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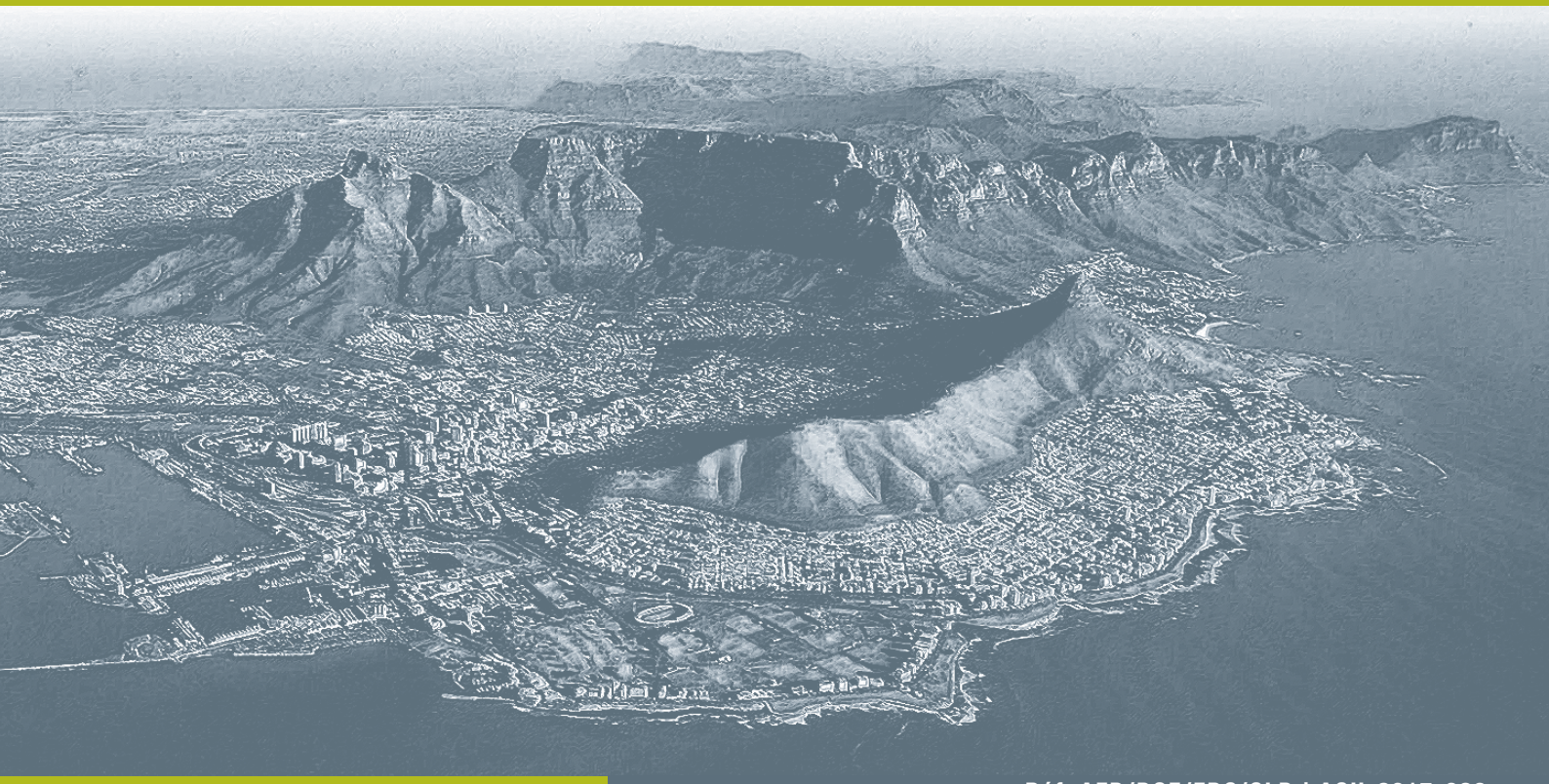
09
2019

City of Cape Town:
Climate Change Hazard, Vulnerability and Risk Assessment

CLIMATE RESILIENCE INVESTMENT MANUAL



Réf. AFD/DOE/EBC/CLD I ACH-2017-026

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PROJECT BACKGROUND

This report is submitted under the French Development Agency (AFD) project: City of Cape Town: Climate Change Hazard, Vulnerability and Risk Assessment. The project falls under the CICLIA Framework Agreement for Studies and Technical Assistance for the Cities and Climate Change Initiative in Sub-Saharan Africa, funded by the French Development Agency (AFD), EU and the Swiss State Secretariat for Economic Affairs (SECO). This report is submitted on the back of the outcomes of Phases 1, 2 and 3, in accordance with the requirements of the Contract for Réf. AFD/DOE/EBC/CLD | ACH-2017-026. As such, this report constitutes Deliverable 4 under this contract and includes: i) an introduction to the manual; ii) a discussion on the framework for climate resilience investment planning; iii) a detailed breakdown of the proposed climate resilience investment programmes; and iv) an outline of proposed financing and implementation arrangements.

ACKNOWLEDGEMENTS

We would like to thank all representatives of the City of Cape Town who participated in the various workshops and focus group discussions and those that provided data and other inputs into the analysis.

Thank you to our leading experts and OneWorld Team who delivered the objectives of this Investment Manual: Belynda Petrie, Jonty Rawlins and Struan Monteith.

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ABBREVIATIONS AND ACRONYMS

AE	Accredited Entity
AFD	French Development Agency
BEPP	Built Environment Performance Plan
CCT	City of Cape Town
CSR	Corporate Social Responsibility
CRISC	Climate Resilience Investment Steering Committee
DEA	Department of Environmental Affairs
DGAs	Discouraged Growth Areas
DRR	Disaster Risk Reduction
ECAMP	Economic Areas Management Programme
EGS	Economic Growth Strategy
EMDE	Emerging Market and Developing Economies
EWS	Early Warning System
FDI	Foreign Direct Investment
GCF	Green Climate Fund
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
IUDF	Integrated Urban Development Framework
LDC	Least Developed Countries
M&E	Monitoring and Evaluation
MSDF	Municipal Spatial Development Framework
NDP	National Development Plan
ODA	Official Development Assistance
OECD DAC	Development Assistance Committee of the Organisation for Economic Co-operation and Development
PPP	Public Private Partnership
PSC	Programme Steering Committee
PSDF	Provincial Spatial Development Framework
R&V	Risk and Vulnerability
RfP	Requests for Proposals
SDGs	Sustainable Development Goals
SDS	Social Development Strategy
SIDS	Small Island Developing States
STA	Spatial Transformation Area
TOD	Transit Oriented Development Framework
ZAR	South African Rand

DEPARTMENT ABBREVIATIONS

BD	Budget Department
CHD	City Health Department
CM	City Manager
DMD	Development Management Department
DRMC	Disaster Risk Management Centre
EI	Enterprise and Investment Department
EGDD	Electricity Generation and Distribution Department
EMD	Environmental Management Department
MO	Media Office
OEM	Office of the Executive Mayor
PECC	Public Emergency Communication Centre
PMD	Property Management Department
RD	Revenue Department
RPD	Recreation and Parks Department
SDECDD	Social Development and Early Childhood Development
SEMD	Sustainable Energy Markets Department
SWM	Solid Waste Management
TranspD	Transport Department
TreasD	Treasury Department
UID	Urban Integration Department
WSD	Water and Sanitation Department

A.

Introduction

The rationale for the City of Cape Town (CCT) investing in climate resilience is clearly established. The CCT and Cape Town as a whole, is facing significant direct and indirect, interrelated risks from climate change. Current and future threats facing Cape Town necessitate that investments in securing the City's – and society's – assets and resources are aligned with the economic aspirations for growth and jobs. These priorities can only be realized if development is transformed to confront climate change and then sustained across Cape Town and in its environs.

Cape Town thus requires an integrated approach to build climate resilience through enhancing adaptive capacities and strategically investing in maintaining and improving social, economic and environmental capital. The primary purpose of this Climate Resilience Investment Manual (manual) is to guide the CCT and its investors in how to strengthen resilience to climate change across the system.

The City of Cape Town, in its draft Resilience Strategy for Cape Town, defines resilience as "the capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt and thrive no matter what kind of chronic stresses and acute shocks they experience".

CCT, 2018

Climate resilience is the capacity for socio-ecological systems to: i) absorb stresses and maintain functionality in the face of external stresses imposed upon it by climate change; and ii) adapt, reorganize, and/or evolve into more desirable configurations that improve the sustainability and performance of the system, leaving it better prepared for future climate change impacts.

FOLKE 2006; NELSON ET AL. 2007

The unique combination of integrated climate risks and developmental challenges facing the City of Cape Town necessitates the identification and assessment of a suite of adaptation responses across spatial and temporal scales that maximise the benefits, minimise costs and mitigate maladaptation potential. All while aligning with existing and emerging policy pathways and developmental trends. **Harmonised investments are essential to ensure sustainability and successes that can be replicated, yielding both public goods and financial and economic returns.**

This Manual, intended as the 'go-to' investment guideline for adapting to climate change and building a climate resilient society (see Box 1), is directly built off the stakeholder validated, detailed Climate Change Hazard, Risk and Vulnerability Assessment and Economic Risk Analysis of Climate Change. Similarly, the investment options have been informed by CCT stakeholder recommendations and priorities. In this way stakeholder inputs and preferences have been iteratively integrated throughout the development of the proposed investment programmes.

Four climate resilience investment programmes emerged from this analysis relating to the key themes of:

1. Municipal Governance;
2. Sustainable Urbanisation;
3. High Value Ecosystems; and
4. Risk Reduction

Together these four programmes aim to achieve four strategic goals, which guide the identification of priority investments and projects according to returns and risk:

- Reduce the likelihood of resource crises in Cape Town through inclusive participation in planning and decision-making processes, and in the benefits arising from enhanced ecosystem health;
- Build commitments to responding to climate change across all levels of governance of the City's systems;
- Promote equitable access to Cape Town's key resources, particularly land and water, through benefit sharing and related trade-offs at all levels of governance; and
- Promote inclusive and green growth and resilient livelihoods by stimulating inclusive participation in a climate resilient society.

BOX 1. What is a climate resilient society?

There are many different understandings of what constitutes a "climate resilient society," but most stem from the notion that a community can enhance its ability to anticipate and reduce risk to climate variability and change. This includes the ability to "bounce back" from the negative impacts, or to "bounce forward," transforming a challenge into an opportunity. The notion includes a focus on reducing inequality and increasing social and other capitals. The definition of a climate resilient society applied in this Manual is one used by South Africa's Department of Environmental Affairs (DEA):

"A society that identifies existing and potential interacting vulnerabilities across social, economic, political, physical and environmental systems, continuously acts to reduce vulnerabilities and create opportunities, and responds to unavoidable impacts quickly and flexibly through inclusive decision making."

DEA, 2014, P.3

A.1 Structure and Overview of the Investment Manual

The Manual is structured to **inform and enable** investment planning and resource mobilization. Section B presents the Investment Planning Framework, comprising sections on climate change risks to the City, an overview of the analysis of investment priorities, strategic pathways for investment and identification of priority areas (locations) for action. Section C presents the four Resilience Investment Programmes: municipal governance, sustainable urbanisation, high value ecosystems and risk reduction. The final section (Section D) presents issues related to **accessing predictable finance** in a brief financing strategy and outlines an implementation strategy, or the key conditions for successful delivery.

B.

The Framework for Climate Resilience Investment Planning

This section presents the climate change risks to Cape Town, then outlines the process of identifying and analysing adaptation options and how these translate into possible adaptation pathways and investment programmes. The last sub-section presents the priority suburbs or planning districts for action resulting from the analysis.

