of innovative financing mechanisms developed in the following section may therefore yield greatest benefit if they are deployed at scale (e.g. investments of the order of $1-10 million), ideally with risk transfer mechanisms that cover high value individual assets, and/ or larger numbers of lower value assets. Ultimately, use cases in high risk areas are more likely to generate high resilience dividends – risk modelling can therefore greatly help to isolate appropriate use cases, and to support prioritisation.

However, in addition to the economies of scale that result from applying this structure to larger projects, there are also obviously additional costs, both in the cost of investment in resilience, and the cost of risk transfer.

### *Cost-Benefit Sensitivity*

The resilience ratio describes the number of years of AAL-based savings that would have to be accrued before the initial cost of the resilience measure is paid for. In reality, the payback period (time after which premium savings pay for additional cost of resilience) is strongly dependent on:

- The actual cost of the insurance premium, which is influenced by the risk, but also other factors including the uncertainty, magnitude of coverage, number of covered assets, and administrative costs. For simplicity, the cost of insurance premiums for a portfolio of assets is assumed to be 2x its AAL in this example- this would reduce the payback period (resilience ratio) by 50%.
- Discount rates – which affect the net present value of spending on resilience and insurance premia[11].

An illustrative range of sensitivity analyses, using the hypothetical schools analysis already discussed, have been completed to demonstrate how insurance premium and discount rate assumptions influence the relationship between total cost and annually accrued benefit (Figure 15).

Note that these sensitivity results are presented to demonstrate the potential impact of higher discount rates on the ability to accrue resilience dividends over time. Results are expected to vary significantly between use cases, and under different product structures.

[10] Exposure refers to the underlying 'assets at risk'. Assets can constitute buildings, infrastructure, people, livelihoods, services, etc.

[11] Discount rate refers to the rate at which future cashflows are adjusted to calculate their present day equivalent value.

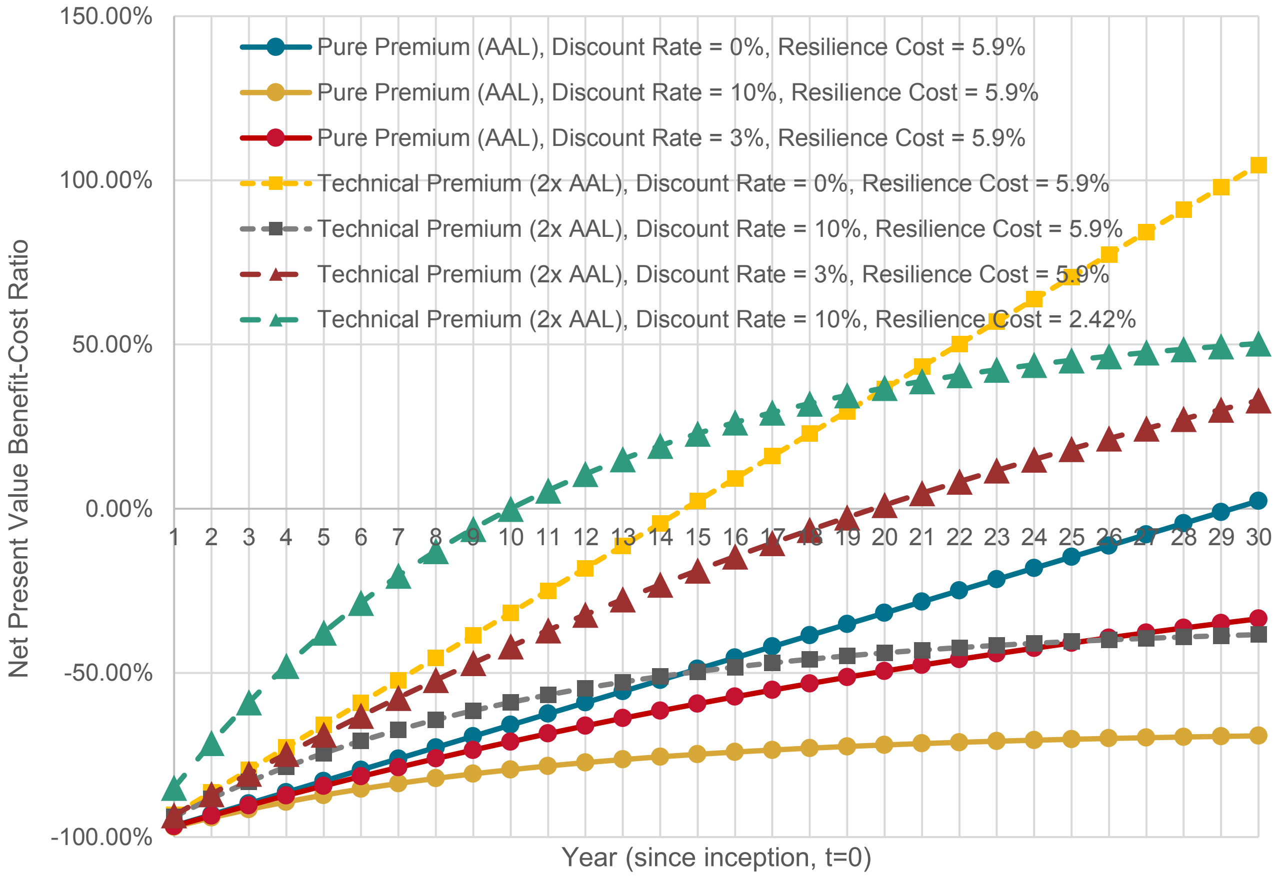



**FIGURE 15** TIME SERIES OF NET PRESENT VALUE BENEFIT-COST RATIO FOR A RANGE OF PREMIUM AND DISCOUNT RATE ASSUMPTIONS

### *Key Sensitivity Results*

- Since the resilience dividend is typically realised on an annual basis, as savings on insurance premiums are paid, high discount rates (of 10%) significantly reduce the ability of the dividend to totally pay for the additional cost of resilience. In the worked example, where the additional cost of resilience is 5.9% and the reduction in AAL is 46%, the following results are seen:
    - A discount rate of 0% and a pure risk-based premium (i.e. insurance premium = Average Annual Loss) yield a payback period of 29.3 years.
    - If a discount rate of 10% is applied in the NPV calculation – the maximum benefit-cost ratio that can be attained is -67.6%. i.e. the resilience dividend never pays totally for the additional cost of resilience.
    - A discount rate of 10% significantly limits the potential for the accrued savings on insurance premium to contribute totally for the additional cost of resilience. If the discount rate is reduced to 3% in the same example, the payback period is of the order of ~20 years.

- To achieve a NPV benefit-cost ratio of 0% after 10 years, assuming a discount rate of 10% (i.e. 10-year payback period):
    - **Pure Premium** (AAL): additional cost of resilience can be no more than 1.21% on top of base cost
    - **Technical Premium** (2x AAL): additional cost of resilience can be no more than 2.42% on top of base cost.

The product solutions contained in the following section aim to demonstrate how some of the potential benefits and challenges of capturing the resilience dividend can be addressed using innovative methods.

# 4. PRODUCT SOLUTIONS

## 4.1. Overview of Product Solutions

**Four main product concepts emerged from the Innovation Lab.** These range from ideas that have already been developed but which can be re-purposed for these challenges which could be brought to market relatively quickly, through to ideas that, although further from current practice, hold significant potential. The four product concepts are:

1. ***Resilience Bond –*** *a risk transfer instrument, in which risk reduction is reflected in a reduced premium paid by the insured across the term of the bond.*

2. ***Resilience Service Company (ReSCo) –*** *a company who bears the initial costs of resilience and is repaid on an annual basis using savings on insurance premium.*

3. ***Resilience Impact Bond (RIB) –*** *a pay-for-performance contract in which an investor is remunerated based on how well they implement resilience measures according to pre-defined performance indices.*

4. ***Insurance-linked Loan Package (ILLP) –*** *an infrastructure loan which has a built-in insurance component. Insurance savings through risk reduction offset loan interest repayments.*

All four product concepts are described in the following section. Of the four concepts, the Resilience Impact Bond (RIB) and Insurance-linked Loan Package (ILLP) were determined to have greatest potential for further development. Further structuring and in-depth analysis, including risk and cash flow modelling has therefore been carried out for these two products.

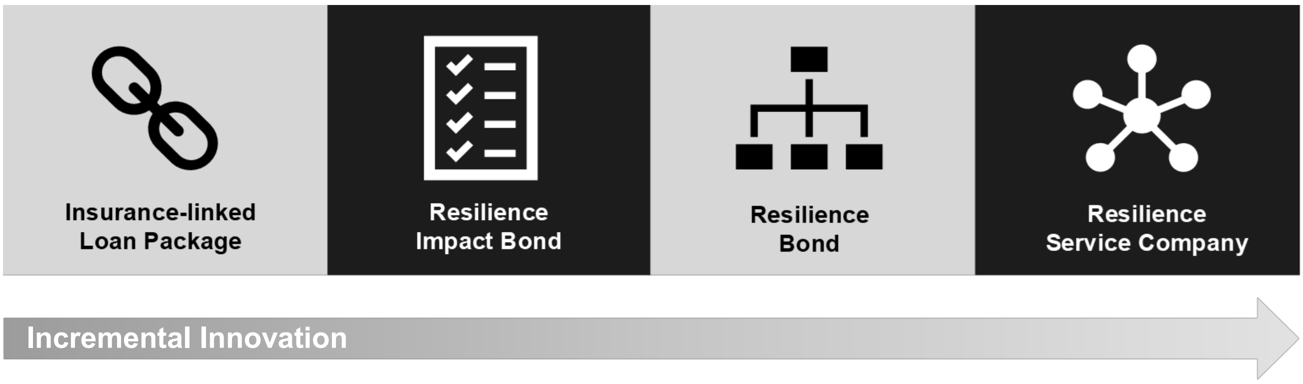



**FIGURE 16** OVERVIEW OF PRODUCT SOLUTIONS

The format for the product solutions section is as follows:

1. *Executive summary of results*
2. *Preliminary analyses of:*
   - *Resilience Bond*
   - *Resilience Service Company*
3. *Detailed analyses of:*
   - *Resilience Impact Bond*
   - *Insurance-linked Loan Package*
4. *Discussion of key findings and next steps*

### 4.1.1. Executive Summary of Results

The process of product development and use case analysis has provided good insight into the potential applicability of the proposed product solutions, and more generally around the challenge of monetizing the resilience dividend. Some key findings, and repeated themes, include:

- Resilience measures can result in realized cash savings through reductions in insurance premium. In other words, where insurance would already be in place, insurance provides a vehicle for monetising the resilience dividend. The products largely focus on the portion of the resilience dividend associated with the reduction in direct physical damage.

- Resilience also leads to benefits resulting from development co-benefits or increased economic activity in a lower risk environment. The RIB structure offers a targeted means of promoting and financially incentivising the non-direct resilience benefits, by assigning a return on investment to desired resilience outcomes.

- It can be challenging to bring the savings up-front; insurance premium can only fall as risks change over time, while there is a risk of misaligned incentives if donor funds are provided in advance of resilience measures being introduced.

- The ILLP, ReSCo, and RIB address this challenge by, instead, transferring the additional upfront costs of resilience to a structure or party who is able and willing to wait to see the benefits of resilience over a longer timeframe.

- The primary factors which influence the ability of the resilience dividend to contribute significantly to the cost of resilience are:

    - **Realised resilience dividend:** the magnitude of risk reduction, as reflected by the savings on insurance premium.

    - **Resilience cost:** the additional costs of the resilience measure.

    - **Timescale:** the timescale over which insurance premiums are paid and savings accrued, strongly influences the size of the monetisable resilience dividend.

    - **Discount Rate:** the potential total resilience dividend is suppressed in a high discount rate environment, if it only possible to realise that dividend over time.

- The resilience dividend to resilience cost ratio is higher for vulnerable exposure which is exposed to high frequency impacts, typically from climate perils. Investment in retrofit for low frequency perils such as earthquakes, where significant absolute reductions in average annual loss may be relatively more difficult (and costly) to achieve, may require consideration of a broader definition of resilience benefits to inform investment decisions than direct damage alone. The additional benefits of seismic resilience could be captured to some extent within a RIB, which offers a structure where the wider benefits of resilience can also be used to motive the outcome funder to pay a dividend commensurate with the broader benefits.

- Public (donor) funding can support investment in resilience where the size of the resilience dividend or the degree to which it can be brought up-front and monetised is insufficient to incentivise resilient building alone. Donors or international financial institutions, as parties more likely to be able to wait to see the benefits of resilience, can also play a structural part in product design.

- A hypothetical portfolio of schools in a hurricane prone region has been used as the basis for the primary risk analysis in each of the RIB and ILLP. The analyses differ slightly in that the resilience benefit of retrofit for existing infrastructure has been analysed for the RIB, whereas the benefit of complete 'resilient construction' versus a standard alternative is used for the ILLP.

- Increased resilience has broader societal and economic benefits, which extend beyond the reduction in expected direct damage and loss. The cashflows associated with these types of downstream resilience benefit are commensurately more complex and varied, it is therefore more challenging to efficiently create monetised resilience dividends from these sources. While not explicitly used in the cash flow analyses for the RIB and ILLP, it is expected that a quantitative assessment of broader benefits can support the direct benefit-cost assessment.

### *Key Product Analysis Results*

**Resilience Impact Bond**

- Applicable where the outcomes funder (e.g. donor) wishes to transfer some of the operational risk of implementing the resilience project, and also benefits from a transparent assessment of how well the project performs against its objectives.
- Strongly aligns the incentives of the outcomes funder with the investor – delivery of different elements of resilience provides substantial upside to the investor but failure to deliver this resilience can result in low or negative returns
- Can be structured to explicitly promote individual elements of resilience, e.g. structural, operational, and financial resilience, offering a targeted approach to building resilient systems.

**Insurance-linked Loan Package**

- A simple and potentially efficient means of monetising the resilience dividend generated through insurance savings within one product structure which is achievable in the near-term.
- The repayment term, and the size of the risk reduction, largely determine how much the accrued insurance savings can contribute to the overall additional cost of resilience.
- Flexibility within the product structure allows for the resilience dividend to contribute to the costs of resilience, loan repayments, or insurance premium payments, as is appropriate to the use case.

### *Interpretation of Analysis Results*

In reviewing the product solutions and in-depth analyses there are a few points to note:

- The results are presented for select applied examples – therefore it should be recognised that the results are expected to vary between use cases, and for the range of structural options that exist within each product. Additional commentary is contained in the discussion which addresses the sensitivity and applicability of the products under a broader range of conditions (e.g. peril type, resilience measure cost and benefit, insurance premia).

- There is inherent uncertainty in the results of catastrophe risk models. Uncertainty is explicitly accounted for in the models, and incorporated in the results, however this should be recognised when model results are used in decision making. In addition, reasonable assumptions, such as marginal construction cost estimates, were selected to assess realistic hypothetical examples, however these assumptions will likely vary in practice.

## 4.2. Resilience Bond

### 4.2.1. Overview

A Resilience Bond is an innovative risk-linked financing mechanism that takes the existing model of a catastrophe bond (cat bond), in common usage within the Insurance Linked Securities market, but also accounts for the impact of resilience measures.

Like cat bonds, sponsors pay premiums on an insurance contract, and these premiums are used to make interest payments to bond investors. In the event of an eligible disaster, investors lose all or a portion of their investment and the bond principle is transferred to the bond sponsors as an insurance payout.

Unlike cat bonds, Resilience Bonds explicitly account for the impact of resilience measures by reducing bond interest payments as the measures are implemented and reduce the financial risk born by bond investors. The difference in interest payment is credited to the resilience measures and can be securitized to provide upfront project capital through project revenue bonds or various types of project loans.

In a development application, resilience bonds could be sponsored by a consortium of stakeholders that have an interest in implementing the resilience measures or in minimizing future disaster recovery costs. Consortia members might include local asset owners and homeowners, local business and industry interests, regional economic development authorities, international development banks, aid agencies, and national governments.

***How could this work?***

The application of a Resilience Bond structure could be suited to upgrading roads in Southeast Asian countries, for example, by focusing on roads not only as a physical asset, but also as potential sources of protection (coastal roads built as dual-purpose berms/barriers) and as a means of delivering transportation services to support both regional economic activity and essential services (access to airports, ports, hospitals, etc.).

Road networks could be categorized by types of users, such as primary beneficiaries who directly lose money if a road is out of service and secondary beneficiaries who experience other disruption. For example, each of the following categories of road types could be associated with different Resilience Bond sponsoring interests:

- *Coastal roads that can be reinforced/upgraded or rebuilt to provide dual purpose coastal protection (Sponsor: MDBs / aid agencies / national gov't)*
- *Major commercial roads that support commercial/industrial operations where long-term disruption would have broad general impacts on the local/regional economy (Sponsor: private sector consortium of beneficiaries)*
- *Essential service roads that support airports, seaports, hospitals and major construction supply lines if/when materials are needed for reconstruction (Sponsor: MDBs / aid agencies / national government)*

### 4.2.2. Stakeholders

- Core Stakeholders: owners of assets protected by dual purpose coastal protections, business and industrial interests that rely on major commercial roads, and essential service providers.

- Optional Stakeholders: development banks, aid agencies, economic development authorities, and national governments.

### 4.2.3. Product components

- Funding mechanism: Upfront resilience costs financed by securitizing future Resilience Bond "rebates"
- Risk transfer mechanism: Catastrophe coverage provided by cat bond features of the Resilience Bond
- Resilience benefit mechanism: Upfront capital for resilience measures is provided according to project-generated risk reductions that are specified and modelled in advance.

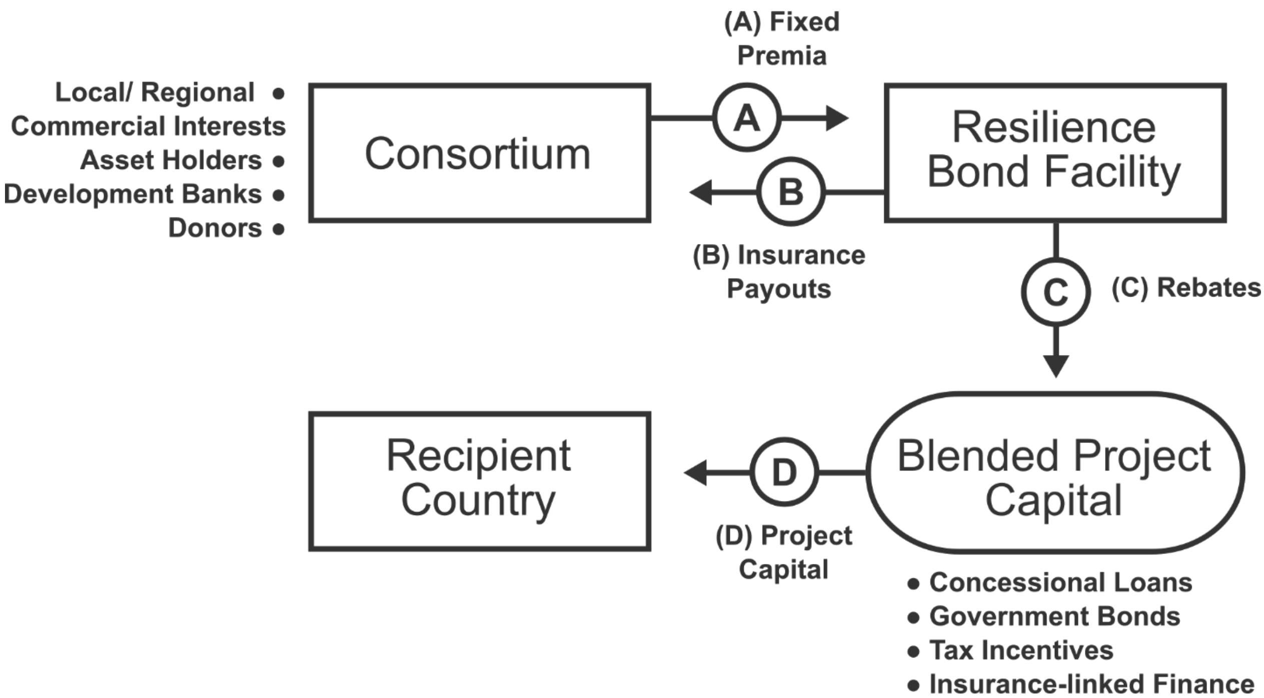



**FIGURE 17** CASHFLOWS UNDERPINNING THE RESILIENCE BOND

### 4.2.4. Cash Flows

- ***P***: Sponsor premiums paid on an insurance contract to the Resilience Bond facility.

- ***I***: Insurance payouts issued by the Resilience Bond facility in the event of a qualifying natural disaster.

- ***R***: "Rebates" paid by the Resilience Bond facility to the source of project capital, which mirrors the reduction in interest payments made to investors as the resilience measures reduce the risk to investor principle.

- $: Upfront capital provided to the resilience project based on projected "rebates" attributable to the project.

### 4.2.5. Challenges and Path to Implementation

Further research, modelling and application to a particular use case is needed to develop this option to a product solution:

- Structural complexity: This mechanism involves multiple stakeholders with complicated incentives structures and may require integrating multiple financial instruments. These complexities may increase the frictional cost of set-up.

- Governance: There are likely to be significant political and administrative challenges associated with aligning and managing large consortia of Resilience Bond beneficiaries and stakeholders.

- Insurance coverage: Resilience Bonds are insurance products that require sponsors who will pay insurance premiums in order to access the rebate. This may be a challenge in markets with low insurance penetration.
  - Clearer opportunities for this approach exist where there is an existing insurance market.
  - Absent existing insurance, co-sponsors need to be incentivised to pay insurance premiums and give up their 'rebate' to contribute to project finance. Is the gain of insurance cover plus reduced disruption and damage from future events sufficient?
  - Insurance cover must align with the proposed resilience project and subsequent resilience dividends. This can be more challenging where indirect losses need to be covered and modelled (e.g. losses to a commercial business due to an impaired road network). Risk reductions for such indirect losses may prove difficult to monetise in a rebate.

- Scale issues: Like cat bonds, resilience bonds generally require large aggregate amounts of insurance coverage. At the same time, the size of rebates may be small compared to project capital requirements. This may be a particular challenge in high discount rate development environments.

### 4.2.6. Does it meet the product objectives?

| | | | |
|---|---|---|---|
| Encourages resilient infrastructure | ✓ | Has a viable path to implementation | ? |
| Monetises resilience dividend | ✓ | Offers flexibility | ✓ |
| Makes resilience dividend available upfront | ✓ | Has a sound economic justification | ✓ |
| Involves risk transfer | ✓ | Causes 'no harm' | ✓ |

# 4.3. Resilience Service Company

## 4.3.1. Overview

The idea of the ReSCo was inspired by the innovative financing mechanisms employed by Energy service companies (ESCOs). ESCOs develop, build, and fund projects that create energy savings. They pay for the project upfront and rely on receiving some proportion of the savings that are realised due to the reduced energy usage to make a return on their initial investment.

A similar innovative mechanism could be used in conjunction with insurance policies to generate resilience savings in the context of assets. Retrofitting a house, for example, reduces risks and results in lower insurance premium (assuming these are risk-based).

The high up-front cost of the retrofit could be borne by a ReSCo (Resilience Service Company), on the basis that;

- The asset insurer recognises the upgraded resilience with a reduced insurance premium.
- The asset owner uses some of the insurance savings to pay back the ReSCo over time. This solution minimizes the up-front cost of resilience and motivates action through reducing annual insurance costs.

The ReSCo is independent from the insurance company, though bilateral agreements are required to ensure that:

- The insurer guarantees a reduction in insurance premium for implementation of a range of retrofit options.
- The ReSCo can guarantee that resilience measures are well implemented.

*How could this work?*

The ReSCo structure could be suited to disaggregated retrofit solutions with small scale yet 'easy win' resilience options, ideally where insurance is already in place. These would likely need to be resilience options which were effective at reducing losses from short return period events. For example, roof anchors and opening protection to increase resilience to hurricane wind damage.

## 4.3.2. Stakeholders

- Core Stakeholders: asset owner (house owner); insurance provider, ReSCo
- Optional Stakeholders: donor, non-insured asset owner

### 4.3.3. Product components

- Funding mechanism: upfront resilience costs financed by the ReSCo; it may be possible to provide a concessional loan to support the ReSCo
- Risk transfer mechanism: catastrophe insurance either exists already or is initially funded by a donor
- Resilience benefit mechanism: Rather than deliver the resilience dividend upfront explicitly, this model would transfer it to stakeholders who are more willing to wait for it (the ReSCo). Resilience measures are implemented upfront with no funding from the asset owner.

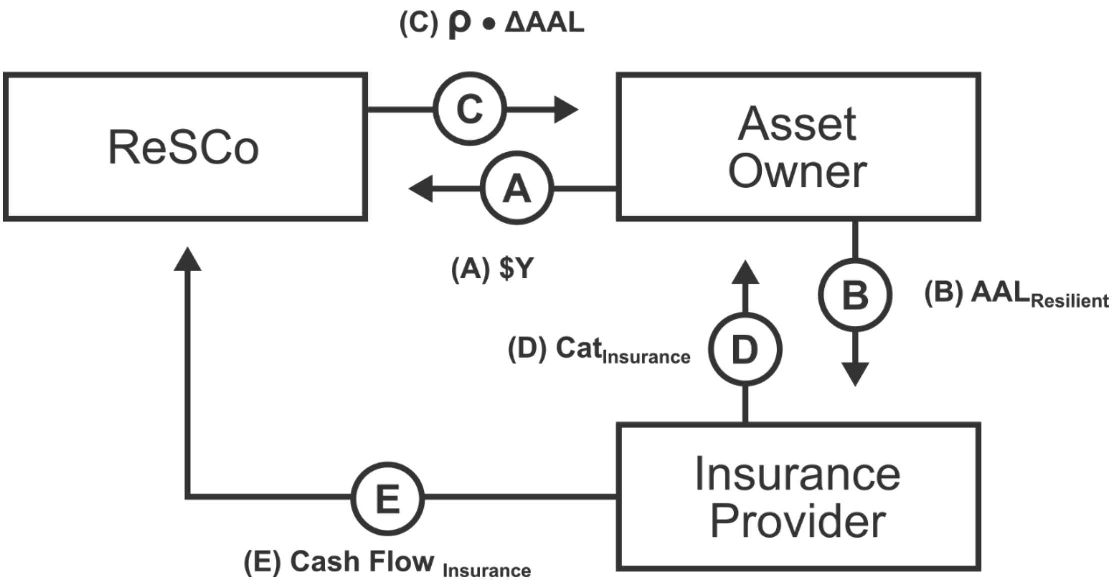



**FIGURE 18** ILLUSTRATIVE CASHFLOWS IN THE RESCO MODEL.

### 4.3.4. Cash Flows

- $\$\boldsymbol{Y}$: The cost of the resilience measure, funded by the ReSCo.
- $\boldsymbol{AAL_{non\ resilient}}$, $\boldsymbol{AAL_{resilient}}$: The annual average loss for non-resilient and resilient assets.
- $\Delta \boldsymbol{AAL} = \boldsymbol{AAL_{non\ resilient}} - \boldsymbol{AAL_{resilient}}$: The Insurer reduces the premium that the house owner pays, to account for the reduction in risk: the resilience dividend is equal to the reduction in Average Annual Loss. The house owner now pays a fraction, $\boldsymbol{\rho}$, of the resilience dividend to the ReSCo each year, to payback the initial cost of the resilience $\$Y$.
- $\boldsymbol{Cat_{insurance}}$: The payment by the insurers in the event that a catastrophe occurs.
- $\boldsymbol{CashFlow_{insurance}}$: The cost of insurance taken out by the ReSCo to cover their cash flow to cover a situation whereby the ReSCo does not receive the agreed payment from the Asset Owner.

## 4.3.5. Challenges and Path to Implementation

Further research, modelling and application to a particular use case is needed to develop this option to a product solution:

– Developed insurance market: a functioning insurance market would likely need to exist locally and premiums need to reflect actual levels of risk (risk-based premiums). In addition, typical insurance contracts are much shorter than the repayment terms of retrofit options – a development of long term agreements is key. If insurance doesn't exist, donor or state involvement is required to make this viable.

– Set-up of ReSCo: Resilience Service Companies need to be developed. This requires legal and technical assistance, provision of initial capital, insurance against the risk of no repayment, cashflow modelling for viability studies. This would likely require development partner support, who may need to explicitly seek to catalyse an early example of a ReSCo.

– Economically viable use cases: some assets may not be appropriate for retrofit (practically and/ or economically). Where retrofit is appropriate, available options should be low cost and high impact to ensure that the reduction in premium payments pays for the cost of the resilience measure (in a reasonable timeframe). Sourcing use cases and modelling cashflows is a critical step to ensure sound economic justification. Care should be taken in calculation of the benefit-cost ratios to ensure that the societal benefit of an intervention is recognised, donor support may be appropriate in cases where the societal benefits of the intervention are high.

