NET ZERO CITIES
SGA3-NZC

Adaptation Project Preparation, Business Model and Finance Framework

A practical guide for European municipalities

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Abbreviations and acronyms

Acronym	Description
BPCA	Battery Park City Authority
CAPEX	Capital Expenditure

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CBA	Cost-Benefit Analysis
CFR	Commercial Funding Ratio
D	Deliverable
FEMA	Federal Emergency Management Agency
IFI	International Financial Institution
I2FF	Impact To Finance Framework
LVC	Land Value Capture
NR	Non-Repayable Capital from Impact Monetization
NZC	NetZeroCities
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational Expenditure
RC	Repayable Commercial Capital
TIF	Tax Increment Financing
WP	Work Package

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Terms and concepts

Term / Concept	Description
Bankable Project	A (climate adaptation) project structured with clear legal ownership, predictable revenue or savings streams, and manageable risks, making private banks or investors willing to lend money to finance it.
Beneficiary Cost-Sharing	An arrangement where key local entities (such as municipal governments, regional authorities, and transit operators) who all face heavy losses from a climate hazard pool their money upfront to co-finance a shared protective asset.
Betterment Levies / Developer Impact Fees	Dedicated charges levied on property owners or real estate developers who directly benefit from nearby public flood defenses or whose new developments place additional demands on municipal drainage infrastructure.
Blended Finance	The practice of mixing different types of funding—such as public grants, subsidized loans, and private commercial investments—so that public funds lower the financial risk for private investors, unlocking larger pools of capital.
Blue-Green Infrastructure	Nature-based urban solutions (such as swales, rain gardens, retention parks, and green roofs) designed to absorb stormwater and cool cities, replacing or supplementing traditional concrete drainage.
Budget Re-allocation from Avoided Service Costs	Shifting municipal funds previously spent on recurring emergency cleanups, road repairs, and flood responses into paying off long-term infrastructure that prevents those emergencies from happening.
Capital Expenditure (CAPEX)	The upfront money required to plan, design, and construct physical infrastructure assets (such as building a flood relief tunnel or retention basin).
Commercial Funding Ratio (CFR)	CFR defines the share of an adaptation project funded via market-based mechanisms and impact contributions, leaving the remaining percentage as a Residual Funding Gap which is to be closed with traditional non-repayable public budgets and non-repayable grants.
Concessional Capital / Concessional Loans	Subsidized loans or investments offered on softer terms than commercial banks provide (such as lower interest rates or longer grace periods), typically provided by development banks or public funds.
Cost-Benefit Analysis (CBA)	An evaluation method that compares the total calculated costs of a project against the financial benefits, economic growth, and avoided disaster damages it produces over time.
Cost of Inaction	The estimated total financial, physical, and operational losses a community or business will suffer over time if no preventive climate adaptation measures are taken.
Development Impact Levies / Section 106 Agreements	Mandatory financial contributions or infrastructure requirements imposed on private developers during the building permit process to ensure they fund the drainage or green spaces needed to absorb their project's runoff.
Existing Tariffs	Funding adaptation projects by incrementally raising a charge a municipal utility (water, energy or waste) already bills to its customers (residents and businesses), rather than creating a new standalone adaptation levy from scratch. This avoids the political and administrative friction of introducing a new tax.
Externalities (Positive & Negative)	Unintended side effects of economic activity or development, which can be positive when a project creates unpaid benefits for neighbors

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	(e.g., cooler air from a park) or negative when an action creates unpaid costs for others (e.g., paving land and causing downstream flooding).
First-Loss Capital	Public or grant money set aside to absorb initial financial losses if a project underperforms, creating a safety buffer that encourages private investors to participate.
General Obligation (GO) Bonds vs. Revenue Bonds	GO Bonds are municipal borrowings backed by the city's general power to collect taxes; Revenue Bonds are borrowings repaid exclusively from the income generated by a specific project or utility fee.
Impervious Surface Tax / Stormwater Utility Fee	An annual fee charged to property owners based on the total area of paved, non-porous land on their site (roofs, parking lots), charging them for the rainwater runoff their property forces into city sewers.
Land Value Capture (LVC)	A public-finance tool enabling a municipality to recover a portion of the increased real estate value created by public investment; in the adaptation context, it applies specifically to value uplift when infrastructure protects private property from climate risks.
Negative Impact Avoidance (Pillar 2)	Structuring a project's financing around the physical damages, business disruptions, and emergency response costs that the project prevents (using expected avoided costs to justify upfront construction).
Negative Impact Internalization (Pillar 3)	Applying the "polluter-pays" principle by charging fees or taxes to entities whose activities worsen local climate risks (such as paving permeable land), using that revenue to build public defenses.
Off-Take Agreement / Off-Take Tariff	A long-term contract where a major user (such as a factory or utility) commits to purchasing a set volume of a service or resource (like reclaimed water) at pre-agreed prices, guaranteeing steady income for the provider.
Operational Expenditure (OPEX)	The ongoing, day-to-day costs required to maintain, repair, and operate infrastructure over its entire working lifespan.
Outcome-Linked Repayment / Environmental Impact Bonds	A financing arrangement where investor returns or repayments depend directly on whether the project achieves verified resilience outcomes (such as reducing stormwater runoff by a target percentage).
Polluter-Pays Principle (Verursacherprinzip)	The regulatory rule requiring those who create or worsen environmental hazards (such as increasing flood risks through land sealing) to bear the financial cost of managing those hazards.
Positive Impact Monetization (Pillar 1)	Generating municipal revenue by selling or capturing the new economic, social, or environmental value created by a resilience project (such as leasing commercial space in a flood park or capturing higher real estate value).
Repayable Capital vs. Non-Repayable Capital	Repayable Capital is borrowed money (loans, bonds) or equity that must be paid back with interest or returns; Non-Repayable Capital consists of grants and subsidies that carry no repayment obligation.
Residual Funding Gap	The remaining cost of an adaptation project that cannot be covered by private or commercial investors and must be absorbed by municipal budgets or government grants.
Resilience Bonds	A catastrophe-bond-style instrument where investors provide capital for a resilient infrastructure project and, in return, the city or utility captures the reduced insurance premiums that result from lowered risk, using those savings to repay the bond.

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Sources of Repayment (Component 2)	The long-term streams of cash (from utility tariffs, user fees, taxes, or saved emergency costs) generated over an asset's lifetime to pay back initial lenders and investors.
Special Purpose Vehicle (SPV) / Virtual SPV	A separate legal entity or formal multi-party agreement created specifically to hold assets, contract debt, and manage a single infrastructure project independently from a city's general operations.
Sponge City (Schwammstadt)	An urban design model where a city is planned to absorb, store, and evaporate rainwater locally where it falls, rather than rapidly piping it away through concrete sewers.
Sustainability Revenue Bonds	Specialized debt instruments issued by public authorities specifically to raise upfront capital earmarked for climate adaptation infrastructure, repaid from a dedicated revenues stream generated through the project.
Tax Increment Financing (TIF)	A tool where a city borrows money to build infrastructure in a vulnerable district and repays the debt using only the additional future property tax revenues generated as property values rise in the protected area.
Tragedy of the Horizon (Temporal Misalignment)	The challenge that municipal political and budgeting cycles operate on short timelines (3–5 years), whereas climate infrastructure requires funding today to prevent disasters that unfold over decades, leaving limited incentives for current actors to fund prevention today.
Unmonetized Avoided Risk	A market hurdle where protecting a city saves millions in avoided disaster damage, but traditional financial markets lack a mechanism to convert those saved losses into direct cash payments.
Upfront Capital (Component 1)	The initial pool of funds (sourced from municipal budgets, loans, grants, or private investors) needed to construct a project before it becomes operational.

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Summary

Work Package 3 of NetZeroCities' (NZC) Specific Grant Agreement N°3 (SGA3) supports cities to prioritize, scope, and prepare climate adaptation projects to unlock the necessary capital for their resilience ambitions to materialise. This report aims at developing a structured business model and finance framework - the 'Impact to Finance' Framework (I2FF) - to guide municipal planners from overarching finance concepts to practical, local applications by building a shared understanding of how climate adaptation value can be systematically captured, monetized and financed. While the I2FF has already been applied by municipal leaders in the context of Nature-based Solutions (NbS) (see URBREATH, 2026), this deliverable extends the framework's application to the broader landscape of climate adaptation projects, integrating grey, hybrid, and larger-scale resilience infrastructure into the model.

The focus of this report is mainly on European cities, featuring selective international examples (e.g., from the United States) to offer transferable insights and actionable inspiration. It is based on municipal finance literature (e.g., World Bank, OECD report), European policy frameworks such as NZC and deep dive analyses of cities of different sizes and geographies.

To establish a practical foundation for municipal leaders, Chapter 1 maps the systemic barriers and structural market failures – such as uncaptured positive externalities, unmonetized avoided risks, and unpriced negative externalities – that historically prevent private and commercial capital from flowing toward climate adaptation, illustrating why public funding channels are insufficient and why a new paradigm is required. Building on this context, Chapter 2 introduces the core theoretical framework, the I2FF for Adaptation, which breaks down the value creation of urban resilience projects into three distinct, actionable Pillars: Positive Impact Monetization (Pillar 1), Negative Impact Avoidance (Pillar 2), and Negative Impact Internalization (Pillar 3).

To move from theory to implementation, Chapters 3 and 4 translate this conceptual framework into a highly practical toolkit, real-world proof points, and key guidelines. This includes step-by-step decision-making and quantitative sizing tools designed to align upfront capital needs and early-stage financial structuring (Component 1 – Upfront Capital) with long-term cash flow streams (Component 2 – Sources of Repayment), validated by five empirical case studies spanning urban water utilities, regional flood-protection networks, and industrial reuse models. Finally, Chapter 5 concludes this report and contextualizes these models by detailing the systemic, regulatory and administrative barriers at both local municipal and broader European levels that cities must overcome to successfully deploy the frameworks and tools presented in this report.

In sum, this report highlights that public and private adaptation funding can be unlocked - albeit to a limited extent in some cases - by applying the right tools and demonstrating the business cases for adaptation projects. Achieving this requires actively supporting cities to navigate innovative financial models, establish local legislative or administrative prerequisites, and acquire the technical know-how to build bankable, cash-flow-backed projects. Within this context, adaptation can no longer be treated solely as an unavoidable line item for public expenditure, but rather as an active economic mechanism that captures value, shares physical and financial risks and internalizes external costs. Ultimately, the frameworks, diagnostic tools and case studies presented in this report will enable the NetZeroCities platform to support Mission Cities as they work to leverage capital to achieve their 2030 climate neutrality and resilience objectives.

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Keywords

Climate – Adaptation – Financing – Guidelines – Cities – Monetization – Business Case – Sources of Repayment – Investment – Private – Commercial – Blended Capital – Finance – Polluter Pays – Impact

1 Introduction

European municipalities are at the forefront of climate change impacts, yet they frequently encounter systemic barriers when attempting to mobilize finance for critical adaptation measures (NetZeroCities, 2023, p. 47).

The physical risks – ranging from escalating urban heat island effects to chronic water scarcity and pluvial flooding – are comprehensively documented. Furthermore, the engineering and nature-based solutions required to mitigate these vulnerabilities are well-established. However, while capital flows relatively seamlessly toward climate mitigation (such as utility-scale renewable energy or zero-emission transport), financing for climate adaptation remains limited (Climate Policy Initiative, 2024, p.'X').

For municipal leaders and urban planners, this creates a paradox: there is consensus on the necessity of adaptation infrastructure, yet there is a lack of clarity regarding the mechanisms to fund it.

The primary reason adaptation projects struggle to find finance is structural. Mitigation projects typically generate predictable, traditional cash flows (e.g., electricity sales or quantified energy savings). Adaptation interventions, by contrast, are traditionally categorized as non-revenue-generating public goods. The economic value of adaptation is systemically misaligned within traditional financial models due to market failures (Ahairwe et al., 2023, p.57) across three dimensions:

- Uncaptured positive externalities: Resilience projects frequently generate significant socio-economic co-benefits (such as public health improvements, enhanced biodiversity, and reduction of urban heat islands). However, standard municipal models fail to capture this newly generated value and convert it into a tangible revenue stream (Independent Evaluation Group, 2022, p. 3).
- Unmonetized avoided risk: The primary "return on investment" for adaptation is often the absence of destruction or disruption. Traditional financial markets struggle to underwrite or monetize an avoided disaster, making it difficult to structure preventive measures as investable assets (World Bank, 2021, p. 4).
- Unpriced negative externalities: The actors or developments that contribute and worsen urban climate risks (such as intensive soil sealing increasing flood risk) rarely bear the financial cost of their impact. Consequently, the burden of financing the necessary corrective infrastructure falls disproportionately on the public budget (Independent Evaluation Group, 2022, p. 3).

Beyond these market failures, municipal administrations face three operational bottlenecks when attempting to structure adaptation finance:

- Value capture and the distribution of benefits: When a municipality, for example, implements a comprehensive stormwater management network, the benefits are distributed across multiple stakeholders. Real estate values appreciate, insurers face fewer claims, and utility operators experience reduced strain. Yet, the municipality is typically expected to carry the full capital expenditure (CAPEX) and operational expenditure (OPEX, such as operational maintenance). Without mechanisms to distribute costs among the true beneficiaries, municipal budgets are quickly exhausted (Shalizi & Lecocq, 2007, p.9).
- Project structuring and boundary delineation: Cities excel at formulating comprehensive climate resilience strategies. However, private and institutional capital cannot be invested in a high-level strategy; it requires clearly delineated projects with defined physical boundaries, measurable lifespans, and explicit risk allocation. Adaptation concepts frequently fail to bridge the gap between strategic master planning and the development of bankable project term sheets (OECD, 2025, p.238).

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- Temporal misalignment (The "tragedy of the horizon"): The standard municipal budgeting cycle spans three to five years, whereas the financial and socio-economic returns on major climate adaptation infrastructure materialise over decades. Without sophisticated financial structuring to bridge this temporal gap, short-term fiscal constraints consistently undermine long-term resilience investments (Carney, 2018, p.1).

To unlock capital at scale, municipal governments must therefore undergo a fundamental mindset shift. Adaptation can no longer be treated solely as an unavoidable line item for public expenditure; it must be re-envisioned and structured as an economic mechanism that captures value, shares risks and internalizes external costs.

This report is designed to facilitate that transition. The core of this document introduces the **'Impact to Finance Framework' (I2FF) for Adaptation**, a pragmatic methodology that helps city planners and municipal finance officers identify the key concepts, data points, and financial structures needed to eventually develop the types of business models that capital providers from the public and private sectors require.

Rather than relying predominantly on constrained public budgets or highly competitive national grants, this framework empowers cities to build sustainable business models that link capital providers' interests with outcomes and benefits generated by adaptation projects by leveraging three distinct pillars:

- **Positive impact monetization:** Capturing the new economic value including co-benefits created by the project (e.g., via land value capture mechanisms, increased property tax revenues, new municipal fees or the monetization of ecosystem services).
- **Negative impact avoidance:** Monetizing the future physical damages, operational disruptions, and public health crises that the project successfully prevents (e.g., via resilience bonds or pay-for-success mechanisms).
- **Negative impact internalization:** Structuring policies and levies that shift the financial burden to the entities actively worsening climate vulnerabilities (e.g., via stormwater fees or congestion pricing).

By applying the structured guidance, tools, and best practices detailed in the subsequent chapters, cities can build a stronger foundation for financing their adaptation initiatives. This approach helps transition early concepts into well-structured frameworks, laying the necessary groundwork to eventually meet the rigorous standards expected by institutional investors, development banks or other financiers.

1.1 Purpose and Scope

The primary objective of this report is to equip European municipalities with the practical tools necessary to bridge the implementation gap in climate adaptation. While many cities possess comprehensive climate risk assessments and high-level resilience strategies, they frequently lack the structured methodologies required to translate these strategies into bankable, finance-ready projects.