B.1 Climate Change Risks to the City of Cape Town

Cape Town is expected to experience a drier and significantly warmer future. Changes in these first order climate parameters have widespread impacts throughout biophysical, social and economic systems in and around the City. The key climate-related hazards that pose the greatest risk to Cape Town as a result of climate change are:

1. Drought
2. Fire
3. Heatwaves
4. Floods
5. Strong Winds

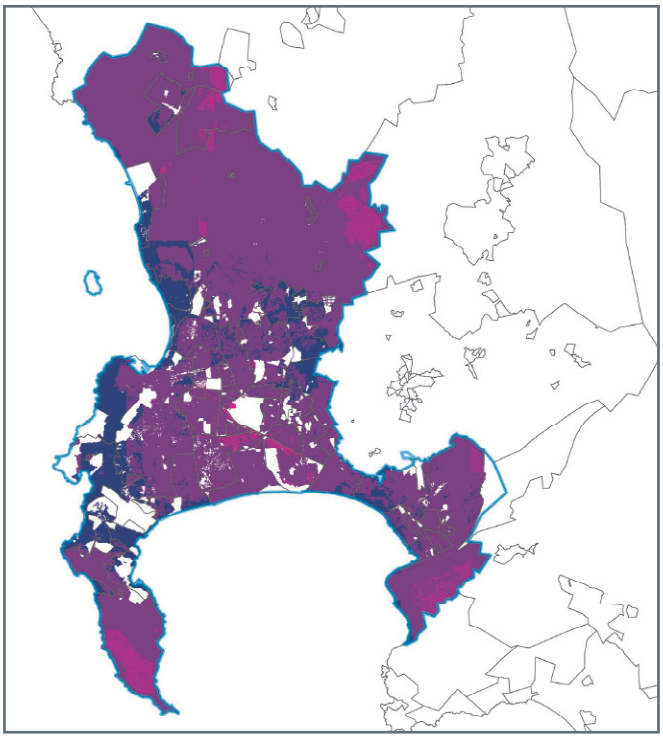
The Western Cape Water Supply System is highly exposed to drought, which poses direct risks to the economy of Cape Town, the natural environment and livelihoods and well-being of residents. The indirect impacts of drought are also far reaching and pose risks both within and beyond the City boundaries. Increased frequency and intensity of fires pose significant threats to human life and mental health, livelihoods and both low- and high-value properties, as well as important nature conservation areas. More intense and frequent heatwaves threaten human and animal life, productivity and health. Low levels of structural resilience, high population densities and high levels of informality increase the risks associated with flooding and strong wind events.

Figure 1 presents climate change risk hotspot maps for the City of Cape Town for the current, mid-future (2021-2050) and far-future (2070-2099) time periods. Over time, as the City becomes more exposed to the impacts of climate change, key risk hotspots emerge along the periphery of the municipal boundary, most notably in the northern regions. Whereas, the least vulnerable areas are seen in the southern peninsula, southern coast, Table Mountain Area and up the west coast. Areas most at risk within the City are those that have limited access to services and financial resources to buffer the impacts of shocks and respond to incremental challenges of long-term stressors. A detailed spatial analysis of climate change risks and vulnerabilities in the City of Cape Town is presented in the **Vulnerability and Hazard Assessment Report**, Deliverable 2 to this project.

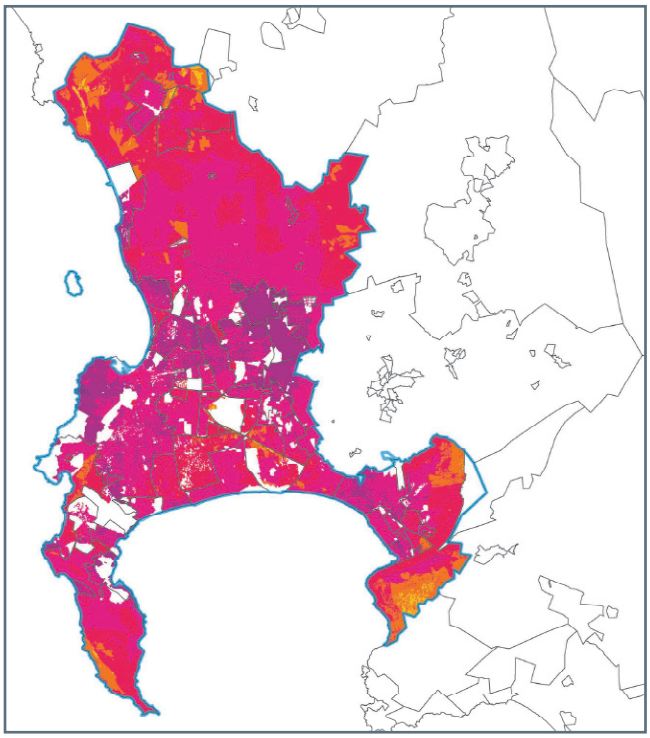
> *Risk is defined as the potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.*
>
> IPCC, 2018

An analysis of the economic risks associated with climate change highlights the need for **integrated and cross-cutting investment in both areas of high and low economic capital in Cape Town** (discussed further below). Economic capital is determined by leading indicators as a function of financial, intellectual, environmental, manufactured, human and social capital. A detailed economic risk analysis for climate change in the City of Cape Town is presented in the **Economic Risk Analysis**, Deliverable 3 carried out under this project.

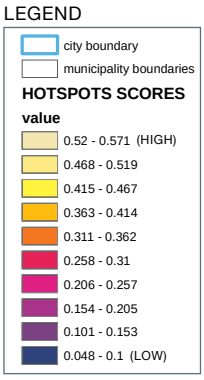
FIGURE 1: Risk Hotspots for the City of Cape Town (Current, Mid- and Far-Future)

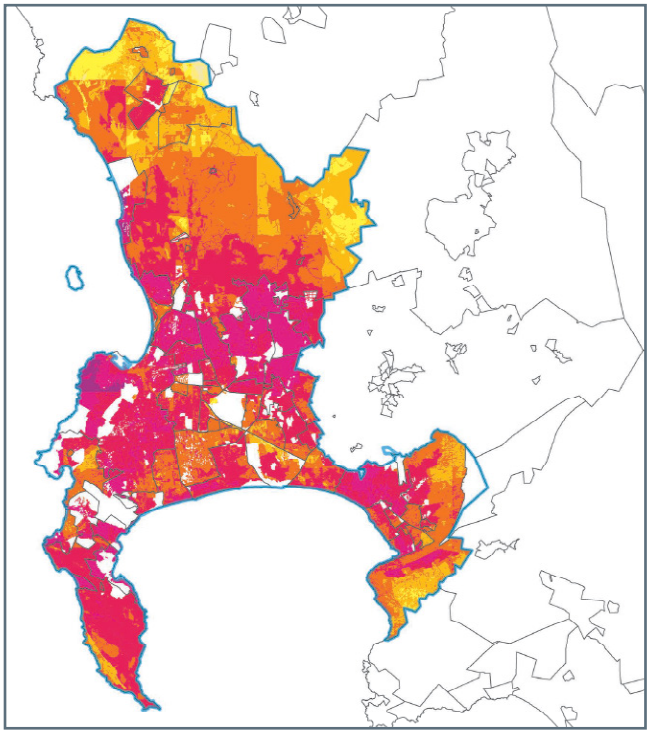


Time period: Current conditions



Time period: Mid future – 2021–2050





Time period: Far future – 2070–2099

B.2 Investment Priority Analysis

A structured analysis of adaptation options was undertaken to identify and iteratively prioritise key adaptation options. This involved a combination of participatory stakeholder analysis and expert assessment of the primary social, economic and environmental risks facing the City of Cape Town. Both incremental and transformational adaptation options are considered in an integrated manner to develop pathways for climate resilience that will maximise the benefits (including co-benefits) and minimise the costs of investing in climate change adaptation.

This section outlines the typology of adaptation options and conceptual framework used to classify and conceptually frame the analysis and the options assessment matrix, and describes the associated processes. Lastly, it presents the process of translating the technical adaptation options into integrated, high-impact pathways.

B.2.1 Typology of Adaptation Options

Figure 2 presents a typology of adaptation options and conceptual framework for building pathways to climate resilience and inclusive growth through these actions.

Adaptation in human systems is defined as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. Incremental adaptation maintains the essence and integrity of a system or process at a given scale, while transformational adaptation changes the fundamental attributes of a socioecological system in anticipation of climate change and its impacts.

IPCC, 2018

An inclusive economy and society is characterised by equitable participation in growth across the formal and informal sectors - in decision making in growth processes, and in the benefit of the growth itself. Participation of vulnerable population groups in growth processes is via non-discriminatory employment, while participation in the benefits manifests in income improvement and in increased social expenditure benefits that reduce disadvantages, such as education and human capacity development.

RAMOS ET AL. 2013; FOURIE, 2014

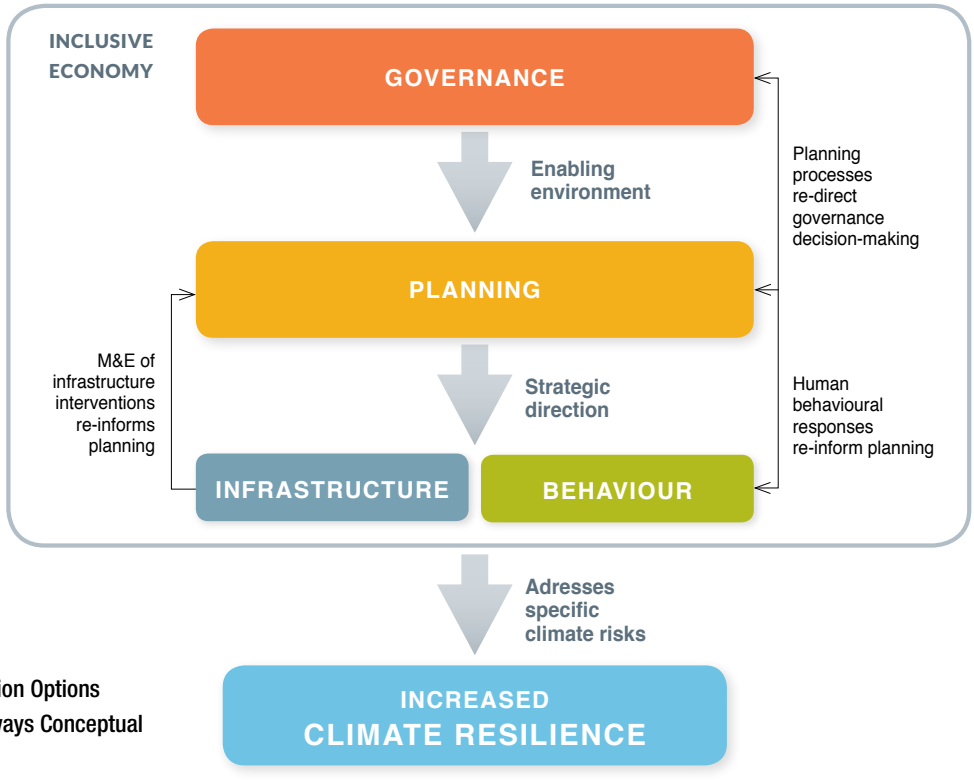


FIGURE 2: Adaptation Options Typology and Pathways Conceptual Framework

Adaptation options are broken down into four broad categories:

- **Governance:** Investments for and commitments to using and/or adapting leadership, policy, regulations, laws and strategies, and institutional arrangements for climate mainstreaming and enhancing the enabling environment for climate resilient development.
- **Planning:** Investments in climate adaptive and transformational planning, strategy development and incentives that are jointly conducted and integrated across relevant sectors and departments to provide strategic direction for climate resilient infrastructure development and behavior change.
- **Infrastructure:** Investments in a suite of integrated infrastructure development and maintenance actions, balancing green and grey infrastructure, with Nature Based Solutions that limit the incidence of stranded economic assets and reduce or eradicate the impact of extreme climate events.
- **Behaviour:** Investments in changing behavior for climate adaptive decision making, planning and management by all stakeholders and social partners (government, labour, industry and civil society) through education, mobilization and sensitization toward the realisation of a social contract for climate resilience.

A social contract is an implicit agreement or compact between the members of a society, or the people of a state and the government of a state, to cooperate for collective social benefits. Philosophers from the 16th, 17th and 18th centuries, such as Jean-Jacques Rousseau and John Locke, saw good governance originating from social contracts. Critical to building climate resilience, is that a social contract defines and limits the rights and obligations of its parties, paving the way for the individual sacrifices potentially required to enable inclusive social benefits.