## 4.3.6. Does it meet the product objectives?

| | | | |
|---|---|---|---|
| Encourages resilient infrastructure | ✓ | Has a viable path to implementation | ? |
| Monetises resilience dividend | ✓ | Offers flexibility | ✓ |
| Makes resilience dividend available upfront | ✓ | Has a sound economic justification | ? |
| Involves risk transfer | ✓ | Causes ‘no harm’ | ✓ |

## 4.4. Detailed Analysis – Resilience Impact Bond

**Primary Objective:** To finance measures that increase the physical, operational, and financial resilience of essential services (e.g. schools, social care, hospitals).

**Impact Bonds:** Impact Bonds are pay-for-performance type contracts in which the return on investment is a function of both the original principal amount and the success of the project.

The desired project outcomes are defined at inception – performance is ultimately measured against these defined outcomes. Once terms are agreed, an impact investor supplies project capital and carries out the project through an implementation agent in order to deliver the desired outcome. The success of the project is assessed against pre-defined criteria by an outcomes funder, who makes repayments which are based on the original principal amount and measured performance of the project. Performance criteria take the form of outputs (action-based criteria) and outcomes (results-based criteria), which are independently measured at defined intervals during the term of the bond.

In the context of physical, operational, and financial resilience of essential services, impact bonds can be a useful instrument to combine multiple objectives via a set of performance criteria. The performance criteria can be based on both outputs and outcomes, going beyond the physical asset and considering the services that the asset provides (e.g. continuity of service after disaster, and during retrofit). An impact bond is appropriate where (i) an outcome funder wishes to transfer some of the operational risk of implementing a project, and (ii) outcomes are clear and measurable, and can provide clear evidence as to the effectiveness of the program. Most importantly, the product structure can result in profitable returns on investment for the investor and value for money for the project sponsor.

### 4.4.1. Objectives

The impact bond for resilience aims to promote the physical, operational, and financial resilience of essential services. These components can be broadly defined as follows:

- **Physical resilience – ability of buildings to withstand impacts of natural disasters**. The physical resilience of a structure can be increased through:
    - Installation of retrofit measures (e.g. bolt and braces, roof anchors, opening protection)
    - Construction of green or grey infrastructure to reduce the hazard (e.g. coastal defences)

- **Operational resilience – ability of service provider to ensure delivery of quality services.** Operational resilience can be increased through a range of risk management practices, including:
    - Design and implementation of pre-arranged disaster response and contingency plans
    - Use of early warning systems

- **Financial resilience – rapid and reliable access to sufficient funds to support costs of response, recovery, and reconstruction following disaster.** Financial resilience can be addressed using a range of mechanisms, including:
    - Separately held and managed capital reserves
    - Traditional indemnity-based insurance
    - Parametrically triggered funds, sourced through (re)insurance or capital markets

Clearly defined performance indices are assigned to each of these components of resilience. The investor is financially incentivised to deliver a successful project – this aligns with the outcome funder's objectives of increasing the resilience of essential services, and objectively quantifying the impact of their investments.

### 4.4.2. Motivation

Impact bonds offer a number of distinct potential advantages over more traditional financing mechanisms.

- The structure explicitly creates aligned incentives across its stakeholders. All stakeholders are motivated for the DIB to result in the overall outcome of increased resilience, be this for financial gain, or to mitigate the severity of future shocks, thereby reducing the impact on services and the financing required for recovery.
- Outcome-led project design offers a targeted approach to building resilience. Projects managed under this structure have clear definitions of success from the start and have pre-defined mechanisms for assessing project performance.
- The additional initial costs of building resiliently are transferred to a party who is willing and able to bear these costs (the impact investor), and to realise a return on investment on a rolling annual basis.
- The impact bond acts to partially transfer the operational risk of implementing a resilience project away from the project sponsor. This is a useful feature for donors, who are motivated to invest efficiently in projects that achieve their desired outcomes.
- Well designed performance indices are valuable in their own right, as a means of demonstrating that investments have been impactful.
- The payments made by an outcomes funder can offer an attractive return for an investor, while still being considered good value for the sponsor, when the costs are compared to the magnitude of immediate impact and future savings.

### 4.4.3. Structure

A generic structure for an impact bond for resilience is described within this section, including the roles and responsibilities of involved parties, project phases, example performance indices, and the role of insurance within the structure. An applied example of the impact bond in a defined use case is presented afterwards – this includes definition of the use case, the results of risk, resilience, and cash-flow analyses, and a commentary on the applicability of the product in this instance.

#### *Roles and Responsibilities*

The generalised roles and responsibilities of the parties involved in the product are as follows:

- **Outcomes funder (e.g. donor[12])** – designs structure of the impact bond and repays the bond at defined intervals. They structure the return on investment is a function of; (1) the initial loan amount, and; (2) performance indices which reflect the 'success' of the project.

- **Impact investor (e.g. UBS Optimus Foundation[13])** – provides capital and carries out project using an implementation agent. The impact investor is financially incentivised to carry out a project that performs well against its defined objectives. The investor stands to make a loss if the project performs poorly against the defined performance indices.

- **Implementation agent (e.g. Build Change[14])** – acts on behalf of the impact investor to implement project locally. Responsible for ensuring that outputs are carried out effectively, and that outcomes are maximised.

- **Insurance provider** – structures and supports insurance products that provide coverage for the physical assets, operational costs of disaster, and investor cash flows as required.

[12] https://assets.publishing.service.gov.uk/media/57a0896b40f0b64974000092/DIB_Study_Final_Report.pdf
[13] https://www.ubs.com/microsites/optimus-foundation/en/stories/development-impact-bond-in-education.html
[14] http://www.buildchange.org/programs/safeschools/

### *Phases*

There are a number of analogous pilot projects that have been completed to test the impact bond concept in a range of use cases. The actual content and sequence of tasks is likely to be variable between projects, but might include the following:

1. Outcome funder agrees impact bond structure with impact investor, including defining; (i) project objectives; (ii) outputs and outcomes with associated performance indices and ROI credits, and; (iii) task and repayment schedule.
2. Impact investor engages with implementation agent to design project plan.
3. Impact investor purchases appropriate insurance coverages.
4. Implementation agent coordinates across local service providers, construction and planning firms, insurance providers, disaster planning agencies etc. to implement the project and deliver against the defined outputs and outcomes.
5. Outcomes funder independently audits the outputs and outcomes at defined intervals during the term of the bond.
6. Repayments are made based on the work completed, and the success of the project according to the performance indices.

Upon completion of the bond term, final payments are made, and responsibility for the asset insurance, maintenance, disaster response and contingency plans pass to the authorities responsible for the assets and service provision.

### *Performance Indices*

The physical, operational, and financial components of the project each have their own performance criteria, with associated outcomes/outputs. Performance is measured against the target outputs and outcomes – the performance across multiple criteria determines the return on investment for the impact investor. The applied use case helps to shape what elements of physical, operational, and financial resilience are appropriate to the product structure. Criteria and performance indices can be deigned to support project needs (Table 1).

| Component | Criteria | Description | Options (situation dependent) | Output Example (action-based) | Outcome Example (result-based) |
|---|---|---|---|---|---|
| Physical Resilience | Construction and/or Retrofit | Building physical resilience to hazard can be achieved though; (i) designing and constructing disaster resistant structures, and/ or; (ii) retrofitting existing structures to become more resistant to damage. | Complete construction, or retrofit, depending on situation. | Increase the wind resistance of the structure by X % at a wind speed of Y mph (equivalent to an annual return period of Z years). Assessed using engineering and modelling assessments. | Engineering audit to assess implementation during construction, and upon completion. |
| | Maintenance | Maintenance involves the ongoing monitoring and repair of structural degradation through time, this is required to ensure physical resilience is maintained to initial levels. | | Carry out site monitoring and maintenance exercises on a 6-month recurring schedule across the term of the bond. | |
| Operational Resilience | Disaster/ Contingency Planning | The resilience of services is strongly dependent on the strength of plans that are made prior to disaster occurring. Contingency plans will include preparing for provision of services assuming structures have been damaged, and usual resources are compromised. | Disaster response plans can be assessed according to expert review, and/ or through scenario-based exercises. | | Demonstrate that suitable plans and resources are in place to ensure continuity of service provision following disaster. |
| | Continuity of Services | In addition to increasing the resilience of services in the face of external shocks, high quality services must remain available for the duration of the construction or retrofit phases - resilience projects should not disrupt service provision. | Qualitative and/ or quantitative assessment of continuity of service. | | No deterioration in educational outcomes when compared with the previous 3 years while construction or retrofit phase is in progress. |
| Financial Resilience | Asset Insurance | The underlying physical assets should be insured, so that financing is available for complete repairs following damage. | Insurance can be paid for by asset owner/ service provider/ government/ donor/ investor. Insurance can be arranged separately to the impact bond or included within it. | Demonstrate that appropriate levels of insurance are in place for the underlying asset. | |
| | Pre-arranged Financing | Appropriate financing mechanisms should be in place to support immediate disaster response needs and contingency plans. | Reserved funds, or parametrically triggered relief funds. Funds can be sourced privately, or from the insurance, reinsurance, or capital markets. | Demonstrate that suitable financing will be available to support disaster response plans. | |

**TABLE 1** OVERVIEW OF POTENTIAL PERFORMANCE CRITERIA FOR IMPACT BOND

### *Insurance*

There are a number of roles for insurance within the impact bond structure, both in increasing the financial resilience of the essential services and protecting the investors potential returns. The insurable elements within an impact bond for resilience include:

- **Physical assets** – even structures which have been retrofitted are at risk of damage – it is important that there are sufficient funds to cover costs of repair and reconstruction following impact from a disaster. If an event occurs during the term of the bond and there are no funds available for repair and reconstruction, then the impact bond is subject to significant risk of failure. The service provider, impact investor, and outcomes funder are therefore all incentivised to ensure that asset insurance is in place. Depending on the situational context, there are multiple options for insurance of the underlying assets, including:
    - Insurance premium paid by the service provider or outcomes funder as a pre-condition to the impact bond. From a sustainability and efficiency perspective, it may be most efficient for the asset owner to purchase insurance coverage.
    - Insurance sourced through local insurance markets, or international reinsurance/ capital markets
    - If no insurance is in place for the asset initially, then insurance purchase by the impact investor can be included as an output of the impact bond. This insurance is taken out on the behalf of the asset owner – the investor is compensated using a return applied on the cost of insurance.

- **Operational costs** – capital is required to implement disaster response and contingency plans, both immediately following disaster, and over the longer term following more severe events. Risk transfer and insurance mechanisms are ideally placed to supply this short-term, rapid, reliable liquidity and long-term capital if an event does happen. Funds for operational costs must be reliable, and rapidly accessible following disaster. There are a range of options for this type of fund, the appropriateness of each depends on the magnitude of the capital required, and the local situational context. These options include:
    - A disaster fund, managed and held by any of the involved parties – the most sustainable option over the long term would likely be for the fund to be managed locally by the service provider
    - Parametric risk transfer, using the reinsurance or capital markets. When designed well, parametrically triggered funds can be efficient in delivering capital rapidly.
    - The impact bond can include cover of operational costs as an output

- **Future cashflows** – when included as outputs, the impact investor is incentivised to provide coverage for the physical assets and operational costs. However, even when these measures are taken, if an event occurs during the term of the bond then performance indices are likely to be negatively impacted, and the future returns on investment reduced. It may be possible for the impact investor to take out insurance against their invested capital and future potential cashflows.

The impact bond for resilience presents an opportunity to create an insurance product that provides coverage across each of these needs, where all insurable elements would be packaged under the same product. The specific needs will vary distinctly between individual projects, so a flexible modular insurance product would be required if it were to be easily replicated across different impact bonds.

### *Product Schema*

Figure 19 presents a product schema, which highlights the relationships between involved parties, and the direction of cash-flows between them.

In this example, the project timeline runs for 5 years, the vertical arrows show the direction and timing of payments between parties, including two hypothetical events which occur within the term of the bond, and the associated insurance payments.

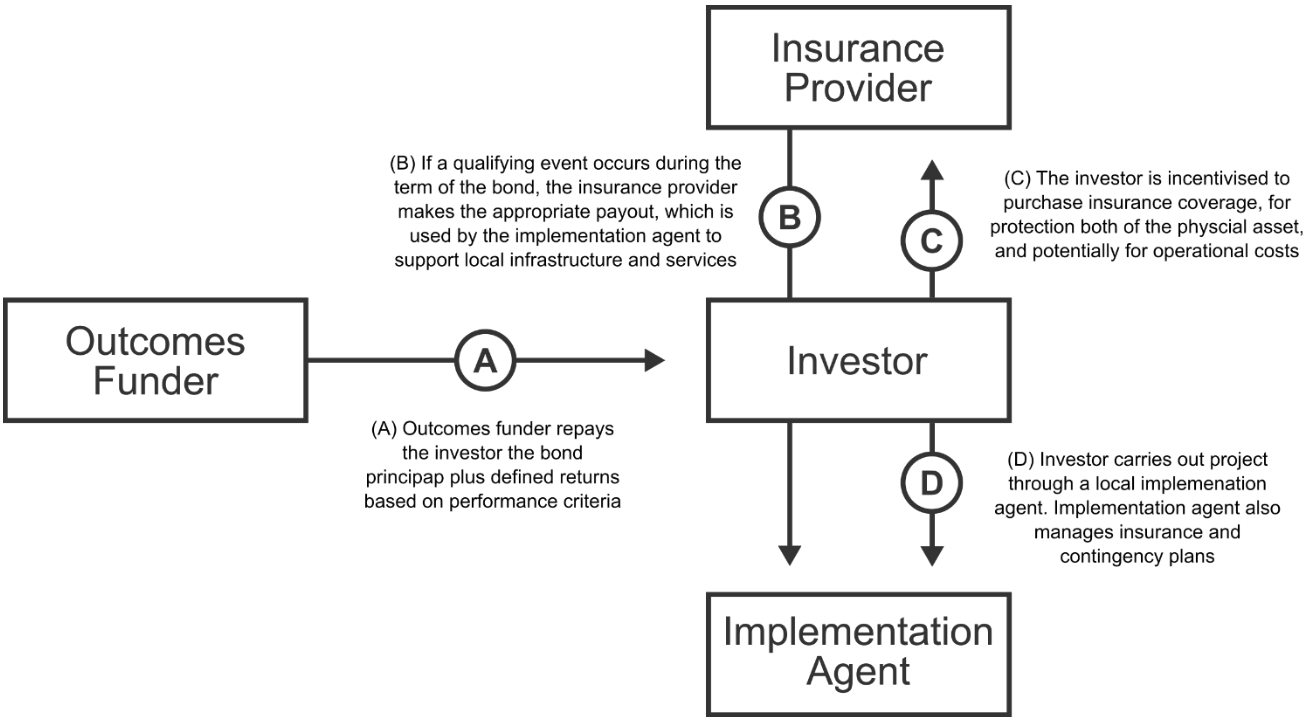



**FIGURE 19** PRELIMINARY SCHEMA FOR RESILIENCE IMPACT BOND (RIB)

## *4.4.4. Applied Example: School Retrofit Program*

The resilience impact bond is applied to a theoretical use case, highlighting how it might be used to increase the resilience of education services in Dominica though a program of school retrofit, and disaster response and contingency planning.

### *Situational Context*

The following use case has been designed to interrogate the applicability of resilience impact bonds in a hypothetical, but real-world setting. The costs and risk information contained in this analysis are reasonable for the defined use case, however, results are likely to vary significantly between use cases.

The uncertainty in results with respect to this use case have been presented (e.g. mean, standard deviation metrics) – to give a sense of the uncertainty within this modelling, but it should be assumed that results will vary for different combinations of exposure, peril-region, assumptions, or risk models. Modelling should therefore be updated if the product is to be applied in a different context.

### *Summary of Use Case*

- For ten existing schools located across the island of Dominica, the outcomes funder wishes to increase the resilience of school infrastructure and education services to hurricane risk.
- The resilience program has multiple components, which are intended to address the physical, operational, and financial components of resilient systems:
    1. Wind retrofit program to upgrade the structural resistance to wind damage
    2. Implementation of disaster response and contingency plans to ensure continuity of service following disaster
    3. Establishing suitable funding mechanisms for transfer of excess wind risk, and to support disaster response and recovery costs
- The term of the bond is 5 years, resilience measures will be implemented across the portfolio of schools throughout this period, and the performance indices will be measured at defined intervals (e.g. yearly) throughout the project, as appropriate.
- The existing school infrastructure is uninsured.
- No retrofit measures or contingency plans are in place, and there is no existing funding to support the costs of deploying contingency plans following disaster.

| Analysis Component | Assumption | Notes | Source |
|---|---|---|---|
| Modelling | Region | Dominica - schools distributed islands districts. | RMS |
| | Peril | Hurricane - wind only | RMS |
| | Base school construction | Construction Type: Masonry, Occupancy Type: Education, Year built: 1995, Number of Stories: 2 | RMS |
| | Base value of school buildings | $10 million total, $1 million per. unit. Construction costs are expected to vary, though the additional costs of retrofit and the risk are assumed to scale linearly with base value, so all metrics scale linearly and cost benefit ratios are conserved with changes in base structure value. | RMS |
| | Additional retrofit measures | Roof Sheathing, Roof Covering, Opening Protection | RMS |
| | Additional cost of retrofit | +5.9% on top of base structural value assumption - equivalent to $590k for a school portfolio of $10 million | RMS, National Institute of Building Sciences[15] |
| | Model version | RMS North America Hurricane Models v17.0, wind model (vintage 2017). Long-term Rate (LTR) perspective. | RMS |
| Economics | Bond term | 5 years | Typical duration for impact bond pilot projects |
| | Low interest rate | 1.5% (near risk-free, below market rate) | 5-year UK treasury rate (1.10%) + a small premium (40bps) |
| | High Interest Rate | 15% | Similar to high return rate on existing pilot stage development impact bonds |
| | Discount rate | 3.5% | Green Book Long Term Discount rate, 0-30 years |
| | Insurance load factor | 2x Pure Premium for indemnity-based insurance; 1.5x Pure Premium for parametric insurance | Sensitivity Assumptions |
| | Maintenance cost per. year | 2% of base value | Kaiser, Harvey H., Capital Renewal and Deferred Maintenance Programs, The Association of Higher Education Facilities Officers (APPA), 2009, p9. |

**TABLE 2** MODELLING AND ECONOMIC ASSUMPTIONS USED FOR ANLAYSIS

[15] https://www.nibs.org/general/custom.asp?page=mitigationsaves

### *Risk Analysis Results*

RMS has carried out a risk analysis to quantify the hurricane wind risk to the hypothetical portfolio of school buildings in Dominica. The base view quantifies the risk as if no retrofit measures have been installed, the resilient view quantifies the reduced risk that would occur if the range of resilience measures were installed.

The retrofit options that have been assessed for this analysis are upgrades to the roof sheathing and covering[16], and additional opening protection[17]. These are retrofit measures that can be applied to existing school infrastructure. The costs of implementation are typically related to the overall base value of the asset – the building and retrofit cost assumptions have been derived from internal RMS expertise and additional research.

Costs are expected to vary by region, although relative costs and risk reductions will be largely conserved, so results from this section can help to inform expected results in other regions.

| | Costs (% of Building Value) | | | | Value | |
|---|---|---|---|---|---|---|
| Construction | Roof Sheathing | Roof Covering | Opening Protection | Total | Total Insurable Value ($ million) | Additional Cost ($ million) |
| Base | - | - | - | - | 10 | - |
| Retrofit | 0.40% | 1.50% | 4.00% | 5.90% | 10.59 | 0.59 |

**TABLE 3** CONSTRUCTION AND RETROFIT COST ASSUMPTIONS

The following 'retrofit' risk results assume that all retrofit options described in Table 3 have been implemented to the 'base' school construction. The risk and resilience metrics presented in Table 4 show that on average, annual losses are expected to reduce by 46% as a result of retrofitting. It is theoretically possible to monetise this risk reduction through savings on insurance premium.

| | Average Annual Loss | | | Loss Cost | Resilience Metrics | | Premium |
|---|---|---|---|---|---|---|---|
| Construction | Absolute ($) | Standard Deviation ($) | Reduction (%) | (AAL*1k/Value) | Resilience Ratio | Benefit-Cost Ratio | (2x Technical Loading Factor) |
| Base | 43,633 | 308,764 | - | 4.36 | - | - | 87,265 |
| Retrofit | 23,502 | 187,553 | 46% | 2.35 | 29.31 | 0.03 | 47,004 |

**TABLE 4** RISK REDUCTION AND RESILIENCE DIVIDEND METRICS

A combination of the high base risk (loss cost of 4.36) and the large risk reduction (46%) contribute to a high potential resilience dividend in this example.

16 https://www.fema.gov/media-library-data/20130726-1706-25045-9347/chapter8.pdf

17 https://www.fema.gov/media-library-data/20130726-1707-25045-9020/chapter10.pdf

### *Hurricane Wind Risk Model Results*

Figure 20 presents loss-based exceedance probability (EP) curves. The EP curves incorporate secondary uncertainty, which is a model estimate of the uncertainty that exists within the risk analysis. Note that the model also incorporates an estimate of post-loss amplification (PLA), which can result in total event losses that exceed the total value of the school portfolio.

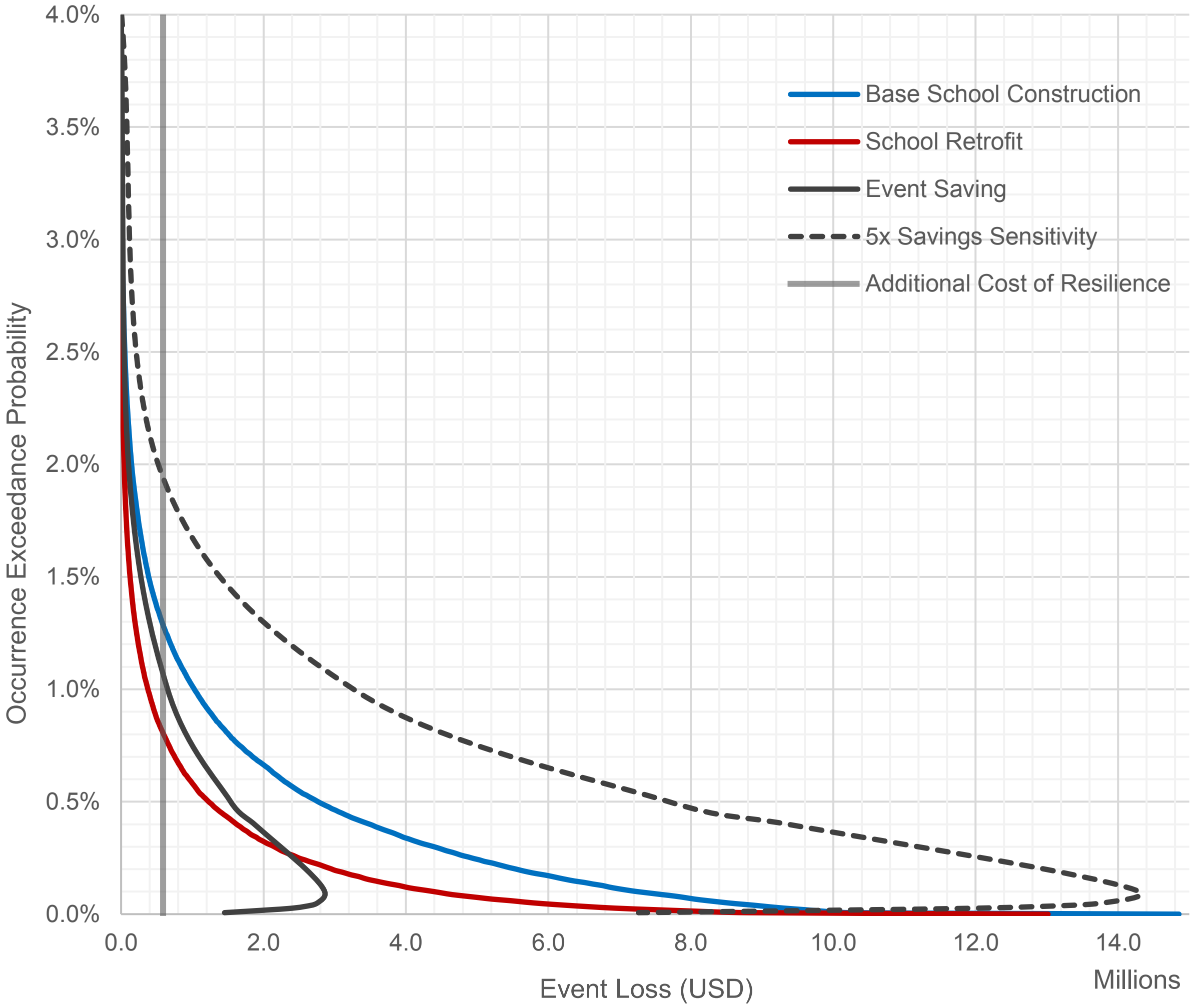



**FIGURE 20** LOSS OCCURRENCE EXCEEDANCE PROBABILITY CURVES FOR BASE AND RETROFIT CASES, AND FOR EVENT SAVINGS (INLCUDING 5X SAVING SENSITIVITY TO REPRESENT NON-DIRECT BENEFITS)[18] .

As is expected from the convergence of the base and resilient vulnerability curves at high wind speeds, the absolute event savings decrease for more severe events (the 'tail' of the distribution). However, given the scale of these losses, the absolute event savings are still greater than the additional cost of resilience for all events with an annual probability in excess of the 1 in 100-year return probability (RP100, 1% EP).

A sensitivity is included to demonstrate how the event savings EP curve would look if additional non-direct event savings are included. The 5x sensitivity represents an assumption that for every dollar saved in direct damage,

[18] Note that the event savings, and sensitivity curves are not strictly exceedance probability curves, but rather represent the difference in loss between the base and resilient EP curves across the range of probabilities. They demonstrate that there the event savings are relatively reduced in the tail of the distribution.

$4 are saved in additional costs[19]. The result of this sensitivity shows that the point at which the event savings are equal to the additional cost of retrofit changes from approximately RP100 to RP50.

Additional benefits of resilient infrastructure include reduction in injury and loss of life, reduced impact to essential services and livelihoods, reduced impact on quality of education and the long-term societal and economic benefits that result. The financial benefits of these elements have not been captured explicitly in this analysis since they are less well able to be monetised. However, it is fair to assume that the savings on direct damage and loss represent the lower bound of the total event savings that are expected as a result of increasing structural resilience.

### *Summary of Risk Analysis Results*

- Retrofit generates significant risk reduction on an annual average perspective (46% reduction in AAL).
- This risk reduction can be monetised through reduction in insurance premiums, benefit-cost ratios are expected to increase after application of technical pricing formulae.
- The relative benefit of retrofitting decreases in the extreme tail (in excess of RP1000), though large magnitude of loss for these tail events still yields event savings that are large relative to the cost of retrofit.
- From a direct loss perspective, there is approximately a 1% annual probability of an event occurring in which the saving as a result of retrofit is greater than the cost of retrofit.
- However, on average, the annual reduction in risk as a result of retrofit is significant, and from a pure risk-based perspective, the annual average risk reduction would cover the additional costs of resilience after ~30 years.
- When the pure premium is transformed into a technical insurance premium, the absolute annual savings increase, and the effective payback period is expected to reduce. For example, if there is a straight premium loading of 2x on average annual loss, the higher premium results in a greater saving, so the effective payback period would reduce from 30 to ~15 years. The amount spent on insurance premium is also commensurately higher.]
- The results support the need for a range of measures to manage the wind risk – including retrofit to reduce the overall severity of impacts, and risk transfer to help manage the excess risk.

### *Cash Flow Analysis*

Vivid Economics has carried out a cash flow analysis to illustrate how the impact bond structure would operate in the applied example. The performance of the bond is quantified for a range of scenarios. The scenarios describe a range of possible situations, in which the impact investor either completes, or fails to deliver, against the determined performance criteria (outcomes and outputs). The scenarios also describe the investor and outcome funders net present value adjusted return on investment (ROI), assuming that events of varying magnitudes occur within the term of the bond.

The cash flow analysis is carried out from perspectives of the impact investor and outcome. Returns are a function of work completed, performance against criteria, expected operational costs of disaster, and whether the bond runs to completion.

Note that the additional costs of implementing the resilience impact bond have not been quantified and are not included within the cash flow analysis, neither are any additional costs to the outcome funder.