This document serves as an actionable guide to overcome this barrier. By introducing the 'Impact to Finance' framework (I2FF) for Adaptation, the report provides municipalities with a structured pathway to scope adaptation projects, develop early-stage business models, and establish preliminary financial structures. The ultimate goal is to empower city planners and municipal finance officers to collaboratively identify revenue streams, monetize avoided risks, and internalize costs – thereby reducing the reliance on constrained public budgets and unlocking institutional, blended and private capital.

In terms of scope this report is specifically tailored to the financing of adaptation projects within European Cities, aligned with the objectives of the NetZeroCities (NZC) programme. While the European regulatory and governance landscape is unique, this report deliberately also features selective international examples, particularly from the United States. These non-European case studies highlight mature, market-tested financial structures, offering European municipalities actionable inspiration and transferable frameworks to accelerate their own adaptation projects.

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1.2 Methodology and Structure

The foundation of this report is built upon a comprehensive review of current municipal finance literature, including institutional reports (e.g World Bank, OECD) and European policy frameworks such as NZC. This initial phase identified the structural market failures, such as uncaptured positive externalities and unmonetized avoided risks, that currently hinder adaptation finance. To ensure the resulting 'Impact to Finance' framework remains highly practical and actionable, the theoretical research was subsequently complemented with an empirical case study analysis. The authors examined mature, market-tested financial mechanisms deployed by pioneering municipalities across Europe and other regions. This inductive approach facilitated the identification of best practices and scalable financial mechanisms that have successfully bridged the adaptation funding gap. Finally, drawing on both the academic literature and these empirical observations, the findings were synthesized into the newly developed 'Impact to Finance' framework (I2FF). To make this framework operational for city planners, a practical tool - specifically the Repayment Source Identification Tool - was designed to guide users from initial project conceptualization through to early-stage business model development.

The deliverable is structured to guide the reader logically from overarching theory to practical application. **Chapter 2** introduces the core theoretical framework (I2FF), breaking down the monetization of adaptation projects into three actionable pillars: Positive Impact Monetization, Negative Impact Avoidance, and Negative Impact Internalization. Building on this foundation, **Chapter 3** contextualizes the I2FF within the temporal lifecycle of an adaptation project and its cash flow stream, detailing the distinct actors involved in securing initial upfront financing versus ensuring long-term repayment. Crucially, this chapter also introduces the Repayment Source Identification Tool, providing municipalities with a strategic tool to identify the most viable financial structures for their specific local context. Finally, **Chapter 4** transitions from theory to practice by presenting in-depth, real-world case studies of municipalities that have successfully deployed value-based, savings-based, and regulatory-based repayment mechanisms before the **Conclusion** closes the report.

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2 'Impact to Finance' Framework (I2FF)

It is increasingly clear that public funding is insufficient to meet the large-scale financial demands of adaptation infrastructure (Eurocities, 2024, p.19). This structural shortfall asks for an urgent search for alternative capital; however, even combined contributions from philanthropic foundations and grant providers will not be enough to cover the full scope of municipal needs.

To bridge this gap and successfully transition from strategic master plans to operational infrastructure, municipalities must unlock private and institutional investment. To do this, it is key that municipalities overcome the fundamental hurdle of commercial finance: *the identification of reliable, localized impact-capture mechanisms.* By moving beyond traditional funding models, establishing impact-capture mechanisms allows for a dual opportunity: they can either be structured as predictable cash flows over an asset's lifetime, or leveraged to mobilize upfront capital contributions from beneficiaries or risk-creators.

Investors operate on the core principle of risk and return. To commit the upfront capital required to get an adaptation project off the ground and built, commercial and corporate investors need full confidence that the project will generate sufficient financial and climate impact value over time to repay the initial investment alongside a risk-adjusted return. Historically, because adaptation has been viewed merely as a public good, these vital impact-capture mechanisms – and the related predictable cash flows required to secure external investment – have been largely missing.

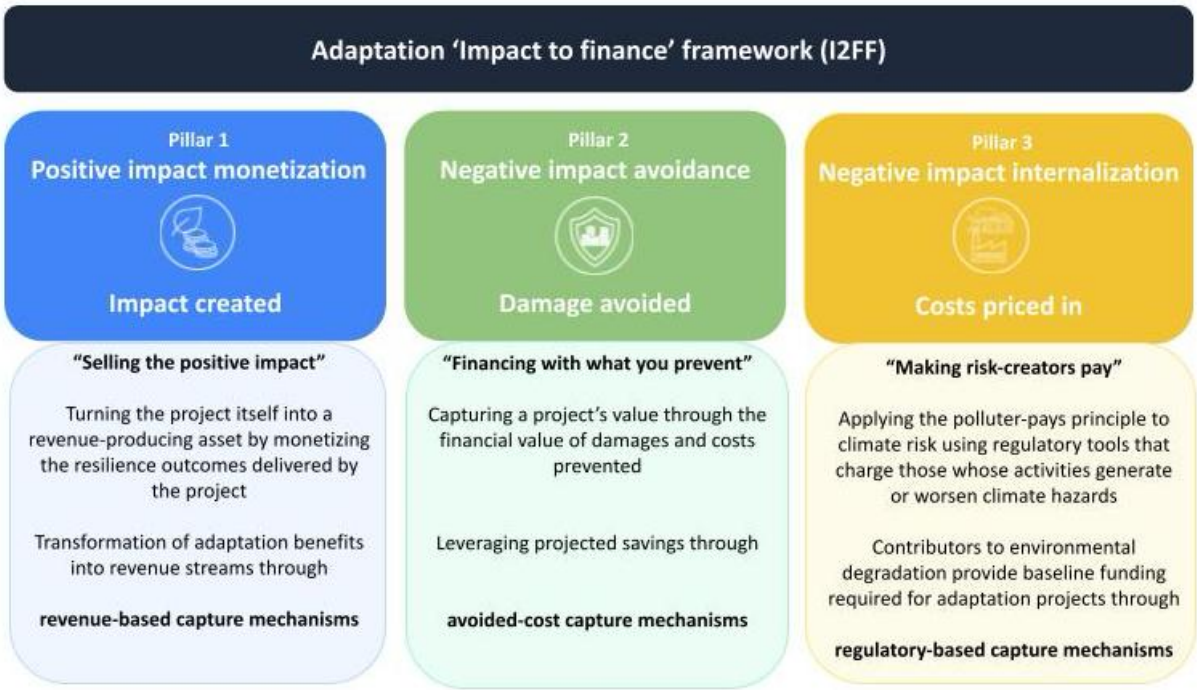


Figure 1:'Impact to Finance' framework (I2FF) for Adaptation (own graphic)

The **I2FF for Adaptation**, as outlined in Figure 1, is designed to explicitly solve this problem. It operates on a central logic: by rigorously identifying and structuring the physical and socio-economic *value* created by an adaptation project, municipalities can *define clear sources of repayment*. When these sources of repayments are contractually secured, they generate trust with capital providers. This trust can then unlock the upfront capital required for construction.

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The I2FF categorizes this value creation into three distinct, actionable pillars: **Positive Impact Monetization**, **Negative Impact Avoidance**, and **Negative Impact Internalization** that will be described in detail in the following subchapters. Full length case studies for each pillar can be found in Chapter 4.

As municipalities explore these options, it remains important to keep in mind that the positive adaptation co-benefits, avoided damages, and internalized regulatory costs identified through the I2FF will rarely cover 100% of an adaptation project's total capital and operational expenditures (see Chapter 3.3). Instead, the I2FF is designed to help de-risk projects and secure alternative revenue streams, thereby drastically downsizing the reliance on constrained public budgets.

The following types of capital providers are considered in the I2FF Framework, and they principally differ in their financing motivation, which is linked to their willingness to absorb financial risks across a project's stage. Considering this risk tolerance will help with identifying which types of capital providers are most relevant across each project stage (see Chapter 3 for the relationship between stakeholders and the two fundamentally different dimensions of a project's cash flow stream).

Type of Financer	**Public Sector (& Donors)**	**Institutional & Impact Investors**	**Commercial Investors**	**Corporate Investors**
Examples	Municipal & national Governments, philanthropies	Development Banks, venture capital funds, private equity firms, institutional asset managers	Commercial banks, bondholders	Corporates with their operational sites and suppliers
Type of Finance Provided	Grants, subsidies	Private & venture capital equity, concessional loans and equity and first-loss tranches	Bonds, corporate credit lines & debt facilities via banks	CSR funding (grants), corporate CAPEX from internal balance sheets
Relevant Project Stage	Early stage, long-term OPEX and modernization	Initial scale	Full scale	Early stage, ringfenced capital asset construction
Financing Risk Tolerance	High; concept and feasibility stage is supported	Medium; require initial proof of concept and impact potential	Low; require confirmation for scaling of impact	Medium; require initial proof of concept and impact potential

Table 1: Types of Capital Providers

2.1 Positive Impact Monetization: Pillar 1

The first pillar challenges the assumption that adaptation projects are purely defensive. Its core directive is to **sell the positive impact they create**.

Many adaptation interventions generate substantial, localized co-benefits that possess intrinsic market value. For instance, transforming a degraded urban waterfront into a resilient, flood-absorbing eco-park inherently raises surrounding commercial real estate values, creates new recreational benefits and stimulates local economic activity.

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- **The Mechanism:** This pillar focuses on turning the project itself into a revenue-producing asset by monetizing the new financial values generated by the resilience outcomes of the project. It is the direct transformation of adaptation co-benefits into revenue streams.
- **Capturing Created Value:** Municipalities can capture the created value through mechanisms such as Land Value Capture (LVC), Tax Increment Financing (TIF), the introduction of direct user fees (e.g., leasing commercial space within a new resilience hub), or leveraging existing tariffs – see Chapter 2.1.1.
- **Building Capital Provider Trust:** Demonstrating that a project will generate net-new cash flows that would not exist without the intervention enables capital providers to reliably model future revenues. These targeted revenues can then be ring-fenced, for example, to service municipal green bonds or repay direct project loans. To attract corporate capital in particular, resilience outcomes from these interventions need to be verifiable and linked to standard corporate reporting indicators. This alignment allows corporations to deploy their sustainability budgets into public infrastructure by transforming measurable physical impacts, such as net positive water gains, into validated metrics for their corporate ESG disclosures.

2.1.1 Value-based Capture Mechanisms

To operationalize positive impact monetization, municipalities must deploy specific financial mechanisms that capture the new value generated by adaptation projects. Four suitable mechanisms for converting these positive externalities into reliable cash flows are Land Value Capture (LVC), Tax Increment Financing (TIF), Direct User Fees and Commercial Leases, and Existing Tariffs.

1. Land Value Capture (LVC)

- **The Concept:** Public infrastructure investments almost always increase the value of adjacent private real estate. LVC is a policy approach that allows the municipality to recover a portion of this privately captured asset appreciation to pay for the public infrastructure that created it.
- **The Adaptation Application:** When a city builds a new coastal seawall or an urban sponge park, the adjacent properties directly benefit from reduced flood insurance premiums and enhanced aesthetic or recreational value. Through LVC mechanisms – such as betterment levies, special assessment districts, or developer impact fees – the city charges a dedicated fee to the property owners who directly benefit from this newly created resilience.
    - Social Equity & MRV Note: Tying financing to property value uplift risks gentrification and displacement of existing lower-income residents who do not capture the uplift themselves. Gentrification-driven displacement can undermine adaptation goals of a project by pushing out the residents most in need of the added resilience – a maladaptive outcome. These risks must be tracked in the project's MRV system. While direct mitigation of displacement falls outside the adaptation project's scope, this data should inform broader municipal urban planning, risk mitigation, and overarching adaptation strategies.
- **The Capital Provider Appeal:** LVC creates a highly targeted, localized revenue stream. Because the fees are legally tied to property ownership within a defined geographic boundary, commercial investors view this as a highly secure, predictable cash flow that can be ring-fenced to service green bonds or initial project loans.
  In addition, Developer Impact Fees or Land Sales/Leases can generate immediate, upfront capital injections that reduce or eliminate the need to borrow upfront debt altogether.
- **Examples:**
    - HafenCity Hamburg Flood Protection (Germany): To develop Europe's largest inner-city waterfront regeneration project in a flood-prone former port, Hamburg established a special municipal fund. The city prepares the sites – which includes building massive public promenades and elevating the plots on flood-proof terraces (Warften) – and captures the immense value uplift through the sale of these premium, climate-resilient land parcels to private developers. This captured land value helps finance the €3 billion public investment in the area's infrastructure including flood defences (HafenCity Hamburg GmbH, n.d.).

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2. Tax Increment Financing (TIF)

- **The Concept:** TIF subsidizes infrastructure projects by borrowing against the future, anticipated increase in property-tax revenues that the project will generate.
- **The Adaptation Application:** A municipality designates a climate-vulnerable, degraded neighbourhood as a "TIF District" and issues bonds to fund a major adaptation intervention (e.g., elevating infrastructure and installing green drainage). As the area becomes climate-resilient, private developers return, and property values rise. The baseline property taxes continue to fund standard city services, but the *increment* – the new, additional tax revenue generated purely from the area's increased value – is captured separately and channelled exclusively toward repaying the bonds that financed the adaptation project.
    - Social Equity & MRV Note: As with LVC, increased property value can drive maladaptation through gentrification and resident displacement-. Consequently, this risk needs to be tracked for projects integrating TIF in their financing structure, to ensure that relevant decision-making processes in urban planning consider countermeasures.
- **The Capital Provider Appeal:** TIF directly aligns the project's success with the commercial investor's return. It proves that the adaptation project will spur economic revitalization and guarantees that the resulting fiscal upside is contractually dedicated to repaying the initial capital providers.
- **Example:**
    - Falkirk Council Grangemouth TIF (Scotland, UK): The Scottish Government authorized Falkirk Council to establish a Tax Incremental Financing (TIF) district to protect and regenerate the Grangemouth industrial and commercial zone. The council borrows upfront capital to build critical enabling infrastructure – explicitly including major flood defence systems – and repays the debt using the "increment" (the additional future non-domestic business rates) generated by the newly protected and expanded commercial activity in the zone (Scottish Futures Trust, n.d.).

3. Direct User Fees and Commercial Leases

- **The Concept:** Generating revenue by charging individuals or commercial entities directly for the use of the newly created asset or the specific services it provides.
- **The Adaptation Application:** Multi-purpose adaptation infrastructure can be designed to include commercial components. For example, a large-scale underground stormwater retention basin can feature a paid municipal parking garage on its surface. A coastal flood barrier can be integrated with commercial real estate, allowing the city to lease waterfront retail or restaurant space. Alternatively, the city can charge entrance or membership fees for new recreational facilities built into the resilience zone.
- **The Capital Provider Appeal:** Direct user fees represent the most traditional and easily modelled cash flows in project finance. Commercial leases, parking tariffs, and entrance fees provide immediate, tangible, and recurring liquidity that commercial lenders recognize and trust.
- **Example:** In Europe, pure user fees or commercial leases (like parking tickets or retail leases) are almost never used to directly finance adaptation infrastructure. Because of strict European public accounting laws, climate adaptation projects such as flood defences are often still classified as pure public goods, funded by taxes, grants, or specialized utility tariffs (see 4. "Existing tariffs" further down). In the US however, municipalities frequently use commercial leases and direct user fees to service resilience bonds.
    - Battery Park City Authority Coastal Resiliency (New York, US): While technically not a municipality, but a New York State public benefit corporation, the Battery Park City Authority (BPCA) operates as a highly localized, quasi-municipal government for a 92-acre planned neighbourhood on the southern tip of Manhattan. It serves as a blueprint for municipal-level adaptation finance. The BPCA is currently undertaking a massive $1.7 billion climate resiliency program to protect Lower Manhattan from storm surges and sea-level rise. To finance this adaptation infrastructure, the BPCA issues Sustainability Revenue Bonds to investors. The explicit repayment mechanism for these bonds relies purely on commercial revenues: the BPCA owns the land and charges

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ground rents and other fees to the commercial and residential buildings located in the neighbourhood. These direct commercial sub-leases generate the cash flow that first funds the Authority's debt service to pay for the resiliency capital projects (Battery Park City Authority, n.d., 2025).