The social, political, environmental and economic systems that contribute towards building resilience in a city are highly interlinked, and Cape Town has a complex socio-economic context. In this context, the assessment of adaptation options is conceptually framed to achieve the critical, broader objective of an inclusive economy and society. Figure 2 illustrates the logic of how these different types of adaptation options contribute towards building climate resilience in this context. Governance creates the enabling environment for effective planning processes that provide the strategic direction for infrastructure development and behaviour related adaptation actions. Logical feedbacks exist between these aspects, as monitoring and evaluation (M&E) of infrastructure development activities and changes in human and institutional behaviour re-inform planning. Moreover, the evolution in planning processes re-informs governance decision-making. Ultimately, these combined interactions of various adaptation actions contribute towards an inclusive economy and society that is thus enabled to respond to specific, and cumulative climate change risks.

To promote climate resilience, an inclusive economy and society necessitates a sustainable long-term outlook among all the social partners. This is an important characteristic of the pathways for resilience in this investment manual.

B.2.2 Translating Options into Pathways

A structured matrix of adaptation options (see Appendix 1) was iteratively developed, assessed and ranked in terms of benefits (including co-benefits), costs and maladaptation potential. The selection and prioritisation of key adaptation options were aligned with relevant existing policies and strategies such as the City of Cape Town's Resilience Strategy, Water Strategy, Municipal Spatial Development Framework and the draft Green Infrastructure Plan. In this way, prioritised adaptation options were identified that complement the proposed activities and overarching approaches presented in these documents. Four primary adaptation programmes, or pathways emerged from this analysis:

1. Municipal Governance
2. Sustainable Urbanisation
3. High Value Ecosystems
4. Risk Reduction

B.3 Investing in Climate Resilience: Strategic Pathways

An integrated and programmatic investment approach is critical and necessary to enable both incremental and transformative climate change adaptation in Cape Town. As is the case with most Government institutions, CCT operates or functions in relative siloes, a difficult but necessary mould to break out of when encountered with the cross-cutting impacts of climate change. This strategy seeks to balance resilience and adaptive capacity building investments with capital investments, short-term with medium- and long-term investments, and household with community, city-wide and regional investments. Importantly, this is done in a way that reflects cross-sectoral objectives, with a strong focus applied to managing trade-offs of taking a developmental approach towards addressing South Africa's triple challenges

of poverty, inequality and unemployment. The Resilience Investment Pathways are aligned with mainstreamed indicators of climate resilience to be applied as a monitoring and evaluation framework. Ultimately, this strategy provides a suite of complementary and integrated investment pathways that are designed to deliver greater impact when implemented together rather than as individual projects.

Table 1 illustrates the four resilience pathways in terms of the baseline condition and central actions and processes that would need to be implemented over time to realise specific objectives. Indicative timelines are presented to highlight the sequential and incremental nature of adaptation interventions, the inextricable interlinkages between different interventions within and across different pathways, and to provide high-level targets for implementation, and for monitoring and evaluation of progress. These pathways were developed with three overarching objectives: i) to address key and cumulative climate change risks identified in the hazard, risk and vulnerability assessment in an integrated manner; ii) to be relevant and useful to CCT as informed by stakeholders; and iii) to maximise the benefits and minimise the costs of adaptation action centred around building an inclusive and climate resilient economy. Ultimately, these pathways provide the platform to identify structured and itemised investment programmes to maximise both the impact of investing in climate change adaptation and likelihood of attracting investment.

A flexible yet programmatic strategy for investing in climate resilience is necessary to promote a long-term approach to sustainable development and maximise the opportunity of attracting investment finance across the spectrum (Refer to Section D). This strategy is captured across the Resilience Pathways in Table 1. These resilience pathways are designed to maximise the benefits of investing in building climate resilience over time. Hence, investments are stacked in the short-term to maximise their impact and to effectively develop the enabling environment to support resilience building.

TABLE 1: Climate Change Adaptation Pathways for the City of Cape Town

Baseline	Short-Term	Medium-Term	Long-Term	Overall Objectives
1. Municipal governance				
Municipal revenue and resource risk closely linked; weak cooperative governance; governance paradigm focused on provision rather than support and incentives; high levels of inequality in resource access/consumption; district plans currently under review; revenue structures potentially increase the impact of climate change through encouraging urban sprawl. Some planning and governance models promote climate vulnerability; etc.	• Review of current financial and revenue models • Advocate for the devolution of management of critical infrastructure and assets to CCT • Transform sector and district plans and planning processes to target inclusive climate resilience • Develop cooperative governance institutions and partnerships for managing trade-offs	• Develop climate risk insurance schemes & sustainable resource use incentives • Implement policies and incentives for the sustainable and inclusive use of land, water and energy	• Champion cooperative regional systems coordination and management, particularly of catchment areas	• Resource risk is decoupled from revenue and adequate municipal revenue is generated. Governance paradigm shifted from provider to enabler. Revenue structures incentivise sustainable urban development. • All governance and planning models and processes promote resilience building objectives.
2. Sustainable Urbanisation				
Urban sprawl; rapid urbanization growth; unplanned human settlements; significant distances to work, culture and amenities; poor waste water treatment works compliance; poor air quality; by laws in progress	• Formalise/implement long term approach to guide densification and sustainable land-use • Facilitate dialogue between key development stakeholders & partners • Pass by-laws and regulations for sustainable and inclusive development • Incentivise affordable and sustainable housing/ infrastructure development • Implement strategies for mitigating increased land-use competition	• Review/revise land use zoning for optimal and sustainable land use • Support and develop affordable transport and clean energy to improve air quality to acceptable standards across the City	• Use City-owned land to influence mixed use growth & alternative revenue streams	• Densification is synonymous with sustainability. Planned, quality density with proximity to work, amenities, culture and transport facilities. High degree of positive interaction between people

continued

Baseline	Short-Term	Medium-Term	Long-Term	Overall Objectives
3. High Value Ecosystems				
Hazardous land occupied for informal settlements; inequitably distributed green spaces; unsustainable land use practices; low levels of community ownership; catchments and most food systems are outside of CCT jurisdiction Reduced functionality and quality of wetland and river systems	• Identify & implement ecosystem and polluted land restoration & management • Design resource sensitive urban design policy & climate resilient stormwater management • Sensitize, mobilise and empower communities for sustainable land use • Promote resource conservation AND increase consumption to reduce resource poverty	• Transform and implement integrated catchment management • Implement resource sensitive urban design and infrastructure development • Equitably distribute and sustainably manage green spaces	• Restore all wetland and river systems to best practice standards	• Critical ecosystems are sustainable Citizens 'own' ecosystem management and services. Improved management and cooperation across the spheres of governance
4. Risk Reduction				
Developments & informal settlements within flood lines / hazardous areas; Disaster Management Plan; DRR under-integrated across the City; inadequate storm water drainage – flood risks; increased fires in vulnerable human and eco-habitats; droughts and water scarcity Low levels of vulnerable communities' ownership of EWS and DRR	• Develop and implement EWS with communities • Sensitise and educate citizens to forecasted hazardous events • Mainstream / integrate risk reduction into all sector & district plans • Incentivise long term hazard risk reducing behaviour & disincentivise settlement in flood lines or hazardous areas • Implement short term climate hazard risk reduction in vulnerable areas	• Implement inquiry systems for examining the cause and effect of disaster events • Roll out/incentivise affordable, safe energy solutions in all Low Income Households	• Monitor risk reduction activities to re-inform relevant strategies and drive behaviour change	• Disaster losses are substantially reduced for the CCT and its citizens. Hazard and disaster risk reduction systems is a local priority with a strong institutional base for implementation.

A Resilience and Adaptation Investment Planning Tool allows the users to interrogate supporting data and information behind each investment pathway. How to access and apply the tool is outlined in Box 2.

BOX 2. Resilience and Adaptation Investment Planning Tool

The accompanying excel-based tool provides an interactive user interface for engaging with the various investment pathways and the underlying information. The tool allows the user to compare adaptation options in terms of benefits, costs, potential maladaptation, key resilience M&E indicators and potential co-implementers within CCT. It shows the integrated nature of the four resilience investment programmes and how these address different aspects of each adaptation pathway. Users can explore the underlying exposure and resilience index data that combine to create the overall climate change risk index and the economic capital data at both the planning district and major suburb level.

All in all, the tool provides strategic support for both technical planning and investment in specific adaptation actions, which should be used hand-in-hand with this investment strategy.

How to use the tool:

The tool is designed to be used systematically to incrementally dig deeper into each of the resilience pathways and underlying data. It comprises four dashboards in separate tabs:

1. Resilience Pathways
Select one of the four resilience pathways from the drop-down list below "1. Select Resilience Pathway". This will bring up a list of the various actions and associated adaptation options with indicative timelines. A summary showing the relative benefits, costs and maladaptation potential for each option is also shown, scored from lowest (1) to highest (3).

Then select the specific adaptation option to be investigated in more depth from the drop-down menu below "2. Select Specific Adaptation Option". This will bring up more detailed general descriptions and references to key literature relevant to each option. Possible actors and relevant indicators are also detailed.

Then with the specific adaptation option selected, navigate to any of the other three dashboards using the red buttons.

2. Planning Summary
Compare climate change risk summary index for current and mid-future time horizons (select from drop-down list to the right of "1. Risk") against economic capital summary index for current, strong future and weak future scenarios (select from drop-down list to the right of "2. Economic Capital"). The two scatter graphs compare the selected index variables against one another by planning district and suburb (select suburbs for each planning district from the drop-down list to the right of "Suburb").

Use the key to identify the different suburbs and district acronyms.

3. Risk Data
Compare resilience and exposure indicators that make up the summary climate change risk indices. Select current, mid-future or far-future time horizons for exposure data (drop-down list on the right of "2. Exposure") and summary risk indices (drop-down list on the right of "3. Risk").

continued

Select and compare individual sub-indicators of resilience (drop-down list on the top right of the District/Resilience pane) and exposure (drop-down list on the top right of the District/Exposure pane). These individual variables will be compared at the district level on a scatter plot in the District/Risk pane (centre row, right column). Individual suburbs for each district can be compared for the same resilience and exposure variables in the bottom three panes (select district from drop-down list above "Suburb").

4. Capital Data
Compare economic capital and exposure indicators that make up the summary capital at risk indices. Select baseline, strong or weak capital scenarios (drop-down list on the right of "1. Economic Capital") and current or mid-future exposure time horizons (drop-down list on the right of "2. Exposure").

Select and compare individual sub-indicators of economic capital (drop-down list on the top right of the District/Economic Capital pane) and exposure (drop-down list on the top right of the District/Exposure pane). These individual variables will be compared at the district level on a scatter plot in the District/Capital at Risk pane (centre row, right column). Individual suburbs for each district can be compared for the same economic capital and exposure variables in the bottom three panes (select district from drop-down list above "Suburb").