[19] Natural Hazard Mitigation Saves: 2017 Interim Report

### *Overview of Cash Flow Analysis*

- Impact investor funds 100% of the investment and is remunerated by the outcome funder over a period of 5 years (bond term).
- The resilience program is carried out simultaneously across all 10 schools, phasing is at the discretion of the investor, though they are incentivised to carry out work efficiently.
- The criteria for success are a mix of outputs (low risk) and outcomes (high risk). Performance criteria outlined in Table 5.
- Criteria are binary in this example, i.e. the investor receives nothing if they fail to meet the required standard, 100% of invested capital + return if they successfully fulfil the pre-agreed criteria.
- Low rate of return applied to low risk physical tranche, which is an output almost exclusively dependent on the investor's ability to design, implement and maintain pre-agreed measures to the required resilience level.
- Operational resilience tranches are riskier in terms of investor's ability to meet the required outcomes. They are therefore remunerated at the high rate of return (15%).
- Financial resilience (asset insurance and relief funds) are critical elements of the structure and are therefore also remunerated at a high rate of return (15%).
- Asset insurance is a pre-condition for the bond in this example. The impact investor therefore benefits directly from any insurance savings.
    - The alternatives would be (i) for the schools to pay for asset insurance coverage, or (ii) for the outcome funder to purchase asset insurance.
    - The most sustainable and efficient arrangement may be for the asset owner to hold the insurance. If this was the case, then the impact investor would still receive a return on resilience through the payments made by the outcome funder, but the asset owner would benefit from reduced insurance costs.
- A 30% share of physical resilience capital is retained for maturity (5 years) if all operational resilience conditions are jointly satisfied by the investor;
- Cashflows are modelled by estimating the annual cost of various resilience measures and applying a return (high or low) on this cost.
- Discounted cashflow model applied over the term of the impact bond to compute the net present value of future return (capital + interest) with the net present value of cost.
- 11 scenarios are modelled. These are non-exhaustive: given the complexity of the structure, they aim to capture the key scenarios from the perspectives of the outcomes funder and investor and demonstrate the range of potential returns.
- The scenarios are ordered to illustrate the sensitivity of the structure to; (i) extreme event risk, and; (ii) failure to complete some or all of the criteria.
- For any event above 175mph, the bond is reimbursed immediately – it "converts". Given the extent of damages and the investor's capital at risk (value of retrofit), it is unrealistic to expect investors to continue services or deploy a sufficient disaster relief plan. From this perspective, the structure is a mix between an impact bond and a Resilience Bond. Tail risk events are therefore borne by the outcome funder. The outcomes funder can choose to insure against this event in order to protect their capital outlays and the school services in an extreme event.
- The speed of retrofit is at the discretion of the investor and has to be completed over 5 years. They are incentivised to complete it quickly since; (i) a large share of their initial investment (70%) is returned as retrofit measures are completed, and; (ii) the price of insurance decreases as risks are reduced, which generates further savings for the investor (insurance rebate).

| Resilience Type | Criteria | Credit | Objective | Output Criteria (action-based) | Outcome Criteria (result-based) | Options and Notes |
|---|---|---|---|---|---|---|
| Physical Resilience | Retrofit | 1.5% | Implement retrofit measure that increases the wind resistance of the school building. | - | Reduce expected MDR at 140 mph by 50%. Damage reduction independently assessed at design stage, and after installation. Potential to 'outperform' against criteria. | The resilience metric is dependent on the specific measures implemented. A combination of engineering assessments and risk modelling should support definition of this metric on a case by case basis. |
| | Maintenance | 1.5% | Sustain resilience benefits of retrofit. | Demonstrate that the installed retrofit measures have been inspected and are fully operations at defined intervals across the term of the bond (annually and following major wind events). | - | Option to establish a maintenance function, which would support maintenance over the long-term following completion of the 5-year program. |
| Operational Resilience | Disaster Planning | 15% | Ensure there are adequate disaster response and contingency plans for provisions of service following an event. | - | Demonstrate that comprehensive plans have been designed – use scenario-based drills to test that defined disaster response plans are adequate for a range of event severities. | If maintenance function is established, option to include responsibility for disaster and continuity planning under the same function. |
| | Continuity of Services | 15% | (i) Decrease the potential impact of shocks on service provision, and (ii) ensure that the retrofit program does not negatively affect education services. | - | No deterioration in educational outcomes versus the previous three years prior to the start of the retrofit program or following a hurricane. | Depending on the data that is available to establish a baseline metric for prior quality of service provision, a range of qualitative and quantitative assessments can support measurement of this outcome. |
| Financial Resilience | Asset Insurance | Pre-requisite (return made on premium savings) | Ensure that there is sufficient insurance coverage to support costs of school reconstruction following damage. | A pre-condition for beginning the retrofit program. Demonstrate that the schools are covered by adequate insurance policies, which reflect the risk assuming no resilience measures. | - | Options: (i) Indemnity asset insurance is a pre-condition for the bond, remunerated at a high rate of return - investor retains any insurance savings. (ii) It would be more efficient, and therefore less expensive for the outcomes funder or to purchase this insurance. |
| | Disaster Relief Funds | 15% (only achieved if both asset insurance and relief funds are in place) | Ensure that there are sufficient funds to cover the operational costs of implementing disaster plans. | Demonstrate that there is access to funds that are sufficient to cover 'worst-case' scenario (defined as 175 mph event). Options include a separately held and managed fund, or parametrically triggered insurance. | - | Options: (i) Investor holds sufficient capital in a special purpose vehicle (SPV). (ii) Wind stations are installed, and parametric insurance is structured to provide variable payouts for a range of event severities, this may be more sustainable over the long-term, after the bond has terminated. |

**TABLE 5** APPLIED IMPACT BOND PERFORMANCE CRITERIA

| | | Positive Investor Return on Investment | | | | |
|---|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
| **Resilience Type** | **Criteria** | **Best case (no major disaster during term of the bond), investor fulfils all criteria** | **90mph event occurs in year 3, causing 3.3% damage to non-resilient schools, and 1.7% damage to resilient schools** | **140mph event occurs in year 3; causing 31% damage to non-resilient schools and 14.6% damage to resilient schools. Investor deploys disaster relief plan for 1yr period, after which the bond matures.** | **160mph event occurs in year 3 causing 52% mean damage to non-resilient schools and 36% damage to resilient schools. Investor deploys disaster relief plan for 1yr period, after which the bond matures.** | **Scenario - Disaster strikes in year 3 (180 mph) causing 73% mean damage to non-resilient schools and 64.2% damage to resilient schools. Bond matures immediately - no continuation of services is required or realistic.** |
| Physical Resilience | Retrofit | Y | Y | Y | Y | Y |
| | Maintenance | Y | Y | Y | Y | Y |
| Operational Resilience | Disaster Planning | Y | Y | Y | Y | Y |
| | Continuity of Services | Y | Y | Y | Y | Y |
| Financial Resilience | Asset Insurance | Y | Y | Y | Y | Y |
| | Disaster Relief Funds | Y | Y | Y | Y | Y |
| Investor's ROI (%) | | **18.3%** | **12.3%** | **7.5%** | **6.9%** | **7.0%** |
| Payments by Outcomes Funder (NPV) | | **$1,196,912**[20] | **$1,196,912** | **$596,252** | **$596,252** | **$492,954** |
| Insurance Payments (NPV) | | **-** | **-** | **$173,579** | **$230,888** | **-** |

**TABLE 6** CASH FLOW SCENARIOS WHICH YEILD A POSITIVE INVESTOR ROI.

[20] Note that in this example the bond is designed to pay for the cost of retrofit, which are to be applied to existing school infrastructure (the notional value of the 10 schools is $10 million total).

| Resilience Type | Criteria | Negative Investor Return on Investment | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Scenario 6** | **Scenario 7** | **Scenario 8** | **Scenario 9** | **Scenario 10** | **Scenario 11** |
| | | **Scenario - no major disaster until maturity, investor puts together disaster relief plan, but it is judged insufficient; fails at education criteria, losses retained initial investment of 30%** | **Scenario - no major disaster until maturity, investor fails at financial resilience (both asset insurance and parametric coverage for disaster relief), losses retained initial investment of 30%** | **Scenario - no major disaster until maturity, investor fails at part of financial resilience - asset insurance, losses retained initial investment of 30%** | **Scenario - no major disaster until maturity, investor fails at part of financial resilience - disaster relief-related financial resilience (in this case parametric insurance), losses retained initial investment of 30%** | **Scenario - no major disaster until maturity, investor fails against all operational resilience criteria, foregoes all of the high return tranche, losses retained initial investment of 30%** | **Scenario - investor fails at physical resilience in year 1, steps out of the project to avoid further cumulative losses and losses all costs incurred in year 1** |
| Physical Resilience | Retrofit | Y | Y | Y | Y | Y | N |
| | Maintenance | Y | Y | Y | Y | Y | N |
| Operational Resilience | Disaster Planning | N | Y | Y | Y | N | N |
| | Continuity of Services | N | Y | Y | Y | N | N |
| Financial Resilience | Asset Insurance | Y | N | N | Y | N | N |
| | Disaster Relief Funds | Y | N | Y | N | N | N |
| Investor's ROI (%) | | **-11.6%** | **-19.0%** | **-17.7%** | **-4.8%** | **-27.8%** | **-43.9%** |
| Payments by Outcomes Funder (NPV) | | **$846,268** | **$519,253** | **$566,178** | **$919,170** | **$399,424** | **$137,305** |
| Insurance Payments (NPV) | | **-** | **-** | **-** | **-** | **-** | **-** |

**TABLE 7** CASH FLOW SCENARIOS WHICH DEMONSTRATE THE RETURN ON INVESTMENT, AND COST INCURRED TO THE OUTCOME FUNDER, BASED ON SITUTATIONS IN WHICH THE PROJECT FAILS TO DELIVER AGAINST THE DEFINED PERFORMANCE CRITERIA.

### *Results of Cash Flow Analysis*

**The investor stands to make significant positive returns on their investment when they fulfil all criteria and no or very minor disaster events occur.** The cash flow outcomes should the investor meet all criteria under a range of disaster scenarios is presented in Table 6. Scenario 1 presents the easily interpretable 'base case' – here all criteria have been met and no disaster occurs over the course of the bond, in which case the investor stands to make a return of 18.3% on their invested capital. Under scenario 2, a minor event occurs which does not trigger the insurance payout and is not damaging enough to trigger early maturity of the bond. The investor will need to pay for the damages to the school from their own funds, which will reduce their overall ROI to 12.3%. They will be financially incentivised to carry out these repairs as, by contrast, failing to meet the 'asset insurance' criteria of the project will lead to them earning a negative ROI.

**When all criteria are met but tail-end events occur, insurance covers the damage to the asset and the bond matures early – the ROI to the investor in these cases is lower due to early maturation but still positive.** Scenarios 3 and 4 detail cases where high-intensity disaster events occur but which are still within the range where insurance will cover the damages that arise due to the event. The insurer covers the cost of damages to the asset rather than the investor and the bond ends prematurely as repairs will need to be carried out on the asset. The investor implements their disaster plan but overall earns a slightly lower ROI (around 7%) as a result of this early maturation.

**Insurance transfer risk away from the outcomes funder.** Scenarios 3 and 4 also illustrate the benefits for insurance in this type of instrument: if instead of taking out insurance the investor is expected to repair damages to the asset, it would require a substantial payout from the outcomes funder to correctly incentivise the investor to carry out those repairs, potentially an order of magnitude larger than the investor's original investment. For example, in scenario 3 - where a 140mph event strikes in year 3 when 40% of schools have been made resilient – the investor receives a total of $378,322 from the outcomes funder for having taken out insurance. By contrast, the event causes damages to the resilient schools of $582,400 and the non-resilient schools suffer damages of $1,865,400, a cost that would need to be made by the outcomes funder to the investor in order to ensure that the investor would not rather exit the structure.

**Should the investor fail to meet all criteria they will earn a negative ROI – a range of scenarios where various criteria are not met is are presented in Table 7.** These scenarios help to illustrate that an investor would be financially incentivised to perform well on the project and meet the criteria as the result of any criteria not being met is a negative ROI for the investor. In other words, the payment structure monetises the resilience dividend for the investor. Of particular interest is scenario 8 which shows the case where asset insurance is not provided by the investor. When insurance is a criteria, there is clear incentive for the investor to procure insurance and protect the asset from disaster risk. As discussed previously, if the defined criteria was to carry out repairs should an event occur the investor may either choose to fail the project and not repair the asset or the outcome funder could be burdened with an extremely large payout to correctly incentivise repairs.

### *Product Evaluation*

| | | | |
|---|---|---|---|
| Encourages resilient infrastructure | ✓ | Has a viable path to implementation | ✓ |
| Monetises resilience dividend | ✓ | Offers flexibility | ✓ |
| Makes resilience dividend available upfront | ~ | Has a sound economic justification | ✓ |
| Involves risk transfer | ✓ | Causes ‘no harm’ | ✓ |

**A. Encourages resilient infrastructure**

- The product promotes resilient infrastructure as one component of building resilient services. The performance criteria are explicitly linked to resilience outcomes, and the overall structure creates alignment between the outcomes funder (project sponsor) and the investor, who is financially incentivised to deliver a project that increases the resilience of the underlying infrastructure, and the services it supports.

**B. Monetises resilience dividend**

- The resilience dividend is monetised twofold:
  - The investors return on investment is linked to the resilience benefit that the retrofit generates. For example, the investor makes an RoI of 18.3% in cases where the resilience measures are fully implemented but makes negative returns in cases where some or all of the resilience measures are not met.
  - the resilience dividend is captured again through reduced asset insurance costs – depending on who purchases the insurance, the savings can pass through to any of the impact investor, outcomes funder, or service provider. This is realised on a rolling basis, as resilience is implemented.

**C. Makes resilience dividend available upfront**

- The resilience dividend is monetised as described above. The structure relies on the credible commitment by the outcomes funder to the investor being sufficient to incentivise the investor to undertake the upfront and other measures that promote resilience. In other words, rather than resilience dividend being provided upfront, it is transferred to an investor who, as a result of contractual commitments with the outcomes-funder, is patient enough to receive the monetised resilience dividend over time. The product therefore does not satisfy the criteria, though this does not restrict the upfront spend on resilience.

**D. Involves risk transfer**

- There are multiple roles for insurance within the resilience impact bond, including; (i) asset insurance for the underlying infrastructure; (ii) parametrically triggered funds to cover the operational costs of disaster, and; (iii) insurance that is intended to provide coverage for the impact investor, so that they can protect future cashflows and expenditures against the risk of disasters impacting the project.

**E. Viable path to implementation**

- Impact bonds and pay-for-performance contracts more broadly, are already being implemented. There are donor funded development impact bond pilots which have tested the structure in a range of scenarios. This paves the way for a resilience impact bond focused on resilience in terms of built experience, further work would need to be carried out to identify a suitable use case for the resilience impact bond.

**F. Offers flexibility**

- The performance criteria can be fully tailored to reflect the desired project outcomes, for a range of use cases. The structure is also fully flexible in terms of the rate of return that is offered for each of the performance criteria, such that outcomes that are more important to the sponsor can be remunerated more highly if desired.

G. **Has sound economic justification**
  - From the perspective of the impact investor, the bonds are remunerated at a rate that is consistent with the risk of non-delivery, impact bonds can therefore offer attractive returns.
  - From the perspective of the outcomes funder, further work would need to be undertaken to assess the value for money of this instrument compared to alternative grant-based structure. In particular, this additional research would need to generate an evidence-based assessment of the probability of the different resilience measures being undertaken through a more convention grant-based funding instruments.
  - It is inefficient to incentivise insurance through this structure, since the remuneration will have to be greater than the total premium cost for it to become an attractive option for the investor. This is why asset insurance is a pre-requisite within the applied example.

H. **Causes 'no harm'**
  - There are in built performance criteria which aim to minimise disruption to services. There is a risk that the resilience measures fail to deliver the desired risk reduction, but appropriate engineering and modelling exercises can help to manage this risk.

## Challenges to Implementation

- **Complexity.** The impact bond for resilience has a significant number of complex and interconnected elements. These include the performance indices themselves, which require a range of bespoke qualitative and quantitative methods for both their design and measurement. If the product is well structured, then there will be little flexibility in determining how well the impact investor has performed against the performance criteria. However, due to the uncertain nature of quantifying resilience benefits, some of the performance criteria are necessarily objective – which introduces the risk that there are disputes over assessment of performance. This risk increases as the number of subjective performance criteria within the product increases. Risky structures become unattractive to investors who are solely interested in financial gain. The scale of the management task also increases with the complexity and scale of the project.

- **Efficiency.** The outcomes funder is motivated to use an impact bond structure for two main reasons (i) the link between investment in resilience and the ultimate event savings can be quantified, and the returns that are offered are understood to be good value for money in this context, and: (ii) impact bonds are a useful tool for monitoring and demonstrating the positive impact of their investment. Within this context, impact bonds can be efficient delivery mechanisms from the perspective of the outcomes funder. However, it is inefficient to use impact bonds to incentivise the purchase of insurance, because the outcomes funder will have to ultimately pay more than they would spend if they paid for the insurance directly. Insurance can therefore be motivated by making it mandatory within the structure (as is the case in the applied example), or, a more efficient option may be for the service provider or outcomes funder to purchase the asset insurance directly.

- **Sustainability.** There is a risk that the responsibility for the resilience of the infrastructure and services falls too heavily on the impact investor and outcomes funder during the term of the bond. Retrofit measures, disaster plans, contingency funds, and asset insurance all need to be ultimately maintained by the service provider and asset owner. The long-term resilience of the infrastructure and services depends on how well the responsibility for the risk is transferred upon completion of the bond.

## 4.5. Detailed Analysis – Insurance-Linked Loan Package (ILLP)

**Primary Objective:** To incentivise resilient infrastructure and financial resilience through insurance savings within an integrated loan and insurance product.

### 4.5.1. Overview

This approach, requiring only small modifications from current practice, proposes a solution that explicitly integrates risk transfer solutions into the (concessional) loans provided by international financial institutions intended to either (i) finance new infrastructure where a resilient design alternative exists or (ii) fund retrofit or infrastructure upgrade programs.

Resilience can be incentivised by reduced upfront costs of insurance and/or by offering more favourable lending terms (implemented by use of a conditional grant element delivered by a donor) upon demonstration that identified resilience measures have been delivered. The flexibility of the structure also allows for the provision and funding of maintenance.

**Resilience Incentive**: Saving on insurance premiums can be made available for reinvestment in resilience, either upfront by allowing expected future savings to be repurposed or withdrawn or over time as savings are realised.

**Insurance Element:** A portion of the loan is earmarked for the provision of insurance. In order to allow disbursal of funds within the early years of the loan, this capital is held and managed in a separate resilience fund for the lifetime of the loan in order to meet future premium payments. This fund could take one of a number of forms, depending in part on the level of donor involvement, including a returnable grant from a donor placed into a trust fund or a Special Purpose Vehicle (SPV). Pricing assumes that resilience measures provided for in the loan are successfully implemented, subject to pre-agreed checks. With resilience measures in place, the premium is lower for the duration of the loan, providing a 'dividend' to the asset owner that can at least partially offset any cost of implementing resilience. Dependent on scale, insurance cover could be sought through multi-year contracts or capital markets placements, with the ability to reset contracts and re-assess the underlying risk and subsequent premium at regular intervals.

**Use Case:** Suitable for financing build from scratch or upgrade/retrofit of critical infrastructure where ongoing resilience to disaster is crucial.

### 4.5.2. Motivation

Potential exists for the successful development and implementation of standalone multi-year insurance contracts or alternative risk transfer mechanisms, designed to reflect future expected risk reductions from investment in resilience in premium reductions. Wrapping such a product into an infrastructure financing loan from an international financial institution provides the flexibility to monetise the resilience dividend upfront through either reducing the initial loan amount, or more practically allowing the resilience 'dividend' attributed to future insurance payments to be withdrawn from the insurance fund.

It also recognizes the important role already played by these types of loans in infrastructure financing and the opportunity available to further incentivise resilient building and the uptake of insurance. Furthermore, the recipient should be able to benefit from improved access to a range of potential product, technical assistance as well as due diligence and scrutiny by sourcing insurance in conjunction with the loan provider.

***Development Bank Loans and Infrastructure Financing***

Patterns in infrastructure financing sources mean that instruments linked to development bank loans may present one of the biggest and most practical near-term opportunities for innovation.

The contribution of multilateral agencies to ODA for infrastructure financing has been growing in recent years with share of total ODA rising at a rate of 5.7% per annum over 2007-2016, peaking at 45% in 2014 (OECD, 2017c). This has been associated with an increased role for loans rather than grants: 85% of the increase in ODA from multilateral agencies since 2007 was due to a rise in lending.

Development bank financed infrastructure projects typically include insurance during the construction phase, and in some cases during the first couple of years after completion, but no further. Similarly, maintenance is not usually considered beyond the completion of a project. Typical project length is 3 to 5 years and funds need to be fully disbursed during this time. In contrast, loan repayments may be made over a 20-year period or longer.

Projects are scrutinised for viability and conformation with bank standards and aims, including vetting of procurement processes and service providers. Additional site inspections to confirm structures are built to code are not typically included within this process.

Concessionality on bank interest rates beyond established pre-agreed lending terms can be achieved through donor funding channelled via a trust fund, which pays the difference between concessional and non-concessional rates.

**Case Study: Global Concessional Financing Facility (GCFF)**

The GCFF provides development support on concessional terms to middle-income countries impacted by refugee crises across the world (https://globalcff.org/). The GCFF routes donor funds from supporting countries to unlock concessional lending at rates at or closer to those available to IDA eligible countries. Donors fund the concessionality spread - the difference between the IBRD interest rate, used in lending to middle-income countries, and the IDA rate, recalculated on a quarterly basis. The concessionality amount for a given loan is calculated as the net present value of the concessionality spread during the life of the loan, given the financial characteristics of each loan. Donor contributions are allocated to qualifying projects by the GCFF. The Facility allows benefitting countries to access affordable and more sustainable financing.

[21]

[21] Information sourced through communications with the World Bank.

## 4.5.3. Structure

A generic structure for an ILLP is described within this section, including roles and responsibilities of stakeholders, product components and principal cash flows and the form of insurance. In its simplest form, the insurance-linked loan package is an infrastructure financing loan that; (i) includes the additional cost of resilience in the initial notional; (ii) embeds the cost of insurance premium; (iii) monetises the resilience dividend as a result of insurance premium reductions arising from investments in resilience and (iv) holds capital for future premium payments in a separate vehicle.

The product could be targeted at new infrastructure, either large high value single assets or more likely, a portfolio of a larger number of assets representing either a significant construction or retrofit/upgrade program across a country or region.

**Key features**

The initial loan amount equals the total cost of resilient construction plus an amount targeted to cover the future cost of insurance and/or maintenance. The portion of the loan attributable to construction and resilient building costs is disbursed over a time horizon of 3 to 5 years, through standardized procurement and contracting processes with service providers. A separate vehicle such as a trust fund or SPV is required to manage the portion of the loan allocated to insurance, allowing premium payments to be made across the lifetime of the loan whilst permitting full disbursal by the lending entity within the 3 to 5-year disbursement period. This vehicle needs to accommodate variable cashflows through time, i.e. the risk is expected to change across the term of the loan, as are the insurance premium costs. Depending on the level of donor involvement other grant structuring options such as returnable grants may be feasible. This analysis does not extend to a comparison of the cost-benefit of different fund models including associated opportunity costs.

The net present value of future expected premium payments is paid into the resilience fund. The recipient country repays the loan through regular interest payments at pre-agreed lending rates, which may be supplemented to varying degrees by donor funds to achieve the equivalent of concessional lending rates. The roles and incentives of the various stakeholders are outlined in Table 8.

| Stakeholder | Role | Example | Incentive | Challenges |
|---|---|---|---|---|
| **Development Bank** | Provide initial capital | International Bank for Reconstruction and Development, Caribbean Development Bank etc. | Realize a return on investment and achieve development goals | Risk of default on payment and not achieving development goals |
| **Donor** | Funding increased resilience through support of concessional interest repayments | NGO, State | To increase community resilience and the resilience of nations so as to achieve development goals | Managing effective implementation of funds |
| **Recipient** | Funds construction and a component of the additional costs of resilience. Benefits from resilient infrastructure and financial resilience provided by insurance | National/Local Government | Increased resilience and accompanying socio-economic benefits of resilience | Justifying additional spend on insurance and resilient infrastructure |

**TABLE 8** PRODUCT STAKEHOLDERS

A detailed breakdown of the constituent product components to be considered within a cash flow analysis are included in Table 9, accompanied by a product schema in Figure 21.

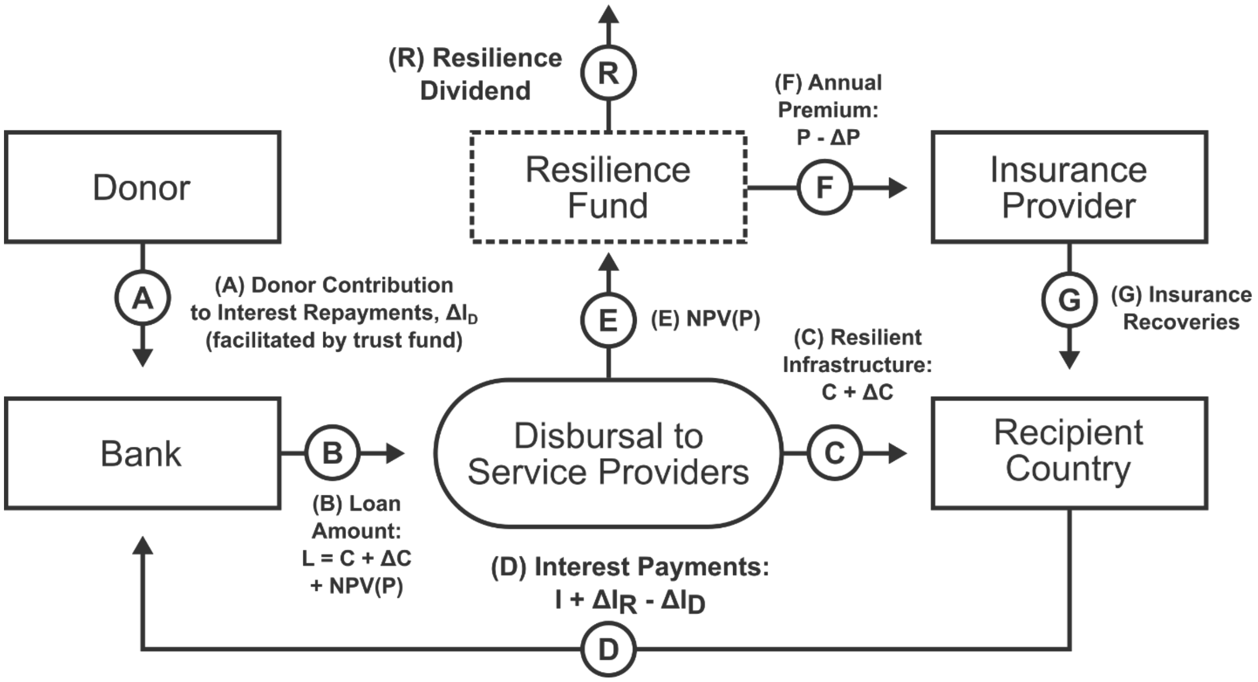



**FIGURE 21** GENERIC EXAMPLE PRODUCT STRUCTURE FOR INSURANCE-LINKED LOAN PACKAGE

| Component | | Funding Mechanism | Timing/ Delivery |
|---|---|---|---|
| **Infrastructure Financing** | | | |
| **Base cost of infrastructure** | C | Loan – recipient country bears cost | Project outset, disbursed over 3-5 years through procurement process |
| **Base interest repayments** | I | Paid by recipient country | Over 15-25 years |
| **Insurance** | | | |
| **Annual insurance premiums** | P | Financed by development bank through loan and ultimately borne by recipient country | NPV of future expected insurance premiums managed in an SPV or trust fund for future disbursement and transferred to insurer in a series of multi-year contracts. |
| **Resilience Features** | | | |
| **Additional cost of resilient building** | *ΔC* | Financed by development bank through loan and ultimately borne by recipient country. Potential for donor contribution. | Project outset, disbursement dependent on funding mechanism |
| **Additional interest repayments due to additional cost of resilience** | $\Delta I_R$ | Financed by recipient country | Over 15-25 years |
| **Rebate on insurance premiums** | ΔP | Either reduced cost of insurance upfront or used to part-fund interest repayments | Reduced future insurance premiums or reduced upfront cost of insurance |
| **Optional concessionality spread to reward resilience** | $\Delta I_D$ | Financed by donor through trust fund | NPV of concessionality spread funded by donors at outset |

**TABLE 9** ILLP COMPONENTS

### *Insurance Component and Monetisation of the Resilience Dividend*

The product is predicated on the assumption that risk reductions achieved through investment in resilient infrastructure design or adaptation, can be quantified and captured in associated future premium reductions. This in turn relies on these three statements being true:

1. The underlying risk can be quantified using commercially available catastrophe models
2. The impact of investment in resilience can likewise be quantified
3. Insurance providers will fully recognise this reduction in risk and pass on the benefit in the form of reductions in premium
4. An insurance product can be structured so that premium reductions are understood and defined at project outset

The Applied Example to follow demonstrates the first two statements to be true at least for the chosen case study. Note that potential risk reductions for some types of resilience measure such as green infrastructure (e.g. mangroves, storm water storage systems) and some types of heavy infrastructure (e.g. roads and power) are more challenging to quantify using commercially available models and may require bespoke solutions.