4. Existing tariffs

- **The Concept:** Rather than creating a new charge, this mechanism repays capital providers by directing a share of a revenue stream the city or its utility is already collecting toward the adaptation investment - avoiding the political and administrative cost of introducing an entirely new fee.
- **The Adaptation Application:** Works best where a municipal utility (water, energy, waste) already bills a broad customer base and can incrementally raise that existing charge to cover resilience-related capital costs, rather than the city needing to establish a bespoke adaptation levy from scratch.
- **The Capital Provider Appeal:** An established billing relationship carries low collection risk and high predictability - because the revenue stream and collection infrastructure already exist, this source of repayment involves less implementation risk than a mechanism dependent on a fee not yet in place.
- **Example:**
    - HOFOR, Copenhagen's water utility, funds its share of the Cloudburst Management Plan, that was initially budgeted to cost roughly €1.7bn in implementation. Approximately €1.3bn of the budgeted costs were financed by recovering costs through the water tariff its customers already pay, raising that tariff by 10-15% as needed rather than introducing a separate cloudburst-specific charge. It is worth noting though that it is a utility tariff, not a general tax, and Copenhagen still had to secure a national legislative change before this existing revenue stream could be used to fund surface level (not just underground) infrastructure and hence adaptation projects for flood control. (Metropolis, 2018, Danish Parliament, 2012). See case study in Chapter 4.1 for details.

2.2 Negative Impact Avoidance: Pillar 2

The second pillar tackles the most traditional, yet financially complex, benefit of climate adaptation: the disaster that did not happen. Its core directive is to **finance what you prevent.** The consideration of potential "Cost of Inaction" is driving the business case.

When a city installs a comprehensive stormwater management system, the primary value is the absence of flooded basements, the preservation of continuous public transit operations, and the avoidance of emergency response deployments for example. While these represent massive economic savings, "avoided costs" do not naturally appear as cash in a municipal bank account.

A more direct cost savings calculation than for the municipality can be drawn for a company's investment into water infrastructure, when the investment secures more reliable water provision for their own production processes and their supplier sites. That is because the standstill of a production line due to lack of water for water-reliant sections of the production process is typically linked to clearly quantifiable costs and productivity losses for the company. Particularly when there have already been such water-related production shutdowns, the "Cost of Inaction" can become a convincing quantifiable financial burden.

- **The Mechanism:** This pillar involves capturing a project's value through the financial value of damages and costs prevented. It is the practice of leveraging projected savings.
- **Capturing Avoided Costs:** To capture avoided costs (e.g., by turning them into a reliable cost-recovery stream), the entities that benefit from the avoided damage must agree to pay a fraction of those avoided costs back to the project. This can be structured through mechanisms like outcome-linked repayments, insurance-linked premium reductions, budget re-allocation or beneficiary cost-sharing. Besides the outcome-linked mechanisms, upfront cost-sharing or co-

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investment from beneficiaries who recognize the potential “Cost of Inaction”, can represent a significant contribution to the initial investments. Additionally, individual or co-investments of companies into water infrastructure that prevent water-related production shutdowns can be quantified into avoided productivity losses over time, which can directly be compared to the capital expenditure for building the new infrastructure.

- **Building Investor Trust:** Investors require rigorous data to trust avoided-cost models. By utilizing actuarial data to baseline the "Cost of Inaction," municipalities can mathematically prove to investors that the guaranteed cost-avoidance outstrips the project’s cost-recovery requirements, providing a secure, data-backed rationale for investment. Similarly, companies can measure the guaranteed cost-avoidance over time against the project’s cost recovery requirements.

2.2.1 Avoided-Cost Capture Mechanisms

Damage prevented is money never spent, but that avoided cost does not automatically translate into a predictable cash flow - it must be captured and directed towards whoever financed the prevention in the first place. The mechanisms identified below are at different points along the maturity spectrum: outcome-linked repayment and insurance premium reduction both depend on independently verified performance or risk data; beneficiary cost-sharing requires naming the specific parties exposed to the avoided damage; and budget re-allocation, while the most direct expression of the pillar’s logic is the hardest to verify externally and therefore serves mainly as an internal tool for municipal planning rather than investor repayment. Avoided-Cost Cash Flows for Corporates might be the most straightforward mechanism, as it depends on the quantification of the cost of production shutdowns, which typically is a calculation already conducted within a company’s operations, and will need to be run for the water-dependent sections (e.g. using water for cooling) of the company’s production. It mainly requires to additionally consider the probability of recurrence over time due to climate impacts on water availability.

As with the first pillar, the same logic holds: the more objectively avoided costs can be measured and attributed to a specific stakeholder, the more easily it is to convert a potential saving into an impact-capture mechanism that represents significant upfront capital contributions or supports long-term cost-recovery cash flows.

1. Outcome-linked repayment

- **Concept:** A financial mechanism (typically executed via an impact bond or outcome-based loan) where investor repayment is tied, at least partly, to a measured environmental or resilience outcome rather than being fixed in advance. If the funded intervention performs well, investors may receive standard or bonus repayment; if it underperforms, repayment terms adjust – sharing outcome risk between the city and the investor rather than placing it entirely on one side.
- **Adaptation application:** Used to finance green or grey infrastructure where the actual performance (e.g., stormwater runoff reduction, flood risk reduction) is genuinely uncertain at the time of construction, letting a city or region try a promising but unproven approach without bearing all the downside risk itself.
- **Capital Provider appeal:** Attracts impact-oriented and institutional investors willing to accept outcome-linked terms in exchange for the reputational and portfolio value of financing a verified environmental result – and, if the project outperforms, potentially a higher return than a conventional bond or loan would offer. For corporate investors, a proximity or direct impact to their operations, including supplier network, is essential both to unlock contributions from corporate CSR budgets, as well as potentially more extensive corporate balance sheet investments.
- **Example:**
    - DC Water Environmental Impact Bond (Washington D.C., US): In 2016, DC Water issued a $25 million Environmental Impact Bond to finance unproven green infrastructure across two neighbourhoods. The outcome-linked mechanism dictated that investors (including Goldman Sachs Urban Investment Group and Calvert Foundation) were repaid based on the measured stormwater runoff reduction.

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Depending on the infrastructure's performance, a contingent payment of approximately $3.3 million swung between DC Water and the investors, perfectly sharing the financial risk of a novel adaptation approach (U.S. Environmental Protection Agency, 2017).

- Wyre Catchment Natural Flood Management Project (Lancashire, UK): This project serves as a premier European example of outcome-linked adaptation finance. Following devastating local floods, a partnership including the local council, the Environment Agency, and United Utilities needed to finance over 1,000 natural flood management interventions – such as leaky dams, ponds, and wetland creation – to protect downstream communities. To overcome the limitations of traditional grant funding, a purpose-built Community Interest Company raised an upfront £850,000 private loan facility from impact investors (arranged by Triodos Bank) to construct the natural infrastructure. A coalition of beneficiaries - including United Utilities, the Environment Agency, Wyre Council, and Flood Re – then signed multi-year, outcome-linked contracts to pay recurring service fees over time to service the debt. This structure ensures that the public and corporate beneficiaries do not fund the construction directly; instead, their ongoing payments are contingent strictly upon verified flood-mitigation outcomes. Crucially, after an initial optimization phase, the payments switch strictly to an outcomes-based model dependent on verified reductions in peak water flow during storm events. If the natural infrastructure fails to perform, the buyer contracts can be reviewed, meaning the private investors bear the ultimate financial downside risk of the unproven adaptation measures (Green Finance Institute, n.d.).

2. Insurance Premium Reduction (Self-Insurance or Commercial)

- **Concept:** A city reduces its own future insurance costs – either the premiums it pays for commercial coverage on public assets, or the claims payouts it draws from its own self-insurance reserve – by investing in risk-reducing infrastructure and redirects some of that saving toward repaying the investment.
- **Adaptation application:** Applies where flood or storm mitigation measurably lowers a community's insurable risk profile, translating into a documented, third-party-verified premium discount rather than a self-assessed cost-reduction the city has to justify on its own.
- **Capital provider appeal:** The saving is externally validated (by an insurer or a national program) rather than internally estimated, which reduces the credibility risk investors face when a city claims savings from its own accounting – a real advantage over the "budget re-allocation" mechanism below.
- **Example:**
  - Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (US): The FEMA's Community Rating System (CRS) in the US is the globally recognized model for this mechanism. It gives U.S. communities flood insurance premium discounts of 5–45% (in 5% increments across 10 classes) based on documented floodplain management and mitigation activities. This third-party verified system is currently applied in over 1,700 participating communities, providing a clear financial reward for municipal adaptation (Federal Emergency Management Agency, n.d.; 2024).
  - Because Europe relies on a patchwork of private insurers and national disaster funds rather than a single federal insurer, a direct equivalent to the CRS is still evolving. To apply this mechanism in Europe, national reinsurance pools (such as the UK's Flood Re or Spain's Consorcio de Compensación de Seguros) or consortiums of private insurers must establish standardized municipal rating systems. If a European municipality builds verified stormwater or coastal defences, the insurance consortium formally recognizes the lowered risk and mandates a localized premium discount. To actually repay investors, the municipality must then use an impact-capture mechanism – for instance, introducing a small, localized resilience fee that absorbs a portion of the

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citizens' insurance savings, converting a dispersed private saving into a consolidated municipal revenue stream to service the infrastructure debt.

3. Beneficiary Cost-Sharing

- **Concept:** Multiple parties – each of whom would face measurable damage without the project – contribute to its cost roughly in proportion to the loss each would individually avoid, rather than one investor financing the whole project and being repaid by one revenue stream.
- **Adaptation application:** This mechanism works well where flood or hazard risk concentrates identifiable damage on a small number of named infrastructure operators or asset owners (a railway, a utility, a city centre), making it possible to negotiate direct contributions instead of relying solely on general taxation.
- **Capital provider appeal:** This mechanism is not designed to attract external commercial capital in the traditional sense – there is no bond or loan instrument here, and no repayment event separate from the upfront contribution. Its appeal is rather political and administrative: it lets a city fund a project without bearing the full cost alone. It does so by making the case that other named beneficiaries should share the costs.
- **Example:**
    - The Sihl Entlastungsstollen (relief tunnel) (Zurich, Switzerland): In Zurich, the river Sihl runs directly beneath the city's central railway station (Zürich Hauptbahnhof), creating a severe vulnerability to extreme weather. If a massive flood event were to occur, the resulting inundation of the lower Sihl valley, the city centre, and the subterranean rail and retail hubs would cause an estimated CHF 6.7 billion in economic and physical damages. To eliminate this concentrated risk, the Canton of Zurich engineered a targeted adaptation asset: a 2-kilometer underground relief tunnel designed to intercept peak floodwaters upstream and divert them safely into Lake Zurich before they can reach the city. The total capital investment required to plan and construct this infrastructure was CHF 175 million. Because the CHF 175 million investment is a tiny fraction of the CHF 6.7 billion in avoided damages – and because those damages would disproportionately strike a few specific asset owners – the Canton did not fund the project entirely through its own general budget. Instead, it structured a multi-party cost-sharing agreement. The upfront costs are co-financed directly by the consortium of entities whose balance sheets are protected: the Canton of Zurich (protecting the broader regional economy), the City of Zurich (protecting municipal infrastructure), the Swiss Confederation, the Swiss Federal Railways (SBB, protecting the national rail hub), and the SZU (protecting the regional rail line in the valley). By contributing upfront capital, these named beneficiaries collectively finance a project that saves each of them from catastrophic future losses (Kanton Zürich, n.d., 2022). For details see case study in Chapter 4.2.

4. Budget Re-allocation from Avoided Service Costs

- **Concept:** A city tracks the ongoing operating and emergency-response costs (repair crews, disaster response, service disruption) that a resilience investment prevents and redirects the resulting freed-up capital toward repaying that investment, rather than leaving it in general reserves.
- **Adaptation application:** Fits situations where a resilience asset primarily reduces a city's own recurring operating expenditure (fewer emergency callouts, less infrastructure repair) rather than generating third-party revenue or an insurer-verified saving.
- **Capital provider appeal:** This mechanism is weaker than the previous three mechanisms. Because the "saving" is self-reported by the city's own budget office rather than independently verified (unlike a CRS discount or a measured bond outcome), it is harder for an outside investor to underwrite with confidence – this mechanism is more commonly used for internal capital planning than as the basis for external investor repayment.
- **Example:**

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- Copenhagen Cloudburst Management Plan (Denmark): Following a massive 2011 rainstorm that paralyzed the city and required continuous, expensive emergency response and repair, the City of Copenhagen and its municipal water utility (HOFOR) developed the Cloudburst Management Plan. To finance the €1.7 billion investments in blue-green surface infrastructure, the municipality conducted a strict Cost-Benefit Analysis (CBA) based on avoided costs. The city tracked the escalating operational burden of doing nothing – including the ongoing costs of emergency pumping, repair crews, sewer system overhauls, and service disruptions – which were projected to amount to €2.1 billion in long-term damages of inaction. By proving that the blue-green infrastructure would permanently eliminate these specific operational and emergency response costs, as well as proving in the CBA that the overall "Cost of Inaction" vs the "Cost of Action" for the implementation of the plan would be net-positive, the city justified both the upfront capital expenditure as well as the required change in legislation needed to use water tariffs as a repayment mechanism (see Chapter 2.1.1 under 4. Existing tariffs). While the debt is technically serviced through a structured increase in the municipal water fee (positive impact monetization, see case study in Chapter 4.1 for details), the financial business case – and the resulting budget capacity to allow that fee increase – was explicitly built on capturing the avoided costs of emergency management and infrastructure repair (European Environment Agency, n.d., City of Copenhagen, 2012 & 2014).

5. Avoided-Cost Cash Flows for Corporates

- **Concept:** This mechanism captures value by converting positive biophysical externalities (like water-table stabilization) into direct, quantifiable operational cost savings or avoided risk-mitigation overhead for downstream commercial off-takers.
- **Adaptation application:** This mechanism is highly effective in arid or water-stressed regions where heavy industrial or high-technology manufacturing faces severe drought, regulatory groundwater extraction caps, or escalating municipal water tariffs. By deploying direct corporate treasury capital to build advanced on-site recycling and brine reduction infrastructure, a corporate operator can internally recycle most of its process water. This drastically reduces its physical dependence on vulnerable municipal potable grids and minimizes regional water-table depletion.
- **Corporate investor appeal:** The primary appeal is operational de-risking and direct cost avoidance from water-linked operational shutdowns for corporates. For high-volume manufacturers, the financial cost of a water-linked operational shutdown is highly critical, as the potential losses can quickly mount to millions of dollars per day. When capitalizing these assets through corporate treasury, the water-linked environmental threat can be transformed into a predictable cost-avoidance calculation. The main financial impact for the companies is linked to avoiding the potential costs of millions from municipal potable water charges.
- **Example:**
  - Camp de Tarragona Water Reuse Project (Catalonia, Spain): Following severe drought restrictions on the Ebro River, combined with strict European environmental mandates, companies were facing several water usage limitations and strict European environmental mandates, mounting to a threat for operational shutdowns in Europe's largest chemical park. To implement the project, the regional public water agency Agència Catalana de l'Aigua (ACA) partnered with a private corporate consortium. Under this framework, thirty chemical companies pooled €19.5 million in private balance-sheet capital through their shared infrastructure entity, Aguas Industriales de Tarragona S.A. (AITASA), alongside €28 million in public and EU structural grants to construct a 35,000 m^3 advanced wastewater reclamation facility and pressurized distribution network. Instead of utilizing traditional public debt, the project recovers capital via a multi-tiered industrial off-take tariff: private industrial anchors pay a fixed capacity charge to amortize AITASA's capital and a variable volumetric charge for actual consumption, securing an uninterrupted, high-purity water supply while releasing

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12.8 million m^3 of freshwater back to the public municipal grid. (Sanz et al., 2015). For details see case study in Chapter 4.3.