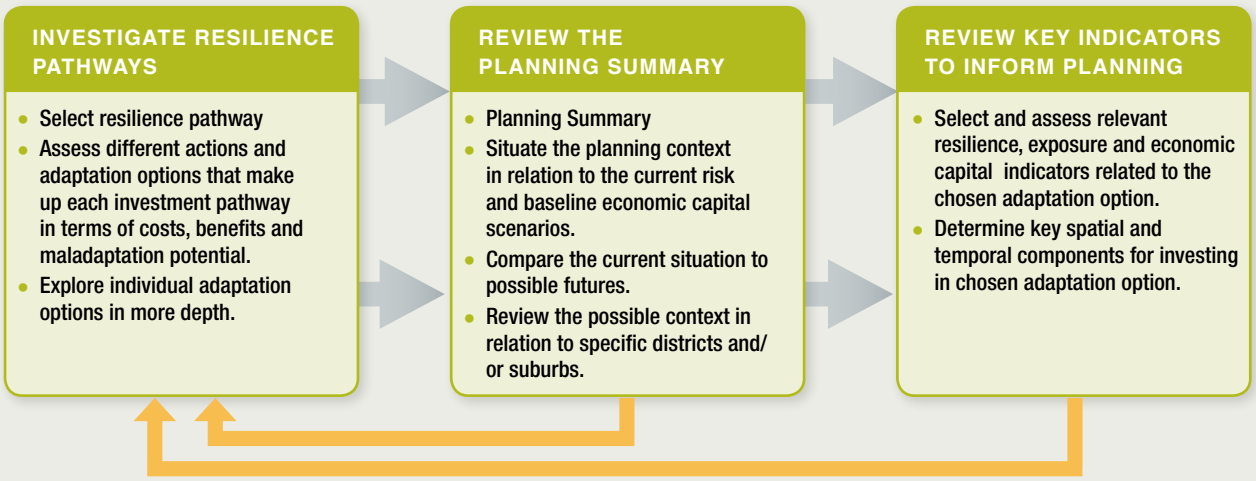


FIGURE 3: Using the Resilience and Adaptation Investment Planning Tool

B.4 Priority Areas for Action

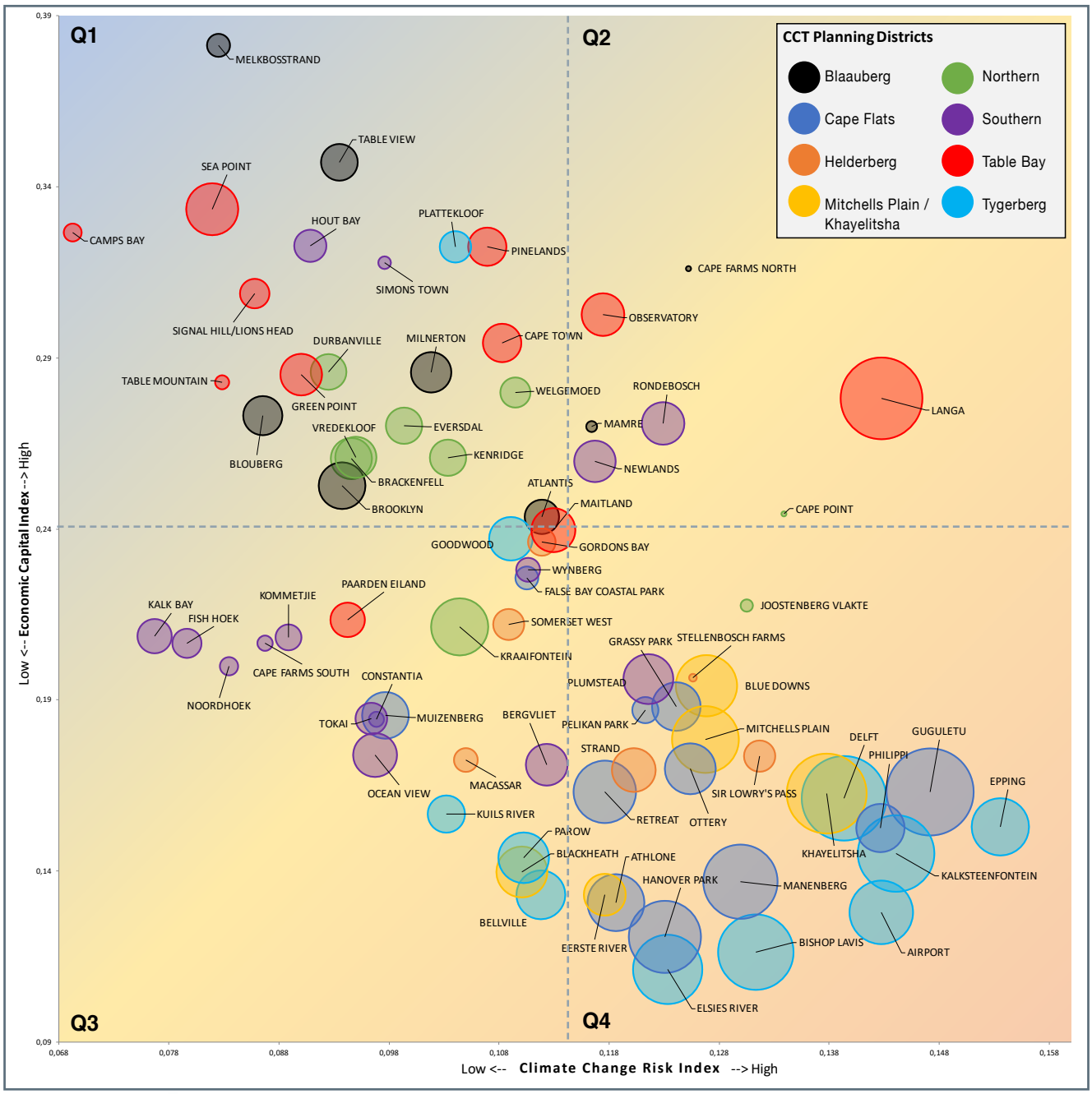
This section outlines the key areas of action identified in the City in relation to their relative climate change risk and level of economic capital. Areas refer to the different spatial units of the City and/or key types of risks that need to be addressed.

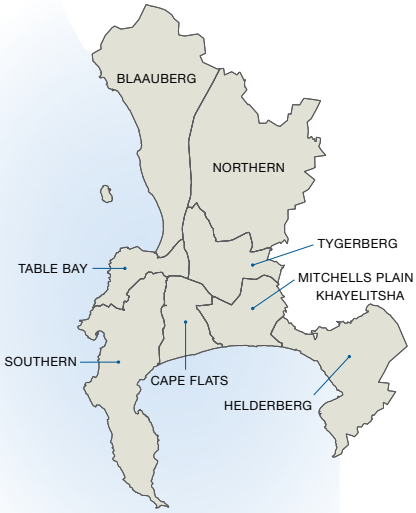
The risks associated with climate change are significant and manifest through multiple pathways that impact people, the economy and the environment. Complex interlinkages and cumulative impacts between the thematic areas of livelihoods, poverty and inequality, the built environment and disaster risk highlight that **building resilience is the key to reducing vulnerability in Cape Town**.

Figure 4 compares the major suburbs and planning districts of Cape Town in terms of their overall risk to climate change and their overall economic capital score (for the current timeframe), with the relative population densities shown by the size of the bubbles. The most vulnerable areas correlate strongly with low economic capital scores and higher population densities in the Tygerberg, Cape Flats and Mitchells Plain / Khayelitsha districts in quadrant 4 (Q4). In contrast, the less vulnerable areas are generally the more affluent areas with lower population densities and higher economic capital scores in quadrant 1 (Q1). The least number of people reside in areas in quadrant 2 (Q2), however these areas present a strong case for composite adaptation investments focused on maintaining or utilising existing strong capital bases to build resilience and reduce vulnerability. Whereas, adaptation investments in Q4 will need to focus on both sustainably building economic capital and improving resilience, which is likely to come at a greater cost in the long run. Thus, integrated climate resilience and adaptation investments should be focused on building long-term resilience in areas that are identified to have long-term latent economic and environmental potential, as well as investing in areas that have higher levels of capital at risk.

Understanding the spatial and temporal trade-offs between investing in adaptation across the City is critical to determining priority action areas. From a human development perspective, many of the most vulnerable people are living in areas that offer limited development potential as many informal (and even formal) settlements are situated within flood lines, on hazardous land or in general areas that are considered discouraged growth areas (DGAs). Moreover, these are the types of areas that are expected to see the most settlement/population growth in coming years. Thus, there is a temporal trade-off to make in terms of investing in short-term resilience building in the most vulnerable communities with longer term development objectives to maximise.

FIGURE 4: Capital and Risk Scatter Plot by Major Suburb and Planning District





Areas considered to be of high economic potential (or to exhibit latent economic potential) provide a strategic entry point for long-term investment in developing economic capital, while simultaneously providing the opportunity to efficiently build climate resilience of the most vulnerable populations. The CCT Economic Areas Management Programme (ECAMP) classifies the economic nodes within the City according to their current market performance as well as the location potential for economic development. Areas that show currently low levels of economic capital and are relatively at risk (i.e. Q4 in Figure 4) should be prioritised for long-term adaptation investments if they exhibit relatively higher potential for economic development. Whereas shorter-term investments aiming to improve resilience to climate shocks and stressors in the near future should be prioritised in relation to the human population benefit (i.e. areas with higher population are likely to receive greater short term benefits from adaptation investments). For example, areas such as Epping Industria and Elsies Rivier Industria show high levels of economic potential and are located in Q4. Whereas areas such as Khayelitsha, Mitchells Plain, Retreat exhibit relatively low levels of economic potential yet have highly vulnerable populations.

From a spatial planning perspective, it is critical to have clear parameters for prioritising investment in one area over another, which also need to align strongly with existing development planning policies and strategies (see Box 3). **Ultimately, investments need to be strategically programmed and prioritised to manage areas with both high and low capital stocks to maximise the use of existing investments in capital. While at the same time, targeting areas with high latent economic development potential for long-term resilience building and to protect the most vulnerable populations from risks of climate shocks in the near future.**

The Adaptation Planning Investment tool should be used to explore the underlying drivers of risk and relative levels of economic capital across the City, to most effectively plan investments at different spatial and temporal scales. The tool provides a standardised investment screening method to ensure consistency and fairness, while maximising the outcomes of public expenditure (see Section D). Moreover, international and domestic private finance and international public finance investment opportunities can be strategically and technically supported using the planning tool (discussed further in the next section).

It should be noted that many of the specific adaptation options within each pathway will not require detailed spatial analysis as they will be applied across the City as part of the enabling environment through for example investments in municipal governance and planning processes. In these cases, the tool can be used to assist the sequencing of both enabling and direct resilience building investments over time as socio-economic, environmental and regulatory conditions and climate change knowledge evolves.

BOX 3. Alignment with CCT Development Planning

Spatial development planning policy and strategy in CCT is centred around the Integrated Development Plan (IDP) and the Municipal Spatial Development Framework (MSDF). The Integrated Urban Development Framework (IUDF), National Development Plan (NDP) and Provincial Spatial Development Framework (PSDF) guide and inform city-level planning and implementation. Other key city-level policies and strategies that inform spatial planning include the Built Environment Performance Plan (BEPP), Transit Oriented Development Framework (TOD), Economic Growth Strategy (EGS), the Cape Town Densification Policy and Social Development Strategy (SDS) amongst others.

The MSDF presents a highly integrated approach towards sustainable development (CCT, 2018). Policy statements align strongly with the priority adaptation options identified in this manual. The specific areas with the greatest alignment are related to:

- the intensification and diversification of land use in areas supportive of transit-oriented development with incremental housing opportunities specific to each context
- the provision of adequate and equitable distribution of essential services, urban greenspaces and critical infrastructure
- transformation of marginalised areas with latent economic potential into socially and economically integrated neighbourhoods
- encouraging PPPs to implement the strategy and support private sector development initiatives, while supporting small business development
- addressing current regulatory challenges to sustainable development and de-risking/incentivising investment
- enabling and promoting resource-efficient development that integrates land-use, economic and transport planning

These strong areas of alignment suggest that there needs to be a strong focus on creating and strengthening the enabling environment to speed up sustainable development processes. However, there are a few areas of weaker alignment, as well as existing governance and planning processes, that need to be addressed in order to effectively mainstream climate resilience in CCT. Climate change is included as a key driver of areas considered to be at 'risk'. For example, Policy Statement 22 in the MSDF is to "discourage urban growth in areas at risk from natural hazards/coastal processes which are expected to be amplified by climate change impacts" and refers to Map 5a and b in the MSDF. These two maps highlight precautionary areas and the biodiversity network / marine protected areas. Understandably, there is limited consideration of climate-related hazards and risks, being limited to identifying flood prone areas, high/low fire risk lines and showing wetlands, rivers and the 1:100 year flood line. Moreover, environmental considerations are framed eco-centrically in the MSDF, as biodiversity protection, and the focus on reducing the impacts of development on rivers, wetlands, ecosystems, etc. Whereas the priority adaptation options frame these considerations from more of an integrated development and ecosystem services perspective, where development and environmental conservation, protection and restoration go hand-in-hand with human development to find a workable and sustainable balance.