The third and fourth statements are discussed in the following two sections.

*Risk-Based Pricing*

Industry feedback from the Innovation Lab suggests there are challenges to achieving adequate risk-based pricing in practice. These challenges are case specific and include:

- *Market dynamics and pressures.* Primary insurance underwriters may be unable to pass on benefits from reductions in the underlying risk to the policy holder if this is not recognised during their reinsurance purchasing, for example due to data resolution. Impact on profitability and local pricing dynamics may also lead to risk reductions not being fully recognized.

- *Model and data uncertainty.* Underwriters load the model derived expected losses during pricing to account for model and data uncertainty amongst other factors. Depending on the methodology used this may dilute the impact of modelled risk reductions. Data quality and completeness can also be an important factor for pricing risks in developing insurance markets.

- *Uncertainty in performance of resilience measures.* Some common resilience measures such as roof ties protecting against wind risk are well understood and modelled and have been tested in recent events. Newer more innovative resilience measures may be less well understood, and underwriters may be unwilling to recognise the modelled risk reductions in premium reductions.

These challenges can be mitigated by piloting the product in regions where the risk is robustly modelled and using accepted resilience measures. The full collection and disclosure of asset characteristics will also reduce data uncertainty. As the uncertainty in the benefit of resilience measures decreases as the number of assets increases. Risk reduction measures deployed at scale are more likely to be recognized in reduced insurance premiums.

In the U.S. mandatory wind mitigation credits have been used in many southern hurricane exposed states to address these challenges and pass on benefits to homeowners. For example, Wind Mitigation Credits available in the State of Florida can offers discounts of more than 50% dependent upon an inspection of wind mitigation measures in place (RMS, 2010).

*Form of Insurance Product*

This product assumes the following basic form for the embedded insurance component. Further development is required to lock down policy details.

- Insurance contracts are multi-year up to a maximum of three years with built in resets/renewals at the end of each three-year period. Three years is the maximum period that was deemed to be feasible by industry participants of the Innovation Lab. Long duration multi-year contracts face a number of challenges including the higher cost of capital requirements (Maynard, T., Ranger, N., 2012).

- Any individual insurance provider is not locked in for the duration of the loan (15-25 years). A pool of participating insurers may be required.

- Future pricing can be adjusted in a pre-determined way (using a defined relationship between the modelled expected loss on the policy and the premium payment). This feature is commonly seen in catastrophe bonds which typically have a duration of three to five years and reset annually to accommodate changes in underlying exposure or modelled risk.
    - This exposes the insurance provider to potential opportunity cost in the case that (re)insurance pricing hardens during the interim.
    - Flexibility of pricing at each 3-year reset needs to be carefully considered against possible market dynamics in the intervening period. It may be required for the insurance provider to take the potential downside and accept that that they are being compensated for the risk they are taking on.
    - Resets/renewals will take into account changing views of risk by using the latest commercially available models.

- Uncertainty in future prices could be accommodated by adjusting the cover provided to keep premiums stable. For example, if the risk is believed to have increased, either the limit offered to the recipient can be lowered or the recipient can 'top-up' the insurance payments. The stability offered by the coverage flexing allows the funding requirements to be determined at outset.

- Alternative risk transfer methods may provide access to risk-based pricing for large portfolios of assets where the investor is less exposed to model uncertainty on an individual asset and economies of scale can be realized.

### 4.5.4. Applied Example: Reconstruction of Schools in a Hurricane-Prone Middle Income Small Island Developing State (SIDS).

The following use case has been designed to assess the benefits of one possible realization of the ILLP in a hypothetical real-world setting. Reasonable assumptions have been selected and are presented below but could be expected to both vary significantly in practical implementation and between different perils, regions, asset types and resilience measures. The potential net benefit of the proposed structure should therefore be assessed on a case by case basis.

#### *Summary of Use Case*

Ten schools distributed across a hurricane-prone middle-income SIDS are to be reconstructed following a damaging hurricane using a loan from an international development bank. Schools can be rebuilt according to current practices, the 'Base Case', or at additional cost, further strengthened to increase their wind resilience, the 'Resilient Case'.

The costs of implementation are typically related to the overall base value of the asset – the building and marginal cost assumptions have been derived from internal RMS expertise and research underlying the development of the RMS North Atlantic Hurricane Models. Costs are expected to vary by region, although relative costs and risk reductions will be largely conserved

Estimated costs and modelling assumptions are contained in Table 10.

| Analysis Component | Assumption | Description | Source |
|---|---|---|---|
| Modelling | Region | Middle Income Small Island Developing State (Dominica) | - |
| | Peril | Hurricane - wind only | - |
| | Model version | RMS North Atlantic Hurricane Models v17.0, wind model (vintage 2017) | RMS |
| | Exposure | 10 Schools, located 1 per district | - |
| | **Base Case** | | |
| | Base Construction Type | Construction Type: Masonry, Occupancy Type: Education, Number of Stories: 2 | RMS |
| | Base Construction Cost (per unit) | US$1 million per unit.<br>Construction costs are expected to vary in practice, though the additional costs of wind mitigation features are expected to scale linearly with base value. | RMS |
| | Total Base Construction Cost | US$10 million | RMS |
| | **Resilient Case** | | |
| | Additional Structural Features | Roof Sheathing, Roof Covering, Opening Protection, Roof Anchor, Roof Geometry | RMS |
| | Marginal Cost of Resilient Construction | +6.95% on top of Base Construction Cost assumption - equivalent to $695k for a school portfolio of $10 million | RMS |
| | Total Resilient Construction Cost | US$10.695 million | RMS |

**TABLE 10** MODELLING ASSUMPTIONS USED IN THE RMS ANALYSIS FOR BASE AND RESILIENT CASE

### *Risk Analysis and Assessment of Physical Resilience Benefit*

RMS has carried out a risk analysis to quantify the hurricane wind risk to the hypothetical portfolio of school buildings for the Base and Resilient Case under the assumptions detailed in the previous section. The modelled structural vulnerability of the school buildings is lower in the Resilient Case leading to a 47% reduction in the Average Annual Loss (AAL), the average financial loss incurred from physical damage in an average year. Note that the AAL represents an average across thousands of simulated years, in which some will experience no loss and others will experience more extreme losses. The standard deviation around the AAL is also shown indicating the level of volatility and uncertainty in the losses experienced in any one year. This can also be seen to reduce in the Resilient Case.

| Option | Cost ($) | AAL ($) | $\sigma_{AAL}$ ($) |
|---|---|---|---|
| Base Case | 10,000,000 | 35,955 | 266,603 |
| Resilient Case | 10,695,000 | 18,958 | 154,775 |
| Marginal Impact of Resilience | +6.95% | -47.3% | -41.9% |

**TABLE 11** COSTS, AVERAGE ANNUAL LOSSES AND ASSOCIATED STANDARD DEVIATIONS FOR BASE CASE AND RESILIENT CASE

The likelihood of incurring a financial loss greater than a certain value in any one year, the occurrence exceedance probability, is shown in Figure 22.

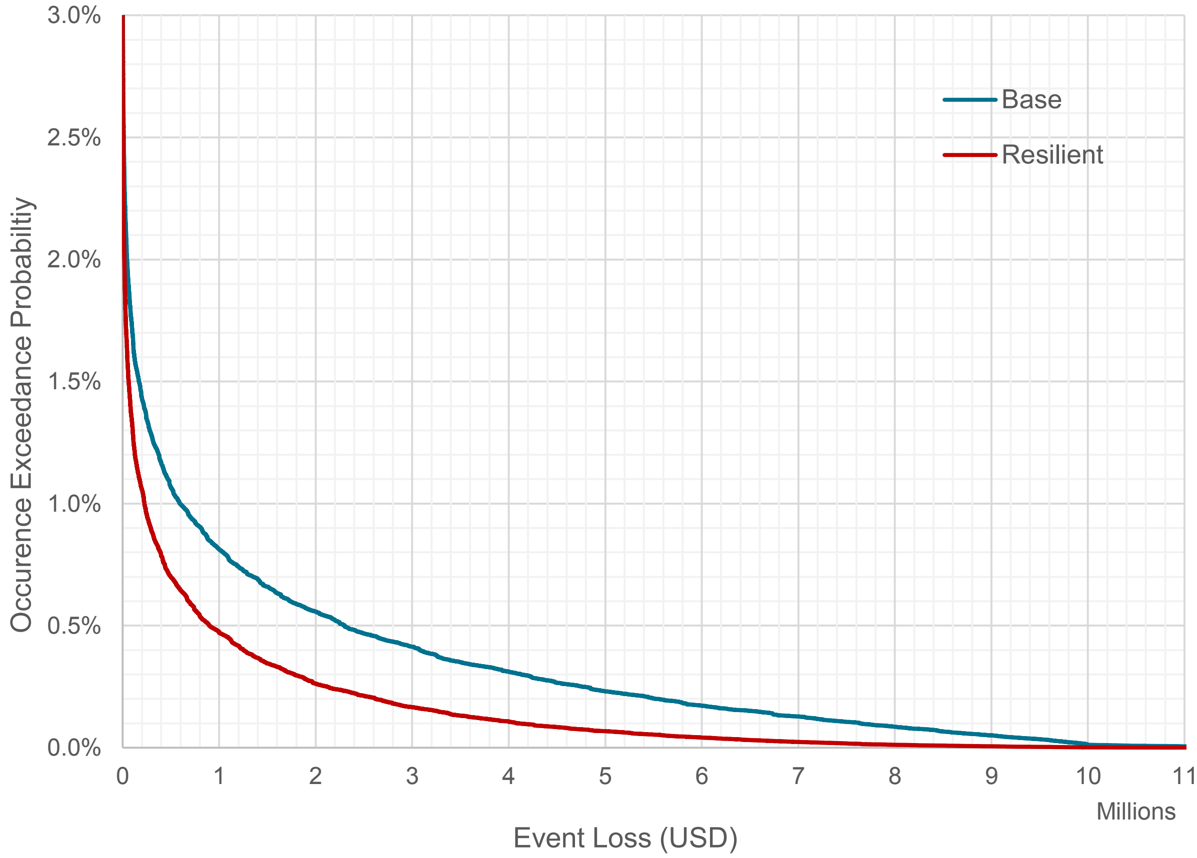



**FIGURE 22** LOSS OCCURRENCE EXCEEDANCE PROBABILITY CURVES FOR BASE AND RESILIENT CASES

### *Cash Flow Analysis*

This applied example works through one implementation of the generalized product for this use case and sets the following product features:

- The asset owner (recipient country) has the choice between a) a loan covering the cost of a non-resilient asset (Base Cost of Construction, C) and the cost of insurance; or b) the Resilient Cost of Construction (C+ ΔC) and the cost of insurance.

- In both cases, the lender earmarks an amount equivalent to the cost of insurance for a non-resilient asset and sets it aside in an SPV.
    - An SPV is chosen for simplicity and as a flexible structure that is agnostic as to the degree, if any, of donor involvement.
    - As the resilient case and non-resilient counterfactual both set aside an equivalent portion of the loan within an SPV structure, the opportunity cost of the SPV is not considered.
    - If the borrower opts for resilience measures, the resulting insurance savings are used to offset the additional cost of resilience through lower annual repayment or upfront savings that can be reinvested. In the modelled example, the insurance rebate is used to lower the annual repayments of the loan.

- The insurance premium is assumed to be constant throughout the lifetime of the loan and paid annually. The cash flow analysis is agnostic to the precise policy details, but the policy could be assumed to be a multi-year contract renewing every 3 years, with the premium payments held constant under changing risk by adjusting the coverage level.

- A donor steps in to reduce the overall interest repayments by providing an upfront amount equivalent to the additional interest paid on the cost of resilience measures ($\Delta I_D$). This is a modelling choice requiring a relatively small donor support; other structures may include a more important donor involvement depending on the economic viability of the product.

- Insurance is a pre-condition, built into the loan package. Resilience is a choice of the recipient country.

- The development institution loan consists of 1) a disbursement phase and 2) a repayment phase. During the disbursement phase, amounts are disbursed uniformly in each year.

- The loan is amortizing. The notional amount is progressively paid back after an initial disbursement period and interest is due on the outstanding amount in every given year.

- Several simplifying assumptions are made:
    - SPV set-up costs are assumed to be zero, as are other frictional costs and there is no fee for renewal of insurance policies. Includes a one-off commencement fee at the start of the loan period.
    - The underlying asset value of the school portfolio is assumed to remain constant over the lifetime of the loan following construction. Inflation in value is assumed to offset expected deterioration.

- A discounted cashflow model is applied over the term of the loan to compute the net present value of future loan repayments (capital and interest) with the net present value of the cost of infrastructure.

- The analysis uses a discount rate of 5% based on a social time preference perspective[22]. However, a sensitivity is provided at 10% reflecting the opportunity cost of capital.

[22] For instance, under the simplest derivation of the social time preference rate, 5% would be consistent with a utility discount rate of 3.2% (compared to the 1.5% value in the Green Book, reflecting the likely higher pure rate of time preference in the region), the elasticity of the marginal utility of consumption being 1.5, and a per capita growth rate in consumption of 1.5% (consistent with the simple average for this parameter over the last 10 years in Latin America and the Caribbean, excluding high-income countries).

- Key input assumptions are detailed in Table 12.

| Product Component | | Assumption | Notes |
|---|---|---|---|
| Loan | Base Loan Value | US$10,876,685 | Base cost of infrastructure + NPV(Annual Insurance Premiums) |
| | Resilient Loan Value | US$11,571,685 | Base cost of infrastructure + additional cost of resilience + NPV(Annual Insurance Premiums) |
| | Loan Term | 25 | Typical loan duration, can vary. |
| | Loan Disbursement Period | 5 | Typical disbursement period, can vary. |
| | Loan Interest Rate | 4.00% | http://www.worldbank.org/en/about/unit/treasury/financial-products/ibrd/ibrd-lending-rates-and-fees#2 |
| | Discount Rate | 5% | Social time preference perspective[13] |
| | Asset Building Time (Years) | 5 | To conform with disbursement period. |
| Insurance | Base Case Annual Premium | US$71,910 | Proportional loading factor of 2x. See Sensitivity Tests for further information. |
| | Resilient Case Annual Premium | US$37,916 | Proportional loading factor of 2x. See Sensitivity Tests for further information. |
| | Base Replacement Cost | US$10 million | Equals Total Base Construction Cost, assumed to increase linearly from 0 to 100% of total value during 5-year construction period |
| | Resilient Replacement Cost | US$10.695 million | Equals Total Resilient Construction Cost, assumed to increase linearly from 0 to 100% of total value during 5-year construction period |

**TABLE 12** PRODUCT LOAN AND INSURANCE ASSUMPTIONS

## *Results of Cash Flow Analysis*

Two options are studied: 1) a non-resilient infrastructure loan; 2) a resilient infrastructure loan. The additional cost of resilience is compared to the net present value of resilience-related future savings.

| **Base Construction Cost (t=0) [C]** | **Resilient Construction Cost (t=0) [C+∆C]** |
|---|---|
| 10,000,000 | 10,695,000 |
| **Interest + Capital Repayment (Base)** | **Interest + Capital Repayments with Resilience & Donor Contribution on extra interest** |
| -9,034,344 | -9,013,644 |
| **Asset/Loan NPV ratio** | **Asset/Loan NPV ratio** |
| 1.11 | 1.19 |

| | |
|---|---|
| (a) | **Insurance Savings (NPV)** |
| | 414,435 |
| (b) | **Additional resilience loan (NPV)** |
| | -393,736 |
| (c) | **Interest payment & service cost for additional resilience loan, - NPV [∆I]** |
| | -188,003 |
| (d) | **Donor Contribution, NPV [∆I]** |
| | 188,003 |
| | **Net resilience benefit** |
| (e) = (a)+(b) + (c) + (d) | **20,700** |

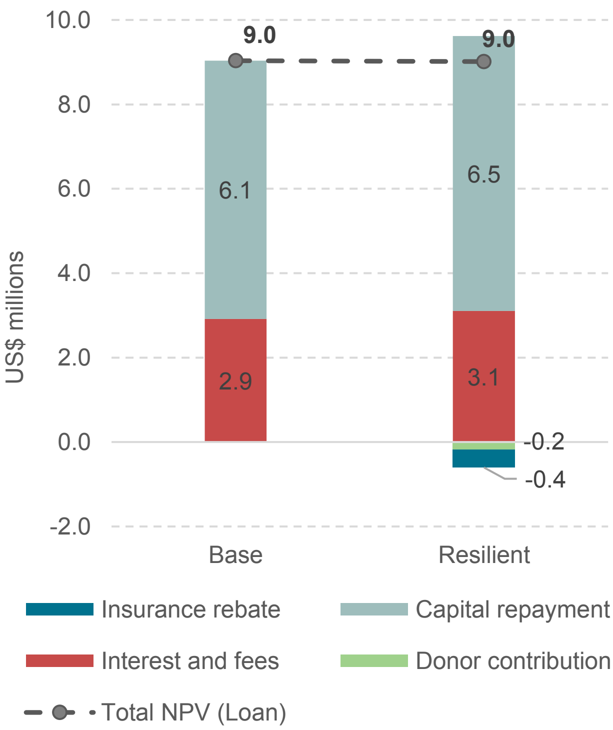



**FIGURE 23** CASH FLOW ANALYSIS, ALL AMOUNTS IN US$ UNLESS SPECIFIED

The additional cost of resilience is defined as the net present value of additional lending required and associated fees and charges (capital repayment, additional interest, additional service fee). Resilience-related savings consist of the net present value of resilience-induced insurance savings and donor contribution. The results of the cash flow analysis are presented in Figure 23, with a summary in Table 13.

| Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case insurance costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Funds |
|---|---|---|---|---|
| **20,700** | 47.3% | 47.3% | 71.2% | 4.0% |

**TABLE 13** KEY METRICS

**Given that the recipient has taken out risk-priced insurance, they are financially incentivised to build resiliently as long as the insurance savings from building resiliently outweigh the additional capital costs.** The costs and benefits of building resiliently for our base case are shown above in Table 13: the insurance savings (a) plus donor contribution for resilience (d) are larger than the additional costs of resilience [(b) + (c)], which makes it financially beneficial to build resiliently. The net benefit is $20,700 with insurance savings of 47.3% of the net present value of future expected premiums, which are equivalent to 71.2% of the marginal cost of resilient building. Hence in this example, an investor would prefer to incur the initial extra cost to build resiliently as it would reduce the total NPV of loan repayments. However, this positive net benefit disappears in the absence of the donor contribution to the interest repayments on additional cost of resilience, as demonstrated by the insurance saving being less than 100% of the NPV of the marginal cost of resilience.

**Whilst the insurance premium savings accumulate over the duration of the loan, the loan recipients themselves effectively aggregate those savings and choose to build resiliently today.** By creating insurance savings from resilience, the instrument monetises the resilience dividend. This guarantee of savings in the medium term might be enough, in theory, to promote resilience building today. There is also the option of allowing the loan recipient to withdraw additional funds from the SPV equal to the NPV of future insurance premium savings if they commit to building resiliently. This option brings the resilience dividend upfront in pure monetary terms but may have lower efficiency due to the potential moral hazard from the loan recipient.

**Building resiliently becomes more attractive and provides larger savings as the repayment period of the loan increases.** A longer loan repayment period creates more years where insurance is needed and therefore more years where the resilience rebate exists. Keeping all other assumptions constant, the total loan repayment with resilience building is lower for a loan term of 24 years or longer. For loan terms of 23 years or less, it would be more difficult to financially incentivise the additional resilience measures. Note that the positive net resilience benefit assumes a counterfactual where insurance cover is in place; against a counterfactual where no insurance is in place, an additional cost of insurance remains (Figure 24).

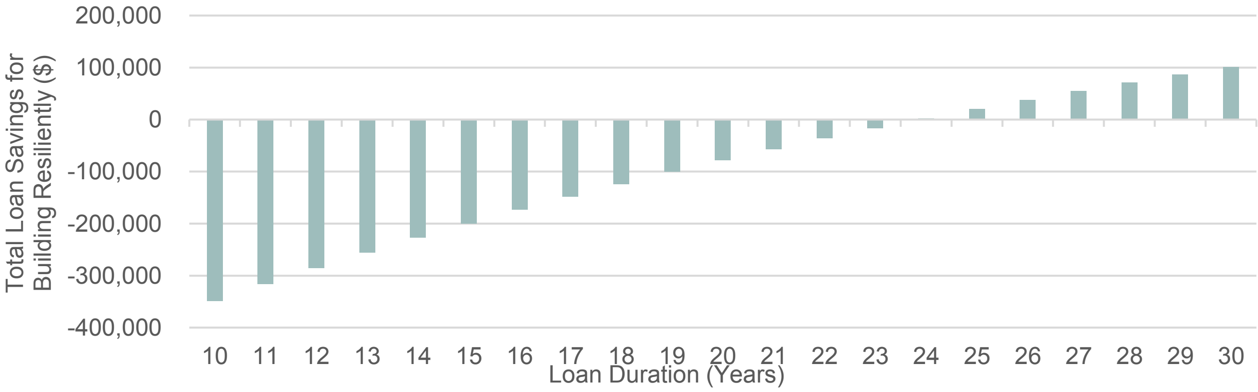



**FIGURE 24** TIME SERIES OF LOAN SAVINGS THAT RESULT FROM BUILDING RESILIENTLY

**The instrument relies entirely on reduced insurance premiums as the vehicle to create the 'resilience dividend'.** As such, insurance is an indispensable aspect for this instrument and the cost-benefit of insurance to the loan recipient versus other forms of disaster risk financing should be assessed on a case by case basis.

## *Sensitivity Testing*

The economic benefit of the proposed structure is highly sensitive to the interplay between the additional cost of resilience, the absolute value of the AAL, the percentage risk reduction achieved and the insurance pricing assumptions. The combination of these factors will vary case by case depending on the geographic location, type of infrastructure, peril and resilient measure chosen. In general, sensitivities show that optimal conditions include low additional cost of resilience, high insurance loading factors and high absolute risk reduction in terms of the reduction in AAL, but that the relativities of these factors will also determine the net resilience benefit. It is not meaningful to select a single point at which the structure becomes viable in a multi-variate problem.

*1. Cost of Resilience Assumptions*

Key output metrics from the cashflow analysis are shown for differing assumptions on the marginal cost of more resilient construction. Results show as the cost of resilience increases above the base case whilst the absolute insurance savings remain more or less constant, the structure becomes uneconomic.

| Additional Cost of Resilience | Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case Insurance Costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|---|
| 5.0% | 139,600 | 48.2% | 48.2% | 101.0% | 4.0% |
| 6.95% | 20,700 | 47.3% | 47.3% | 71.2% | 4.0% |
| 10.0% | -165,273 | 45.8% | 45.8% | 47.9% | 4.0% |
| 20.0% | -775,020 | 40.8% | 40.8% | 21.4% | 4.0% |

**TABLE 14** KEY CASHFLOW METRICS

*2. Insurance Assumptions*

| Insurance Assumptions | Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case insurance costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|---|
| P=m.AAL + c.σ, where m is the expense loading factor and is set equal to 1.15 and c is the risk loading factor and is set equal to 0.3 | 253,568 | 47.3% | 43.8% | 111.3% | 6.8% |
| Proportional loading factor of 1.5 | -82,909 | 47.3% | 47.3% | 53.4% | 3.1% |
| Proportional loading factor of 2 | 20,700 | 47.3% | 47.3% | 71.2% | 4.0% |
| Proportional loading factor of 3 | 227,917 | 47.3% | 47.3% | 106.9% | 5.8% |

**TABLE 15** INSURANCE PREMIUM SENSITIVITY TESTING

Table 15 shows key output metrics for differing insurance pricing models. The analysis presented so far assumes a simplistic proportional loading factor where the annual insurance premium equals 2 times the modelled AAL (show here for comparison, highlighted in grey). This loading factor is assumed to contain both expense and uncertainty loading factors. Premium loading will vary by region, by provider and by underlying asset and data quality. Additional sensitivities are shown for proportional premium loading factors of 1.5 and 3, and for premiums estimated using the technical pricing formula, P=m.AAL + c.σ, where P is the annual premium, m is the expense loading factor, c is the risk loading factor and σ is the standard deviation of the AAL. The technical pricing formula considers the impact of the uncertainty in the AAL. The magnitude of the standard deviation reflects the volatility in annual losses and the value of c reflects the risk tolerance of the underwriter. Typical values are chosen for soft market conditions.

As both the AAL and the standard deviation in AAL reduce in the Resilient Case (Table 15), the benefit of risk reduction is preserved in both the proportional loading factor and technical pricing (including uncertainty) sensitivities. In fact, premium loading actually increases the potential for insurance savings between the Base and Resilient insurance premiums.

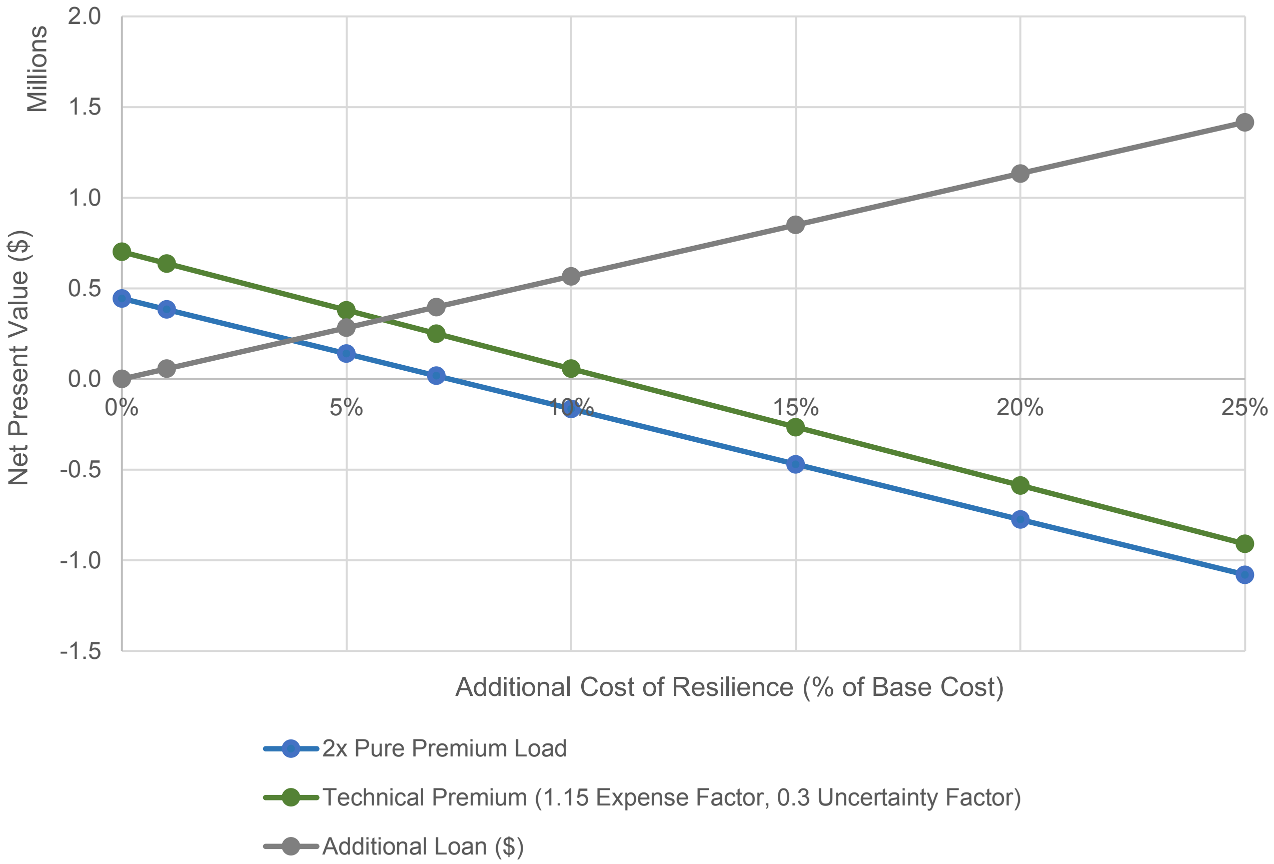



**FIGURE 25** SUMMARY OF SENSITIVITY RESULTS. SHOWING THE POINTS AT WHICH THE NPV OF THE STRUCTURE REACHES A BREAKEVEN POINT FOR A SELECTION OF ASSUMPTIONS ON THE COST OF RESILIENCE AND INSURANCE PREMIUM CALCULATION.