- Intel Ocotillo Closed-Loop System (Arizona, United States): To sustain high-volume semiconductor manufacturing in an extremely water-stressed desert basin, Intel constructed the Ocotillo Water Reclamation Facility (OWRF). Intel co-financed the hundreds of millions in CAPEX as a *virtual Special Purpose Vehicle (SPV)* development agreement with the local municipality to process and recycle over 94% of its process water. This *virtual SPV* framework replicates the risk-allocation, asset-delivery, and joint-governance capabilities of a traditional SPV through a series of legally binding, multi-decadal Master Development Agreements (MDAs) and Intergovernmental Agreements (IGAs) executed between Intel Corporation and the City of Chandler. These agreements dictate water supply allocations, wastewater discharge rights, and joint capital facility construction. For shared public-private assets, the MDA establishes a clear 50/50 public-private cost-split. For example, the $26 million Reclaimed Water Interconnect Facility was funded with $13 million in upfront cash from Intel's corporate treasury and $13 million from Chandler's municipal utility capital funds, which the city mobilized via municipal water revenue bonds. Intel's corporate treasury justified the investment through a direct cost-avoidance model: financial returns are captured internally as prevented costs, offsetting the high municipal tariffs Intel would otherwise pay for raw freshwater intake and de-risking the plant from drought-driven production shutdowns. Internal cost avoidance is measured by the output of recycled water per day, allowing Intel to avoid purchasing equivalent volumes of municipal water. This yields direct operational savings of over $12 million per year while preventing water-related semiconductor line shutdown revenue losses estimated between $10 million and $50 million per day. (City of Chandler, 2022; Intel Corporation, 2023). For details see the case study in Chapter 4.4.

2.3 Negative Impact Internalization: Pillar 3

The third pillar addresses the systemic market failure where the creators of climate vulnerability do not pay for the consequences of their actions. Its core directive is to **make risk-creators pay**.

Urban climate risks are frequently intensified by specific economic activities or developments. For example, large-scale commercial developments with extensive non-permeable surfaces (like massive parking lots) drastically increase stormwater runoff, compounding flood risks for the rest of the municipality.

- **The Mechanism:** This pillar focuses on applying the polluter pays principle to climate risk. It utilizes regulatory tools that charge those whose activities generate or worsen climate hazards. Consequently, contributors to environmental degradation provide the baseline funding required for adaptation projects.
- **Regulatory-based Capturing of Externalized Costs:** Municipalities can capture externalized costs by enacting policies that internalize these costs, such as impervious surface taxes, stormwater utility fees, or development impact levies.
- **Building Investor Trust:** Revenue generated from these regulatory fees provides one of the most stable, predictable cash flows available to a municipality. Because these funds are often legally mandated and continuously collected, they offer Capital Providers a highly secure, low-risk source of repayment that can reliably guarantee the debt issued for the initial construction of the adaptation infrastructure.

2.3.1 Regulatory-based Capture Mechanisms

To operationalize negative impact internalisation, municipalities must deploy specific regulatory mechanisms that capture the true costs of risk-generating activities. Rather than relying on general taxpayer funds to mitigate hazards amplified by private actors, these tools legally link a property's financial contribution directly to the scale of the environmental burden it produces. By doing so, cities achieve a dual objective: they actively disincentivize maladaptive urban design – such as paving over

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natural drainage areas – while simultaneously carving out dedicated, legally enforceable revenue streams to fund public resilience. The three most robust mechanisms for converting these negative externalities into reliable, Capital Provider-grade cash flows are Impervious Surface Taxes, Stormwater Utility Fees, and Development Impact Levies.

1. Impervious Surface Taxes

- **Concept:** A recurring tax levied on property owners based specifically on the total area of sealed, non-porous ground on their parcel (such as concrete driveways, asphalt parking lots, or conventional roofs). It strictly applies the polluter-pays principle by charging landowners for the volume of rainwater their property prevents from naturally infiltrating the ground, forcing them to pay for the resulting runoff.
- **Adaptation application:** This mechanism is highly effective for urban flood management. It incentivizes behavioural change – property owners can lower their tax bill by unsealing surfaces or installing green roofs and permeable pavements. Meanwhile, the municipality uses the collected revenue to fund city-wide blue-green infrastructure, sponge city transitions, or drainage upgrades**.**
- **Capital Provider appeal:** This mechanism provides a highly stable, predictable, and legally mandated revenue stream. Because it is a tax explicitly linked to real estate, collection rates are near 100%. This makes it an exceptionally low-risk collateral source to secure and service municipal green bonds over a 20- or 30-year term.
- **Examples:**
    - “Niederschlagswassergebühr” (Berlin, Germany): In Berlin, the municipal water utility (Berliner Wasserbetriebe) uses a targeted impervious surface tax – the Niederschlagswassergebühr – as the primary financial engine for its ambitious Schwammstadt (Sponge City) transition. Rather than a flat-water rate, property owners are charged a baseline fee of €1.809 per square meter of sealed, runoff-generating surface per year. However, the mechanism is specifically designed to drive behavioural change through massive financial incentives: owners who manage their rainwater decentrally by installing green roofs, infiltration swales, or permeable pavements receive substantial fee reductions or complete exemptions. To accelerate this transition, Berlin updated its statutes in 2024 to offer even deeper discounts; for example, properties that capture rainwater in cisterns for indoor use (like toilet flushing) now pay only 10% of the standard fee for those connected roof areas. This elegant policy internalizes the cost of flood risk, generating millions to fund public drainage upgrades while directly financially rewarding private landowners who actively reduce their climate footprint (Berliner Wasserbetriebe, n.d., 2024).
    - City of Hamburg Stormwater User Fee (Hamburg, Germany): As part of its Rain Infrastructure Adaptation (RISA) initiative to combat severe pluvial flooding, Hamburg implemented a targeted stormwater user fee. Instead of using a general tax, property owners are charged a specific annual fee per square meter of sealed, impermeable surface on their land. This provides the municipality with a dedicated, ring-fenced cash flow to recover the costs of upgrading drainage infrastructure and simultaneously incentivizes private owners to unseal surfaces and install green roofs (INTERLACE Hub, n.d.).

2. Stormwater Utility Fee

- **Concept:** A dedicated, recurring user charge collected by a municipal water authority or specialized public utility. Unlike a general tax that goes into a city’s central treasury, this fee is ring-fenced entirely within an independent "enterprise fund" dedicated exclusively to managing stormwater and flood defence systems across the jurisdiction.
- **Adaptation application:** It guarantees that adaptation funding is not competing with schools or hospitals in a general municipal budget. The ring-fenced capital is used specifically to finance large-scale structural adaptation, such as expanding sewer capacity, building massive underground retention tanks, or restoring natural floodplains to handle cloudbursts.

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- **Capital Provider appeal:** Because the revenue is captured by a standalone utility enterprise fund rather than a general municipal treasury, the cash flow is legally protected from shifting political priorities.
- **Example:**
    - The Dutch Regional Water Authorities (Waterschappen): The Netherlands manages flood risk through independent, regional water authorities that function like specialized utilities. They charge a dedicated, legally mandated fee called the Watersysteemheffing (Water System Levy) to all residents, property owners, and businesses within their jurisdiction. This fee is strictly ring-fenced to operate pumping stations, reinforce dikes, and adapt regional waterways to rising sea levels and heavier rainfall. Because this utility fee is independent of national or municipal general budgets, the Waterschappen maintain a AAA credit rating, making them highly attractive to institutional Capital Providers financing long-term climate adaptation (Hoogheemraadschap Hollands Noorderkwartier [HHNK], n.d.).

3. Development Impact Levies

- **Concept:** A one-time fee or legally mandated financial contribution imposed on asset owners and real estate developers during the planning and permitting process or via annual fees. It forces the stakeholder to internalize the cost of mitigating the environmental stress (such as increased runoff, coastal vulnerability, or urban heat) caused specifically by their new construction. Also, polluters and infrastructure users such as vehicle owners can be mandated to contribute through parking fees or congestion charges at city level. On the national level, the concept of polluter-pays climate compensation funds which charge fossil fuel companies is taking shape.
- **Adaptation application:** Vital for rapidly growing urban areas where new commercial or residential construction, as well as traffic and its harmful emissions, threaten to overwhelm existing environmental limits. The funds are used to directly finance the upfront construction of localized adaptation assets – such as new retention ponds, reinforced seawalls, or expanded green spaces – that directly offset the actions of the creator of the negative impact.
- **Capital Provider appeal:** While these levies can provide one-off upfront capital injections rather than a recurring source of repayment, they generate massive, concentrated pools of cash tied directly to economic growth. Municipalities can pool these developer financial contributions into a dedicated "adaptation trust fund," which can then be used to co-finance large-scale resilience projects via upfront investments or to pay down the principal on existing adaptation investments, heavily de-risking the project for private Capital Providers.
- **Example:**
    - The UK's Section 106 Agreements and Community Infrastructure Levy (CIL): In the United Kingdom, local planning authorities use these statutory mechanisms to force developers to fund mitigating infrastructure as a strict condition of receiving building permits. For example, if a developer wants to build a new housing estate that increases surface water runoff, the local council will use a Section 106 agreement to legally mandate that the developer either pays to upgrade the local municipal drainage network or fully funds the integration of sustainable drainage systems – such as swales and attenuation ponds – before a single brick is laid (Ministry of Housing, Communities & Local Government, n.d.).

In practice, a robust municipal adaptation project rarely relies on a single pillar. The true strength of the Impact to Finance Framework lies in stacking and combining these mechanisms. By combining a stormwater fee (negative impact internalization) with increased property tax revenues from a newly protected district (positive impact monetization), a municipality creates a diversified, secure cash flow profile. This multifaceted approach is what ultimately convinces private and institutional investors that the project is not just a necessary public good, but a financially sound, bankable asset (see also Chapter 3.2.1).

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3 Project Cash Flow: Upfront Capital & Repayment

Understanding the financial viability of an adaptation project and options for early-stage financial structuring requires mapping the flow of capital across the project's entire lifespan. The adaptation finance cash flow stream operates across two fundamental dimensions: the initial upfront investment required to build the project, and the long-term returns generated over time to pay back that investment (see Figure 2).

The transition from a vulnerable baseline to a resilient future requires an orchestration of distinct financial actors and instruments. This chapter outlines how initial pools of upfront capital are sourced to fund the physical intervention (Component 1) and how the resulting monetized impacts (see Chapter 2) flow back as structured Sources of Repayment over time (Component 2).

Worth noting here is that in some cases, the impact-capture mechanisms listed under Component 2 (see also Chapter 2) can also serve as the initial financing mechanism itself. As an example, see the case study around the Copenhagen Cloudburst Management Plan in Chapter 4.1, where water tariffs paid by customers are used to both initially (partly) fund the project as well as a mechanism to recover a share of the project's cost after construction, helping to finance the asset's operations during its lifetime.

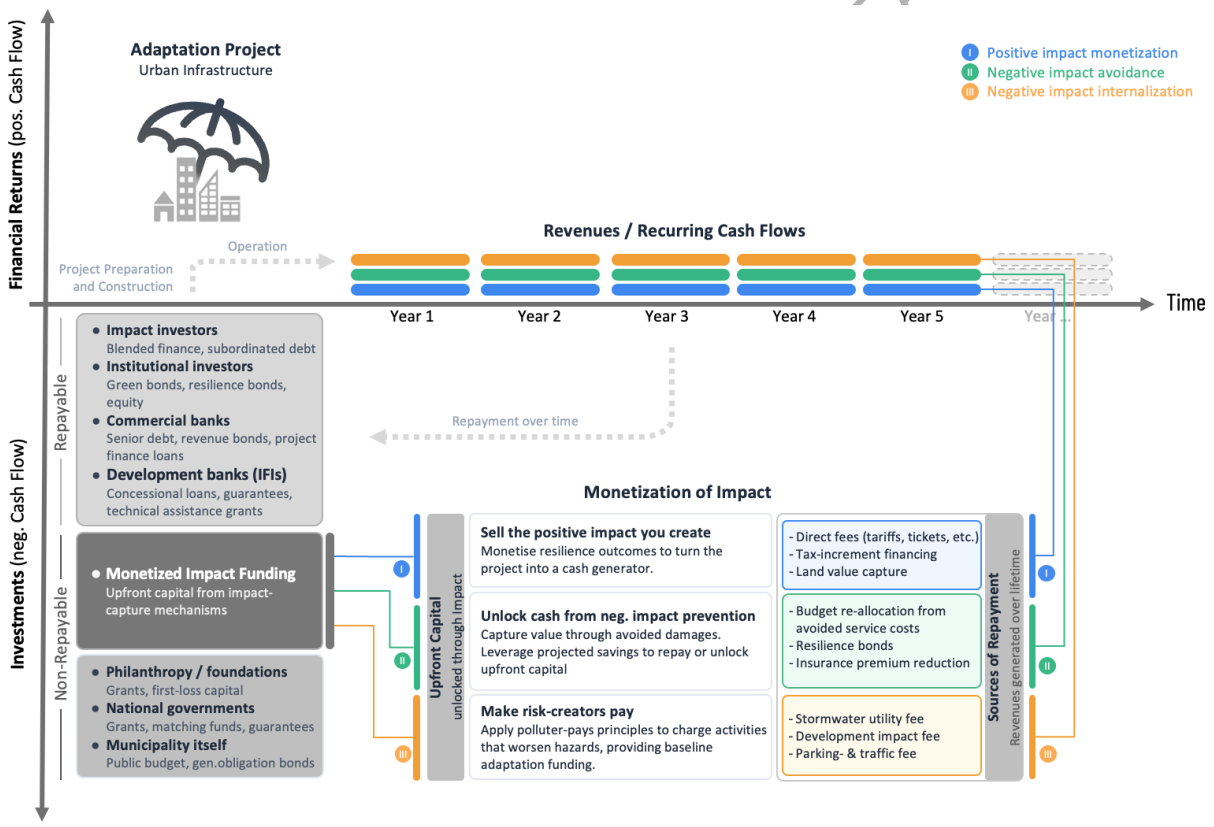


Figure 2: The Cash Flow Stream of Adaptation Projects: Investment, Monetization, Repayments (illustrative, own graphic)

3.1 Upfront Capital (Component 1)

Before any climate resilience benefits can be realized, significant upfront capital is required for the design, construction, and implementation of the adaptation project, such as a large-scale stormwater management system. In a municipal context, relying on a single source of funding is rarely sufficient. Instead, cities must look to a diverse ecosystem of capital providers for a blended finance solution. Crucially, certain impact-capture mechanisms identified in Chapter 2 – such as Development Impact

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Levies (Section 2.3.1) or upfront Beneficiary Cost-Sharing (Section 2.2.1) - are operationalized during this phase to capture capital immediately, directly funding the initial construction.