These areas of weaker alignment provide a significant opportunity to use the findings presented in this manual (and supporting work) to further inform spatial development planning. Specifically, a nuanced understanding of both current and future climate risks and areas of vulnerability will provide a further necessary layer of technical analysis to apply to the MSDF. Furthermore, the priority adaptation options present some innovative approaches to these areas of alignment between this work and the MSDF (e.g. the notion to implement planned rapid settlement in support of proactive development and settlement planning).

Figure 5 presents the consolidated spatial plan as illustrated in the MSDF. Importantly this map highlights the basis for growth management across the City that was established via four primary Spatial Transformation Areas (STAs) and four localised 'unique' areas namely:

- An Urban Inner Core (estimated 17% of geographic area of the City)
- Incremental Growth and Consolidation Areas (20%)
- Discouraged Growth Areas (28%)
- Critical Natural Areas (34%)
- Unique Cases: Atlantis, Paardevlei, Philippi Agricultural Areas and Swartklip.

The focus on urban densification within the urban inner core should also include ecosystem management activities that complement densification actions. Discouraged growth areas should also include those that fall within hazardous areas, and flood lines and those too far away from identified economic growth nodes (i.e. areas of latent economic potential). Thus, a greater spatial resolution of planning is needed as many of these areas overlap (e.g. some areas in the urban inner core should be considered as discouraged growth areas), which will be complemented by the integration of detailed climate change risks.

Mainstreaming of the most recent climate change knowledge into current spatial development planning should also include alignment with recent strategic documents such as the Cape Town Resilience Strategy, Green Infrastructure Plan and Water Strategy. Each of the strategic adaptation investment programmes (discussed in the next section) were developed in line with these strategic documents, therefore explicitly integrating these strategies should be relatively simple. Ultimately, the sustainable development trajectory of the City needs to be explicitly stated as one that is climate resilient and low carbon.

continued

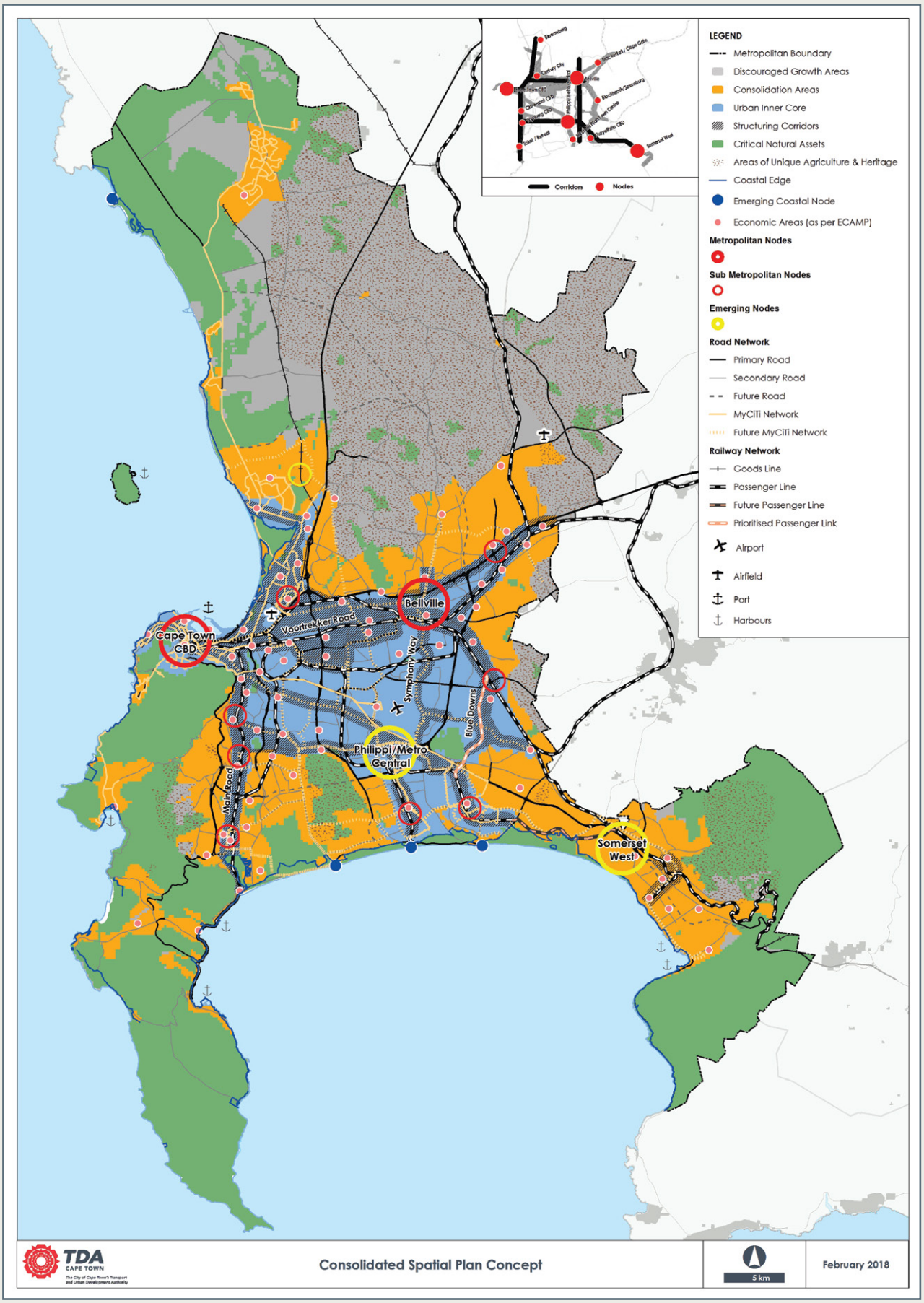


FIGURE 5: City of Cape Town MSDF Consolidated Spatial Plan Concept (CCT, 2018)

C.

The Resilience Investment Programmes

This section expands on the Pathways for Resilience outlined in Table 1. The Resilience and Adaptation Investment Planning Tool facilitates the exploration of all four resilience investment programmes, as well as the underlying data and information to support the planning of specific adaptation actions. The adaptation options that the four investment programmes comprise are detailed in Appendix 1.

The sub-sections below highlight key indicators, potential lead and support actors and estimated costs for each of the four investment programmes related to the resilience pathways. The indicators identified in Appendix 1 and below are derived from the 'State of Preparedness of South African Cities in Addressing Climate Change Challenges and Building Climate Change Resilience' project funded by the German Development Corporation (GIZ). It should be noted that the estimated costs below are not cumulative across the four investment programmes because key adaptation options contribute towards activities across multiple resilience pathways.

C.1 Municipal Governance

This programme seeks to decouple resource risk from revenue and to ensure that all municipal governance processes promote climate resilience, while ensuring that adequate municipal revenue is generated and available for the CCT to meet its mandate. Shifting the governance paradigm from provider to enabler is a key to achieving these objectives.

The specific adaptation interventions that together comprise this pathway, the objective for each, along with the expected co-benefits and high-level costs, are outlined in Table 2 below.

TABLE 2: Municipal Governance Programme for the City of Cape Town

Activity	Adaptation Options	Key Indicator	Department(s)	Cost/Cost Centre/Purpose
Short-Term				
Review of current financial and revenue models	• Revenue model reform • Review all existing governance and planning models and processes to ensure they do not impede resilience building objectives • Review of existing by-laws and regulations • Redesign revenue structures to disincentivise urban sprawl and unsustainable urbanisation	Budget for maintenance of infrastructure	Environmental Management; Revenue; Treasury; Water & Sanitation; Electricity Gen & Distribution; Development Management; Urban Integration	Inhouse research and analysis: over 6-8 months. Internal budget
Devolve management of critical infrastructure and assets to CCT	• Advocate for/incentivise national government to devolve management • Propose alternate options/pathways for devolution of management from national to local government	Level of decentralisation of management of resources	Transport; Urban integration; Property Management; Budget	Intergovernmental transfer of assets, or the management thereof (partially/in full) central to CCT's basic service delivery, e.g. dams
Transform sector and district plans and planning processes to target inclusive climate resilience	• Climate resilient sector and district plans	Collaborative and cross sectoral policy design, planning and review	Environmental Management; City Manager; Office Exec Mayor; Budget	Inhouse expert support and stakeholder engagement over 2 years. Internal budget
Develop cooperative governance institutions and partnerships for managing trade-offs	• Partnerships for trade-offs • Climate change coordination hub	Existence of climate resilience hub	Environmental Management; City Manager; Enterprise & Investment; Office Exec Mayor; Media Office	

continued

Activity	Adaptation Options	Key Indicator	Department(s)	Cost/Cost Centre/Purpose
Design a programme and incentives for affordable, safe energy solutions in all Low Income Households	• Renewable energy options and smart grids	Percentage of renewable energy capacity	Environmental Management; Electricity Gen & Distribution; Sustainable Energy Markets; Disaster Risk Management; Media Office; Public Emergency Communication Centre	Partner with J-PAL to raise funding (~USD 500,000) for randomised control trials (RCTs) to generate rigorous evidence on the costs and impacts of lowering electricity prices for the poor (includes surveys, high frequency consumption monitoring and support for the design and analysis of a pilot involving ~2,500 low income households for one year). Also discussed under municipal revenue reform.
Medium-Term				
Develop climate risk insurance schemes & sustainable resource use incentives	• Risk insurance mechanisms	Level of insurance cover	Environmental Management; Treasury	Expert support and stakeholder engagement: ZAR 2 million over 2 years
Develop climate risk insurance schemes & sustainable resource use incentives	• Financial incentives for sustainable water, energy and land use • Resource poverty and resilience policy • Pollution control taxes and subsidies	Financial incentives for improved climate resilient initiatives; Water resources availability	Environmental Management; Electricity Gen & Distribution; Water & Sanitation; Sustainable Energy Markets; Revenue; Treasury; Media Office	Internal budget, revised subsidisation structures
Long-Term				
Champion cooperative regional systems coordination and management, particularly of catchment areas	• Regional systems coordination	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries	Environmental Management; City Manager; Office of Exec Mayor; Water & Sanitation; Urban integration; Development Management;	Internal budget

C.2 Sustainable Urbanisation

This programme seeks to promote sustainable densification of the City through planned density that is sustainable because it enables proximity to work, amenities, culture and transport facilities. The programme will promote a high degree of positive interaction between people, thus improving social cohesion.

The specific adaptation interventions that together comprise this pathway, the objective for each, along with the expected co-benefits and high-level costs, are outlined in Table 3 below.

TABLE 3: Sustainable Urbanisation Programme for the City of Cape Town

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Short-Term				
Formalise/implement long term approach to guide densification and sustainable land-use	• Revised urban densification policy • Resilient and adaptive land-use action plan	Urban density; Urban planning informed by R&V assessments	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Recreation & Parks; Solid Waste; Water & Sanitation; Electricity Gen & Distribution	Internal budget to design policy and benchmark against international best practice (e.g. study tour for key planners and decision makers to cities implementing sustainable urban densification)

continued

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Facilitate dialogue between key development stakeholders & partners to develop a social contract on sustainable urban densification	• Partnerships for trade-offs • Rural to urban migration research and forecasting	Partnerships between cities and NGOs; Collaborative and cross sectoral policy design, planning and review	Environmental Management; City Manager; Enterprise & Investment; Office of Exec Mayor; Urban Integration;	Internal budget for a 3 year programme to facilitate a social contract on sustainable urban densification
Pass by-laws and regulations for sustainable and inclusive development	• Review of existing by-laws and regulations in line with the social contract	Climate-smart infrastructure planning and the integration of green and grey infrastructure	Environmental Management; Development Management; Urban Integration	Internal budget
Incentivise affordable and sustainable housing/infrastructure development	• Sustainable and equitable densification incentives	Financial incentives for improved climate resilient initiatives	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Recreation & Parks; Budget; Treasury	Internal budget to commission advisory services/research on incentives/Collaborate with research institutions, such as the African Centre for Cities at the University of Cape Town
Short-Term				
Implement strategies for mitigating increased land-use competition	• Densification sensitisation and mobilisation schemes • Solid Waste Management	Urban density	Environmental Management; Media Office; Social Development & Early Childhood Development; Water & Sanitation	3m ZAR over 2-3 years (for mobilisation and sensitisation programmes and participatory strategy development)
Medium-Term				
Review/revise land use zoning for optimal and sustainable land use	• Resilient and adaptive land use action plan • Revised Urban Densification Policy • Rural to urban migration research and forecasting	Urban planning informed by R&V assessments	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Recreation & Parks; Water & Sanitation; Solid Waste; Electricity Gen & Distribution; Office of Exec Mayor	Internal budget
Support and develop affordable transport and clean energy to improve air quality to acceptable standards across the City	• Renewable energy/ clean energy transport options and smart grids	Percentage of renewable energy capacity	Transport and Urban Development Authority; Environmental Management; Electricity Gen & Distribution; Sustainable Energy Markets; City Health; Development Management; Recreation & Parks	Capex and Opex budgets to be determined by the CCT and evaluated through a cost benefit analysis that considers the socio economic co benefits (e.g. human health) Potential for financial support from development partners, for example through a partnership/ co-funding approach
Long-Term				
Use City-owned land to influence mixed use growth (e.g. schools as social hubs)	• Resilient and adaptive land use action plan	Urban planning informed by R&V assessments	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Recreation & Parks; Water & Sanitation	Internal budget: direct part of the budget for each planned facility toward integration of mixed use in design and implementation

continued

C.3 High Value Ecosystems

Ensuring that all of Cape Town's critical ecosystems are sustainable, with increasing reliance on Nature Based Solutions (NBS), is at the heart of this programme. Promoting citizen 'owned' ecosystem management and services is considered central to achieving this objective, as is improved management and cooperation across the spheres of governance.