### *3. Risk Level and Risk Reduction*

The following tables show summary results for (i) a range of absolute values of the non-resilient AAL, holding the % risk reduction constant for the resilient case; (ii) a range of percentage risk reductions holding the non-resilient AAL constant. These ranges are chosen to be physically realistic in terms of the hazard environment and potential risk reductions seen across different mitigation measures and infrastructure types.

| Non-Resilient AAL | Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case Insurance Costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|---|
| 10,000 | -278,471 | 47.3% | 47.3% | 19.8% | 1.2% |
| 20,000 | -163,206 | 47.3% | 47.3% | 39.6% | 2.3% |
| 35,955 | 20,700 | 47.3% | 47.3% | 71.2% | 4.0% |
| 40,000 | 67,324 | 47.3% | 47.3% | 79.3% | 4.4% |
| 50,000 | 182,589 | 47.3% | 47.3% | 99.1% | 5.4% |

**TABLE 16** AAL SENSITIVITY ANALYSIS

| % Risk Reduction (AAL) | Net Resilience Benefit | % Insurance Savings (relative to Base Case Insurance Costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|
| 10% | -306,067 | 10.0% | 15.1% | 6.8% |
| 25% | -174,564 | 25.0% | 37.7% | 5.7% |
| 47.3% | 20,700 | 47.3% | 71.2% | 4.0% |
| 75% | 263,778 | 75.0% | 113.0% | 1.9% |
| 90% | 395,281 | 90.0% | 135.6% | 0.8% |

**TABLE 17** RISK REDUCTION (AAL) SENSITIVITY ANALYSIS

### *4. Alternative Applied Example: Water Infrastructure in an Earthquake Prone South-East Asian Country*

A hypothetical counter-example is included for a water plant situated in a high hazard region within an earthquake prone South-East Asian country (the Philippines for the purposes of modelling). A hypothetical asset value of US$3m is chosen alongside a conservatively low marginal cost of resilience (and an additional 5%), and the asset is modelled under the assumption of poor construction quality and good construction and maintenance.

| Option | Cost ($) | AAL ($) |
|---|---|---|
| Base Case | 3,000,000 | 3,480 |
| Resilient Case | 3,150,000 | 2,924 |
| Marginal Impact of Resilience | +5% | 16.0% |

**TABLE 18** EARTHQUAKE RISK SENSITIVITY ANALYSIS

In this case, despite the low marginal cost of resilience assumed, the lower value of AAL relative to the asset cost, even in a high hazard earthquake region, and the low percentage reduction in AAL, mean that a negative net resilience benefit is seen overall. This example is included to be illustrative of the variation that can be seen in the ability to achieve significant risk reductions and that cost-benefit analyses can vary significantly for low frequency perils such as earthquake.

| Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case insurance costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|
| -71,407 | 16.0% | 16.0% | 10.8% | 2.2% |

**TABLE 19** EARTHQUAKE RISK SENSITIVITY RISK RESULTS

### *5. Discount Rate*

Key output metrics from the cashflow analysis are shown for a high discount rate environment with the discount rate set to 10%. Results show that the net resilience benefit remains positive at the high discount rate of 10% but that the absolute value of that benefit significantly decreases compared to the base assumption of 5%.

| Discount rate | Net Resilience Benefit | % Risk Reduction (AAL) | % Insurance Savings (relative to Base Case Insurance Costs) | Insurance Savings as % of Marginal Cost of Resilient Building | % Loan Taken Up by Insurance Costs |
|---|---|---|---|---|---|
| 5.0% | 20,700 | 47.3% | 47.3% | 71.2% | 4.0% |
| 10.0% | 304 | 47.3% | 47.3% | 64.8% | 2.5% |

**TABLE 20** DISCOUNT RATE SENSITIVITY ANALYSIS

### *Evaluation*

| | | | |
|---|---|---|---|
| Encourages resilient infrastructure | ✓ | Has a viable path to implementation | ✓ |
| Monetises resilience dividend | ✓ | Offers flexibility | ✓ |
| Makes resilience dividend available upfront | ✓ | Has a sound economic justification | ✓ |
| Involves risk transfer | ✓ | Causes ‘no harm’ | ✓ |

**A. Encourages resilient infrastructure**

- Rebates resulting from reduced insurance premiums significantly offsets additional cost of resilient infrastructure, further incentivisation can be provided by donor support.
- Product can be structured to enable ongoing maintenance of infrastructure

**B. Monetises resilience dividend**

- The rebate arising from the reduction in insurance premia can be monetised either by (1) reducing the initial loan amount in recognition of lower expected future costs, (2) in offsetting interest payments or (3) making insurance savings available for withdrawal through the resilience fund, either gradually over time or upfront and used for specified resilience purposes.

**C. Makes resilience dividend available upfront**

- Whether the funds are made available upfront or over time (see B), a key feature of the product is pre-agreed reductions in insurance premia rather than waiting for uncertain future benefits.

**D. Involves risk transfer**

- Risk-based insurance contracts are key to monetising the resilient dividend by recognition of the risk reduction achieved through resilient building in premium reductions.
- Uptake of insurance and use of local insurance providers can both increase financial resilience and aid with the development of the insurance market.

**E. Viable path to implementation**

- International development bank loans are a significant source of infrastructure financing and this product represents incremental development to pre-existing products. The most significant challenges remain in accessing risk-based insurance pricing and developing appropriate multi-year policies which also meet the needs of the insurance provider.

**F. Offers flexibility**

- The product has simple defining characteristics, namely the set-up of a resilience fund to manage the insurance funds provided by the loan, and the monetisation of risk reductions in the form of reductions in premium payments. The precise structuring and loan amounts can be tailored to consider individual case insurance requirements. The product structure may also be able to support ringfencing of a portion of the loan for regular maintenance, additionally placed into the resilience fund. Provisioning for adequate maintenance may in turn also have a beneficial impact on risk and premium levels.

**G. Has a sound economic justification**

- The applied example indicates that there is a positive net resilience benefit to the proposed structure when set against a counterfactual that presupposes the take-up of insurance. This will vary depending upon different marginal costs of resilience set again the risk reduction and associated premium reduction and should be assessed on a case by case basis.
- In addition, the cost-benefit of different structuring solutions for managing the insurance portion of the loan should be consider. Both the proposed structure and counterfactual presuppose an SPV set-up and so the opportunity costs of the SPV are not considered.

**H. Causes 'no harm'**

- Inclusion of insurance within the loan will lead to an overall larger loan amount and ultimately high repayments. Options exist for donor involvement in funding interest on the additional loan amount or funding the marginal cost of resilience and/or insurance, but decisions by recipient countries to fund the additional cost of insurance should be taken in consideration of other spending priorities.

## *Challenges to Implementation*

- **Robust quantification of risk reduction associated with some resilience measures, infrastructure types, and peril-regions.** Commercial catastrophe models include as standard the ability to quantify the risk reduction associated with common resilient building design features for residential, commercial and industrial structures for key natural perils such as wind and earthquake risk. They also typically include the ability to model local defences against water perils such as raised entrance elevations, flood walls etc. As a result, the impact of resilience investments can in many cases be robustly modelled for portfolios of assets. However, potential risk reductions for some types of resilience measure such as green infrastructure (e.g. mangroves, storm water storage systems) and some types of heavy infrastructure (e.g. roads and power) are more challenging to quantify using commercially available models and may require bespoke solutions.

  Catastrophe model coverage is expanding rapidly to cover global peril-regions, however, the completeness and resolution of models does vary regionally. Exposure and vulnerability data can be readily collected at the point of construction, though for less developed regions, the availability of hazard models may inhibit the ability to support such a product with robust risk modelling. Where this is the case – simplifying assumptions may be sufficient to price the expected risk reduction into the product.

- **Ability to achieve risk-based pricing and full recognition of modelled risk reduction as a reduction in premium payments**. See Section 'Insurance Component and Monetisation of the Resilience Dividend' for further discussion.

- **Challenges in design and implementation of a suitable multi-year insurance product that provides sufficient certainty at outset to allow the resilience to be fully funded and the resilience dividend to be monetised**, at least in part, upfront. See Section 'Insurance Component and Monetisation of the Resilience Dividend' for further discussion.

- **Uncertainty in implementation of building standards and resilience measures, as well as efficacy of resilience measures**. The former may be mitigated by regular inspections during and on completion of construction. Solutions at a sovereign level might include introduction of building certification policies. Insurance contracts should allow for pricing to be reset to address changes in view of risk i.e. if new information becomes available on the performance of resilience measures, pricing should be allowed to adjust.

- **Motivation and ability for recipient country to bear additional cost of insurance**, if insurance was previously absent or not assumed. In the applied example of a SIDS school portfolio, the cost of insurance adds 9% onto the notional amount of the loan or as little as 4% if resilience measures are fully recognised and expected insurance savings are used to reduce the notional amount. depending upon the full recognition of resilience measures. Whilst the additional cost of resilient construction is covered by the reduced premium payments over the lifetime of the loan under the base cash flow analysis, if insurance was not originally in place, this remains an additional cost of 4% compared to not taking out insurance. Donor funding may be leveraged to ease funding challenges if the cost-benefit of insurance can be shown.

## 4.6. Discussion

### 4.6.1. General Findings on Capturing the Resilience Dividend

The product solutions proposed aim to capture a resilience dividend generated through building resilient infrastructure and use it to contribute towards the additional initial costs of building resiliently. The most direct means of monetising the resilience benefits is through creating a saving on insurance premiums, though reducing the risk of physical asset damage. This approach has a number of challenges:

- **Insurance Coverage –** savings can only be made on insurance premiums if the asset is insured to begin with. In instances where there is no provision for premium payments, it may be challenging to motivate risk holders to pay for premium while also promoting resilience. The sustainability of these types of product is contingent on the ability of the risk holder to pay for premiums over the long-term, ideally for the full life of the asset.

- **Insurance Pricing -** savings on insurance premiums are only made if the insurance provider explicitly recognises the risk reduction with a lower insurance premium. A range of interrelated factors influence the cost of an insurance premium, including the covered risk and associated uncertainty, the volume of coverage and number of covered assets, the peril-region, the administrative and distribution costs, and the current market dynamic among others. The complexity of insurance pricing means that the modelled risk-reduction may not be fully recognised in a reduced premium. These types of structure will work best if they are developed in collaboration with insurance providers, and agreements are made as to the expected near-term premium and recognition of risk reduction. They are also likely to be more feasible with large portfolios of assets where the reduced uncertainty and volatility is more attractive to the insurer.

- **Benefit-Cost Ratio –** the ability of insurance premium savings to contribute meaningfully to the cost of resilience varies significantly. These types of product solutions are therefore best suited to use cases where the underlying risk is high, the additional cost of resilience is low, and risk reduction is recognised with large premium reductions. These factors vary between use cases; the Dominica schools hurricane risk analysis demonstrated a use case where these conditions were relatively favourable:

  - The annual average loss for the base schools construction is of the order of 0.43% of the total value of the asset (loss cost of ~4.3), which would be considered a relatively high risk asset.
  - Additional assumptions and results include:
    - A flat technical premium loading factor of 2x AAL
    - Total additional cost of resilience of 5.9%
    - Total risk reduction of 46% resulting from a combination of retrofit measures
    - Assuming no discount rate, the payback period is 15.8 years
  - However, if a discount rate of 10% is applied in a NPV calculation, the total accrued savings can never pay for the additional cost of resilience. The challenges of high discount rates apply more broadly for long-term investments in developing economies.

  Additional factors which affect the total potential premium savings include:

  - The additional costs of resilience increase the total value at risk, which acts to offset the risk reduction benefit on insurance premiums. This is most pronounced where the additional costs are large compared with the value of the base asset.
  - The expected life of the asset, and the associated timescales over which premiums are paid, and savings on insurance premiums can be accrued.

- **Timing –** insurance premiums are typically paid annually, so the savings can only be realised on a similar basis. The implications of this include:

    - For the resilience dividend to be made available up front expected future premium savings have to be aggregated, either within a product structure, or by an entity who is willing and able to accrue the savings over time.
    - Insurance providers ultimately retain control of the annual cost of premium in order to reflect changing market dynamics and changes in the underlying risk, among other factors. Uncertainty in future insurance savings means that the total size of the resilience dividend is also uncertain. A possible solution to this problem is to fix the amount of capital that is available annually for insurance, and to have contracts that vary the underlying coverage. However, this may lead to unexpected underinsurance if the mechanisms are not transparent.
    - Insurance contracts are typically renewed on an annual basis – there may be options to extend contracts to 3-5 years, and catastrophe bonds can extend to 5 years, though this still generally falls short of the periods over which insurance savings can fully pay for the additional cost of resilience.
    - Given that future potential insurance savings are aggregated to form the overall monetised resilience dividend, the present value of the resilience dividend can be strongly inhibited by the applied discount rate. In developing economies where the discount rate can be of the order of 10%, it becomes significantly more difficult to realise positive cost benefit ratios on near-term horizons.

- **Sustainability** – as well as implementing resilience across the term of the financial instruments, it is important to consider how the resilience measures are maintained by the local asset holder or service provider over the long-term. How the responsibility for maintenance and insurance premium payment transfers to the local agencies should be clearly defined at the start of the project – this is critical to ensure that the products create sustainable resilience solutions.

- **Captured Benefits –** the benefit-cost analyses produced for this report mainly quantify reduction in direct asset damage as the benefit, since this is what drives reduction in asset insurance premiums. The benefits of resilient infrastructure extend beyond reduction in direct damage and loss – these benefits should also be considered when assessing the value of products which motivate the development of resilient infrastructure.

### *4.6.2. Product Assessment*

The two developed product solutions were structured to address four defined ex-ante criteria. These criteria and an assessment of how the product solutions address them is contained in the following tables:

| | Description | | Assessment |
|---|---|---|---|
| Motivate the development of resilient infrastructure | The product structure aims to increase the resilience of the services supported by the infrastructure. The product therefore explicitly promotes and financially motivates development of resilience across multiple dimensions; including physical, operational, and financial resilience. | + | The product goes beyond just promoting resilient infrastructure, in that the operational and financial resilience of the services are also considered. The flexibility of this structure means that a targeted approach to increasing resilience is possible under a wide range of use cases. |
| | | - | Given that the outcome funder ultimately pays for the resilience, they are probably motivated to develop resilience in any case. The availability of a product such as this offers a means of developing resilient infrastructure, rather than motivating it. |

| | Description | | Assessment |
|---|---|---|---|
| Monetise the resilience benefits | The impact investor is remunerated for increasing resilience across the multiple dimensions. The resilience benefits generated are therefore monetised by the payments the investor receives. In addition, the entity who pays for asset insurance stands to monetise savings on their annual premium as a result of the reduced physical vulnerability. | + | The product structure offers a useful means of capturing the broader benefits of resilience, by enabling the outcome funder to use their understanding of the direct and downstream benefits of resilient infrastructure to support pricing for the returns they pay to the impact investor. |
| | | - | This may be considered an artificial way of monetising the benefits of resilience, given that the outcome funder determines the ROI to the investor based on their understanding of the resilience benefits. In addition, asset insurance is not strictly required under this structure, so the insurance savings may not be monetised at all in some cases (e.g. where there is not asset insurance, or when the insurance premiums are paid by the asset owner or other entity). |
| Deliver resilience benefits up-front | The investor is responsible for raising funds for resilience, their capital is not limited, therefore the need to monetise and bring forward a resilience dividend is not applicable. Impact investors are willing to receive a return on their investment across the term of the bond, as the resilience project is carried out. | + | The product solution matches resilience projects with an investor who has funds available to spend immediately on the project. |
| | | - | Rather than bringing a future dividend up-front, the structure provides the investor with a resilience-linked ROI at payment dates throughout the term of the bond. |
| Involve risk transfer | There are various insurable elements within this structure, including (i) the underlying asset, (ii) the operational costs of disaster response, and (iii) the investors' future cashflows. Any of these can be explicitly required by the product structure, and equally, the structure can work without an insurance element. In the developed example, the investor is incentivised to ensure that the underlying asset and operational costs are covered by some form of risk transfer. | + | Risk transfer and insurance mechanisms are applicable within the structure, as a means of managing the risk to the assets, and as a means of providing liquidity when an event does occur. Funds can be used for reconstruction, and to support disaster costs. The applied example shows that retrofit only reduces disaster costs, and does not eliminate them, so insurance or some form of disaster fund is required to pay for reconstruction costs. |
| | | - | The relatively short term of the bond (3-5 years) means that the risk to the investor's capital is tied to the catastrophe risk to the assets for a short enough time that the total risk of being impacted by an event is relatively low. The investor may therefore feel that they don't require asset or operational insurance, and indeed may just take out insurance against their future cash flows. The applied example is structured to make this option less desirable. However, this introduces inefficiencies into the process, in that the outcome funder has to make insurance purchase financially more attractive than not purchasing insurance, at which point it may cost the outcome funder less to directly purchase insurance. Ultimately, the most sustainable and efficient option is for the asset owner to purchase insurance, though this is a decision that needs to be made on an individual basis. |

**TABLE 21** RESILIENCE IMPACT BOND ASSESSMENT AGAINST EX-ANTE CRITERIA

| | Description | | Assessment |
|---|---|---|---|
| Motivate the development of resilient infrastructure | The ILLP aims to incentivise the adoption of resilient infrastructure designs by using reductions in insurance premia to offset the additional cost of resilience, with a minimal level of donor involvement. | + | Cash flow analysis results show that under the base case assumptions in the worked example, the net resilience benefit is positive, incentivising the borrower to choose the resilient option. In many cases expected future saving in premium payments can cover a substantial portion of the cost of resilient building. |
| | | - | Donor involvement (limited, on the interest portion of repayments on the additional cost of resilient construction) and a presupposition of insurance take-up is required. Sensitivity results show the net resilience benefit may also be negative in many cases. The opportunity cost of retaining funds in the SPV is also not considered. |
| Monetise the resilience benefits | The rebate arising from the reduction in insurance premia can be monetised either by (1) reducing the initial loan amount in recognition of lower expected future costs, (2) in offsetting interest payments or (3) being made available through the SPV, either gradually over time or upfront and used for specified resilience purposes. | + | Significant risk reductions can be achieved through resilient building, of the order of 50% in the example provided. The high risk reduction relative to the cost of resilience ratios mean a significant resilience dividend is available to be monetised through the structure, resulting in a positive net resilience benefit. |
| | | - | Challenges exist in the ability to achieve risk-based pricing and in the implementation of an insurance product that provides sufficient certainty at outset to fully fund the SPV and estimate future savings. Sensitivities suggest the structure may be uneconomic in examples with higher marginal costs of resilient building and lower risk or potential absolute risk reduction. |
| Deliver resilience benefits up-front | Optionality exists within the product structuring to bring the resilience dividend upfront by allowing early withdrawal from the SPV or in the medium term through reduced interest repayments or release of dividends as accrued. | + | The structure of the product has the flexibility to recognise future expected premium reductions by transferring the need to wait to a party with greater capacity to do so (either the lender or through an SPV structure). If instead realised over the lifetime of the loan in reduced interest payments or otherwise, whilst it is true that insurance risk reductions could be accrued similarly on an annual basis outside of this structure, additional certainty around savings in the medium term is provided. |
| | | - | Delivery of the resilience dividend upfront is not an implicit part of the product structure and may face challenges through uncertainty in the total value of the future saving in insurance over the lifetime of the loan. |
| Involve risk transfer | Risk transfer is fundamental to the product concept by taking standard infrastructure loans and ring-fencing a portion of the loan for future insurance spending. This mechanism is essential to capturing the resilience dividend. | + | Risk transfer is implicit in the structure which may incentivise increased insurance uptake against natural catastrophes so reducing the funding gap for reconstruction post event. Use of local providers can aid with development of the insurance market. |
| | | - | Challenges remain in the detailed definition and attractiveness of the required insurance product which needs an element of multi-year commitment and pre-agreed recognition of risk reduction. Cash flow analysis is also conducted against a non-resilient counterfactual where insurance is already in place (or is mandatory). Where there is no motivation or ability to seek insurance, the structure becomes less attractive. The opportunity cost of additional spending on insurance and the overall cost-benefit compared to other forms of financing should be considered. |

**TABLE 22** INSURANCE-LINKED LOAN PACKAGE ASSESSMENT AGAINST EX-ANTE CRITERIA

### 4.6.3. Summary and Next Actions

Within the analyses, the products have been structured to reflect the needs of the underlying use cases. There is sufficient flexibility within the product structures that they can and should be amended to reflect the specific needs of any scenario in which they are applied. The appropriateness of the product solutions will vary by use case, as will the results of the risk and cash flow analyses. The results we have presented demonstrate that the products can be appropriate in certain hypothetical, but realistic examples – the analyses can be used as a template for the types of results that can support product structuring.

There are clear roles and opportunities within these types of product for the donor community, NGOs, local and international insurance and reinsurance markets, capital markets, development banks, investors, and local service providers. The analyses suggest that both of the products are viable in the near-term, the following are some actions that would support implementation:

- **Development community**
    - Identify appropriate use cases for these products and design pilot schemes to apply these products at a reasonable initial scale.
    - These products are most appropriate in vulnerable high-risk areas, where the benefit of resilience is greatest. A quantification of the non-monetiseable benefits of resilience within these use cases will further amplify the value of using products that incorporate resilience.
    - Use partnerships with local agencies, development banks, impact investors, insurance and risk service providers to structure pilot products that work to the benefit of all parties.
- **Insurance services**
    - As far as is possible, set appropriate expectations around long-term coverage so that products which incorporate an insurance element can be costed appropriately at the start.
    - This may involve writing multi-year insurance contracts or entering into partnerships with donors and development banks with the aim of supporting coverage across longer timescales.
    - Define clear and objective criteria which can be used to determine whether risk reduction measures are recognised in a reduced insurance premium. This is expected to vary, though guidance on this point will be critical during the design stage of this type of product.

The innovation lab and product development have provided a foundation for further investigation into these product solutions. Further work is required to develop these product solutions to a point where they can be fully deployed, though the analysis indicates that there is good potential given the right use case.

# 5. APPENDIX

## i. Summary of Existing Instruments

### i.i. Risk Transfer Instruments

**Traditional insurance instruments effectively transfer risk but may not carry strong resilience building incentives.** Traditional insurance instruments, by definition, allow for the transfer of disaster risk to an insurer, the market, investors or a pool of peers. However, their ability to provide economic incentives to build resiliently are questionable. While it is possible that resilience investments could lead to lower future premium payments, the incentive effect of this mechanism is often weak due to most insurance contracts only lasting for one year (which means that the insured has less confidence over what premia may be beyond the term of the contract and makes the insurer less interested in resilience investments) and due to the less than full use of risk-based pricing. Another way traditional catastrophe insurance and reinsurance could motivate resilience building would be through making resilience investments a prerequisite for providing an insurance cover, but in a competitive industry such pre-conditions are often unrealistic.

**Traditional risk transfer instruments – Catastrophe insurance and reinsurance**

**Overview**

**Definition**
- Risk transfer instruments through which catastrophe risk is ceded to a third party (insurance or reinsurance company) in exchange for a premium
- Can have traditional or parametric pay-outs (triggered by pre-defined parameters such as windspeed of a hurricane); term usually 1 year

**Context**
- Appropriate for high risk, low frequency events
- Not directly related to resilience, particularly in light of the short length of the contract (annual)
- Available for both property and infrastructure

**Example**
- US DOT FTA Emergency Relief Program (ERP) requires flood insurance to disburse funds
- US transit organisations seek private insurance for catastrophe risks (Kunreuther et al,2016)

**Criteria**

**Encourage Resilience?**
Not directly – insuring against risks over the short term can lead to moral hazard; resilience building however can be a pre-requisite for cover ✕

**Monetise resilience benefits?**
Maybe – if pricing is risk-based then resilience may reduce premiums but is difficult in practice as the understanding of risk differs between agents ?

**Resilience Benefits Upfront?**
No – premia savings, if they exist, only accrue in the future and in any case are renegotiated annually and uncertain ✕

**Involve Risk Transfer?**
Yes – by definition ✓

**Conclusions**

**Benefits and Key Features**
- Well established risk transfer product for catastrophic events
- Relevant for infrastructure, commercial and residential property
- Several options exist to make insurance policies incentivise policy holders to introduce resilience:
1) risk-based premiums
2) resilience as a pre-condition for insurance
3) offer the option to policy holders to share a greater proportion of the risk through higher deductibles (leaves the policyholder exposed to more risk, may incentivise action to reduce their residual risks) (Lloyds, 2017)
- Insurance companies can make use of risk pooling to issue levels of cover that does not need to be backed by the same amount of capital in hand

**Barriers and Lessons Learned**
- Insurers may increase prices or not renew coverage after significant events, as was the case for the NYC MTA
- Cannot be used to transfer risk from high frequency events – may need to be considered in conjunction with other financing options in a risk layering structure
- Short term nature of contracts and competitive nature of the market makes embedding resilience incentives difficult;
- Developing countries' catastrophe insurance penetration is low (due to affordability, financial literacy etc.) while even in developed countries, coverage is low: of $4.8 billion damage suffered by the NYC MTA in 2012, $1 billion was covered by insurance
- 41% of damaged homes from the 2005 hurricanes were uninsured or underinsured (Kunreuther et al,2016)

**Relevance to Infrastructure**
- Is in use for infrastructure, commercial and residential property
- Risk-based pricing is an obvious way to make insurance incentivise infrastructure resilience, but is difficult to implement in practise
- There are often significant differences in understanding between insurers, brokers and infrastructure owners around the risks that critical infrastructure faces (Kunreuther et al, 2016)
- Without acceptable risk mitigation levels, some types of infrastructure see denial of coverage – this is the case for power utilities

**FIGURE 26** TRADITIONAL INSURANCE IS WELL-ESTABLISHED BUT HAS SEVERAL BARRIERS TO DELIVERING RESILIENCE BUILDING INCENTIVES. SOURCE: (KUNREUTHER ET AL. 2016; LLOYD'S OF LONDON 2017).

**Multi-year contracts have the potential to create the correct resilience building incentives, but long-term contracts may increase premiums.** The longer-term relationship between insurer and insured could allow for the benefits from resilience building to be internalized; the insured would be confident that their resilience investments would be reflected in lower premia while the insurer would be motivated to support investments that reduce the long-term risks they face. However, in practice, these contracts rarely exist as they entail significantly higher capital requirements for insurers, which increases premia relative to single year contracts. To deliver a resilience dividend, the instruments would also need to incorporate full risk-based pricing which may be challenging for regulatory, social or data availability reasons. Used in isolation, they also would not allow the resilience dividend to be captured upfront.

**Traditional risk transfer instruments – Multi-year insurance (MYI)**

**Overview**

**Definition**
- Also known as "long term insurance"; insurance contracts over a term of 3 to 25 years
- An agreed, fixed premium level is set at the start of the contract (Maynard, Ranger, 2013)

**Context**
- Rare in general retail insurance markets
- Has been explored for catastrophe insurance policies related to commercial and residential property
- No evidence found for infrastructure but considered in literature

**Example**
- No known implementations for catastrophic events despite experimental evidence that individuals would prefer it (Kunreuther, Michel-Kerjan; 2015)
- Exists in commercial insurance lines and for high net-worth individuals term is rarely >3 years in practice

**Criteria**

**Encourage Resilience?**
Yes – if accompanied with transparent risk-based premium pricing. Longer term nature of the contract supports implementation of resilience measures ✓

**Monetise resilience benefits?**
Uncertain given higher premium and capital requirements than short term contracts. ?

**Resilience Benefits Upfront?**
No – resilience measures may lower yearly premium payments but there is no lump sum gain upfront ✕

**Involve Risk Transfer?**
Yes – by definition ✓

**Conclusions**

**Benefits and Key Features**
- Long term risk transfer tool that can encourage resilience if combined with risk-based pricing
- The longer term relationship between insurer and the insured is key in encouraging resilience
- Can be done in conjunction with low interest rate loan to cover the high upfront cost of resilience measures – if annual rate of repayment is smaller than the annual insurance premium discount gained, the insuree sees immediate benefits from resilience (Kunreuther et al, 2016)

**Barriers and Lessons Learned**
- Fixed price leads to reduced flexibility in the face of severe losses for private insurers (Maynard, Ranger, 2013)
- High capital requirements: could be around 50% higher for a 10-year contract than an annual contract and the annual premium around 5.5% higher under conditions of known and stationary risk and higher in conditions of uncertain risks (Maynard, Ranger, 2011)
- There is a need for risk-based pricing, to provide infrastructure owners with accurate signals (Kunreuther et al, 2016) but there are practical challenges to implementation (regulated prices, cross-subsidisation, technical asset-level risk barriers, admin costs etc) (Maynard, Ranger, 2013)

**Relevance to Infrastructure**
- Political risk insurance often spans longer time horizons (up to 10 years) and has been applied to large infrastructure projects
- Insurance of this type is most common in the construction phase of large infrastructure projects
- The long lifespan of large infrastructure assets may help to create the long term relationship between the insurer and the insured that is needed to incentivise resilience improvements

**FIGURE 27** MULTI-YEAR INSURANCE CAN THEORETICALLY BOTH PROMOTE RESILIENCE AND INSURE AGAINST DISASTERS, BUT THE HIGH COSTS FOR BORROWERS AND LOW FLEXIBILITY FOR LENDERS MAKES IT UNATTRACTIVE. SOURCE: (KUNREUTHER & MICHEL-KERJAN 2015; MAYNARD & RANGER 2011; MAYNARD & RANGER 2013; KUNREUTHER ET AL. 2016).