The following actors and financial instruments typically provide the necessary upfront capital:

- **The Municipality Itself:** The city remains a foundational funder, utilizing its internal public budget and issuing General Obligation (GO) bonds. GO bonds are secured by the municipality's overarching ability to levy taxes, providing a reliable, low-interest mechanism to raise upfront capital for public works. Further, municipal utilities can use e.g water tariffs to finance projects.
- **National Governments:** Central governments often support municipal resilience through non-repayable grants, matching funds, and guarantees. Matching funds incentivize local municipal spending by doubling or augmenting the city's financial commitment, while sovereign guarantees lower the risk profile for external lenders.
- **Development Banks & International Financial Institutions (IFIs):** These are critical partners for cities, offering concessional loans, guarantees, and technical assistance grants. Concessional loans provide repayable capital at below-market interest rates with longer grace periods, making large infrastructure projects more affordable for municipal balance sheets.
- **Philanthropy and Foundations:** These entities typically provide grants and non-repayable first-loss capital. In a municipal context, first-loss capital is highly strategic; it acts as a financial buffer that absorbs the initial risk of a novel adaptation project, thereby making the investment safer and more attractive for subsequent private investors.
- **Impact Investors:** Driven by both financial returns and measurable environmental outcomes, these investors provide blended finance and subordinated debt. Subordinated debt ranks below senior debt in the repayment hierarchy; by accepting this higher risk, impact investors help de-risk the project for traditional commercial lenders.
- **Institutional Investors:** Pension funds and insurance companies represent massive pools of capital looking for stable, long-term returns, investing primarily through green bonds and resilience bonds. These instruments allow cities to raise vast amounts of capital specifically earmarked for verified climate adaptation infrastructure.
- **Commercial Banks:** Traditional financial institutions provide senior debt, revenue bonds, and project finance loans. Revenue bonds are particularly relevant in this framework, as they are repaid exclusively by the specific revenue streams generated by the project, rather than the city's general tax pool.
- **Corporates:** Private sector corporations' provision of large-scale private capital is motivated by operational risk-mitigation and corporate sustainability targets, investing primarily through corporate treasury allocations, non-repayable CSR grants, and long-term take-or-pay off-take agreements. These investments directly fund municipal-scale distribution upgrades or underwrite project-finance debt without relying on public borrowing. By absorbing these upfront costs, corporates secure continuous manufacturing lines while capturing returns via volumetric utility savings, state tax deductions, or verified ESG water-replenishment offsets.

3.2 Sources of Repayment (Component 2)

Once the Upfront Capital is secured and the adaptation project is implemented, the temporal dimension of the lifecycle begins. Over time, the physical intervention allows the city to generate monetizable impacts, which are to be used as Sources of Repayment.

The core idea of this lifecycle is that the value the project (and/or other interventions) creates must be captured and translated into structured Sources of Repayment that pay back the initial investors. Aligning with the Impact to Finance Framework, these repayment streams are derived from three avenues:

1. **Selling the Positive Impact (Value-Based Cash Flows):** As the project monetizes resilience outcomes and turns into a revenue-producing asset, the resulting cash flows are used to service the debt. Instruments here include direct fees (such as tariffs or tickets), Tax-Increment

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Financing (TIF), and land value capture. This is positive impact monetization as a source of repayment.

2. **Financing What You Prevent (Avoided-Cost Cash Flows):** The project captures value through avoided damages, leveraging projected savings to fund the upfront capital. As damage is avoided over time, the city or specific corporate beneficiaries can allocate those operational cost-reductions to investor repayment through resilience bonds, self-insurance premium reductions, and budget re-allocations from avoided service costs. This represents an Avoided-Cost Capture Mechanism operationalized as a repayment cash flow. This is a negative impact avoidance as a source of repayment.
3. **Making Risk-Creators Pay (Regulatory-Based Cash Flows):** Applying the polluter-pays principle ensures that those who worsen hazards provide baseline funding. This continuous, regulatory-driven revenue stream - such as stormwater utility fees and development impact fees - creates a highly reliable pool of capital to steadily pay down the initial investment over the project's lifespan. This represents a Regulatory-Based Capture Mechanism operationalized as a repayment cash flow. This is negative impact internalization as a source of repayment.

By properly structuring Component 2, a municipality demonstrates to the capital providers in Component 1 that a reliable, continuous flow of capital will exist over time to service the initial investment, proving project bankability.

3.3 Cash Flow Identification Tool

Having established the theoretical components of the 'Impact to Finance' framework and the lifecycle of capital flows in Chapter 2 and Chapter 3.1 as well 3.2, the challenge for city officials shifts from understanding the concepts to applying them in a specific local context. To operationalise these strategies, this chapter presents the Cash Flow Identification Tool (see Figure 3), a practical navigational tool designed to guide municipalities through the process of gathering the data necessary for setting up the business model of their adaptation projects.

Its primary goal is to provide a structured, step-by-step pathway that connects a project's specific characteristics to the most viable revenue streams which can become structured cash flows. By systematically assessing whether the conceptual impact-capture mechanisms identified in Chapter 2 can be operationalized in a local context – checking data readiness, legal enablers, and beneficiary agreements – it identifies how to successfully transform these concepts into either upfront capital contributions (Chapter 3.1) or sources of repayments (Chapter 3.2). Ultimately, by assessing the project's ability to generate revenue, produce verifiable cost-avoidance, or leverage regulatory tools against risk-creators, this tool empowers decision-makers to identify the precise approaches required to secure bankability and hence the upfront capital.

Specifically, the identification tool addresses the following core questions to determine the appropriate repayment approach:

- **Value-based Cash Flow Assessment:** Does the project generate a chargeable service or asset (Q1A), and can the city reliably bill and charge for this service (Q1B)?
- **Avoided-cost Cash Flow Assessment:** Does the project produce measurable, verifiable savings from avoided risks (Q2A), and can these savings be tied to a specific entity that financially benefits from them (Q2B)?
- **Regulatory-based Cash Flow Assessment:** Is there an identifiable party whose activities cause or worsen the targeted risk (Q3A), and are there existing regulatory tools (e.g., fees, levies) to charge them (Q3B)?

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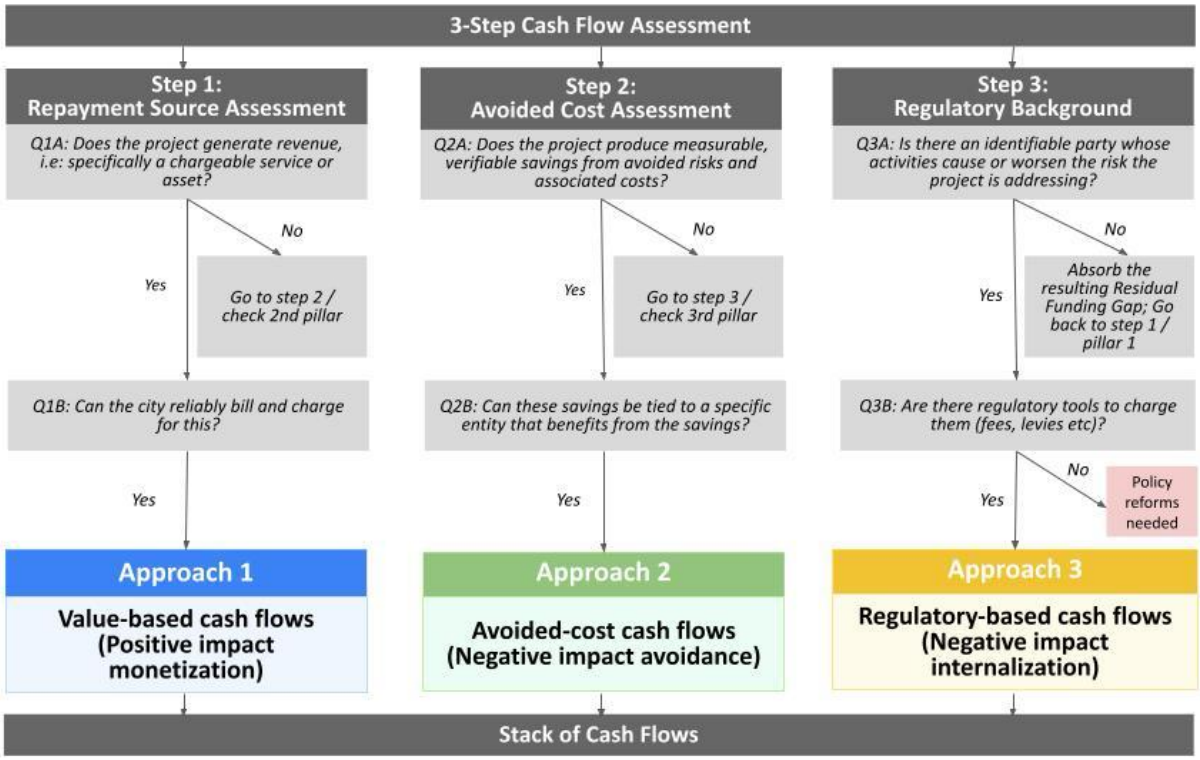


Figure 3: Cash Flow Identification Tool (own graphic)

User Guideline: Using the Cash Flow Identification tool

This identification tool is designed as a dynamic navigational tool rather than a rigid checklist. To maximize its utility in identifying viable cash flows (Value-based, Avoided-Cost-based, or Regulatory-based), city officials should apply the following guidelines:

- **Preparation and data readiness:** Before engaging with the identification tool, ensure key data points are preliminarily estimated. The project team must understand if the intervention generates a tangible asset, what specific risks it mitigates, and who exacerbates those risks. This baseline information is essential for effectively answering the questions of Step 1 (Repayment Source Assessment), Step 2 (Avoided Cost Assessment), and Step 3 (Regulatory Background).
- **Iterative refinement:** Evaluate the project across all three steps based on its specific characteristics:
    - **Answering "No" at Step 1 (Q1A or Q1B)** directs municipal leaders to check Step 2 (Avoided-Cost Cash Flow Assessment)
    - **Answering "No" at Step 2 (Q2A or Q2B)** directs municipal leaders to check Step 3 (Regulatory-Based Cash Flow Assessment)
    - **Answering "No" at Step 3 (Q3A or Q3B)** directs municipal leaders to absorb any residual funding gap that cannot be structured into an innovative cash flow (see Chapter 3.3)

  Note that the evaluation is not static; decision-makers should re-evaluate the project at key lifecycle milestones:
    - *Post-Feasibility phase:* When new data or structural adjustments allow the city to reliably bill for a service, shifting a "No" to a "Yes" at Q1B, thereby unlocking Approach 1: Value-based cash flows.

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- *Detailed design phase:* When advanced modelling or actuarial data can finally tie avoided costs to a specific beneficiary, shifting a "No" to a "Yes" at Q2B, thereby unlocking Approach 2: Avoided-cost cash flows.
- *Regulatory updates:* If the city identifies risk-creators (Q3A -> Yes) but lacks the current legal mechanism to charge them (Q3B -> No), the tool highlights that "Policy reforms needed". Once those local or national reforms pass, the project can shift to unlocking Approach 3: Regulatory-based cash flows.

- **Cash flow stacking identification:** A comprehensive adaptation project rarely depends on a single repayment stream. City officials are encouraged to run different components of their project through the identification tool multiple times to build a "stack" of cash flows. For example, a coastal resilience hub might secure part of its financing through a chargeable service like commercial space leasing (a Value-Based Capture Mechanism, Pillar 1), while another portion is funded by levies on upstream developers worsening runoff (a Regulatory-Based Capture Mechanism, Pillar 3). The goal is to maximize private and alternative financing sources, leaving only the residual funding gap to the public budget.
  The viability of stacking different cash flows depends on the project's maturity, as different capital providers have different levels of risk tolerance across the typical stages of a project (see Table 1). Sources of repayment where the participating capital providers share similar levels of risk tolerance and requirements for investment-readiness will be more apt for stacking at any given project development stage. However, the structuring of different financial mechanisms for an adaptation project should not only be evaluated through the lens of the project's current stage and immediate financing needs; rather it must be planned along the full project lifecycle, covering Upfront Capital and Repayment.

3.4 Commercial Capital Capacity and Funding Gaps

The Impact to Finance Framework (I2FF) provides structured mechanisms to unlock private capital, monetize adaptation co-benefits, and internalize negative externalities. However, municipal planners must recognise that impact monetization will rarely cover 100% of an adaptation project's total capital and operational expenditure (CAPEX and OPEX).

In practice, adaptation assets remain fundamentally hybrid investments. The projects deliver high socio-economic value alongside distinct, monetizable revenue streams. Consequently, a critical step in project preparation is conducting a Commercial Capital Capacity Assessment to determine a key project KPI - the **Commercial Funding Ratio (CFR)**.

The CFR defines the exact proportion of an adaptation project funded via market-based mechanisms and impact contributions, leaving the remaining percentage as the Residual Funding Gap.

Commercial Funding Ratio (CFR in %) is calculated from

- NR = Non-Repayable Capital from Impact-Capture Mechanisms (Pillars 1 to 3) [1]
- RC = Repayable Commercial Capital
- $CAPEX$ = Total Project Capital Expenditures

$$Commercial\ Funding\ Ratio = 100\% \cdot \frac{(Non - Repayable\ Capital + Repayable\ Commercial\ Capital)}{Total\ Project\ Capital\ Expenditures} \qquad CFR = 100\% \cdot \frac{(NR+RC)}{CAPEX}$$

Because the Repayable Commercial Capital (RC), typically sourced via bank debt, green bonds, or private equity, cannot be chosen arbitrarily, it must be estimated based on the net recurring cash flows for potential re-payments of investments, generated across the three impact-capture mechanisms related to Pillars 1–3, considering the operating expenditures (OPEX) and capital provider requirements.

[1] It is assumed at this point that upfront capital from impact-capture mechanisms (Pillars 1,2 and 3) is non-repayable

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Using reasonable assumptions, municipal finance officers should execute an early assessment for this in order to have clarity about realistically available Repayable Commercial Capital (RC) and the Residual Funding Gap. By executing this assessment early in project scoping, municipalities avoid unrealistic expectations regarding private debt or equity appetite and financial structure.

Where the Commercial Funding Ratio is below 100%, cities need to absorb the resulting Residual Funding Gap and structure Blended Finance solutions. To cover the gap, the upfront capital can potentially be complemented with traditional non-repayable public budgets and non-repayable grants. The introduction of repayable concessional finance from the public and private sector allows municipalities to service a larger pool of Repayable Commercial Capital using the same underlying Sources of Repayment. In addition, it needs to be assessed to what extent these cash flows can be complemented with matching subsidies over time.

At a later stage of the project, a detailed, more accurate analysis will become available from the establishment of a comprehensive financial modelling developed for the business case.

3.4.1 Key Determinants of Commercial Capital Capacity

The proportion of capital an adaptation project can secure from private or institutional investors across the three pillars is governed by five key economic and risk variables:

Revenue Yield & Coverage Ratios: The magnitude and predictability of recurring cash flows or internal, balance-sheet cost savings (Chapter 3.2) directly dictate the capital capacity for Repayable Commercial Capital. These recurring cash flows or operational expenditure offsets can potentially be complemented by long-term public subsidies.

Cost of Capital & Required Returns: Higher prevailing interest rates increase debt service costs, while higher equity return hurdles shrink the principal amount of Repayable Commercial Capital supported by a given revenue or savings stream. The introduction of concessional finance allows municipalities and corporate partners to lower the costs.

Inflation Risk & Indexation: If recurring revenue streams are not legally indexed to inflation, real net revenues decay over time, reducing long-term Repayable Commercial Capital capacity.

Asset Risk Profile & Capital Structure: Adaptation interventions often deploy novel green-grey designs. Lenders price performance uncertainty into higher required coverage buffers or interest rates, tightening borrowing capacity. To manage these risks, public municipalities and private and institutional investors can use shared corporate entities or long-term legal agreements to clearly divide and share technical responsibilities, while non-repayable capital and guarantees can improve the risk profile.

Repayable vs. Non-Repayable Blend: Upfront Non-repayable Capital mobilized through impact-capture mechanisms directly reduces baseline CAPEX without incurring debt service obligations. Conversely, repayable capital requires dedicated, multi-year recurring cash flows or verified balance-sheet cost savings to service principal, interest, or equity yields over the asset's lifespan.

3.4.2 Illustrative Example: Funding Gap of a 10MEUR Project

To see a calculation of the Commercial Funding Ratio in practice, consider a municipality scoping a 10 MEUR flood-mitigation park.

Baseline Data:

- **CAPEX:** 10.0 MEUR
- **Non-Repayable Capital (NR):** 1.5 MEUR in developer impact levies **(a Regulatory-Based Capture Mechanism; Pillar 3)** collected upfront during planning.
- **Net Annual Cash Flow:** 500,000 EUR per year from commercial cafe leases **(a Value-Based Capture Mechanism; Pillar 1)** and stormwater utility fees **(a Regulatory-Based Capture Mechanism; Pillar 3).**

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A private infrastructure fund commits 1.5 MEUR in equity to own/operate commercial elements in the park, while the remaining recurring revenue supports 3.08 MEUR in long-term debt (combining to yield an estimated total Repayable Commercial Capital capacity of 4.58 MEUR).