The specific adaptation interventions that together comprise this pathway, the objective for each, along with the expected co-benefits and high-level costs, are outlined in Table 4 below.

TABLE 4: High Value Ecosystem Programme for the City of Cape Town

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Short-Term				
Identify, implement and regulate for ecosystem and polluted land restoration & management	• Resilient and adaptive land use action plan • Valuation of ecosystem services research • Design and implement, a Payment for Ecosystem Services (PES) regulatory system • Review of existing by-laws and regulations • Pollution control taxes and subsidies	Ecosystem health	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Treasury; Revenue; Recreation & Parks; Water & Sanitation	Internal budget plus external support of ~ZAR 3 million to value key ecosystem services (e.g. water) and design a PES mechanism
Design resource sensitive urban design policy & climate resilient stormwater management	• Climate resilient sector and district plans • Densification sensitisation and mobilisation schemes	Collaborative and cross sectoral policy design, planning and review	Environmental Management; City Manager; Office of Exec Mayor; Budget; Social Development & Early Childhood Development;	Discussed under sustainable urbanisation pathway
Promote resource conservation AND increase consumption to reduce resource poverty	• Design a programme and incentives for affordable, safe energy solutions in all Low Income Households • Energy and water conservation • Uptake of decentralised renewable energy and water supply systems • Increase equitable uptake of sustainable electrification	• Equitable resource availability • Increased energy and water conservation • Increased off grid solutions	Media; Environmental Management; Electricity Gen & Distribution; Water & Sanitation; Sustainable Energy Markets; Revenue	Partner with J-PAL to raise funding (~USD 500,000) for randomised control trials (RCTs) to generate rigorous evidence on the costs and impacts of lowering electricity prices for the poor (includes surveys, high frequency consumption monitoring and support for the design and analysis of a pilot involving ~2,500 households for one year). (Also discussed under municipal revenue reform.) Establish incentives and regulations for increased off grid energy and water solutions
Sensitize, mobilise and empower communities for sustainable land use	• Partnerships for trade-offs • Community gardening and ecosystem management schemes	Partnerships between cities and NGOs; Collaborative and cross sectoral policy design, planning and review	Environmental Management; City Manager; Enterprise & Investment; Office of Exec Mayor; Development Management; Media Office; Recreation & Parks; Urban Integration	Internal budget

continued

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Medium-Term				
Transform and implement integrated catchment management	• Regional systems coordination • Riverine and wetland restoration	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries	Environmental Management; City Manager; Office of Exec Mayor; Water & Sanitation; Urban Integration; Development Management; Solid Waste	Co-funding partnership between CCT and external development partners to finance identification and adoption of Nature Based Solutions and other means of restoration of wetlands and rivers. ~1.5m ZAR to scope systems restoration and identify long term NBS and other sustainable restoration activities and solutions. The scope of work to include costing of implementation.
Implement resource sensitive urban design and infrastructure development	• Wastewater reuse and stormwater harvesting • Sustainable Urban Drainage Systems (SUDS) • Tree planting and implementation of other Nature Based Solutions such as water sensitive urban planning	Climate-smart infrastructure planning and the integration of green and grey infrastructure	Environmental Management; Water & Sanitation; Development Management; Recreation & Parks	Budget derived from above scope of work. Co-funding partnership
Equitably distribute and sustainably manage green spaces	• Sustainable urban greenspaces • Tree planting • Solid Waste Management	Ecosystem health	Environmental Management; Recreation & Parks; Urban Integration; Development Management	Internal budget. Integrate with multi-purpose community facilities
Long-Term				
Restore all wetland and river systems to best practice standards	• Riverine and wetland restoration • Densification sensitisation and mobilisation schemes	River and wetlands health	Environmental Management; Water & Sanitation; Media Office; Social Development & Early Childhood Development; Solid Waste	Co-funding partnership

C.4 Risk Reduction

Disaster losses are substantially reduced for the CCT and its citizens through this programme. Coherent hazard and disaster risk reduction systems are embedded as a local priority with a strong institutional base for implementation.

The specific adaptation interventions that together comprise this pathway, the objective for each, along with the expected co-benefits and high-level costs, are outlined in Table 5 below.

TABLE 5: Risk Reduction Programme for the City of Cape Town

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Short-Term				
Develop and implement Early Warning Systems (EWS) with communities	• Adapting hazard monitoring, forecasting and response protocol • Health related impacts of climate change research • Social media campaign & EWS	Effective disaster response plans and communication systems during disasters	Environmental Management; Disaster Risk Management; Media Office; Public Emergency Communication Centre; City Health	Internal budget
Sensitise and educate citizens to forecasted hazardous events	• Climate change and disaster risk school curricula • Household disaster risk preparedness planning	Effective disaster response plans and communication systems during disasters	Environmental Management; Disaster Risk Management; Media Office	Partner with academic institutions, such as the Climate Systems Analysis Group at UCT and cell phone service providers to package mobile based sensitisation and forecasting Partner with schools to develop curricula

continued

Activity	Adaptation Options	Lead Indicator	Department(s)	Cost/Cost Centre/Purpose
Mainstream / integrate risk reduction into all sector & district plans	• Climate resilient sector and district plans • Coastal erosion assessment, wind and swell modelling	Collaborative and cross sectoral policy design, planning and review	Environmental Management; City Manager; Office of Exec Mayor	Internal budget
Incentivise long term hazard risk reducing behaviour & disincentivise settlement in flood lines or hazardous areas	• Financial incentives for sustainable water, energy and land use • Review of existing by-laws and regulations • Energy and water conservation • Uptake of decentralised renewable energy and water supply systems	Financial incentives for improved climate resilient initiatives	Environmental Management; Electricity Gen & Distribution; Water & Sanitation; Sustainable Energy Markets; Revenue; Treasury Development Management; Urban Integration; Media Office; Recreation & Parks	Internal budget to include cost benefit analysis of the trade-offs of developing in hazardous or climate resilient areas
Implement short term climate hazard risk reduction in vulnerable areas	• Mobile Flood Protection Products • Solid Waste Management	Floodplain, flood-prone, exposed coastal zone are mapped and planned for	Environmental Management; Disaster Risk Management; Water & Sanitation; Solid Waste	Partner with academic institutions, such as the Climate Systems Analysis Group at UCT and cell phone service providers to package mobile based sensitisation and forecasting
Medium-Term				
Implement inquiry systems for examining the cause and effect of disaster events	• Adapting hazard monitoring, forecasting and response protocol	Effective disaster response plans and communication systems during disasters	Environmental Management; Disaster Risk Management; Media Office; Public Emergency Communication Centre	Internal budget
Long-Term				
Monitor risk reduction to re-inform relevant strategies and drive behaviour change	• Adapting hazard monitoring, forecasting and response protocol	Budget for Disaster Risk Reduction	Environmental Management; Sustainable Energy Markets; Disaster Risk Management; Media Office; Public Emergency Communication Centre	Partner with academic institutions such as the School of Economics to monitor and drive risk reduction and behaviour change

The four resilience investment programmes are complementary in nature as they are designed to integrate cross-cutting city functions and support various technical aspects related to other programmes. These interlinkages and co-benefits within and across the four investment programmes amplify the impact of investing programmatically. This is not to say that investments into individual adaptation options is not possible nor needed in some cases, but programming individual options into relevant and coherent programmes maximises impact and provides a solid basis for attracting investment.

D.

Financing Climate Resilience

The transition to a low-carbon, climate-resilient City necessitates both a substantial increase in the total quantity of urban infrastructure investment, and a shift in how existing streams of finance are allocated (Colenbrander et al., 2018). Particular emphasis is needed on investments in ecological infrastructure, for example for water security, and on Nature Based Solutions that integrate ecological, or green infrastructure with hard, or grey infrastructure investments. Achieving this balance and redressing the current under investment in equitable ecological infrastructure, necessitates innovation, learning and scaling of financing instruments, financial architecture and governance structures in support of this.

The success of the distinct municipal governance investment programme in a city that, like all South African cities, is entrenched in long term and highly institutionalised planning, revenue collection and management processes and systems, pivots on significant transformation. At the same time, the remaining three programmes all, to some or other extent, rely on inclusive and participatory planning, sensitisation and behaviour change across the CCT and society. Social partnerships, underpinned by a social contract for climate resilience, are central to successful transformational change of municipal governance and planning systems. This further highlights the need for innovation through experimentation, particularly to increase participatory planning and governance. For instance, establishing bottom up governance labs as an interdisciplinary initiative to reduce decision making risk and to increase citizen participation, could provide a platform for experimentation, through piloting practical participatory decision making and governance tools, as briefly described in Box 4 below.

BOX 4. Good governance for climate resilience depends on inclusive decisions

New, bottom-up governance labs established to increase and capacitate citizen participation in city-level decision making provide a platform for experimenting with approaches and tools to drive the social contract for climate resilience. Such approaches and tools aim to reduce decision making risk, through broadening the decision-making base and ensuring that all parties that stand to benefit from the decision made, are also protected from, and aware of the associated risks.

Practical tools are designed and utilised to translate knowledge and lessons about decision-making into practical tools for citizens and those who exercise authority on their behalf (Cambridge Governance Labs, 2019). The aim is to empower citizens and leaders alike to meet existential and universal challenges such as climate change, which result in day to day decisions having even greater impact.

Governance labs bring together officials, academics and civil society to develop and distil new research and thinking into tools and formats that open up pathways for participatory decision making, such as for urban planning, or budgeting, so as to improve the quality and inclusiveness of decisions. Example of practical tools include tools for identifying trade-offs between prioritising one solution over another, identifying conflict of interest, clarifying roles and responsibilities, participatory, high level budgeting, using data to inform decisions and developing the economy, etc.

Applied in the context of this investment plan, a governance lab can be used as a platform for making inclusive decisions, for example, on sustainable urbanisation policy, developing and applying tools for integrating Nature Based Solutions in urban development in a partnership between citizens and the CCT, and for restoring wetlands and riverine systems. The platform can also be used for mobilising sensitisation programmes, incentive schemes and promoting behaviour change. As such, a governance lab can be an enabler of the implementation of the social contract for climate resilience.

Experimental approaches such as described above are important in underwriting the risk of the multi-objective investments required to build climate resilience. Programming adaptation options into bundled multi-objective climate resilience investments will further effectively address the cross-cutting risks associated with climate change. Hence this will facilitate the implementation of a strategic financing strategy that is not entirely dependent on local and domestic public budgets yet is aligned with existing public expenditure and development plans. Table 6 briefly describes the nature of the four key categories of the climate compatible development financing spectrum. However, long-term adaptation investment programmes are almost always financed through some form of blended finance approach.