## i.ii. *Alternative Risk Transfer Instruments*

**Risk pools can be a cost-effective way for smaller countries (or other administrative entities) to transfer risks; some risk pools mandate members develop contingency plans with resilience improvements as a condition for entry.** Recent risk pool arrangements such as CCRIF and ARC have enabled greater access to disaster risk transfer to some of the most vulnerable countries in the world. These can allow countries to transfer risks more cheaply than if they acted unilaterally, and resilience can be boosted indirectly by requirements for post-disaster contingency plans that can encourage building-back-better. In principle, resilience investments could also be incentivised through the prospect of future lower premia, but for the same reasons as discussed in section 1.3.1, the power of this incentive is likely to be weak. The dividend is also not available to the insured upfront at the point of making the resilience investment.

**Alternative Risk Carriers – Risk Pooling (CCRIF, ARC, UK RPA)**

**Overview**

**Definition**
- Risk pools combine the risks faced by several entities into a single, diversified portfolio
- This can create both diversification benefits and economies of scale, which help to reduce insurance premium costs (World Bank, 2017)

**Context**
- Can apply to sovereigns and specific public infrastructures
- Sovereign risk pools adopt a risk-layering approach (World Bank, 2017)
  - Some risk is retained by the pool through joint reserves
  - The excess risk is reinsured and transferred

**Example**
- UK Risk Protection Arrangement (2014): UK government risk pool that provides insurance for academy trusts
- CCRIF (2007, Caribbean): $622m cover, $67.3m cumulative payouts
- ARC (2014, Africa): $150m cover, $34m cumulative payouts

**Criteria**

**Encourage Resilience?**
Yes (depending in design) – ARC requires that members have contingency plans that support the resilience of other member countries (OECD, 2015) ✓

**Monetise Resilience Benefits?**
Maybe – if pricing is risk-based then some monetizable benefit from resilience ?

**Resilience Benefits Upfront?**
No – any benefits from undertaking resilience are realised over the longer term through potentially lower premiums (if at all) ✗

**Involve Risk Transfer?**
Yes – transfers risk from the country or entity to a pool of countries, financial markets and investors ✓

**Conclusions**

**Benefits and Key Features**
- Diversification and economies of scale have led to substantial cost reductions for insurance coverage – roughly 50% in the case of CCRIF and ARC (OECD, 2015), although this is contested by some stakeholders
- There can be an indirect resilience benefit if access to cheap insurance via the risk pool is dependant on implementing resilience plans (ARC)
- The risk pool itself may adopt a risk layering approach to maximise risk bearing efficiency
- CCRIF and ARC employ a degree of risk-based pricing in determining premiums

**Barriers and Lessons Learned**
- All sovereign catastrophe risk pools have required donor support (World Bank, 2017)
- Accurate, cost-saving evaluations are difficult to carry out
- Initial lack of clarity around how payments were used from CCRIF – no clear reporting facility (Dlugolecki, Kalra and Mechler, 2013)
- The Solomon Islands withdrew from PCRAFI after 2 events in 2014 did not trigger payouts – this illustrates the challenge of basis risk in parametric products

**Relevance to Infrastructure**
- Can and has been applied to cover public infrastructure specifically – the UK's RPA provides insurance cover for academy trusts at a lower price than commercial insurers (UK Gov, 2016)
- CCRIF funds have been used to repair critical infrastructure in the immediate aftermath of a disaster
- However, the funds from CCRIF are targeted more at providing immediate disaster relief rather than long to medium term reconstruction and resilience building financing
- The cost savings help to overcome the high insurance costs that can limit insurance uptake in developing countries (OECD, 2015)
- Credible oversight will be needed to ensure disbursed funds are appropriately and as agreed

**FIGURE 28** RISK POOLING IS ECONOMICAL BUT DOES NOT DIRECTLY INCENTIVISE RESILIENCE. SOURCE: (DLUGOLECKI ET AL. 2013; OECD 2015B; UK GOVERNMENT 2016; WORLD BANK 2017).

**Catastrophe (cat) bonds have seen increasing penetration in recent years as a risk transfer tool – however they are not typically structured to provide a resilience dividend.** To some extent, formulaic pricing at the annual resets of indemnity bonds, which allow coupon payments to be adjusted for exposure/risk growth, would also recognize modelled risk reductions in a reduction in coupon payment. However, to date this feature has not been used in this way and is typically capped.

### Insurance-Linked Securities – Catastrophe Bond

#### Overview

**Definition**
- A short-term bond (3-5 years) that can be 'triggered' during the bond term in the event of a disaster (RE:Focus, 2017)
- If triggered, the bond sponsor keeps a portion of the bond value and consequently investors lose some of their principal investment as well as future interest payments

**Context**
- Exact definition of the trigger is important – usually indemnity but parametric is not uncommon for sovereign issuers
- The World Bank 'MultiCat Program' helps countries sponsor cat bonds with the World Bank acting as an 'arranger' – assist in documentation, preparation of legal framework etc (IBRD, 2010)

**Example**
- Mexico 2009: $290 million, first offering under the MultiCat Program
- NYC MTA 2013: $200 million for storm surges following Hurricane Sandy (Kunreuther et al, 2016)
- California Earthquake Authority 2017: $925 million, 3 year bond (Artemis, 2017)

#### Criteria

| Encourage Resilience? | Monetise Resilience Benefits? | Resilience Benefits Upfront? | Involve Risk Transfer? |
|---|---|---|---|
| No – Cat bonds have a pre-defined trigger that is independent of resilience measures ✗ | No – Cat bonds do not directly pay out any monetary resilience dividend ✗ | No – there is no monetary resilience dividend from a cat bond ✗ | Yes – transfers risk from the issuer to capital markets and investors ✓ |

#### Conclusions

**Benefits and Key Features**
- Cat bond usually are indemnity based for private (re)insurers, but those issues by sovereign nations or infrastructure providers are often parametric and allow funds to be disbursed rapidly
- Provides insurance over several years at an agreed upon price
- The returns on a cat bond are uncorrelated with markets – this makes it an attractive investment for diversification
- Cat bonds can provide extremely high levels of cover

**Barriers and Lessons Learned**
- Not appropriate for all types of disaster risk – cannot be used for yearly events, for example, as the bond would always be triggered and investors would consistently suffer losses (Clarke et al, 2015)
- Hence will need to be complemented with other instruments to deliver comprehensive risk cover (Clarke et al, 2016)
- High cost is potentially preventing take up - cat bonds offer high returns for their risk and can cost up to 4 times what governments are willing to pay (Cavallo et al, 2017)

**Relevance to Infrastructure**
- Is applicable to public infrastructure – Mexico's Natural Disaster Fund (FONDEN) uses cat bonds to insure against low-frequency, high damage events
- More common for issuers to be insurers and corporations than countries
- The NYC Metropolitan Transit Authority issued $200 million of catastrophe bonds in 2013 after its insurance premiums doubled following Hurricane Sandy
- There is growing interest from some states, particularly in Latin America and the Caribbean – Peru, Chile and Colombia all released cat bonds onto the market in 2018 (Artemis; 2018, 2017b, 2017c)
- The World Bank helped CCRIF issue a $30 million cat bond in 2014 and the Philippines is close to sponsoring a $206 million cat bond

**FIGURE 29** CATASTROPHE BONDS DO NOT HAVE DIRECT RESILIENCE BENEFITS BUT ARE EFFECTIVE RISK TRANSFER TOOLS. SOURCE: (ARTEMIS, 2017A, 2017B, 2017C; CAVALLO, BORENSZTEIN, & JEANNE, 2017; CLARKE, DE JANVRY, SADOULET, & SKOUFIAS, 2015; CLARKE, MAHUL, POULTER, & LING TEH, 2016; IBRD, 2010; RE:FOCUS PARTNERS, 2017).

**The resilience bond concept is potentially very relevant to this project as it aims to both transfer risk and promote resilience; but it has not yet been used in practice.** Resilience bonds are intended to provide a reduction in insurance costs that can be captured as a resilience dividend or 'rebate'. The bond can be 'triggered' during the bond term in the event of a disaster in an identical fashion to a catastrophe bond. However, in addition, it is also intended to simultaneously promote investment in resilient infrastructure projects. This is achieved by having a caveat where insurance premiums fall after resilience measures are implemented, reflecting the lower risk investors face. This reduction on the insurance premium is then returned to the bond sponsor as a rebate, which can subsequently be used to invest in resilience projects. An analogy is a life insurance policy offering rebates for actions that lessen health risks. Whilst it does manage to create a monetary resilience dividend, the strict requirements such as data on risk exposure and modellable benefits from resilience measure has so far prevented issuance.

**Insurance-Linked Securities – Resilience Bond**

**Overview**

**Definition**
- Similar to a CAT bond – 3-5 year bond that can be 'triggered' so that the bond sponsor keeps a portion of the bond value (RE:Focus, 2017)
- The key difference is that resilience bonds incorporate the risk reduction value of resilience measures on expected losses

**Context**
- Resilience measures lead to reduced risk for investors and reduced premiums for the sponsor
- This manifests itself in a rebate from the investors to the sponsors based on potential insurance savings (RE:Focus, 2017)

**Example**
- There are currently no resilience bonds in issuance

**Criteria**

**Encourage Resilience?** Yes – resilience bonds account for the impact of resilience measures: the reduced risk for investors should create a rebate for the bond sponsor ✓

**Monetise Resilience Benefits?** Yes – resilience measures reduces the risk for investors and lowers the premiums for bond sponsors, creating a monetary resilience benefit ✓

**Resilience Benefits Upfront?** No – resilience bonds deliver a rebate in the form of savings from reduced premium payments rather than a lump sum. ✕

**Involve Risk Transfer?** Yes – transfers risk from the issuer to capital markets and investors ✓

**Conclusions**

**Benefits and Key Features**
- Can theoretically provide a resilience dividend without requiring long-run donor support
- This resilience dividend comes in the form of a reduction on the premiums paid as resilience measures reduce risk for investors
- Transfers burden of disaster risk from countries to capital markets whilst also creating an incentive to develop resilience

**Barriers and Lessons Learned**
- Several conditions need to be fulfilled for this structure to be appropriate (detailed data on exposure, modellable risks, estimates of resilience benefits, clear beneficiaries) (Re:Focus, 2017)
- Short maturity of the bond (3-5 years) limits the extent of yearly rebate savings from resilience measures
- Savings arise compared to taking out regular insurance – the premium is reduced when resilience measures are implemented
- Timing is important so the reduction in premiums is realised

**Relevance to Infrastructure**
- Can theoretically provide both insurance against disasters for infrastructure and also encourage implementation of resilience improving measures
- Has yet to be issued in the market - this is possibly a result of the heavy amount of bespoke modelling that would need to take place before resilience benefits etc are adequately quantified
- There may also be a lack of opportunities due to the time required to design eligible resilience projects

**FIGURE 30** RESILIENCE BONDS REQUIRE ACCURATE ESTIMATES FOR EXPOSURE AND RESILIENCE BENEFITS THAT MAKE IT DIFFICULT TO ISSUE. SOURCE: _(RE:FOCUS PARTNERS 2017).

## i.iii. Funding Instruments

**Whilst delivering upfront capital for project financing is a missing feature amongst existing risk-transfer products, other types of financing instruments have been able to achieve this in a variety of ways.** These financing-focused instruments span both the public and private sector, ranging from basic grants and concessional lending from development agencies, bond-based capital market instruments and more innovative, donor-supported bond issuances such as the IFF's Vaccine Bond program. Studying and incorporating the useful design elements from these upfront financing instruments will be key to developing an end product that involves risk transfer, encourages resilience and can deliver resilience dividends upfront for project financing.

**This section outlines the basic mechanisms and potential application to resilient infrastructure of five financing instruments – loans from multilateral development banks, Green Bonds, Social/Development Impact Bonds, Environmental Impact Bonds, IFFIm's Vaccine Bond Program and the CAT DDO instrument developed by the World Bank.** This set of instruments offers an overview of both the common mechanisms and some of the latest innovative designs in financing instruments, as well as helping to illustrate how capital markets, private investors and donor support can be leveraged effectively to provide project financing.

**Multilateral lending for infrastructure by international development institutions can be extended either on concessional or commercial terms. Concessional loans are loans that are extended on more generous terms than market loans.** The concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these. For example, the World Bank's IDA extends concessional lending to the poorest developing countries – it provides credits at little or no interest rate and repayments are stretched over 25 to 40 years, including 5-to 10-year grace period. Multilateral lenders can also provide loans on commercial terms, often offering long-term source of finance (20/30-year loans) critical for infrastructure projects.

**Green bonds leverage capital markets to provide upfront funding for projects with positive environmental benefits, but do not generate a resilience dividend or involve risk transfer.** They are similar to traditional bonds, but the funding generated from the green bond can only be used for 'green' projects with environmental and/or climate benefits. The mechanism is simple and tested, and is effective at generating large volumes of capital over long durations, making it suited for the demands of infrastructure projects. The rapid growth in green bonds in recent years demonstrates the growing investor appetite for financial instruments with strong ESG credentials, with over $250 billion of green bonds outstanding in 2017.

**Impact bonds, also known as pay-for-performance contracts, transfer the risk of implementing a project to private investors who receive principal repayment plus a financial return if – and only if – independently verified performance targets have been achieved.** They are therefore not 'bonds' in the conventional sense as investors stand to lose part or all of their investment if unsuccessful. Depending on the nature of outcomes pursued, these contracts can be social (SIB), development (DIB) or, more recently, environmental (EIB) impact bonds, typically issued by a government or a donor, funded upfront by private sector investors and executed by private sector service providers. This effectively transfers the project execution risk from governments and donors to investors. Impact bonds are an attractive option in theory as they promote private sector involvement. However, adapting them to resilient infrastructure investment may prove difficult. First, they typically tackle easy-to-measure social, environmental and development outcomes. Applying the same outcome simplicity to resilience can be limiting, given the complicated nature of resilience measures and the associated measurement issues. Second, commercial viability of these instruments for large infrastructure projects is questionable – SIBs have mostly been used for smaller scale projects, there is only one example of a privately invested EIB[23]; though a number of DIBs are in development, there has been no large scale deployment so far.

**The International Finance Facility for Immunization's vaccine bonds convert long-term donor pledges into upfront capital for immediate project finance.** IFFm sells 'vaccine bonds' in capital markets that are

[23] In 2016, DC Water raised $25 million to test the feasibility of green infrastructure for controlling storm water runoff. Should green infrastructure outperform expectations, investors will receive an additional $3.3 million but will lose $3.3 million if it underperforms.

effectively backed by the pledges from donors – this secures favorable pricing and provides immediate resources to support immunization programs (Gargasson & Salomé 2010). IFFIm's structure of involving developed country funding and capital markets to improve outcomes could provide a source of inspiration for this project for how donor support can be utilized effectively. Whilst the instrument does not have any risk transfer element, it has been able to generate large amounts of funding (nearly $6 billion from 2006-2016) and has been effective in mobilizing action. However, thought should be given as to whether the same investor appetite would exist for bonds supporting resilient infrastructure where the outcomes of projects are less obvious and potentially less marketable than for vaccination programs.

**The World Bank's Catastrophe Deferred Drawdown Option (CAT DDO) in an innovative form of contingent capital to provide immediate liquidity in the immediate aftermath of a disaster.** The CAT DDO is separated from more basic contingent credit options by the 'soft trigger' it employs and the flexibility in its terms. Funds of up to $500 million from the CAT DDO are available immediately once a state of emergency is declared due to a disaster, allowing funds to be dispersed rapidly as no evaluation of damages needs to be undertaken (GFDRR 2011). The CAT DDO has a renewable draw down period that can be extended up to 15 years as well as a 'revolving feature' where any funds repaid can subsequently be re-withdrawn if required. This flexibility in access, repayment time and the continued availability of repaid amounts has enabled the CAT DDO to be often used – eight out of twelve countries with CAT DDO agreements in 2016 had utilized it to some degree (The World Bank 2016b), including the Philippines withdrawing $500 million in 2011 after Storm Washi (The World Bank 2011).

An additional caveat is that countries must have disaster risk management programs in place to be eligible for the CAT DDO, further encouraging disaster resilience. In Colombia, 627 municipalities created disaster management plans and there was significant expansion of disaster monitoring stations around the country (The World Bank 2017a). The CAT DDO represents an example of how basic, existing funding instruments can be modified to be better suited for developing countries and providing disaster relief.

## ii. OECD-DAC Database Donor List

| DAC Countries | Non-DAC Countries | Multilateral Agencies |
|---|---|---|
| Australia | Azerbaijan | IMF (Concessional Trust Funds) |
| Austria | Bulgaria | African Development Bank, Total |
| Belgium | Croatia | African Development Bank [AfDB] |
| Canada | Cyprus | African Development Fund [AfDF] |
| Czech Republic | Estonia | Asian Development Bank [AsDB] |
| Denmark | Israel | AsDB Special Funds |
| Finland | Kazakhstan | Inter-American Development Bank [IDB] |
| France | Kuwait | IDB Invest |
| Germany | Latvia | IDB Special Fund |
| Greece | Liechtenstein | Caribbean Development Bank [CarDB] |
| Hungary | Lithuania | Council of Europe Development Bank [CEB] |
| Iceland | Malta | European Bank for Reconstruction and Development [EBRD] |
| Ireland | Romania | Islamic Development Bank [IsDB] |
| Italy | Russia | Food and Agriculture Organisation [FAO] |
| Japan | Saudi Arabia | International Atomic Energy Agency [IAEA] |
| Korea | Chinese Taipei | IFAD |
| Luxembourg | Thailand | International Labour Organisation [ILO] |
| Netherlands | Timor-Leste | UNAIDS |
| New Zealand | Turkey | UNDP |
| Norway | United Arab Emirates | UNECE |
| Poland | | UNEP |
| Portugal | | UNFPA |
| Slovak Republic | | UNHCR |
| Slovenia | | UNICEF |
| Spain | | UN Peacebuilding Fund [UNPBF] |
| Sweden | | UNRWA |
| Switzerland | | WFP |
| U.K. | | World Health Organisation [WHO] |
| U.S. | | World Tourism Organisation [UNWTO] |
| | | International Bank for Reconstruction and Development [IBRD] |
| | | International Development Association [IDA] |
| | | International Finance Corporation [IFC] |
| | | Adaptation Fund |
| | | Arab Bank for Economic Development in Africa [BADEA] |
| | | Arab Fund (AFESD) |
| | | Climate Investment Funds [CIF] |
| | | Global Alliance for Vaccines and Immunization [GAVI] |
| | | Global Environment Facility [GEF] |
| | | Global Fund |
| | | Global Green Growth Institute [GGGI] |
| | | Green Climate Fund [GCF] |
| | | Montreal Protocol |
| | | Nordic Development Fund [NDF] |
| | | OPEC Fund for International Development [OFID] |
| | | OSCE |

**TABLE 23** A LIST OF THE DONORS ACCOUNTED FOR IN THE OECD-DAC AID DATABASE.

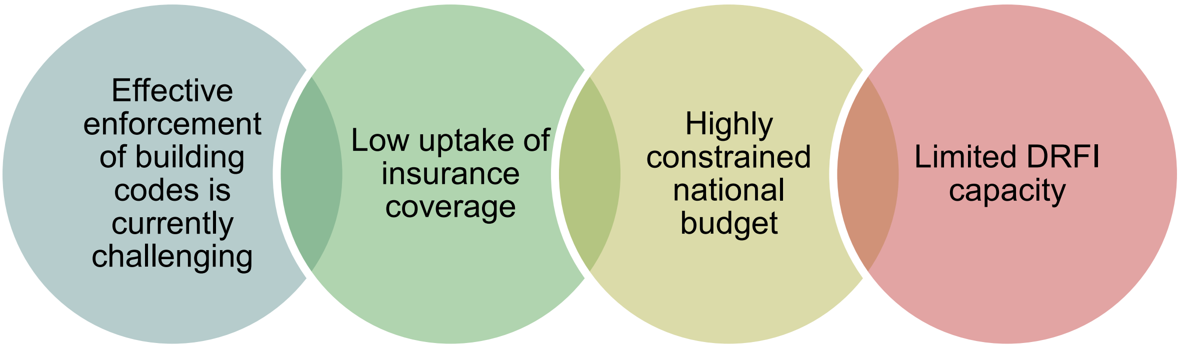
## iii. Innovation Lab Use Cases

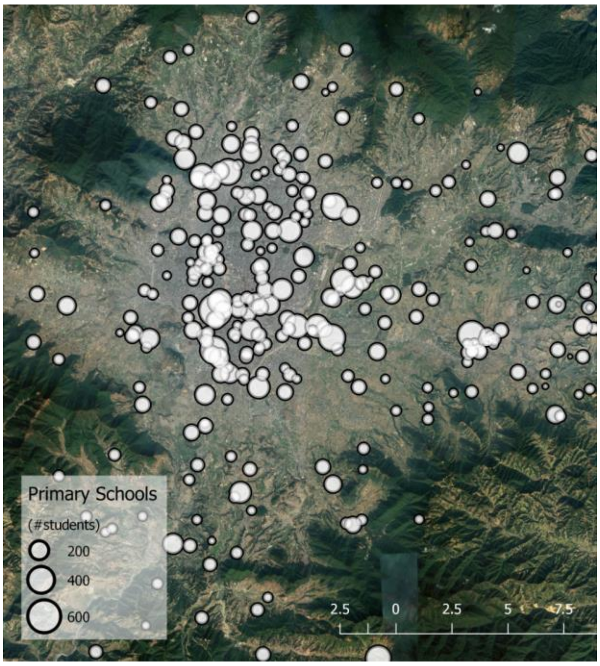
The following use cases were used to stimulate discussion at the Innovation Lab.

# USE CASE 1

## SMALL, LOW INCOME COUNTRY – SCHOOLS – EARTHQUAKE-GROUND SHAKING – BUILDING TO CODE

The Gorkha earthquake in April 2015 destroyed 35k classrooms and left more than 1m children with no school to return to[24]. There are ongoing efforts in Nepal to build according to government approved seismic-resistant designs, however effectiveness of implementation during the construction phase is variable. If constructed using suitable design codes, which are fully implemented, school structures can remain largely intact following earthquakes, protecting the occupants, and subsequently acting as safe communal spaces in the months that follow. This use case presents several challenges to the implementation of innovative financing that are more specific to countries in similar low-income country.




**Case Study**

300 Primary Schools in Kathmandu Valley to be built-back-better (rebuild only, no retrofit)

Building to higher seismic design standards creates a resilience dividend (risk reduction)

**Assumption 1:** Construction costs for 1-storey schools in an urban setting cost ~$1k per. student. Total portfolio value = $28million

**Assumption 2:** Reinforced Concrete Moment Resisting Frame (RC MRF), with excellent construction quality **costs 1.25x** more than the traditional Masonry alternative

**FIGURE 1** MAP OF 300 PRIMARY SCHOOLS IN KATHMANDU VALLEY (CIRCLES SIZE PROPORTIONAL TO NUMBER OF STUDENTS).

[24] https://plan-international.org/press-releases/nepal-earthquake-urgent-need-rebuild-and-repair-schools#

## PRIMARY RESILIENCE DIVIDEND (REDUCTION IN PHYSICAL ASSET DAMAGE)

A comparative risk analysis has been completed to quantify the potential risk reduction possible from building 300 primary schools according to well implemented 'resilient' seismic-resistant design codes rather than using poorly implemented standard design practices[25].

- **Base Case:** Schools built using confined masonry and with poorly implemented building codes
- **Resilient Case:** Schools built to better than code (reinforced concrete moment resisting frame) and building standards are enforced
- **Risk Reduction:** Up to 50% reduction in damage experienced during an event and expected annual loss (comparative vulnerability curves shown in Figure 3).
- **Gorka Earthquake Analysis**: For the portfolio of primary schools in Kathmandu, the ground shaking in MMI at each location is calculated from the USGS ShakeMap[26] of the event (Figure 2), and the potential damage reduction between construction types and methods is shown in Figure 3.

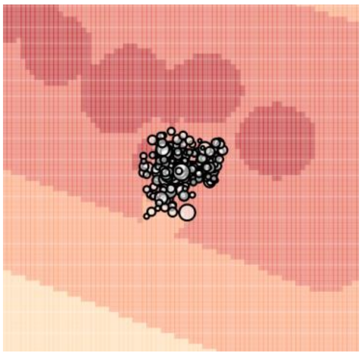


**FIGURE 2** USGS SHAKEMAP (MMI) FOR GORKA EARTHQUAKE OVERLAID ON PRIMARY SCHOOL LOCATIONS

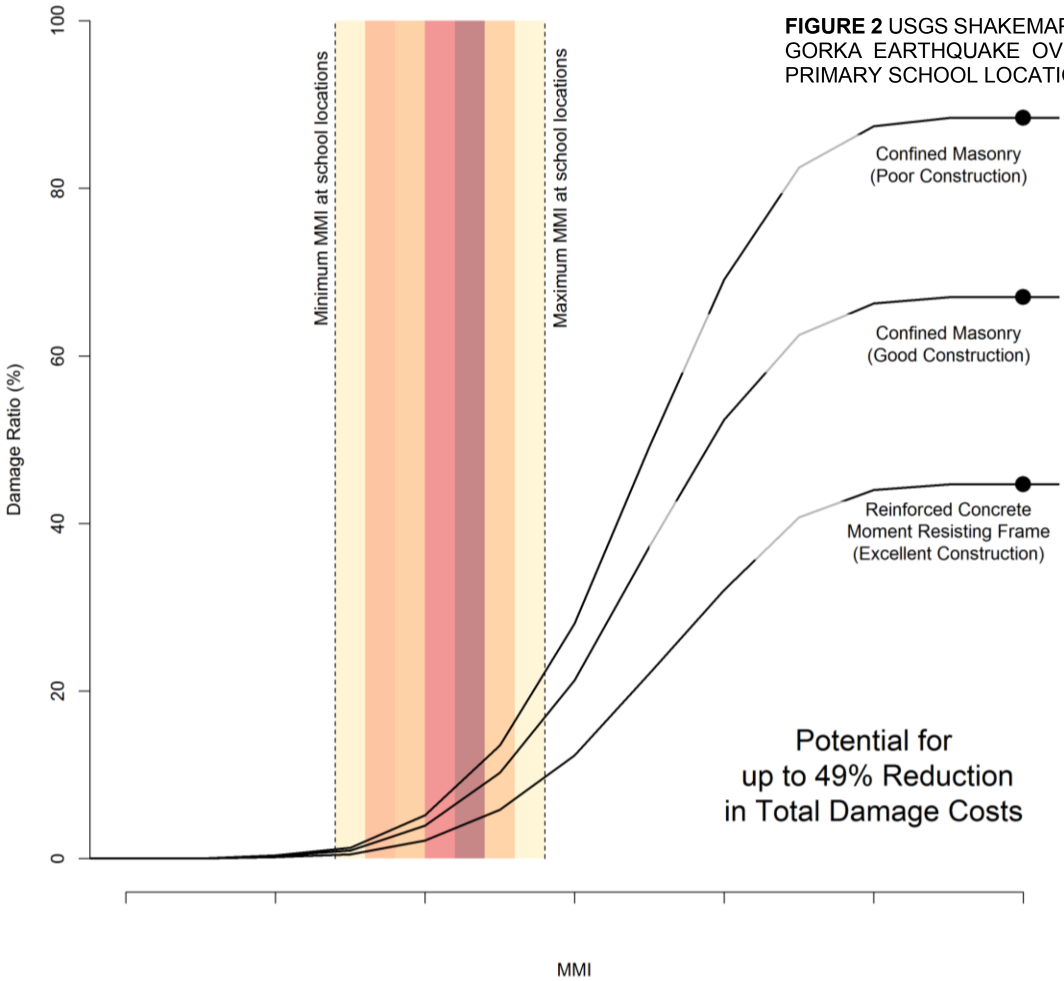



**FIGURE 3** COMPARISON OF VULNERABILITY CURVES FOR BASE (CONFINED MASONRY – POOR CONSTRUCTION) AND RESILIENT CASES (MRF – EXCELLENT CONSTRUCTION), INCLUDING AN INTERMEDIATE ANALOGY WHERE SCHOOLS ARE BUILT TO EXISTING CODES BUT BUILDING STANDARDS ARE ENFORCED. GORKHA MMI RANGE OVERLAID.