Calculation of Commercial Funding Ratio and Gap

$$CFR = ((\ 1.5\ MEUR + 4.58\ MEUR\ ) / 10MEUR\ ) \times 100 = 60.8\%$$

With a Commercial Funding Ration (CFR) of 60.8%, the remaining 39.2% (3.92 MEUR) represents the non-commercial shortfall. To bridge this shortfall, the city structures a blended finance solution using non-repayable public capital:

- 2.50 MEUR in a national climate adaptation grant.
- 1.42 MEUR in a municipal central budget capital subsidy.

This combined allocation of 3.92 MEUR successfully closes the funding gap, enabling construction of the 10 MEUR.

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4 Case Studies

While the theoretical framework (see Chapter 1 and 2) and the cash flow identification tool (see Chapter 3) provide the necessary basis for structuring municipal climate projects, their ultimate value must be proven on the ground. This chapter transitions from conceptual design to practical application by examining real-world case studies of municipalities and their partners that have successfully overcome the structural barriers of adaptation finance. To illustrate the full spectrum of the 'Impact to Finance' framework, the following examples highlight how cities have translated local climate action into bankable projects across all three core repayment approaches: monetizing positive impacts to generate new revenue, leveraging avoided costs to capture long-term savings, and utilizing regulatory tools to make risk-creators pay. By analysing these deployed strategies, municipal planners and finance officers can draw actionable insights on the steps required to move from high-level adaptation master plans toward structured, financially viable projects.

The following case studies will be covered in chapter 4:

Case	Country	Pillar	Impact-Capture Mechanisms
Copenhagen Cloudburst Management Plan	Denmark	Positive Impact Monetization (Pillar 1) (with business model integrating Negative Impact Avoidance - Pillar 2)	Existing Tariffs (Value-based Capture Mechanisms) Budget Re-allocation from Avoided Service Costs (Avoided-Cost Capture Mechanisms)
Sihl Entlastungsstollen	Switzerland	Negative Impact Avoidance (Pillar 2)	Beneficiary Cost-Sharing (Avoided-Cost Capture Mechanisms)
Camp de Tarragona Water Reuse Project	Spain	Negative Impact Avoidance (Pillar 2) (with business model integrating Positive Impact Monetization - Pillar 1)	Avoided-Cost Cash Flows for Corporates (Avoided-Cost Capture Mechanisms) Existing Tariffs (Value-based Capture Mechanisms)
Intel Ocotillo Closed-Loop System	USA	Savings-based repayment (Pillar 2)	Avoided-Cost Cash Flows for Corporates (Avoided-Cost Capture Mechanisms)
Hamburg Stormwater Fee	Germany	Regulatory-Based Repayment (Pillar 3)	Impervious Surface Taxes (Regulatory-based Capture Mechanisms)

Table 2: Overview Case Studies

4.1 Value-based Cash Flows: Copenhagen Cloudburst

Value-based capture mechanisms rely on the ability of an adaptation project to generate a chargeable service or asset. In this example, the municipality or a closely aligned public utility monetizes the newly created resilience value by charging the direct beneficiaries.

Parameter	Project Details

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Pillar & Impact-Capture Mechanism	Value-Based Capture Mechanism (Pillar 1) from existing water tariffs revenue (with business model integrating an Avoided-Cost Capture Mechanism (Pillar 2)
Location & Assets	Copenhagen & Frederiksberg, Denmark; city-wide urban assets (streets, cellars, parks, roads) protecting roughly 1,000,000 residents
Trigger	July 2011 cloudburst event in which ca. 150mm of rain dropped in under three hours
Monetized Value Stream (Value Capture)	€1.3 billion (representing 76.5% of the €1.7 billion plan) in recurring tariff revenues captured continuously from HOFOR's water and wastewater utility customer base
Total Investment	Initially estimated at €1.7 billion over ~20 years for 300+ projects, with current implementation costs totalling around €1.5 billion. The most recent estimation raised the total investment cost estimates for the plan to €2.7 billion (DKK 20 billion).
Upfront Capital (Component 1)	Upfront capital for the plan's initially estimated €1.7 billion required investments blending repayable and non-repayable investment: €1.3 billion from water tax/tariff charges, €0.13 billion from municipal taxes, and €0.3 billion from private sector investments. Project-level co-financing is split (e.g., Karens Minde Axis: €7 million from HOFOR (Greater Copenhagen Utility), €4.4 million from the City of Copenhagen).
Sources of Repayment (Component 2)	Cost recovery through existing HOFOR water and wastewater tariffs, with potential tariff increases of 10-15% subject to political and public hearings to fund additional projects.
Key (legal) enabler	2012 national legislative amendment allowing water utilities to fund surface-level (not just underground) climate adaptation infrastructure
Key stakeholders	City of Copenhagen, HOFOR (Greater Copenhagen Utility), City of Frederiksberg & Frederiksberg Forsyning, private property owners, and the Danish National Government.
Status	Ongoing 20-year programme with several hundred projects completed, underway, or planned.

Project Overview

Copenhagen's Cloudburst Management Plan (CMP) is a city-wide programme consisting of more than 300 individual blue-green and grey infrastructure projects. The plan is designed to manage extreme rainfall and reduce urban flood risks, and it combines traditional underground grey infrastructure projects, such as deep tunnels and underground 'cloudburst pipes' estimated at €358 million, with blue-green surface solutions estimated at €700 million (City of Copenhagen, 2012 & 2014, Metropolis, 2018). The geographic scope encompasses both the City of Copenhagen and the neighbouring municipality of Frederiksberg, directly protecting approximately 1,000,000 residents from extreme climate events (Metropolis, 2018, City of Copenhagen, 2014, European Environment Agency, n.d.).

The blue-green surface infrastructure represents a major technical and physical innovation of the plan, transforming urban spaces to handle excess stormwater. This includes the conversion of urban spaces into parks, retention basins, swales, and 'cloudburst boulevards' (large surface *water highways*) that naturally retain and channel water during severe downpours. Additionally, traditional underground pipes and tunnels are deployed where surface retention is insufficient, thus creating an integrated hybrid system. (City of Copenhagen, 2012 & 2014, Danish Parliament, 2013)

The Context and Catalyst

In July 2011, Copenhagen experienced an extreme cloudburst that dropped 150mm of rain in under three hours, severely flooding streets and cellars. The event caused roughly €800 million in damages, creating the urgent political momentum needed to adopt the city's Climate Adaptation Plan and the subsequent Cloudburst Management Plan (CMP). The scale of this financial loss became the critical benchmark against which future adaptation investments were financially justified.

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Prior to the 2011 flood, extreme rainfall and rising flood risks were recognized, but the magnitude of the 2011 damage created the immediate political and public momentum needed to mobilize institutional action. In rapid succession, the City of Copenhagen adopted the Climate Adaptation Plan in 2011, followed by the detailed Cloudburst Management Plan in 2012. These plans shifted the city's approach from reactive disaster management to proactive, long-term urban risk mitigation. (City of Copenhagen, 2012 & 2014)

Stakeholders and Roles

The governance and implementation of the Cloudburst Management Plan rely on a coordinated partnership between municipal governments, a regional utility provider, neighbouring jurisdictions, and private property owners. The City of Copenhagen acts as the lead planning agency and manages surface-level project delivery. Capital contributions are structured to align with each stakeholder's direct benefit or operational remit. HOFOR (the Greater Copenhagen Utility) serves as the primary financer and delivery agent, funding 100% of underground cloudburst pipes and co-financing surface-level solutions. Since water drains across administrative boundaries, the neighbouring City of Frederiksberg and its utility, Frederiksberg Forsyning, are closely integrated into the planning process to coordinate hydraulic capacity. Private property owners are also involved, co-financing localized measures on or adjacent to their properties while participating in community-level design workshops. The national government serves as the legislative regulator, enabling the financial model through targeted legal amendments and establishing cost-sharing ratios. (European Environment Agency, n.d., Danish Parliament, 2012, City of Copenhagen, 2014, Danish Parliament, 2013).

Stakeholders	Are beneficiaries billed for the service?	Beneficiary of avoided flood losses?	Capital Provided?	Role
City of Copenhagen	No	Yes	Yes, €0.13 billion of the total €1.7 billion cost	Lead public planning agency; responsible for urban planning, surface-level project delivery, and municipal tax-funded co-financing (e.g., contributing €4.4 million for the Karens Minde Axis project). Since 2015, they are required to cover 25% of the hydraulic costs of new surface projects. (State of Green, 2021)
HOFOR (Greater Copenhagen Utility)	No	Yes	Yes, €1.3 billion of the total €1.7 billion cost (including €7 million for Karens Minde Axis and 100% of €358 million underground pipes)	Public water utility; primary financier and delivery agent for both underground pipes and surface solutions, recovering capital via utility water and wastewater charges. (Metropolis, 2018)
City of Frederiksberg & Frederiksberg Forsyning	No	Yes	Yes (concrete amount is unclear)	Neighbouring municipality and utility; coordinates closely with Copenhagen on cross-boundary drainage planning and hydraulic

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				capacity. Frederiksberg Municipality and its utility handle local financing and execution for projects within their jurisdiction. (European Environment Agency, n.d.)
Private property owners	Yes	Yes	Yes, €0.3 billion of the total €1.7 billion cost	Private partners; co-finance localized adaptation measures on or adjacent to their land and engage in workshops and community participation. They are billed for cloudburst-related charges as part of the existing water and wastewater tariffs. (Metropolis, 2018)
Danish National Government	No	No	No	National legislative authority; amended national rules to enable utility tariff funding of surface-level projects and introduced the 2015 25% municipal cost-sharing rule. (City of Copenhagen, 2014)

Upfront Capital (Component 1)

Upfront capital mobilization for the €1.7 billion Cloudburst Management Plan is structured as a blended, multi-stakeholder model, drawing on public utility revenues, municipal taxes, and private capital. The majority of the capital is public, with €1.3 billion mobilized via the water utility tariff channel (HOFOR), €0.13 billion from municipal taxes (City of Copenhagen), and €0.3 billion from private property owners. At the individual project level, costs are split based on the nature of the assets: underground 'cloudburst pipes' (estimated at €358 million) are financed 100% by HOFOR, while surface-level solutions (estimated at €700 million) are co-financed by both HOFOR and the municipality. For example, the Karens Minde Axis project utilized a €10.8 million budget where €7 million was provided by HOFOR and €4.4 million was contributed by the City of Copenhagen.

While the plan's total estimated costs of €1.7 billion (and up to €2.7 billion/DKK 20 billion in more recent estimates) is substantial, it is designed to protect roughly 1,000,000 residents and billions of euros in urban assets over a 20-year horizon. When compared to the €800 million in damages caused by a single three-hour cloudburst event in 2011, the avoided costs create long-term cost efficiency. The financial justification for the project strengthens significantly the further into the future the analysis of cost-benefits are extended, because of how future damage reductions are discounted, as was found in a cost–benefit assessment prepared for the plan. This assessment confirms the economic viability of proactive urban defense particularly when considered over a long-term horizon. (HOFOR & Our Future Water Intelligence. 2023; Metropolis, 2018, City of Copenhagen, 2014, State of Green, 2021).

Sources of Repayment (Component 2)

The core long-term repayment and cost-recovery mechanism for the plan is HOFOR's water tariff channel. Copenhagen utilizes an ongoing cost-recovery structure, in which HOFOR recovers its substantial capital expenditures by incorporating these climate-adaptation costs directly into the existing water and wastewater tariffs that customers already pay. This approach avoids the need to implement politically sensitive new taxes or one-off resilience charges, as it rides on pre-existing billing and collection infrastructure. To fund additional or expanded cloudburst projects, HOFOR is authorized to raise water tariffs by 10% to 15%, subject to approval in political meetings and public hearings.

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For surface-level solutions, the repayment mechanism operates as a reimbursement structure: HOFOR co-finances surface adaptation projects together with the municipality and private landowners. The municipality and the private landowners are reimbursed by HOFOR using water-charge revenues. However, the cash-flow dynamics have faced subsequent regulatory adjustments. In 2015, the national government introduced a rule requiring Danish municipalities to cover 25% of the hydraulic costs of new surface projects themselves, shifting a portion of the financial burden away from utility charges and onto municipal budgets. This regulatory change has constrained municipal finances, making full implementation of the remaining plan more difficult and prompting the city to lobby national authorities for a revision of the cost-sharing split. (Metropolis, 2018, Danish Parliament, 2012, City of Copenhagen, 2014).

Outcomes & Practical Lessons

Utility tariffs are a strong repayment channel because they ride on existing billing infrastructure. As HOFOR already bills all water/wastewater customers, adding cloudburst-related costs to that tariff avoided the need to build new collection infrastructure from scratch. The 20-year Cloudburst Management Plan is actively underway with several hundred blue-green and grey infrastructure projects completed or in progress, directly protecting roughly 1,000,000 residents across Copenhagen and Frederiksberg. A key transferable lesson is that national legislative reform allowing water utilities to include funding for surface infrastructure was an essential precondition to make this value-based repayment model feasible. Without statutory authorization enabling HOFOR to leverage pre-existing water billing channels for surface infrastructure, funding would have been unavailable for 40% of the plan's costs and having to rely on municipal budgets alone for surface-level infrastructure projects. (Metropolis, 2018, Danish Parliament, 2012, City of Copenhagen, 2014).

4.2 Avoided-Cost Cash Flows: Sihl Entlastungsstollen (Sihl River Relief Tunnel)

The Sihl River Relief Tunnel project serves as a good example of an Avoided-cost Capture Mechanism operationalized through upfront beneficiary cost-sharing. This model captures economic value by quantifying and attributing the projected physical damages and operational disruptions prevented by the infrastructure. In this example, a coalition of public and quasi-public entities pooled their capital upfront in proportion to each partner's respective avoided loss exposure.

Parameter	Project Details
Pillar & Impact-Capture Mechanism	Avoided-Cast Capture Mechanism (Pillar 2) from Beneficiary Cost-Sharing
Location & Assets	Zurich, Switzerland – 2 km underground flood-diversion tunnel, discharging into Lake Zurich
Trigger	Near-catastrophic Sihl flood event.
Avoided Losses (Value Baseline)	Estimated potential flood damages of up to CHF 6.7 billion to Zurich's city centre and underground rail network.
Total Investment	Roughly 175 million CHF for tunnel construction and ecological compensation measures
Upfront Capital (Component 1)	Cantonal budget appropriation, co-financed by the City of Zurich, the Swiss Confederation, SBB, and SZU
Sources of Repayment (Component 2)	Beneficiary cost-sharing - each co-financing party contributes roughly in proportion to the avoided losses from the flood damage it would face.

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Key (legal) enabler	Cantonal Council budget appropriation
Key stakeholders	Canton of Zurich (AWEL), City of Zurich, Swiss Confederation (BAFU), SBB, SZU
Status	Under construction; tunnel breakthrough achieved in Q4 2024; planned operation from 2027

Project Overview

The Canton of Zurich initiated a broader, staged flood-protection programme along the Sihl, which includes a driftwood rake (operational since 2017, an enlarged riverbed near Zurich's mains station, and the Platzspitz weir renewal). The centrepiece is the Sihl Entlastungsstollen: a c. 2-kilometer-long, 6.6-meter-diameter underground relief tunnel constructed between Langnau am Albis and Thalwil designed to divert c. 300m^3/second - away from the Sihl valley and directly into Lake Zurich. (Kanton Zürich, n.d.-a)

The Context and Catalyst

In August 2005, Zurich experienced severe regional rainfall cantered outside the Sihl catchment area. Had the storm hit the Sihl valley, the river would have flooded 5km^2 of Zurich's urban core, including the subterranean national railway hub, to the depth of up to half a meter. This near-miss in a context of historical hazards: the Sihl has flooded the city multiple times, making flood risk a long-standing, recurring concern. Potential damages for the city of Zurich were estimated at up to 6.7 billion. (Kanton Zürich, n.d.-b, NZZ, 2024)

Stakeholders and Roles

The Sihl Entlastungsstollen illustrates an example where the project produces measurable verifiable savings from avoided risks and associated costs (3-Step Cash Flow Assessment: Q2A) and the upfront capital providers are the same entities as the ultimate beneficiaries. Hence, savings can be tied to specific entities that benefit from the avoided costs (3-Step Cash Flow Assessment: Q2B). As such, in this example, capital is supplied by the public and quasi-public asset owners (Federal, Cantonal, City-level governments as well as SBB and SZU as railway operators). All stakeholders, except for AFRY, are capital providers who absorb the construction cost, sharing the fiscal burden of the project in proportion to their individually avoided flood losses.