There is no common conceptual understanding of blended finance, but it broadly involves the strategic combination of sources of public and/or private finance to reduce investment risk, lower the cost of capital and crowd-in further investment into targeted programmes.

ATTRIDGE AND ENGEN, 2019; MELTZER, 2018

TABLE 6: Climate Compatible Development Finance (Adapted from World Bank, 2015)

Finance Category	Description
Domestic Public	A country or City's own domestic public resources, such as government income from taxes and its budget. For most countries/cities, domestic public finance is the largest resource to fund their integrated development plans.
International Public	This refers to aid, grants, and concessional finance provided by Advanced and Middle-Income Economies to help support development in EMDEs. Official Development Assistance (ODA) is a term introduced by the Development Assistance Committee of the Organisation for Economic Co-operation and Development (OECD DAC) to measure aid. It is widely used as an indicator of international aid flow that meet the OECD DAC criteria for aid. ODA is unique, as it is the main official international resource flow aimed primarily at the economic development and social welfare of developing countries.
Domestic Private	This refers to a country's domestic private sector resources, including large corporations and SMEs as well as domestic institutional investors, such as the pension funds, insurance funds, and sovereign wealth funds. To be effective, public sector measures to encourage private investment need either to decrease perceived risk or increase anticipated returns.
International Private	These consist primarily of: (i) Foreign Direct Investment (FDI) in developing countries; (ii) remittances from migrants back to their home countries; (iii) private philanthropy, e.g., from foundations; and (iv) financial market-based financing like portfolio equity flows, bonds, short-term debt flows and syndicated bank loans. Some of the newer resource flows are contributed by relatively new actors that are primarily public, but which have private sector-like investment return objectives, such as sovereign wealth funds and pension funds.

D.1 Defining Returns on Investment

Investors seek returns that are not limited only to direct financial returns. Returns depend on the type of investments made, however, **the key benefits** expected to flow from the successful implementation of this strategy are:

- An inclusive, climate resilient economy and society;
- An effective enabling environment for resilience building across the City's governance systems;
- Tangible benefits from resource security (biodiversity, urban agriculture and other land uses, water amongst others);
- Secure livelihoods and economies.

The long-term returns on investing in resilience in Cape Town will be in greatly reduced costs of climate change risks and impacts on livelihoods, human safety, infrastructure, economic assets and the economy. Shorter- or medium-term returns are more likely to be experienced in terms of improved resilience to climate hazards, resource scarcity and related development constraints. The financial returns of the long and medium-term investment horizons will be experienced through development that will be less resource and climate constrained than it is now, yielding greater economic and social investment returns. The environmental and social returns are likely to be more obvious and

direct. For example, the heightened vulnerability of Cape Town means that improving, protecting and restoring infrastructure functioning will have numerous environmental and social returns through the provision of public goods such as reliable and clean water, viable land uses and protected coastal zones, along with private financial returns to land users. The public-good nature of investment actions will translate into long-term socio-economic benefits and will enhance social and environmental capital in the City. This, in turn, will result in positive financial and economic benefits over time.

More specifically, investment returns will be seen through six important dimensions:

i) Greater adaptive capacity and strengthened ability to withstand climate variability and to recover from shocks;
ii) Improved resource efficiencies and access: reducing the financial and natural resources required in production and consumption
iii) Preservation of critical natural capital: halting and reversing declines in natural capital and focusing on the provisioning of ecosystem services as a means of productivity;
iv) Enhanced social equity: barriers to participating in the economy are minimized and access to basic services and the provision of human rights is ensured
v) Growth: Economic growth and the creation of new economic opportunities and jobs while maximizing the number of people in employment and labour intensity
vi) Transformed and/or improved governance: upholding the prevailing regulatory and legal standards and enforcing compliance with regulatory and legal requirements.

The emphasis on economic growth and jobs in the City is such that any investments that yield a combination of returns on these dimensions will create value for the CCT and their investment partners. Job creation, economic growth, and social equity are the most highly desirable co-benefits of, or returns on investments in, climate resilience.

D.2 Investment Planning for Programme Bankability

Strategic and logical programming of adaptation investments is ultimately designed to maximise impact and improve the bankability of proposed actions to maximise investment. This investment manual and the accompanying Adaptation Planning Investment Tool are designed to support and improve the bankability of climate resilience investment programmes. The traditional definition of bankability refers mainly to financial returns and determining the degree to which a project will be profitable for investors. However, in the context of climate change the concept of bankability goes beyond this to encompass socio-economic and environmental metrics, including, for example, improvements in the resilience of communities, and/or alignment with national priorities. In many instances, these additional elements are not easily quantified, which contributes to the grey area between bankability and eligibility, another term commonly referred to in relation to accessing finance (Ellis and Pillay, 2017).

CCT should plan to mobilise all possible sources of finance to increase their combined impact, as one source is rarely sufficient to finance the extensive climate change adaptation needs. This requires integrative and creative approaches to investment planning to improve bankability of the proposed adaptation investment programmes. Importantly this involves:

- Crowding-in the private sector in financing adaptation opportunities
  - Private investment is an engine of growth, productivity, innovation, job creation and development. As the largest potential source of finance, the private sector needs to play a larger role than it does now.
- Leveraging available public finance
  - Cities and countries need to use their balance sheets and platforms to increase private capital and other financial flows. They will thus be able to access finance and investment that is a multiple of their own financing.
- Strengthening the City's capacity to catalyse climate and development finance
  - Scarce domestic public finance must be strategically set-up and used to catalyze other sources of national and international finance. Capacity building and training opportunities should focus on building these skills.
- Creating climate and development finance partnerships and building multi-stakeholder platforms
  - A new level of collaboration is needed to meet financing challenges. By piloting and structuring new partnerships, finance can be aggregated and aligned across the City for greater investment and development impact.

D.3 Financing Mechanisms

Project specific funding is the foremost mechanism to support climate resilience building and adaptation (Joyce & Granit, 2010). The types of financing mechanisms available at the sub-national level include the following (Joyce & Granit, 2010):

- Grants, loans, utility bonds, local debt capital markets, export funds, taxes and sales levies.
- Direct private investment, public-private partnerships (PPPs), private finance initiatives and voluntary finance schemes.

- Payments for ecosystem services.
- Climate, multilateral and national funds.

The challenge for the CCT is accessing and implementing finance for the programmes, which comprise multi-sectoral initiatives. Alternative financing instruments are therefore also likely to be required for multi-sectoral initiatives in the City, such as a climate resilience finance facility.

D.3.1 Climate Resilience Finance facility

A specialized finance facility can assist with project-specific transactions, in addition to developing, funding, building and implementing multi-sector programmes. Finance facilities isolate risk, improve governance, and provide access to lower cost capital (Joyce & Granit, 2010), while also affording the opportunity for coherence and ambition, and for ensuring that the investment programmes are implemented as a whole. A revolving fund model can pool resources from the different departments involved in implementation and benefiting from the programme implementation. Domestic (local and national), public funds can be leveraged with financing from donors and the private sector.

However, the governance of a finance facility must be viable for all beneficiaries if implementation is to be successful. The finance facility must have a charter with collective agreement on the activities that are eligible for funding. Projects that are identified and selected can receive funding from a central source, such as the DEA, the Development Bank of Southern Africa, the African Development Bank or the AFD.

D.4 Sequencing of Investments

The different investment programmes require two classes of investments - enabling or asset investments (see figure 6 below). Both classes are necessary to building resilience in Cape Town. However different classes of investment are required at different times and attract different investors. The mix of investors and the type of investments that are funded will change over time as the climate resilience investments mature. It is therefore helpful to outline which investors are needed for what type of investments at which point in the implementation timelines of the Investment Programmes.

As shown in Figure 6 below, in the early stages of resource mobilization, finance is needed to support enabling investments and this is often provided by domestic sources of finance, donors, philanthropic organizations or through government grants. Multi-sectoral initiatives will need to spend a few years in this stage in order to develop a cohesive vision across the actors concerned that incorporates the diversity of stakeholders and their climate resilience needs. Private organizations may have some limited involvement at this stage as they may look to invest in building partnerships and testing pilots.

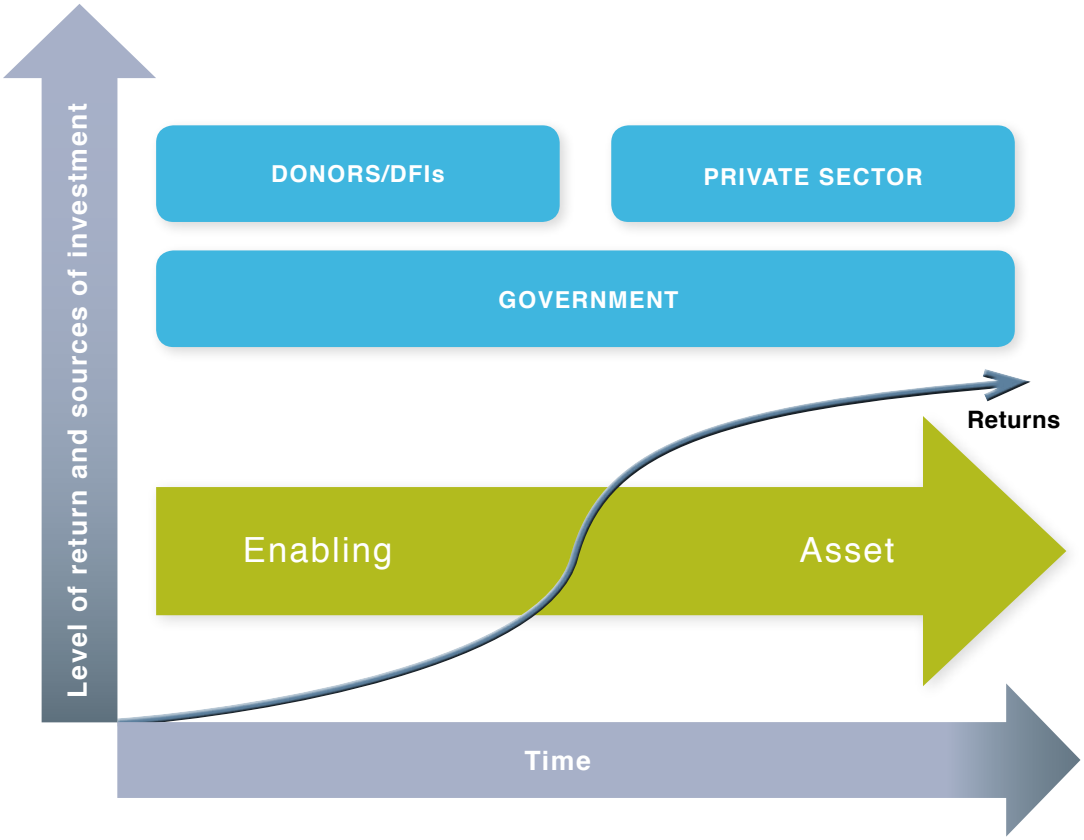


FIGURE 6: Sequencing of Investors and Investments (Adapted from Shames et al., 2012)

After about five years, a programme should look to start diversifying its sources of investment into asset classes of investment. The extent of this diversification will largely depend on the strength of the engagement in the formative years. If the institutional foundations are well established and there has been strong engagement with a diversity of stakeholders, the initiative could start attracting financing from Corporate Social Responsibility (CSR) budgets, companies looking to mitigate against reputational and operational risks, and from government budgets. If it is a government-led initiative, public funding will occur much earlier.

It is important to note that although enabling investments typically happen first, with asset investments, thereafter, enabling investments will need to continue over time in order to facilitate the continued operation of the initiative. The returns line illustrates how, over time, an increase in financial returns should be experienced by landowners and investors, as well as an increase in value of natural capital and services.