[25] For the purposes of this analysis, representative asset loss exceedance probability curves have been developed using a combination of RMS earthquake source models incorporating Nepal alongside RMS model components from comparable/neighboring regions.
[26] https://earthquake.usgs.gov/earthquakes/eventpage/us20002926#executive

## RESILIENCE METRICS

### AAL Reduction and Discount Adjusted Return on Investment ($ROI_{10y}$):

- The case study assesses 300 schools with a total replacement value of $27.9m.
- The Base Case average annual loss (AAL) from ground shaking due to earthquake is $47.8k or 0.17% of total replacement value.
- Building the 300 schools to better than code, the Resilient Case, has an associated cost of resilience of an additional $7.0million or 25%.
- This corresponds to an 53% reduction in the AAL to $25.2, or a $22.6k reduction in absolute terms.
- This reduction in AAL, or ∆AAL, can be equated to an equivalent reduction in insurance premium payment if the premium is purely risk based.
- This reduction in premium payment could be made available as the resilience dividend.
- The cost benefit of investment in resilience can be approximated using the Net Present Value (NPV) of the additional cost of resilience at outset and the discounted[27] future potential cash flow of annual resilience dividends over a 10-year time horizon in the form of a reduction in premium. The Return on Additional Investment is presented as an absolute number describing benefit-cost, and as a percentage
- $ROI_{10y}$ = -$6.83m (total additional cost of resilience = $6.99m), or -97.7% (e.g. -20% implies that 80% of the total initial investment has been made up by 10y of accrued PV adjusted benefits)

## TAIL RISK

### 1 in 100 Saving:

- Earthquake risk is typically low frequency but high severity.
- Decision making around investment in resilience should consider the potential for damage reduction across a range of event severities and likelihoods.
- Figure 4 illustrates the different risk profile of the two construction types.
- The red curve shows the Base Case probability of exceeding a range of loss thresholds on a per occurrence basis, e.g. there is a 1% annual probability that the 300 primary schools will incur at least $1.2 million worth of damage from an earthquake.
- The blue curve shows the Resilient Case, and the dashed curve shows the probabilities of making a range of savings.

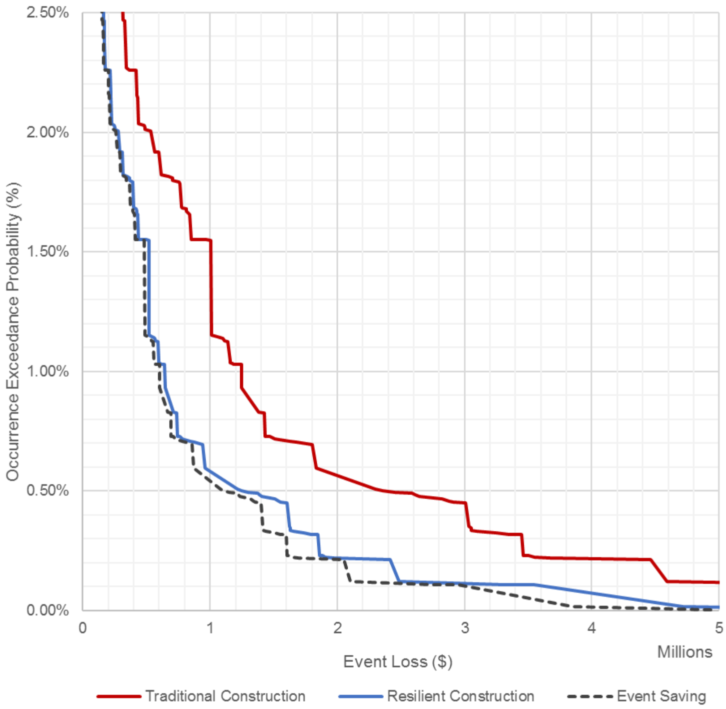



**FIGURE 4** EXCEEDANCE PROBABILITY CURVE DISPLAYING EVENT LOSSES FOR A RANGE OF EXCEEDANCE PROBABILITIES ($5M IS ~20% OF THE TOTAL PORTFOLIO VALUE)

[27] The 10% discount rate is based on the Green Book guidance that discount rates for appraisals in developing countries should be based on the social time preference rate appropriate to those countries. Existing DFID and World Bank practice points to rates in the region of 10-12%. The first resilient dividend is assumed to be realized in year 0 as a simplifying assumption and inflation in insurance premium payments is not considered. More detailed and comprehensive NPV calculations will vary depending upon the product solution and associated cashflows.

## KEY TAKEAWAYS AND METRICS

- Adherence to existing building codes can yield substantial resilience benefits (~25% reduction in damage between poor and good construction)
- Return on investment calculations provide minimal support for investment in resilience measures that are tailored at low frequency events
- Seismic resistant buildings are more designed to protect life than to minimise building damage
- ROI calculations that use reduction in AAL (based only on asset damage) do not account for the additional benefits that result from building more resiliently

| +COST | ΔAAL | Resilience Ratio | 10y DISCOUNTED ROI | 1 in 100 Saving |
|---|---|---|---|---|
| +25% | -50% | 310years | -98% | $0.6 million (21% of TIV) |

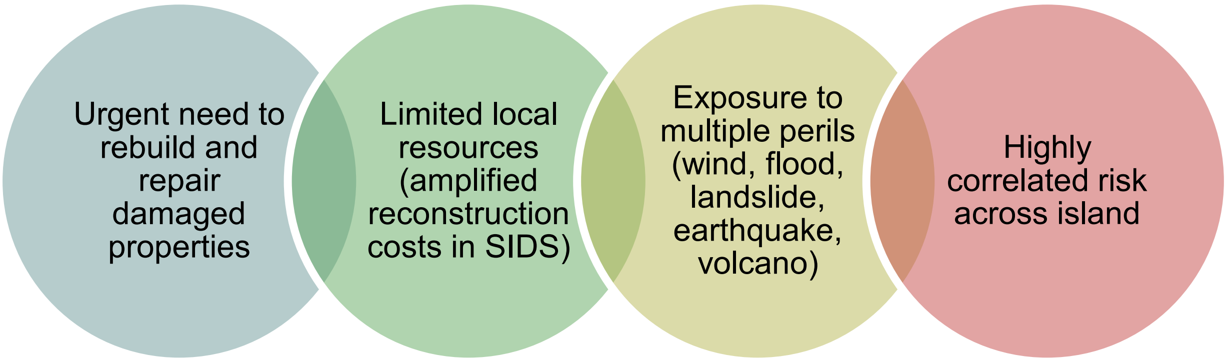
## TECHNICAL CHALLENGES

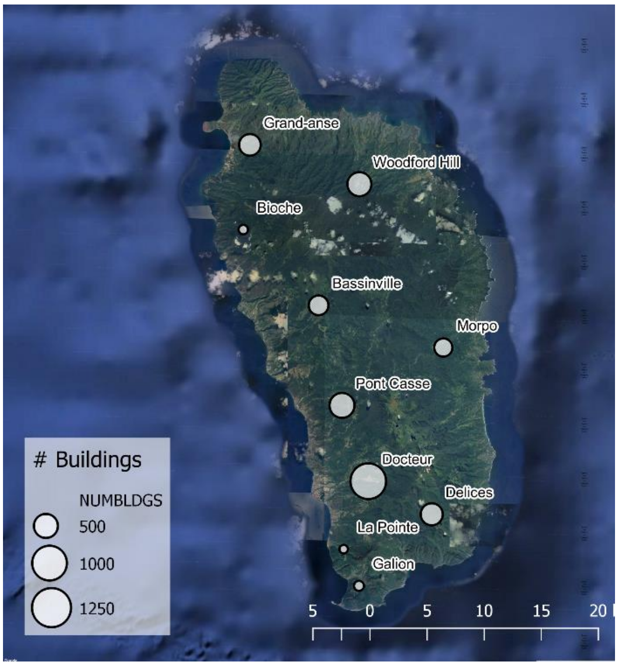
- Cost-benefit of resilience spending to protect against low probability high severity events. There are factors beyond the asset damage costs that must be considered for low-frequency high-severity events in particular
    - Economic loss
    - Protection of life
    - Continuity of education services
- How can the challenge presented by high discount rates be overcome in incentivising spending on resilience?
- Can reductions in AAL translate into meaningful reductions in premium when other contributing factors to the technical premium and pricing are considered e.g. pricing in of data uncertainty?
- What are the challenges of deploying insurance in a non-insured world
- How can the correct implementation of design codes be enforced?
- How should maintenance costs be considered?

# USE CASE 2

## SMALL ISLAND STATE – LOW-INCOME HOUSING – HURRICANE – BUILD BACK BETTER

Low-income housing in Dominica was heavily damaged during the hurricane season of 2017. There is a pressing need to ensure that replacement housing is built in a resilient and sustainable manner, and that partially-damaged and undamaged housing is addressed to ensure that it performs well in the years to come. A combination of rebuild, repair, and retrofit is required to ensure that communities are well protected against wind risk. This use case presents an opportunity to develop a product that is appropriate for lighter infrastructure (shelter & housing), for a combination of rebuild and repair, in a setting which requires immediate attention.




**Case Study**

3000 low-income properties distributed across Dominica, combination of rebuild and repair

Build structural resistance to wind risk

**Assumption 1:** Single storey masonry construction, 500 sq. ft. ($50 psf. base cost = $25k property value) - assume simiar costs across island

**Assumption 2:** Additional costs of resilience measures based on US analogy, from National Institute of Building Sciences

**FIGURE 1** MAP OF 3000 LOW-INCOME PROPERTIES ACROSS DOMINICA – DISTRIBUTED ACCORDING TO LOCATIONS OF INSURED PROPERTIES IN THE RMS EXPOSURE DATABASE[28]

[28] http://www.nibs.org/page/mitigationsaves

## PRELIMINARY IMPACT ASSESSMENT FROM 2017 HURRICANE SEASON

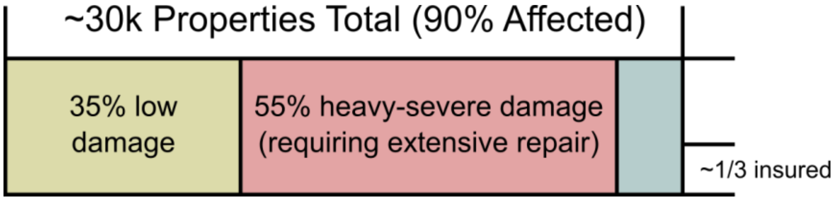



**FIGURE 2** PRELIMINARY DAMAGE ASSESSMENTS FOR HOUSING IN DOMINICA (90% DAMAGED OF ~30K PROPERTIES)

## RESILIENCE OPTIONS (REBUILD AND RETROFIT)

The RMS North Atlantic Hurricane model has been used to quantify the risk reduction to be expected for a range of building and retrofit options across our hypothetical housing portfolio. Results for a range of options are presented below:

| Resilience Options | Cost | | Risk | Reduction in Average Annual Loss (Relative to Base) | | | |
|---|---|---|---|---|---|---|---|
| Resilience Measure (Base Cost +X%) | Additional Cost (%) | Total Cost ($million) | Absolute AAL ($k) | AAL | XS25 years | XS100 years | XS250 years |
| No Protection (+0%) | 0.0% | 96.2 | 289.5 | 0% | 0% | 0% | 0% |
| Roof Anchor & Sheathing (+1%) | 1.0% | 97.2 | 203.0 | 30% | 34% | 33% | 29% |
| Roof Cover & Sheathing (+2.5%) | 2.5% | 98.6 | 192.2 | 34% | 35% | 31% | 26% |
| Roof Anchor & Covering, and Opening Protection (+4.4%) | 4.4% | 100.5 | 195.0 | 33% | 35% | 36% | 33% |
| Full Roof Retrofit (+8%) | 8.0% | 103.9 | 131.1 | 55% | 58% | 54% | 48% |
| Full Retrofit (+9.9%) | 9.9% | 105.8 | 119.9 | 59% | 62% | 60% | 55% |

**TABLE 24** COSTS AND SAVINGS FOR A HYPOTHETICAL HOUSING PORTFOLIO AND A RANGE OF RESILIENCE OPTIONS

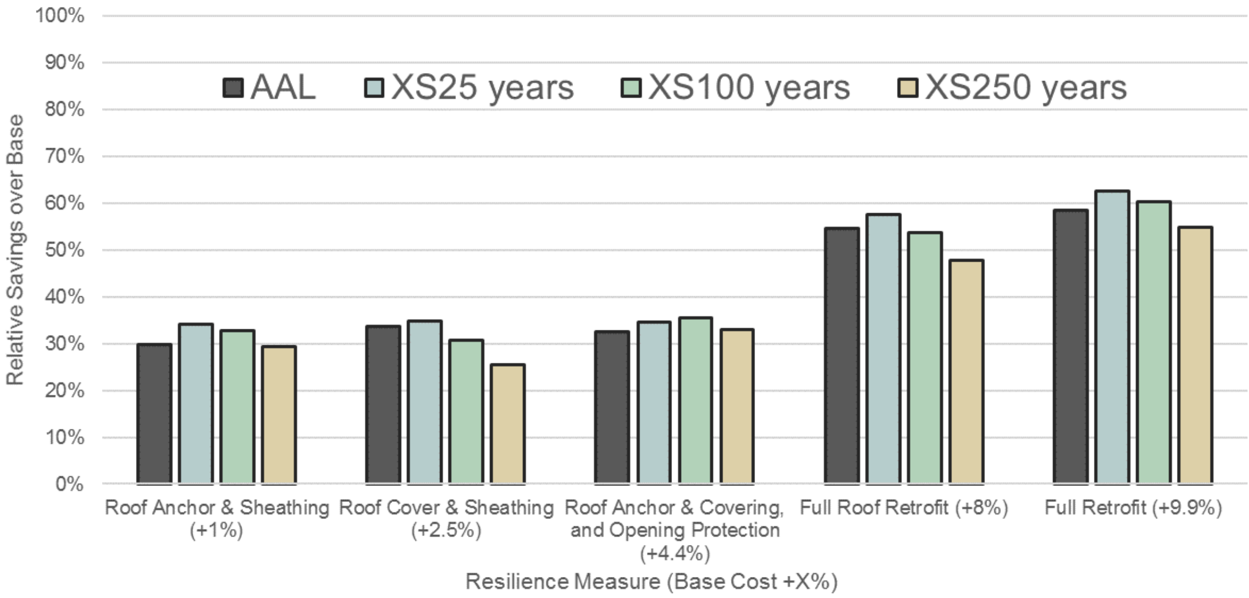



**FIGURE 3** RESILIENCE OPTIONS FOR REBUILD AND RETROFIT: COSTS AND RESILIENCE DIVIDENDS

## SAVINGS EXCEEDANCE PROBABILITY

- The below curves show:
  - Loss exceedance probability for 'base structure' (no additional wind protection)
  - Savings exceedance probability curves for range of rebuild and retrofit options

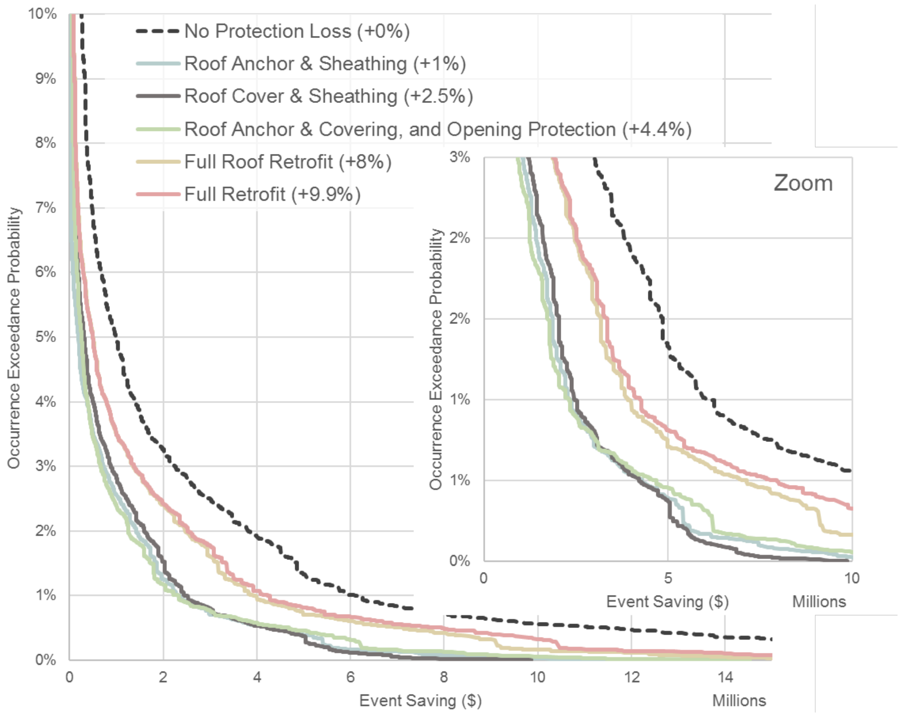



**FIGURE 4** SAVINGS EXCEEDANCE PROBABILITY CURVES

## KEY TAKEAWAYS AND RESILIENCE METRICS

- Large and immediate need for investment in repair and rebuild of homes
- Low-cost resilience measures can yield a tangible resilience dividend when the peril has high frequency. However, they may generate lower damage reductions at higher wind speeds
- Combinations of resilience measure can increase resilience across range of wind speeds (need targeted investment based on defined resilience targets/ risk tolerance levels)
- Possible to generate savings of up to 60% for 10% of additional up front investment
- Even for low-cost resilience measures, present value adjusted resilience dividends are unlikely to pay off additional cost of resilient infrastructure (due largely to discount rate of 10%)
- ROI calculations do not consider other forms of benefit from resilient building such as welfare and other socioeconomic factors

| +COST | ΔAAL | Resilience Ratio | 10y DISCOUNTED ROI | 1 in 100 Saving |
|---|---|---|---|---|
| +1 to 10% | -30 to -60% | 12 to 57years | -37% to -88% | $2.3 to 4.3 million (2.4-4.0% of TIV) |

## TECHNICAL CHALLENGES

- Exposure across multiple perils including landslide – only wind is considered here for simplicity.
  - Mitigation of landslide risk requires larger scale land planning than consideration of individual building risk.
- Low insurance penetration rates
- Risk ownership and responsibility for premium payments (question of premium financing)
- Very high-risk environment, island has been repeatedly impacted by large hurricane events (David 1979, Erica 2015, Maria 2017)
- Limited local resources for rebuilding (<10 architects across the whole island)
- How to maintain resilience of building stock

# USE CASE 3

## CARIBBEAN SMALL ISLAND – PORTS – HURRICANE – DEFENCES+PREPAREDNESS

Tourism provides significant income for Small Island Developing States (SIDS) in the Caribbean. During the 2014-2015 cruise season, cruising generated $2.4 billion in direct economic impact for the Caribbean and created nearly 55,000 jobs and $842 million in wages throughout the region[29]. Maintaining functioning ports helps to promote continuity in jobs and income for impacted islands following disaster[30]. There may be potential to reinforce existing ports to make them more resistant to storm damage, or to develop coastal protection measures to protect the areas surrounding terminals. The benefactors of more resilient terminals vary from the cruise ship companies, to the local business owners and general population. This use case presents an example where defences and/or preparedness plans may be appropriate to reduce the severity of impact.

- Coastal protection infrastructure can be expensive
- Diverse range of benefits and beneficiaries associated with operational ports
- Justifying resilience in vulnerable and changing coastal environments
- Sustainability of green versus grey protective infrastructure


**Case Study**

Hurricane risk from wind and storm surge to 1 port facility in the Caribbean (illustrative example for Turks & Caicos)

Quantify the reduction in number of days to full recovery that result from; (a) storm surge protection, and; (b) better preparedness plans

**Assumption 1:** port location is suitable for construction of surge defence infrastructure (defences are 100% effective at specified defence level)

**Assumption 2:** business interruption vulnerability curves are approximately equivalent to the number of days the port is unoperational for

**FIGURE 1** TURKS & CAICOS PORT LOCATION WITH THEORETICAL COASTAL PROTECTION MEASURES

[29] http://www.f-cca.com/downloads/2015-cruise-analysis-volume-1.pdf
[30] http://www.caribbeanforeveryone.com/

## RISK TO PORTS

The RMS North Atlantic Hurricane model has been used to quantify the Business Interruption (BI) risk to an illustrative port in the Caribbean.

The resilience dividend for this example is measured in ‘Days of Downtime’. The cost of 1 day of BI varies significantly between beneficiaries of a functioning port, from cruise operators to local business owners.

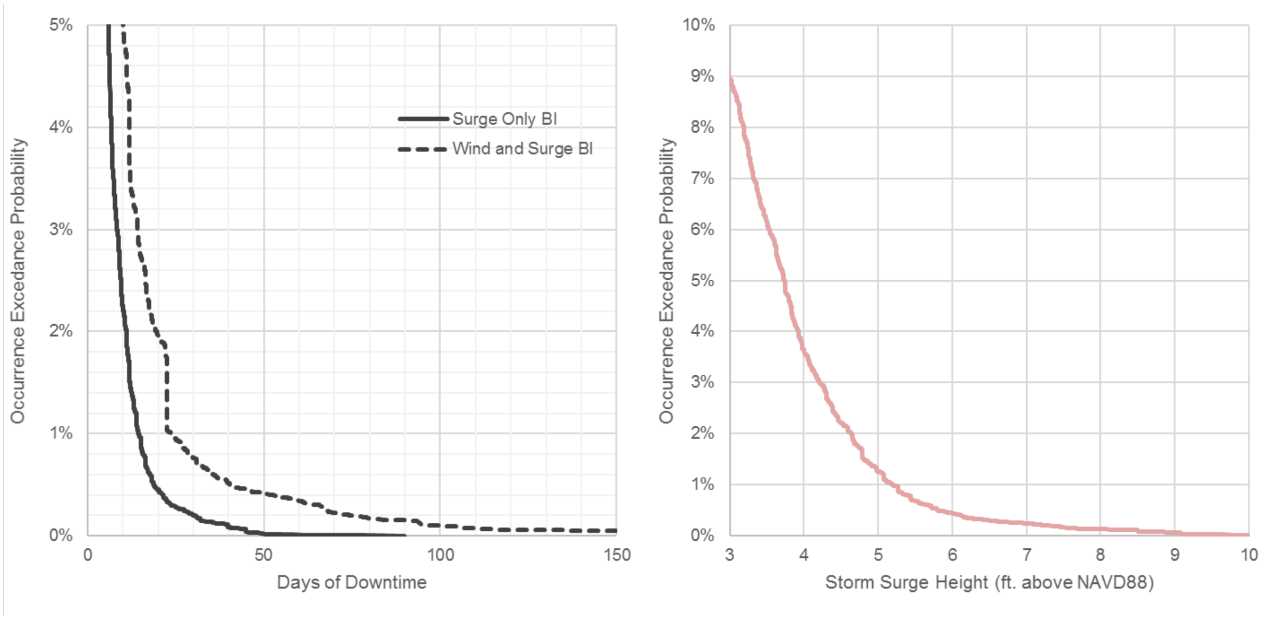



**FIGURE 2** EXCEEDANCE PROBABILITY CURVES SHOWING: (LEFT) DOWNTIME PROBABILITY FOR WIND AND WIND+SURGE COMBINED, AND: (RIGHT) STORM SURGE HAZARD

## EXAMPLE RESILIENCE OPTION 1 – COASTAL DEFENCES (ENGINEERED/NATURAL)

**Storm Surge Protection:**

- Surge defences can reduce the impact from events that cause low levels of storm surge
- Impact to ports is measured in ‘Days of Downtime’ (annualised metric is Average Annual Downtime – AAD)
- There may be additional benefits to coastal communities from reduced storm surge risk
- There may be negative impacts to local ecosystems or nearby unprotected communities from large defence infrastructure
- Natural defences (coral) could be deployed to reduce storm surge impact

| Surge Protection (ft.) | AAD | AAD Reduction | 1 in 25 year saving (days) | 1 in 100 year saving (days) |
|---|---|---|---|---|
| **No Protection** | **0.85** | - | - | - |
| 3 | 0.78 | 9% | 1.4 | 2.22 |
| 4 | 0.51 | 41% | 3.91 | 6.28 |
| 5 | 0.27 | 68% | 5.8 | 9.97 |
| 6 | 0.14 | 84% | 6.37 | 12.33 |
| 7 | 0.09 | 89% | 6.51 | 13.41 |

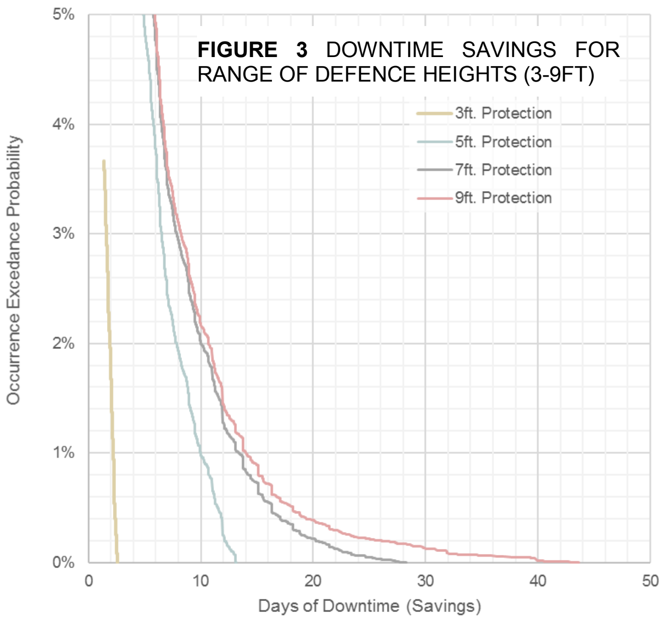
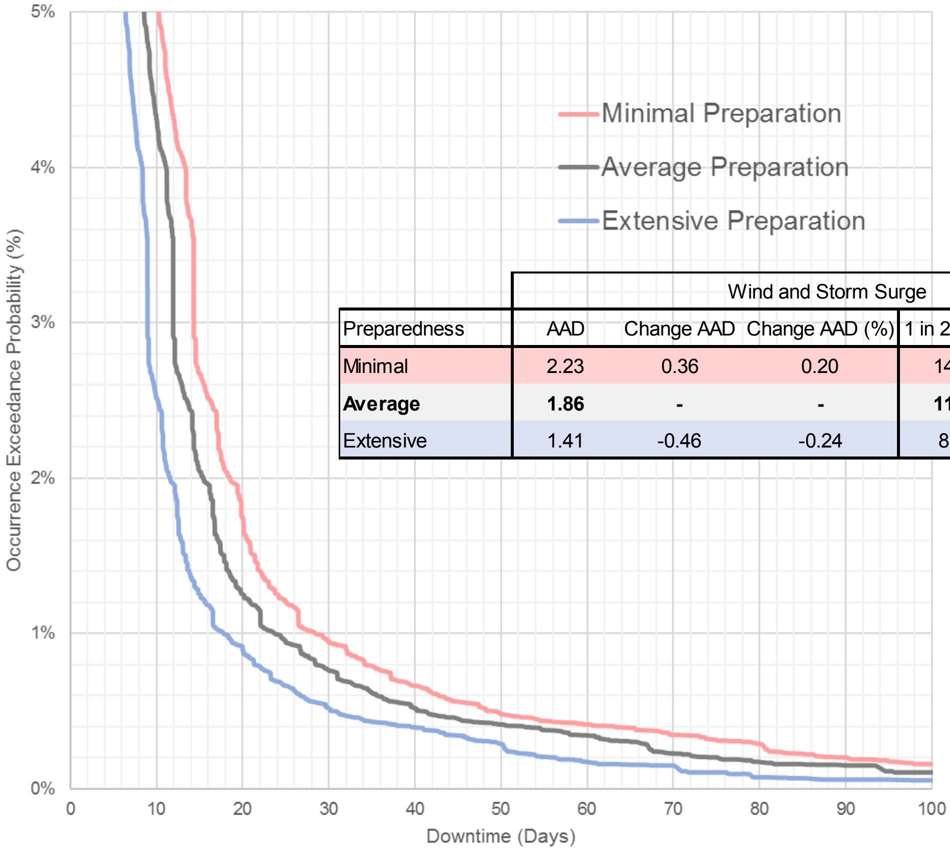