Stakeholders	Beneficiary of avoided flood losses?	Capital Provided?	Role
Canton of Zurich (Baudirektion / AWEL — Amt für Abfall, Wasser, Energie und Luft)	Yes	Yes, 100 million CHF net contribution (out of the 175 million CHF budget)	Project owner, main capital provider. Enabler / catalyst by securing cantonal parliamentary approval for the CHF 175 million budget. Utilizes its own budget to protect regional public infrastructure (Baublatt, 2021).
City of Zurich	Yes	Yes, contributing to the remaining 75 million CHF budget.	Municipal co-capital provider and municipal asset protector. Utilizes its own budget to project municipal assets and safeguard highly exposed city centre and its main station (Kanton Zürich, n.d.-b).
Swiss Confederation / Federal Office for the Environment (BAFU)	Yes	Yes, contributing to the remaining 75 million CHF budget.	Federal co-capital provider and represented at project milestones such as the tunnel breakthrough (Kanton Zürich, n.d.-a).

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SBB & SZU (Railway Operators)	Yes	Yes, contributing to the remaining 75 million CHF budget.	Quasi-public co-capital providers protecting high-exposure rail corridors (Baublatt, 2021).
AFRY	No	No	Engineering firm responsible for construction supervision of the preliminary works and the tunnel, including the intake and outlet structures (AFRY, n.d.).

Upfront Capital (Component 1)

The upfront capital for this asset is mobilized via a direct CHF 175 million cantonal budget appropriation. Rather than relying on a single authority, the Canton of Zurich secured capital contributions from the City of Zurich, the Swiss Confederation, SBB, and SZU, reducing the Canton's net contribution to roughly CHF 100 million (Baublatt, 2021; Zimmerberg Sihltal, 2022). The specific individual split of the remaining CHF 75 million is not publicly documented. The entire project is funded through direct, public and quasi-public capital providers, meaning that no private investors, bond issuances, or loan structures were utilized (BAFU, 2018). These public and quasi-public capital providers were willing to fund this project upfront from their own balance sheets because the total capital cost represents a minor fraction of the collective assets protected. Specifically, the CHF 175 million capital cost is less than 3% of the CHF 6.7 billion in potential physical damages that an extreme flood event would otherwise inflict on their concentrated urban and transit infrastructure. (Kanton Zürich, n.d.-b; Trachsel, 2022)

Repayment Mechanism (Component 2)

There is no separate, delayed repayment stage that is distinct from the initial financing phase. Because the capital contributions from the co-financing partners are paid upfront, as co-financing (Baublatt, 2021), the asset does not need to generate a continuous cash flow to service an external investor, e.g., through debt payments, commercial interest payments, or reimbursements to private investors over time.

Despite the absence of a traditional debt-servicing timeline, the underlying financial logic of the model remains a savings and avoided-cost allocation, as savings can be tied to a specific payer.

Outcomes & Practical Lessons

Construction reached a major milestone in Q4 2024 with the successful breakthrough of the two-kilometre underground tunnel, which is scheduled to become fully operational in 2027 (Kanton Zürich, n.d.-a). A key transferable lesson is that the concentration of risk on specific, high-value asset owners was an important precondition to make this cost-sharing model politically and administratively feasible. Without data-backed evidence showing that billions in potential damages would fall directly on a small, identifiable group of public and quasi-public entities, voluntary cost-sharing negotiations would be challenging.

4.3 Avoided-Cost Cash Flows: Camp de Tarragona Water Reuse Project

The Camp de Tarragona Water Reuse Project provides a good empirical model of an Avoided-Cost Capture Mechanism. It demonstrates how preventing of corporate operational disruption and costly factory shutdowns can be structured into a bankable business model. In this example, a co-financed corporate consortium of 30 petrochemical firms pooled private, balance-sheet capital through their jointly owned industrial water management company, Aguas Industriales de Tarragona S.A. (AITASA). By blending €19.5 million of private capital with €28 million in public and EU grants, they financed a €47.5

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million advanced water reclamation plant. Ongoing operations and private capital recovery are secured through structured, long-term industrial off-take tariffs paid by the corporates, ultimately shielding heavy industry from being affected by imposed drought-related water restrictions while releasing freshwater for municipal use. (Sanz et al., 2015, De Paoli & Mattheiss, 2016, ULTIMATE, 2024).

Parameter	Project Details
Pillar & Impact-Capture Mechanism	Avoided-Cost Capture Mechanism (Pillar 2) from Avoided-Cost Cash Flows for Corporates (with business model integrating Value-based Capture Mechanism (Pillar 1), from reclaimed Water Off-Take Tariffs)
Location & Assets	Vila-seca/Tarragona, Catalonia, Spain; 35,000 m³/day Advanced Water Reclamation Plant (Ultrafiltration and Reverse Osmosis), 14 km pressurized distribution grid
Trigger	Severe Ebro River drought restrictions, EU Water Framework Directive compliance, industrial expansion limits
Avoided Losses (Value Baseline)	Avoidance of complete chemical complex shutdowns during severe Ebro droughts; 12.8M m³/year surface water freed for municipal grid
Total Investment	Initial CAPEX: €47.5 Million
Upfront Capital (Component 1)	41% Private Corporate Balance-Sheet Capital (€19.5M via AITASA consortium), 59% Public Sector Grants (€28.0M via regional public water agency ACA / EU ERDF)
Sources of Repayment (Component 2)	Multi-tiered industrial off-take tariff (fixed amortization capacity charge + variable volumetric operational management charge) paid by industrial off-takers under multi-year water service agreements
Key (legal) enabler	Spanish Water Law (Real Decreto 1620/2007); ACA-AITASA Public-Private Framework Agreement
Key stakeholders	Agència Catalana de l'Aigua (ACA), AITASA, Dow Chemical, Repsol, BASF, Ercros, Veolia Water Technologies
Status	Fully operational; expanded to 35,000 m³/day; supplying >40% of chemical park water demand

Project Overview

The Camp de Tarragona Water Reuse Project is one of Europe's premier industrial circular economy infrastructure assets. Located within the Tarragona Petrochemical Park, which houses over 30 chemical and petroleum processing facilities, the project redirects secondary treated municipal wastewater away from Mediterranean sea outfalls and converts it into high-purity industrial process water.

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The core element of the system is a 35,000 m³/day Advanced Water Reclamation Plant (AWRP) utilizing ultrafiltration (UF) and double-pass reverse osmosis (RO) membrane arrays. Reclaimed water is delivered through a dedicated 14-kilometer pressurized industrial distribution grid directly to cooling towers and boiler feed loops operated by multinational industrial tenants. The system produces water with significantly lower mineral salinity and silica content than raw river water, optimizing industrial cooling efficiency while safeguarding regional freshwater balances. (Sanz et al., 2015, ULTIMATE, 2024).

The Context and Catalyst

The Tarragona industrial complex consumes high quantities of water for cooling and chemical synthesis. Historically, the park relied almost entirely on surface water transfers from the Ebro River managed by the Consorci d'Aigües de Tarragona (CAT), a consortium of 72 municipalities and 25 industries of the Tarragona province. However, recurring severe drought cycles in Southern Catalonia during the 2000s led to strict statutory limits on Ebro River abstractions.

Petrochemical operators faced severe water allocation cuts that threatened to force temporary plant closures, which constituted a high financial risk given that such interruptions in chemical plant operations can cost millions of Euros per day. Concurrently, regional tourism along the Costa Daurada expanded, intensifying municipal competition for potable water reserves. To secure long-term operational viability without increasing river abstractions, the private chemical operators united under their shared infrastructure company, AITASA, to co-finance a dedicated municipal wastewater recycling plant in partnership with the regional government.

Stakeholders and Roles

The project features a clear governance model linking a public regulatory agency with a private corporate consortium.

Stakeholders	Beneficiary of avoided losses?	Capital Provided?	Role
Agència Catalana de l'Aigua (ACA; public water agency of the Government of Catalonia)	Yes (Freed 12.8M m³/year of surface water for municipal use; achieved EU water quality compliance)	€28.0 Million (59% CAPEX share via regional funds and EU ERDF grants)	Regional water grantor, public regulator, baseline feedstock provider. (Sanz et al., 2015)
AITASA (Industrial Consortium)	Yes (Guaranteed continuous process water supply during severe regional droughts)	€19.5 Million (41% CAPEX share co-financed via private corporate equity balance sheets)	Private SPV representing chemical off-takers; lead corporate investor, asset co-owner, and utility intermediary. (Sanz et al., 2015)
Dow, Repsol, BASF, Ercros	Yes (Lowered boiler maintenance costs via high-purity water; eliminated production shutdown risks)	Co-financed AITASA equity outlays proportional to complex water allocations	Primary corporate off-takers; underwrote long-term take-or-pay off-take tariffs. (ULTIMATE, 2024)
Veolia Water Technologies	No	None	Turnkey EPC contractor and ongoing facility operational

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management operator. (ULTIMATE, 2024)

Upfront Capital (Component 1)

The initial capital cost of €47.5 Million was structured as a co-financed public-private investment. Public sector grant funding totalling €28.0 Million (59%) was secured by ACA, the public water agency of the Government of Catalonia, through European Union structural funds (ERDF). The remaining €19.5 Million (41%) was mobilized directly from the balance sheets of private industrial firms through the industrial consortium AITASA.

AITASA's corporate shareholders (including Dow, Repsol, BASF) provided direct balance-sheet equity contributions and corporate credit guarantees to fund construction debt. This co-financing structure proved highly cost-effective: public funds leveraged matching private corporate capital at a 1:0.7 ratio, while private firms acquired access to a €47.5M utility network by paying less than 50% of the upfront construction cost. (Sanz et al., 2015, De Paoli & Mattheiss, 2016, ULTIMATE, 2024).

Sources of Repayment (Component 2)

Capital recovery and ongoing operational funding are managed through an industrial off-take tariff mechanism administered by AITASA (Industrial Consortium). AITASA contracts directly with member chemical companies under multi-year industrial water service agreements. The tariff structure comprises two distinct tiers:

- *Fixed Capacity Charge:* A structured monthly fee assessed based on each plant's reserved volumetric capacity allocation. This component directly amortizes AITASA's €19.5 Million private capital expenditure and services ongoing debt.
- *Variable Volumetric Charge:* A per-cubic-meter charge tied to actual volume consumed, designed to cover raw secondary effluent acquisition fees paid to ACA, electricity costs, membrane replacement funds, and Veolia's operational management fees.

Because the reclaimed water features extremely low conductivity and silica concentrations, industrial off-takers achieve substantial internal balance-sheet savings by reducing chemical treatment additives and blowdown cycles in their boilers and cooling towers, offsetting the volumetric tariff cost. (Sanz et al., 2015, ULTIMATE, 2024).

Outcomes & Practical Lessons

The Camp de Tarragona project is widely cited as a benchmark for industrial water reuse in Europe. The plant successfully reclaimed over 50 million cubic meters of municipal wastewater during its first decade of operation, increasing total industrial water reuse in the chemical complex to over 40%.

The primary transferable lesson is that pooling private balance-sheet capital into a shared corporate intermediary entity (AITASA) enables fragmented industrial companies to collectively aggregate demand, share credit risks, and co-finance utility-scale infrastructure alongside public sector grant agencies. Importantly, clear enabling legislation (including the Spanish Real Decreto 1620/2007) was essential to define reclaimed water quality parameters and provide legal certainty for private balance-sheet investments. (Sanz et al., 2015, ULTIMATE, 2024).

4.4 Avoided-Cost Cash Flows: Intel Ocotillo Closed-Loop System

The Intel Ocotillo Closed-Loop System is global model of an Avoided-Cost Capture Mechanism. It focuses on a private industrial-scale water recycling complex funded primarily through direct corporate treasury allocations under a long-term municipal development agreement with the City of Chandler. Intel invested over $500 million in corporate capital alongside a 50/50 public-private cost-share for municipal

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interconnects to achieve a >94% process water recycling rate. The project mitigates extreme desert climate drought risks, regulatory allocation caps, and municipal peak tariff exposures, securing continuous multi-billion-dollar semiconductor manufacturing operations. (Intel Corporation, 2023, City of Chandler, 2022).

Parameter	Project Details
Pillar & Impact-Capture Mechanism	Avoided-Cost Mechanism (Pillar 2) from Avoided-Cost Cash Flows for Corporates
Location & Assets	Chandler, Arizona, USA; 12-acre on-site Water Reclamation Facility (9.4 million gallons per day capacity), 12-acre off-site Brine Reduction Facility, 10 million gallons per day Interconnect facility
Trigger	Severe drought in Colorado River basin, Arizona Assured Water Supply regulatory mandates, microchip fab expansion needs
Avoided Losses (Value Baseline)	Avoidance of $10M–$50M daily loss from fab shutdowns during water curtailments; >$12M annual avoided potable water tariffs
Total Investment	Direct cumulative water CAPEX >$500 million (embedded in >$32B overall capitalization of Intel's campus); Interconnect facility: $26 million
Upfront Capital (Component 1)	Corporate Treasury balance-sheet allocation (~90-95% total asset cost); 50/50 cost split ($13M Intel / $13M Chandler) for shared interconnect infrastructure
Sources of Repayment (Component 2)	Non-revenue generating; internal operational cost avoidance, peak-tariff mitigation, and continuous manufacturing risk reduction
Key (legal) enabler	Arizona Groundwater Management Act (1980); Intel-City of Chandler Master Development Agreements
Key stakeholders	Intel Corporation, City of Chandler Public Works, Sundt/McCarthy EPC Joint Venture
Status	Fully operational; ongoing capacity expansions aligned with the two Ocotillo campus facilities' commissioning schedules

Project Overview

The Intel Ocotillo Closed-Loop System represents one of the world's most technologically advanced industrial water reuse facilities. Situated within the high-technology corridor in Chandler, Arizona, the system comprises an array of dedicated treatment assets designed to isolate, treat, and recycle semiconductor manufacturing effluents.

The primary asset is the 12-acre on-site Ocotillo Water Reclamation Facility (OWRF), capable of processing up to 9.4 million gallons per day of industrial rinse water using membrane bioreactors, reverse osmosis arrays, and ultraviolet disinfection. Complementing the on-site plant is the off-site Ocotillo Brine Reduction Facility (OBRF), a specialized public-private facility built in partnership with the City of Chandler to process 1.5 to 2.8 million gallons per day of heavy industrial brine and high Total Suspended Solids (TSS) wastewater. The integrated network incorporates a 10 million gallons per day interconnect system and groundwater injection facilities, enabling Intel to recycle over 94% of its industrial process water internally while recharging residual treated streams into local aquifers. (Intel Corporation, 2023, WCDA, 2020).

The Context and Catalyst

The Ocotillo campus operates within the Sonoran Desert, a region subject to persistent hydrological drought and severe long-term reductions in Colorado River surface water allocations. Under the Arizona

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Groundwater Management Act, industrial facility expansions are legally contingent upon demonstrating an "Assured Water Supply" that does not deplete regional groundwater reserves.