**FIGURE 3** DOWNTIME SAVINGS FOR RANGE OF DEFENCE HEIGHTS (3-9FT)

# EXAMPLE RESILIENCE OPTION 2 – CONTINGENCY PLANNING

The level of preparedness of a port with regards to storm surge will also affect the level of business interruption, so should be considered when assessing resilient solutions. The preparedness level relates to business continuation plans that incorporate the following:

- Critical spare parts are stored on site to ensure that post disaster recovery of equipment is as fast as possible
- On site fuel storage and generators so there is power available even if public grid infrastructure is down
- Contingency plans to minimise damage to equipment e.g. storing valuable assets inside or strapping down items
- Mitigation techniques such as boarding up windows




| | Wind and Storm Surge | | | | |
|---|---|---|---|---|---|
| Preparedness | AAD | Change AAD | Change AAD (%) | 1 in 25 Loss | 1 in 100 Loss |
| Minimal | 2.23 | 0.36 | 0.20 | 14.32 | 28.45 |
| **Average** | **1.86** | **-** | **-** | **11.93** | **23.70** |
| Extensive | 1.41 | -0.46 | -0.24 | 8.95 | 17.78 |

**FIGURE 4** DOWNTIME EXCEEDANCE PROBABILITY CURVE FOR RANGE OF PREPAREDNESS OPTIONS (WIND AND SURGE)

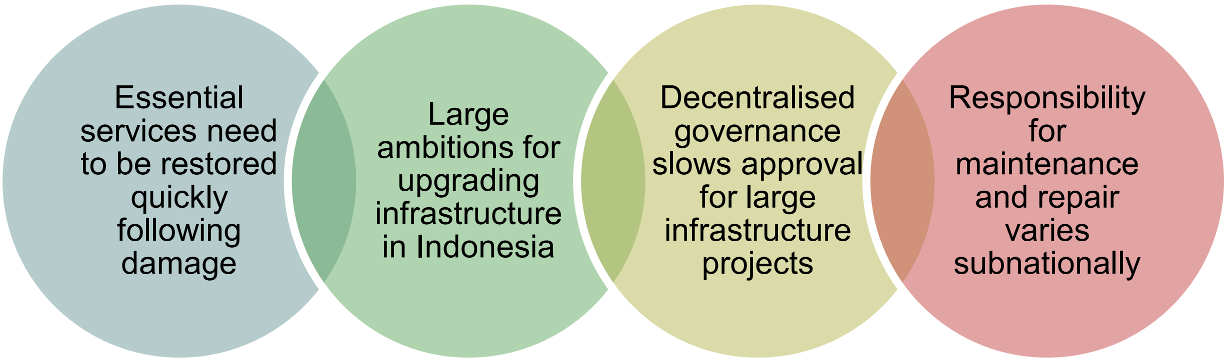
# TECHNICAL CHALLENGES

- It takes time to fully implement coastal protection measures
- Coastal protection may not be 100% effective when surge events do occur
- Storm surge risk is amplified by rising sea-level. How to justify building resilience in a changing environment
- Challenges of green infrastructure (coral reefs, mangroves)
  - Requires long-term investment of resources
  - Sensitive to changes in local conditions
  - How to capture environmental and social benefits of natural defences
  - Not appropriate in all locations
  - Can be severely damaged during hurricanes

# USE CASE 4

SOUTH-EAST ASIA – TRANSPORT INFRASTRUCTURE – EQ – RAPID RECOVERY/ MAINTAINING A SERVICE

Working transportation networks are fundamental to recovery following large disaster events. They enable the movement of rescue teams and the distribution of resources immediately following an event, and in the longer term, the transportation of goods and people. Damages resulting from both seismic and hydrologic events can quickly render a road impassable. It may be uneconomical to make roads universally resistant to earthquakes. Recovery mechanisms that quickly and effectively restore networks may therefore be more appropriate to building road resilience to earthquake risk. This use case provides an example where a financial product could be designed to increase resilience of a service, as well as the physical asset. Products might concentrate on funding effective maintenance or recovery for infrastructure that is 'designed to fail', rather than funding new construction or upgrade.




**Case Study**

Restoring function to essential services following damage (example uses transportation infrastructure in Indonesia)

Presents simple parametric risk transfer trigger to highlight potential role in rapid recovery mechanisms

**Assumption 1:** Value and vulnerability of all major road infrastructure in Indonesia is equivalent

**Assumption 2:** Road incurs 'total' damage when it experiences ground shaking in excess of MMI=8.5

**FIGURE 1** EXISTING PRIMARY ROAD NETWORK ACROSS INDONESIA[31]

[31] https://www.pwc.com/id/en/cpi/asset/indonesian-infrastructure-stable-foundations-for-growth.pdf

## PROBABILITY OF IMPACT

**Probability of Impact –** the earthquake risk to 100,000 km of the primary road infrastructure in Indonesia is presented in the Exceedance Probability curves. The severity is measured as % of Road Impacted, and the separate curves describe the probability of impact by ground shaking in excess of a range of MMI thresholds.

**For example:** the grey dot shows that there is a 2.5% annual probability (1 in 40) that 3.3% of the total road network will be impacted by ground shaking in excess of MMI=6. Road damage experiences significant damage (>10%) in the range MMI=8-10.

**Key Metric: ~1% annual probability (1 in 100) that 1% (1,000km) of road will be impacted by MMI in excess of 8.5**

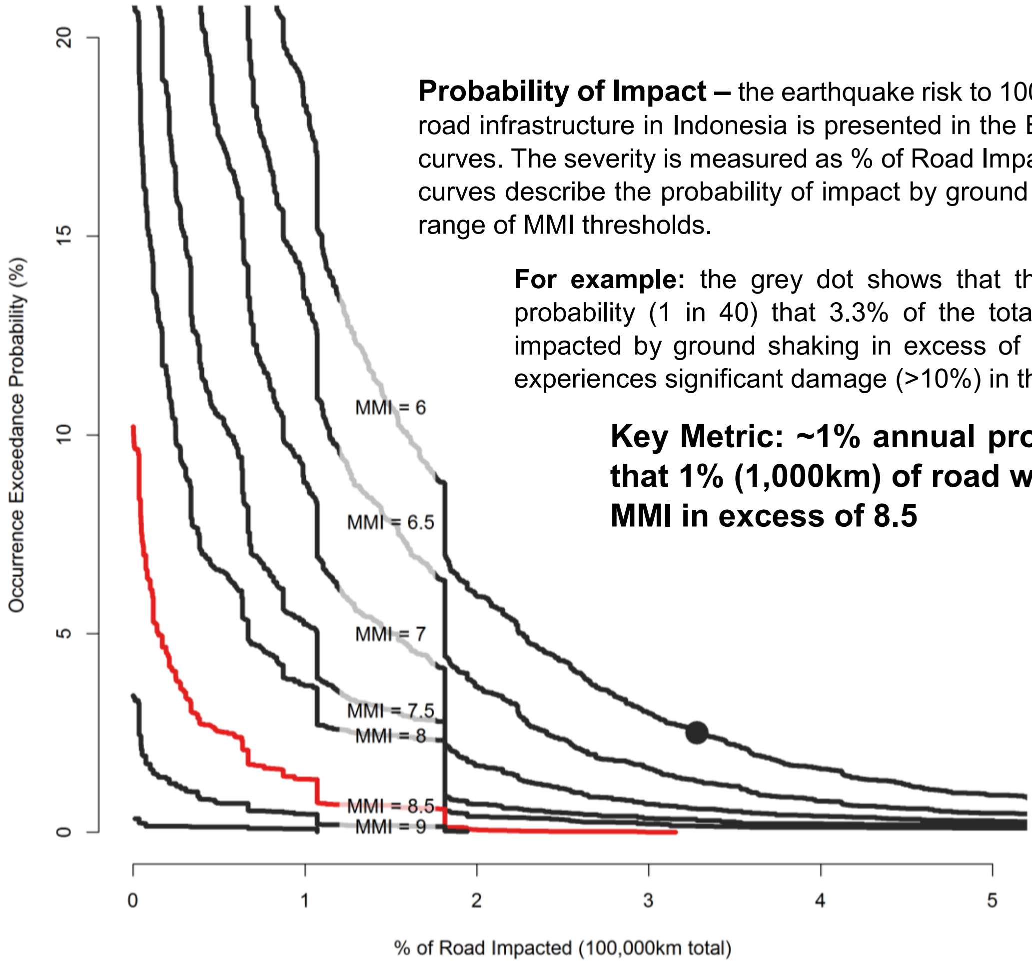



**FIGURE 2** EXCEEDANCE PROBABILITY DISPLAYING PROBABILITY OF EARTQUAKE IMPACT TO ROAD (BY LENGTH OF ROAD AFFECTED)

## RESILIENCE OPTIONS

### Rapid recovery - reduces socio-economic impact

- Building redundancy
- Rapid access to funds and services for repair and build back quicker

### Physical resilience - reduces damage occurrence

- Maintenance
- Slope stabilisation and drainage
- Structural improvement of road

## POTENTIAL FOR COMBINED INDEMNITY-PARAMETRIC COVER

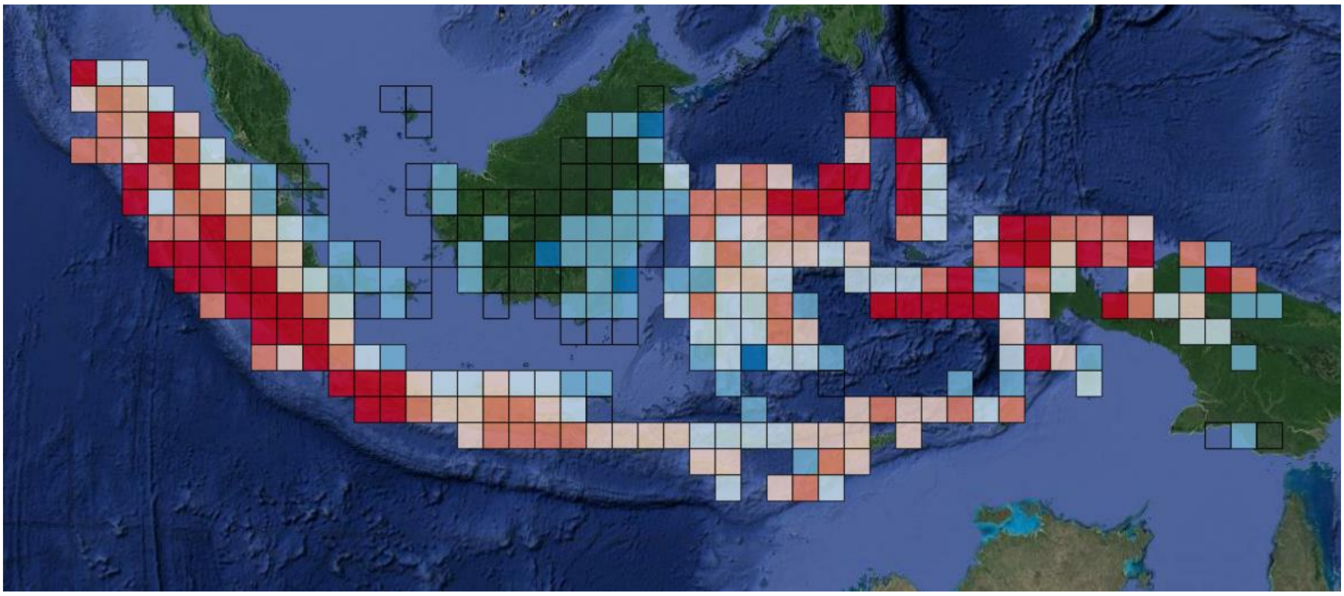


**FIGURE 3** CONTRIBUTION TO AVERAGE ANNUAL LOSS BY GRID CELL (1X1 DEG)

### Parametric

- Based on earthquake location or ground motion thresholds (event parameters)
- Can provide rapid payouts and efficient cover for large events

### Indemnity

- Could combine rapid damage and loss assessments for smaller events/ maintenance
- More suitable for frequent events but likely to be local in scale

## MAIN CHALLENGE

*How to design a financing and risk transfer product that ensures continuity of service as a primary function, provisioning for impacts across the range of frequency and severity (from potholes to sinkholes).*

## TECHNICAL CHALLENGES

- Tension of scale – infrastructure investment/ maintenance at a local level, versus risk transfer at a large scale.
- Does rapid restoration compromise the ability to build-back-better?
- Scarcity of data on public infrastructure assets drives high premiums
- Challenging legal and regulatory environment
- Defining risk ownership and key stakeholders across national scale infrastructure

# USE CASE 5

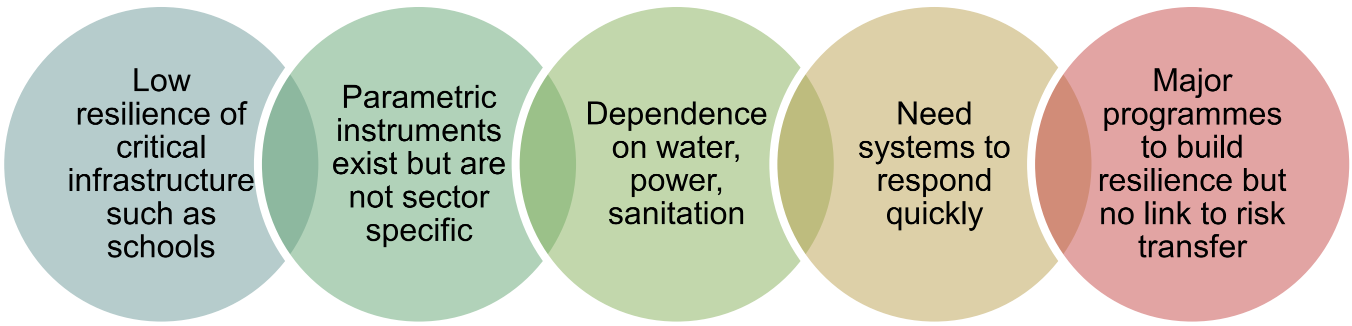
## CARIBBEAN –RAPID RECOVERY OF CRITICAL SERVICES – EDUCATION

Natural disasters and man-made shocks impact tens of millions of children every year, causing both direct damage (e.g. loss of classrooms and books) and, much more critically, indirect damage through lost schooling days and increased permanent drop-out rates. This has long-term impacts on individual prospects and wider economic development. The November 2017 Post-Disaster Needs Assessment (PDNA) for Dominica found that 137 out of 163 (84%) educational facilities have some level of damage (damages of $74m). Access to schooling was interrupted for 100 percent of the student population. Total recovery needs for the sector were estimated to be US$94million. Four months on, Dominica has made steady progress with 94 per cent of schools re-opened albeit with some children accessing schools in temporary settings due to a shift in operations.

Rapid recovery of services is critical to reducing the long-term impacts. In Dominica, the learning time for students is estimated to have been decreased by at least 40 percent, from 930 hours per year to 584 hours per year. Can we build systems that respond quickly while also building resilience long-term?

The recovery of critical services like education is exacerbated by the disruption of access to electricity, water, and waste management. Almost four months since hurricanes Irma and Maria hit the Caribbean islands, the return of some critical services remains slow in some countries. For example, in Dominica, only around 10% of people, mainly in the cities, have access to electricity.

This case study considers whether a risk transfer product could finance rapid recovery of basic services associated with critical infrastructure in immediate aftermath of future events (e.g. schools, hospital, water, power), but linked to preparedness and contingency planning investments pre-disaster that ensure rapid response. How could such an instrument be embedded within programmes to build the resilience of this infrastructure and facilitate longer-term reconstruction where necessary? The case study particularly focusses on education services.




## PREVIOUS HISTORICAL EVENTS

**Hurricane David (1979)** - Strong winds from Hurricane David destroyed or damaged 80 percent of the homes (mostly wood) on the island, leaving 75% of the population homeless, with many others temporarily homeless in the immediate aftermath. In total, 56 people died in Dominica and 180 were injured.

**Tropical Storm Erika (2015) -** Fourteen people were reported dead, 16 missing, 574 rendered homeless, and 1,034 people evacuated due to the unsafe conditions in their communities. Damage and losses were estimated at US$483 million (90% of the country's GDP). Of the 75 schools impacted on the island, 21 schools remained closed at the start of term.
Hurricane Maria (2017).

## SCALE OF 2017 IMPACT

**Case Study**

| | | |
|---|---|---|
| Hundreds of schools potentially damaged, with dependencies on power,water, transport etc. | Rapid recovery has major benefits but risks of trade-offs with longer term resilience | Reconstruction costs,eg. for Dominica $94m |

**FIGURE** 1 DOMINICA POST-DISASTER NEEDS ASSESSMENT.

## PROBABILITY OF IMPACT

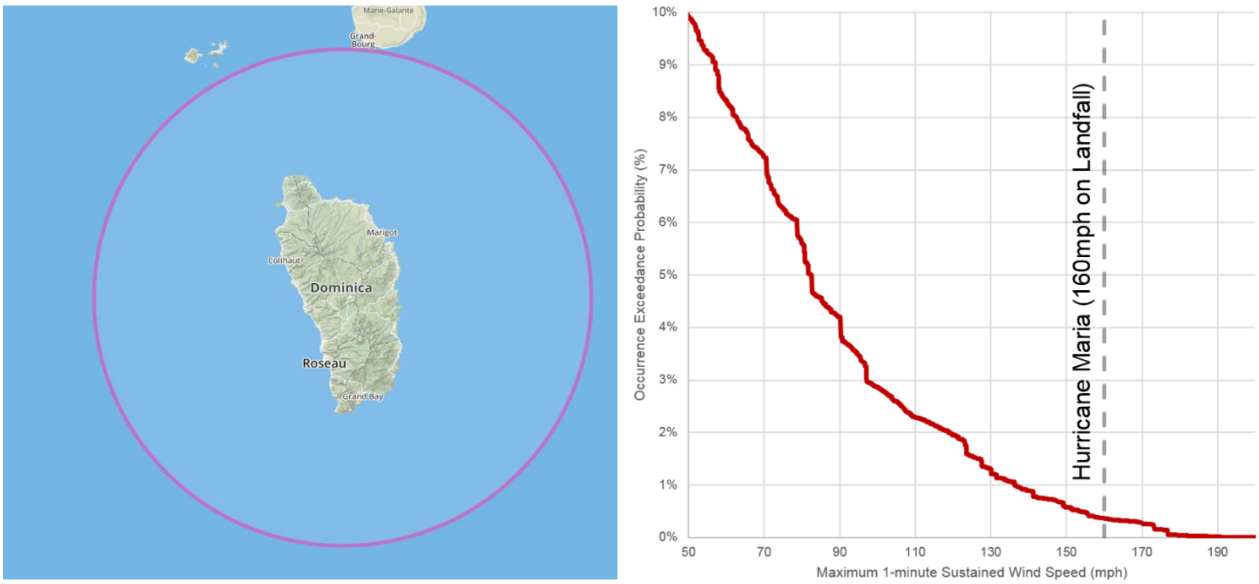



**FIGURE 2** 50KM RADIUS CIRCLE AROUND DOMINICA – THERE IS A 0.37% ANNUAL PROBABILITY THAT A HURRICANE WILL INTERSECT THIS REGION WITH MAX 1-MIN SUSTAINED WIND SPEEDS AT LEAST EQUIVALENT TO THOSE EXPERIENCED DURING HURRICANE MARIA (~160MPH). ON THIS BASIS, MARIA WAS A 1-IN-270 YEAR EVENT

## TECHNICAL CHALLENGES

- Re-establishing education services in a post-disaster setting where other infrastructure has been heavily damaged
- Building resilience in a country that has been severely impacted by multiple recent events
- Building effective disaster response plans into financing and risk transfer instruments

## iv. Key Terms and Calculation Methods

**AAL:** Average Annual Loss (AAL) is equivalent to the expected cost of damage to an asset in a single year.

**∆AAL:** The reduction in Average Annual Loss (AAL) is the difference between the AAL of a traditional build and a resilient alternative. Absolute reduction in Average Annual Loss (∆AAL) is one measure of the resilience dividend.

$$\Delta AAL = AAL_{Base} - AAL_{Resilient}$$

**AAD:** Average Annual Downtime (AAD) is equivalent to the expected downtime, measured in days, that a piece of infrastructure is non-operational for. AAD is indicative of the severity of business interruption after an event.

**Exceedance Probability (EP):** EP is the probability that a loss will exceed a given threshold amount in a single year. It is displayed as a curve, to illustrate the probability of exceeding a range of losses, with the losses represented along the X-axis, and the exceedance probability along the Y-axis.

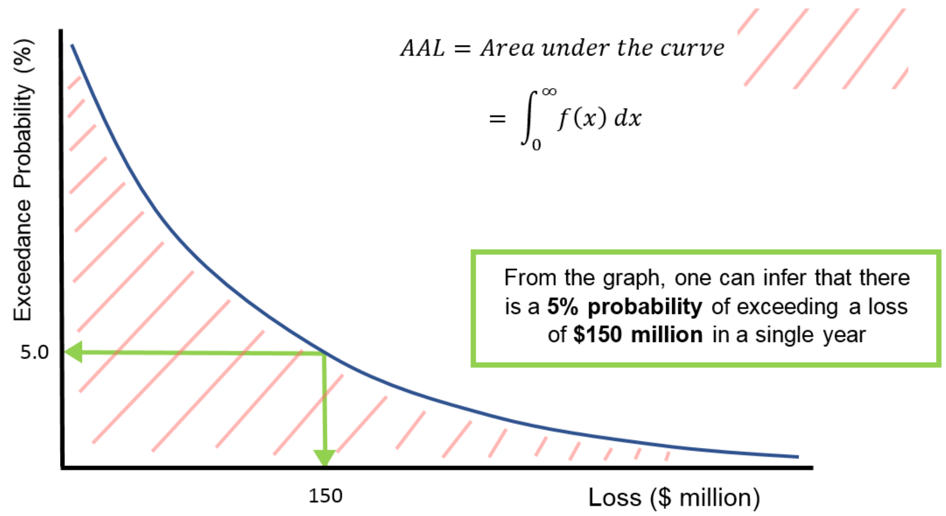



**FIGURE 1** EXCEEDANCE PROBABILITY CURVE

**Return Period Loss:** Rather than describing the probability of exceeding a given amount in a single year, return periods describe how many years might pass between times when such an amount is exceeded. For example, the figure above corresponds to a 20-year return period loss exceeding $150 million.

$$Return\ Period = \frac{1}{EP}$$

**+Cost:** The additional cost of a resilience build, represented as a percentage of the total traditional asset value.

**Resilience Ratio:** A 'resilience ratio' is a measure of risk reduction in comparison to the additional construction costs for resilient structures. This cost-benefit of building more resiliently can be captured using this ratio:

$$Resilience\ Ratio\ (y) = \frac{Additional\ cost\ of\ resilience\ (\$)}{\Delta AAL\ (\$ \cdot y^{-1})}$$

**Net Present Value:** NPV is a measure of the profitability of a given project, by calculating the difference between the present value of incoming and outgoing cash flows over a period of time. For a 10 year NPV, all incoming and outgoing cash flows within 10 years are discounted, with a discount rate of 10% for this report[32], to calculate the present value of the project.

For example, the following diagram illustrates the method to calculate the NPV from a project that requires an initial investment of $Y, and receives payments of $X over the next 10 years. The payments $X are then discounted, to produce the PV of the cash flows, $Z. For the purpose of this report, the initial investment $Y can be thought of as the additional cost of resilience, $X can be the $\Delta AAL$ and $Z is the present value of the $\Delta AAL$.

$$NPV_{10y} = -Initial\ Investment + \sum_{t=0}^{10} Payment_t \cdot e^{(-r \cdot t)}$$

$$= -\$Y + \sum_{t=0}^{10} \$X \cdot e^{(-0.1 \cdot t)} = -\$Y + \sum_{t=0}^{10} Z_t$$

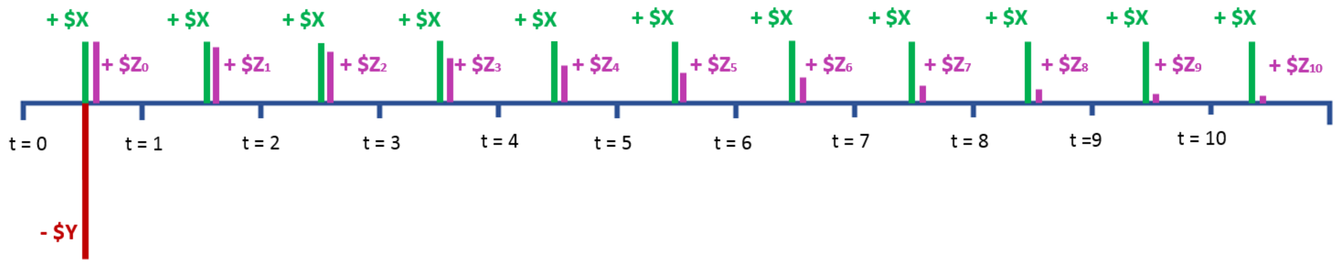



**FIGURE 2** DIAGRAM OF FUTURE CASH FLOWS IN 10 YEAR PERIOD

**Benefit Cost:** The benefit cost of investment in resilience can be captured using the Present Value of the initial cost and discounted future potential cash flow of resilience dividends over a 10-year time horizon.

$$Benefit\ Cost = \frac{PV_{resilience\ dividend}\ (\$)}{PV_{cost\ of\ resilience}\ (\$)}$$

**Discounted Return on Investment (ROI):** The ROI is the return that the owner of the asset will receive from all future discounted resilience dividends, relative to the initial resilience cost.

$$ROI = \frac{NPV_{10y}}{PV_{cost\ of\ resilience}(\$)} = Benefit\ Cost - 1$$

[32] The 10% discount rate is based on the Green Book guidance that discount rates for appraisals in developing countries should be based on the social time preference rate appropriate to those countries. Existing DFID and World Bank practice points to rates in the region of 10-12%. More detailed and comprehensive NPV calculations will vary depending upon the product solution and associated cashflows.

# LIST OF FIGURES

## v. Innovation Lab Attendee List

| Entity | Attendee | Entity | Attendee |
|---|---|---|---|
| ARTA | Harvey Duckers | Refocus | Jamie Rhodes |
| ARTA | Paul Bispham | Refocus | Shalini Vajjhala |
| Amlin | Gilbert Harrap | Ren Re | Ian Branagan |
| Arup | Jo da Silva | RMS | Charlotte Acton |
| AWHA Consulting | Claire Souch | RMS | Conor Meenan |
| Beazley | Emma Whiteacre | RMS | Jed Scanlon |
| Clyde &Co | Nigel Brook | RMS | Peter Datin |
| DFID | Daniel Clarke | RMS | Robert Muir-Wood |
| DFID | Harvey Naylor | S&P Global | Miroslav Petkov |
| DFID | Mark Povey | Securis Investment Partners | Espen Nordhus |
| DFID | Nicola Ranger | Social Finance UK | Jane Newman |
| DFID | Peter Bentley | START Network | Judith Amar |
| European Commission | Federico Berna | Swiss Re | Andreas Prystav |
| First River Partners | Peter Buettner | The Nature Conservancy | Kerstin Pfliegner |
| GAD | Ian Rogers | Vivid Economics | David Ren |
| Global Partnership | Theodore Purnendu Talbot | Vivid Economics | Irena Sekulska |
| Hiscox | Benjamin Baltesar | Vivid Economics | John Ward |
| Lloyd's | Lucy Stanbrough | Westminster University | Tony Lloyd-Jones |
| Lloyd's | Trevor Maynard | Willis Towers Watson | Carlos Sanchez |
| LSE | Swenja Surminski | Willis Towers Watson | David Simmons |
| Mott Macdonald | Madeleine Rawlins | Willis Towers Watson | Gavin Newton |
| Munich Re | Michael Roth | Willis Towers Watson | Jacqueline Wharton |
| Nephila | Adam Beatty | Willis Towers Watson | Simon Young |
| NERC | Ruth Hughes | World Bank | Jun Rentschler |
| ODI | Emily Wilkinson | World Bank | Rashmin Gunasekera |
| Parhelion | Tony Stubbs | XL Catlin | Brendan Plessis |
| PwC | Nick Lane | XL Catlin | Emma Radcliffe |
| PwC | Tom Strickland | York University | Piran White |

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- Lucy Stanbrough, Innovation Associate

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