As Intel initiated multi-billion-dollar investments to build advanced semiconductor fabrication facilities, its potential daily water demand expanded exponentially. Relying purely on municipal potable water supplies posed high risks: municipal tariffs were escalating, and regional drought triggers threatened mandatory industrial supply cuts that could instantly halt production lines. The financial catalyst was therefore a clear case, as the capital cost of building internal recycling infrastructure was far lower than the high revenue losses associated with drought-induced plant downtime. (Intel Corporation, 2023, YourValley News, 2022).

Stakeholders and Roles

The governance structure is founded on direct corporate execution backed by binding legal agreements with local municipal authorities.

Stakeholders	Beneficiary of avoided losses?	Capital Provided?	Role
Intel Corporation	Yes	Direct equity capital outlay exceeding $500 Million via Corporate Treasury; $13M for interconnects	Lead investor, asset owner of the Water Reclamation Facility, industrial off-taker, and primary balance-sheet guarantor. (Intel Corporation, 2023)
City of Chandler	Yes	$13 Million (50% share of interconnect CAPEX via municipal utility capital funds)	Municipal regulatory authority, co-developer of the Brine Reduction Facility, provider of municipal reclaimed cooling water. City of Chandler, 2022)
Sundt / McCarthy EPC JV	No	None	Construction Manager at Risk (CMAR) and turnkey engineering contractor. (WCDA, 2020)

Upfront Capital (Component 1)

Capital mobilization for the closed-loop system departed entirely from traditional public infrastructure financing. Intel deployed direct corporate treasury balance-sheet allocations, categorizing water reclamation investments as essential capital items within its multi-billion-dollar plant construction budgets. For shared public-private assets, such as the $26 million Reclaimed Water Interconnect Facility, Intel signed a cost-share agreement with the City of Chandler, providing $13 million in capital upfront while Chandler financed its $13 million portion through municipal water revenue bonds serviced by utility user fees.

The financial structure yielded a highly effective cost-to-protected-value ratio: a $500 million cumulative water infrastructure outlay protected over $32 billion in high-technology manufacturing assets and sustained annual chip production revenues exceeding tens of billions of dollars. (Intel Corporation, 2023, City of Chandler, 2022).

Sources of Repayment (Component 2)

Because the closed-loop system is an internal corporate utility, it does not rely on public tariffs, debt amortization, or secondary market sales for capital recovery. Repayment is realized entirely through internal cost avoidance and balance-sheet risk reduction.

By recycling 9.4 millions of gallons per day of water internally, Intel avoids purchasing equivalent volumes of expensive municipal potable water, creating a direct operational expenditure savings of over $12 million per year. Furthermore, by converting industrial effluent into high-quality reclaimed water and

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delivering residual flows to municipal aquifers via Chandler's recharge basins, Intel earns long-term groundwater credit offsets under Arizona state water law. These credits satisfy statutory Assured Water Supply mandates, enabling Intel to legally expand its fab footprint without paying financial penalties or purchasing senior surface water rights at speculative market rates. (Intel Corporation, 2023, City of Chandler, 2022, YourValley News, 2022).

Outcomes & Practical Lessons

The Intel Ocotillo Closed-Loop System demonstrates that large industrial water consumers can successfully internalize capital costs to secure absolute operational resilience in water-scarce environments. Key transferable lessons include the importance of structuring flexible municipal development agreements that permit private corporations to build and operate dedicated infrastructure adjacent to public networks. Furthermore, the model proves that corporate balance-sheet funding can deliver large public externalities: Intel's internal recycling reduced overall municipal freshwater withdrawals, stabilizing regional water tables to the benefit of the broader municipal community. (Intel Corporation, 2023, City of Chandler, 2022).

4.5 Regulatory-based Cash Flows: Hamburg's Stormwater Fee (Niederschlagswassergebühr)

Hamburg's Stormwater Fee (Niederschlagswassergebühr) case study shows how a city can fund flood-protection upgrades through a Regulatory-based Capture Mechanism. Developed under the Rain Infrastructure Adaptation (RISA) initiative (2009-2015) to combat severe pluvial flooding, under rapid urban growth, which drives annual surface sealing, the municipal utility in Hamburg implemented a targeted, area-based stormwater user fee (Hamburg Wasser, n.d.-b, Bertram et. al., 2017). Thereby, Hamburg takes a "stick and carrot" approach in its policy design: property owners are charged a fee based on their property's paved area (the stick) but can avoid the fee by installing green roofs or rain gardens with the help of municipal grants (the carrot) (INTERLACE Hub, n.d., IFB Hamburg Wasser, n.d.-a, BUKEA, n.d., Bertram et. al., 2017). This dual approach internalizes negative environmental externalities, allowing the city to finance climate-resilient sewer network upgrades (Bertram et al., 2017).

Parameter	Project Details
Pillar & Impact-Capture Mechanism	Regulatory-Based Capture Mechanism (Pillar 3) from Impervious Surface Fee
Location & Assets	Hamburg, Germany; citywide sewer and drainage network integrated in the localized "Schwammstadt" (sponge city) infrastructure (BUKEA, n.d., Bertram et al., 2017).
Trigger	Need for fair, usage-based cost allocation for stormwater management, and a funding base for Hamburg's flood protection and control under conditions of urban densification (INTERLACE, n.d., BUKEA, n.d., Bertram et al., 2017).
Internalized Negative Impact (Value Baseline)	Local limitations with regards to infiltration, evaporation and drainage caused by citywide soil sealing; internalized by pricing stormwater runoff at €0.83 per m^2 of impervious area per year (Hamburg Wasser, n.d.-b., Bertram et al., 2017).
Total Investment	Continuous capitalization: c. €60 million/year invested in sewage network renewal paired with municipal subsidies for infiltration systems, rainwater cisterns and green roofs (INTERLACE, n.d., Hamburg Wasser, n.d.-a., Bertram et al., 2017).
Upfront Capital (Component 1)	Funded continuously out of Hamburg Wasser's ongoing utility revenue (investing c. € 60 million annually in sewage network renewal). In addition, public grants administered by IFB Hamburg cover 30% to 50% of construction costs for localized water infiltration systems. (Hamburg Wasser, n.d.-a, Bertram et al., 2017)

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Sources of Repayment (Component 2)	Regulatory levy channel: Legally mandated impervious Surface Fee of €0.83 per m^2 of sealed or built-over property area draining into the public sewer network per year, billed alongside standard utility invoices (BUKEA, n.d., Bertram et al., 2017).
Key (legal) enabler	German Municipal Water Laws (enforcing the polluter-pays principle), Hamburg's Sielabgabengesetz (Hamburg Wasser, n.d.-c., Bertram et al., 2017)
Key stakeholders	Hamburg Wasser, BUKEA, IFB Hamburg, Property Owners
Status	Fully operational since 2012. Current rate of €0.83/m² per year as of January 2025, paired with RISA grant funding since 2023 (Hamburg Wasser, n.d.-a.; IFB Hamburg, n.d.; Bertram et al., 2017).

Project Overview

Hamburg is actively transitioning into a "Schwammstadt" (sponge city) in order to capture, store, and evaporate rainwater locally, replicating the natural water cycle (BUKEA, n.d., Bertram et al., 2017). The financing of the project is based on a decentralized, area-based charging model administered by the municipal utility, Hamburg Wasser (Bertram et al., 2017). Rather than charging a flat rate, the city bills property owners based on the square footage of impervious (sealed, non-porous) surfaces on their land that drain into the public sewers (Hamburg Wasser, n.d.-b; Bertram et al., 2017). By pricing the physical driver of urban flooding, Hamburg can fund public network upgrades while actively encouraging private landowners to unseal their soils (INTERLACE Hub, n.d.).

The Context and Catalyst

Urban densification poses a challenge to Hamburg's city wastewater management practises, as this comes with an increase in surface sealing of 0.36% per year (Bertram et al, 2017). Asphalt roads, conventional rooftops or paving prevent rainwater from naturally soaking into the ground, causing runoff into urban sewers, which can lead to pluvial flooding with increasing extreme downpour events (BUKEA, n.d., Hamburg Wasser, n.d.-a.).

Before 2012, Hamburg charged a single, combined wastewater fee calculated purely on a property's fresh drinking water consumption (INTERLACE Hub, n.d.). This legacy method did not distinguish between sewage and stormwater, so cost allocation was structurally decoupled from the actual volume of runoff a given property generated. A heavily paved commercial parking lot with minimal water use, for example, paid almost nothing toward stormwater management despite generating substantial peak runoff that overwhelmed municipal sewers (Hamburg Wasser, n.d.c.).

Separating the stormwater component into its own impervious-area-based fee allows to price the primary physical driver of pluvial flood risk: sealed surfaces. This mirrors a wider German pattern, in which municipal water laws mandate decoupling stormwater charges to enforce the polluter-pays principle (Verursacherprinzip) in urban water management - making Hamburg's model part of an established, low-friction, and highly replicable regulatory practice. (INTERLACE Hub, n.d.)

Stakeholders and Roles

The Hamburg Stormwater Fee is structured around a highly coordinated public-utility and regulatory framework, aligning municipal environmental targets with private property owner incentives (INTERLACE Hub, n.d.; BUKEA, n.d.; Bertram et al.,2017).

Stakeholders	Financial Role	Role
Hamburg Wasser (Municipal Utility)	Fee Collector & Utility Operator	Primary administrative agent. Bills and collects the Niederschlagswassergebühr. It maintains and updates the citywide geographical information system (GIS) impervious surface register (Viersegelungskataster), and processes fee-

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		reduction requests when property owners implement on-site infiltration systems (Hamburg Wasser, n.d.-a-c; Bertram et al.2017)
BUKEA (Environmental Authority)	Policy Maker & Regulatory Enabler	Sets Hamburg's overarching climate adaptation policy, coordinates the RISA programme, and administers municipal sponge city guidelines to guide long-term urban planning (BUKEA, n.d.).
IFB Hamburg (Promotional Bank)	Grant Administrator	Administers the city's non-repayable RISA promotional grants and distributes capital subsidies for on-site decentralised rainwater management such as infiltration systems, rain water cisterns, and green roofs (IFB Hamburg, n.d.).
Property Owners	Fee Payers & Micro-Investors	Direct Beneficiaries / Risk-Creators. Pay the annual stormwater fee based on their property's sealed footprint with the choice to invest in on-site retention measures, leveraging municipal grants to reduce or completely eliminate their annual fee liability (INTERLACE Hub, n.d., IFB Hamburg, n.d., Hamburg Wasser, n.d.-a.).

Upfront Capital (Component 1)

Hamburg Wasser invests approximately €60 million annually in sewage network renewals (Bertram et al., 2017). This capital expenditure is funded continuously out of Hamburg Wasser's ongoing utility revenue, underpinned by the recurring Niederschlagswassergebühr (Bertram et al., 2017). Stormwater management accounts for 29.3% of the utility's roughly €263 million annual wastewater management budget, with the remaining share covering sewage drainage treatment (Bertram et al., 2017; INTERLACE Hub, n.d.).

To accelerate adaptation by private actors, the city pairs the mandatory fee with non-repayable, upfront capital grants administered through IFB Hamburg. These cover 30-50% of construction costs (up to €25,000) for localized water infiltration systems and up to 40% (max €1,500) for rainwater harvesting cisterns (IFB Hamburg, n.d., BUKEA, n.d.).

Sources of Repayment (Component 2)

The core regulatory-based capture mechanism is the Niederschlagswassergebühr itself: a legally mandated annual fee of €0.83 per square metre of sealed area connected to the sewer (BUKEA, n.d.). This is a classic Negative Impact Internationalization (Pillar 3) structure - it forces property owners to internalize the public costs of the stormwater runoff they generate.

The fee is calculated with high precision using a citywide, GIS-based impervious-surface register (Versieglungskataster), which maps the sealed surface of every parcel in Hamburg (INTERLACE Hub, n.d.; Bertram et al., 2017). The framework operates as a transparent price signal - a classic carrot-and-stick model. The stick represents the full annual fee that a property owner whose site is sealed and drains directly into the public sewer is required to pay. The carrot represents the option to fully eliminate the fee liability by disconnecting sealed surfaces from the sewer network - for example, by installing cisterns or green roofs (Hamburg Wasser, n.d.-a).

By answering "yes" to the Cash Flow Identification tool's Q3A and Q3B tests - is there an identifiable party whose activities worsen the risk, and are there existing regulatory tools to charge them? - Hamburg turns a regulatory compliance mechanism into a stable, continuous, and legally protected stream of municipal revenue.

Outcomes & Practical Lessons

Hamburg's stormwater fee functions as a continuous regulatory-based fee that covers rolling capital improvements and operations (Bertram et al., 2017). Thereby, the mandatory fee creates the permanent, recurring incentive (the "stick"), while non-repayable grants lower the upfront capital hurdle

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that would otherwise keep disconnection out of reach for many property owners (the “carrot”) (INTERLACE Hub, n.d., IFB Hamburg, n.d.-a., BUKEA, n.d., Bertram et. al., 2017).

The model also relies on the citywide, parcel-level GIS database (Hamburg Wasser, n.d.-b., Bertram et. al., 2017). An area-based stormwater fee is only administratively feasible with this kind of a register. Without the Versiegelungskataster to verify the amount of area that is impermeable, the presence of green/conventional roofs, and whether drainage is connected to the sewage network, billing costs and disputes would likely make the system unworkable (Bertram et. al., 2017). Finally, because the fee builds on Hamburg Wasser’s existing utility billing infrastructure, no new collection system had to be introduced. Hence, this is an example of a regulatory evolution, which proves helpful in terms of public acceptance (INTERLACE Hub, n.d.).

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5 Conclusion

This report demonstrates that there are opportunities to finance the climate adaptation and resilience interventions of cities using various innovative value-capture and cost-sharing instruments. The Impact to Finance Framework (I2FF) empowers municipal leaders to systematically monetize positive impacts, capture avoided negative impacts and internalize negative environmental externalities.

Crucially, to maximize sustainable revenue streams, project planners should systematically source cash flows across two key phases of an asset's lifecycle: mobilizing upfront capital (Component 1) for the construction phase and securing long-term repayment streams over the project's operational life (Component 2).

To support this effort, municipal leaders must identify viable impact-capture mechanisms that can be operationalized into non-repayable upfront capital contributions, which de-risk initial investments, and/or long-term recurring cash flows, used to service green bonds or commercial loans. The cash flows originate from local revenues based on value provided, cost avoided or regulatory approaches for negative impact internalization. Thereby, upfront cash flows for Component 1 are generated before/during construction (e.g., upfront developer impact fees, land sale proceeds, or upfront beneficiary cost-sharing). Recurring cash flows for Component 2, used to repay debt or equity, are generated over time during operations (e.g., utility tariffs, TIF increments, or annual stormwater fees).

As individual mechanisms rarely cover total project expenditures, multiple impact-capture mechanisms will likely need to be systematically "stacked" across a project's lifecycle to maximize its overall financial viability. However, even when cash flow stacking is optimized as much as possible, these innovative approaches may leave funding gaps resulting from the limited commercial capital capacity of the adaptation projects. Combining adaptation measures with revenue-generating climate change mitigation interventions offers significant potential to bridge these residual gaps.

Cities face many barriers to accessing public and private capital for adaptation. Ultimately, no single financing approach is universally superior, as a municipality's unique institutional capacity, regulatory environment, and local constraints determine which mechanisms are viable in each project context. As such, a key challenge is to navigate and establish the necessary local prerequisites – whether that is a legislative unlock to leverage utility tariffs (Copenhagen), a coordinated multi-owner budgetary process for shared risks (Zurich), a digital GIS-based parcel register to bill negative externalities (Hamburg), a structured corporate off-take framework (Intel Ocotillo), or a mature insurance-linked capital market.

Consequently, climate adaptation finance remains a critical, rapidly evolving field. Municipalities will require deep, ongoing technical, advisory, and capacity-building support to successfully navigate, structure, and implement these complex frameworks.

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