D.5 Implementation Strategy

The Adaptation Planning and Investment Tool should be used to guide investment planning in terms of sequencing and timing across the City and assist with mobilising all sources of possible finance for the four integrated adaptation investment programmes. Although the investment programmes are designed to incentivise investment in certain areas, the majority of investment will need to be sought proactively. Specifically, this involves four key steps:

1. Investment Preparation and Mainstreaming

Preparing investments is a continual and periodic process that needs to ensure the proposed investment programmes are strongly aligned with existing and planned expenditure in ongoing activities and programmes. This process will highlight which areas need to be financed outside of the City budget and where existing expenditure could be optimised to meet certain requirements of each investment programme. Not only will this process assist to mainstream climate change adaptation activities into formal budgeting activities, it will importantly serve to identify current and future co-financing commitments from the City.

The Adaptation Planning and Investment Tool can assist in this process by providing the granularity of detail necessary to align existing and planned expenditure with the specifics of each adaptation option that comprise each of the four investment programmes. Specifically, the technical details of each adaptation option and the underlying data used to prioritise these options will allow for the determination of 'additional financing' required to finance each priority option. The details of each adaptation option will also facilitate the alignment of expenditure with broader national and provincial policy objectives, as well as key international conventions such as the Sustainable Development Goals (SDGs). Completing this step will provide a clear understanding of the priority external areas of investment required and allow for strategic budget optimisation to finance areas least likely to be financed by external donors or the private sector as well as prioritising co-financing of multi-objective investments.

2. Institutional Arrangements

The lead actors or departments, as well as those involved in implementation, for each adaptation option, are identified in the four Investment Programmes (see tables 2, 3, 4 and 5 above). However, coordinated, integrated and holistic implementation of this strategy necessitates cross cutting institutional arrangements, that over time, can include non-governmental partners. A lead entity, for example a Climate Resilience Investment Steering Committee (CRISC), located within, and reporting to the Executive Management structure of the CCT, is envisaged, featuring representation of key departments such as those responsible for planning, water, coastal management, environment, disaster management, resilience, enterprise development, and finances.

The CRISC, or similar entity, would drive the governance lab envisioned in Box 4, and ultimately, the realisation of a social contract for climate resilience. Furthermore, the CRISC, if established, could be well positioned to drive a sustainable budgeting agenda across the CCT and society, for a climate resilient future. Given the transformational nature of the investment pathways, particularly the programmes for municipal governance and sustainable urbanisation, the CRISC has a critical role to play in evaluating possible solutions, for example for alternate revenue streams for the CCT.

This CRISC should meet quarterly to review and evaluate progress, consider financing and human resource mobilisation options, manage risks and challenges, and identify new/revised opportunities and priorities.

In addition, a programme steering (PSC) committee should be set up for each resilience investment programme. These SCs would report to, and be represented on the overarching entity, fulfilling the above functions at a programme level.

The Climate Change Unit in the Environmental Management Department can provide the secretariat function for the CRISC, while a lead department can provide this for each programme respectively. DRM is a natural role player in this regard for the Risk Reduction programme. In addition to coordinating the meetings and providing minutes, this function should include generating annual status reports for each programme, and the overall investment plan implementation respectively.

3. Financing Applications and Engagements

Once the contribution to the proposed investment programmes from local budgets has been confirmed and the local and international private and international public (i.e. external) finance requirements are understood, strategically targeted financing applications and engagements should be undertaken. This involves:

a. *Identifying and applying to key public climate and development financing institutions.*

Key climate and development finance institutions and associated funds need to be investigated in relation to the outcomes of step 1. Requirements and eligibility criteria vary significantly for different climate finance and development financing opportunities. Thus, once the details of the required financing are better understood, then applications to these funds can be targeted to the most appropriate and relevant sources of finance. For example, Box 5 presents the case of the Green Climate Fund (GCF) in terms of relevant eligibility criteria, procurement guidelines and assessment/investment criteria. The Adaptation Planning and Investment Tool can be used to explore necessary reprogramming options and relative benefits, costs and maladaptation potential of identified adaptation options. Moreover, it provides direct reference to key climate resilience indicators to facilitate monitoring and evaluation of projects. All of which are key eligibility criteria for GCF financing.

Box 5. The Green Climate Fund (GCF)

The GCF is a global fund that aims to support developing countries in both climate change mitigation and adaptation. In accordance with The Paris Agreement, the fund seeks to maintain a balanced portfolio between adaptation and mitigation projects and programmes, with the intent to support paradigm shifts in each sphere. Within the adaptation portfolio, the fund aims to allocate at least half of its funds (available to adaptation activities) to particularly vulnerable countries including least developed countries (LDCs), small island developing states (SIDS) and African states in general.

To receive funding from the GCF, Accredited Entities (AEs) of developing countries, with support from the GCF Project Preparation Facility and in close consultation with National Designated Authorities (NDAs) or focal points, develop project/programme proposals. These proposals are developed in response to Requests for Proposals (RfPs) issued by the GCF but can also be submitted to the fund at any time. Concept Notes for small-scale projects can also be submitted by the AEs. The eligibility criteria for these include the readiness for scaling up and the potential for transformation. However, in considering the eligibility of projects, proposed projects/programmes are evaluated and assessed against investment criteria with a set of indicators. These include the impact potential of the project in achieving the funds' objectives and results areas; paradigm shift potential for further impacts beyond a given project/programme; sustainable development potential in terms of environmental, social and economic co-benefits as well as gender sensitive development impact; targeting the vulnerability and financing needs of the recipient/beneficiary country; efficiency and effectiveness of the programme/project; and ensuring country ownership through alignment of policies, stakeholder engagement and capacity development. For adaptation projects, impacts, according to the GCF, are related to the number of lives, physical assets, livelihoods, environmental and/or social losses that can be avoided by an adaptation project (GCF, 2018).

b. *Establish formal partnerships and multi-stakeholder platforms with potential private sector partners.*

To happen concurrently with the identification and application to key public climate and development financing institutions. Strategic partnerships and stake-holder platforms should be sought with potential private sector partners, both possible investors and implementation partners. Clear communication and transparency over the nature of the work that needs to be done and the current financing shortfall is necessary to develop long-term partnerships. Private sector collaboration includes the procurement of support partners to assist with capacity shortfalls in acquiring climate finance, for example detailed project preparation and the development of GCF proposals.

Tackling climate change requires going beyond traditional financing approaches and sources to address the risks and opportunities. Financing arrangements for adaptation investments are continually evolving and the most effective solutions necessitate localised innovation. Thus, both of these two aspects necessitate detailed research and development of innovative financing opportunities and mechanisms to meet the financing shortfall identified in step 1. This requires high levels of communication and engagement with the financial management departments (i.e. revenue, budgets, expenditure, treasury) within the City to determine what is possible given the current regulatory environment and where the City has prior experience in leveraging finance for different purposes.

For example, the Greater Cape Town Water Fund is both a funding and governance mechanism that enables water users to invest collectively in catchment restoration alongside upstream communities to improve the flow of ecosystem services to the City (Stafford et al. 2018). The Climate Change unit of the Environmental Management Department in CCT should be continually reviewing

possible climate finance options and the potential of innovative funding mechanisms to meet both adaptation and mitigation finance shortfalls. These types of innovative financing options range across the investment spectrum from high to low financial, social and environmental returns. Depending on the degree of intolerable climate risk facing a City, some examples include the climate, catastrophe and green bond markets (e.g. see www.climatebonds.net), fund development such as equity and layered-risk funds (EIB, 2014), various crowdfunding schemes, concessionary loans, and the structuring of resources to maximise cost effectiveness of the action through equity/loan participation, first-loss piece or guarantee schemes (UNEP, 2011).

4. Implementation, Learning and Review

Adaptation planning and investment is an iterative process. Investment planning and programming needs to be periodically reviewed and updated to account for developments in technical knowledge of climate change and related impacts, as well as changes in the international climate finance landscape. Moreover, policy and strategic direction within CCT are evolving over time. Thus, a flexible climate finance strategy should be developed and implemented to align with both the adaptation and mitigation objectives of CCT and facilitate the periodic review of climate finance options to meet any adaptation or mitigation financing shortfalls. Robust M&E of the various climate resilience investment programmes is essential to ensure continued and growing investment, especially from external sources. Investors often have specific M&E requirements, which should be consulted when preparing and mainstreaming climate resilience investments and periodically updated to reflect the evolving reporting requirements of investors. Ultimately, this should form part of a broader review and learning process that serves to re-inform further investment preparation and climate mainstreaming activities.

E.

Glossary

Adaptation In human systems is defined as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. Incremental adaptation maintains the essence and integrity of a system or process at a given scale, while transformational adaptation changes the fundamental attributes of a socioecological system in anticipation of climate change and its impacts (IPCC, 2018).

Incremental Adaptation
Adaptation that maintains the essence and integrity of a system or process at a given scale. In some cases, incremental adaptation can accrue to result in transformational adaptation (Termeer et al., 2017; Tàbara et al., 2018).

Transformational Adaptation
Adaptation that changes the fundamental attributes of a socioecological system in anticipation of climate change and its impacts.

Air pollution Degradation of air quality with negative effects on human health or the natural or built environment due to the introduction, by natural processes or human activity, into the atmosphere of substances (gases, aerosols) which have a direct (primary pollutants) or indirect (secondary pollutants) harmful effect (IPCC, 2018).

Blended Finance There is no common conceptual understanding of blended finance, but it broadly involves the strategic combination of sources of public and/or private finance to reduce investment risk, lower the cost of capital and crowd-in further investment into targeted programmes (Attridge and Engen, 2019; Meltzer, 2018).

Climate Change Refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes (IPCC, 2018).

Climate resilience The capacity for socio-ecological systems to: i) absorb stresses and maintain functionality in the face of external stresses imposed upon it by climate change; and ii) adapt, reorganize, and/or evolve into more desirable configurations that improve the sustainability and performance of the system, leaving it better prepared for future climate change impacts (Folke 2006; Nelson et al. 2007).

Early warning systems (EWS) The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or Indigenous knowledge. EWS are also considered for ecological applications e.g., conservation, where the organization itself is not threatened by hazard but the ecosystem under conservation is (an example is coral bleaching alerts), in agriculture (for example, warnings of ground frost, hailstorms) and in fisheries (storm and tsunami warnings) (IPCC, 2018).

Inclusive economy and society Characterised by equitable participation in growth across the formal and informal sectors - in decision making decision in growth processes, and in the benefit of the growth itself. Participation of vulnerable population groups in growth processes is via non-discriminatory employment, while participation in the benefits manifests in income improvement and in increased social expenditure benefits that reduce disadvantages, such as education and human capacity development. (Ramos et al. 2013; Fourie, 2014)

Maladaptation Actions that may lead to increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence (IPCC, 2018).

Nature Based Solutions Actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, whilst simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al. 2016).

Risk The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence (IPCC, 2018).

F.

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APPENDIX 1.

Adaptation Options Matrix

The Adaptation Options Matrix is available for download **here**.

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Appendix 1: Adaptation Options Matrix

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
Adapting hazard monitoring, forecasting and response protocol	Planning	Revise current climate hazard monitoring, forecasting and response protocol given latest climate change knowledge of impacts. Protocol should be designed iteratively and flexibly to allow for updates based on improved climate change knowledge. Disaster Risk Reduction (DRR) Knowledge and innovation informs DRR strategies; Implement and apply inquiry systems for examining the cause and effect of all climate disaster events.	Frequent revisions of the monitoring, forecasting and response protocol for climate-related hazards will improve performance of these processes and ultimately reduce the economic, social and environmental impacts of floods, fires, strong winds, droughts, etc. These benefits will largely accrue to the most vulnerable sections of the population and will help to realise numerous co-benefits related to improved standards of living, reduced risk of economic loss (which has knock-on impacts) for investor confidence, and lower expenditure on aid or disaster recovery (UN/ISDR, 2007).	This field is not widely researched, but in general, preventative actions are less expensive and more cost effective than disaster relief. "It is widely accepted that effective preparedness or preventative actions have lower costs than responding to disaster; prepositioning humanitarian supplies by truck prior to a disaster is an order of magnitude less costly than airlifting it in during the event. In this way, a forecast-based financing system can be an efficient use of resources, making effective use of limited funding…" In addition, … "…noting that disaster prevention-type actions that avoided losses altogether were significantly less costly than actions that prepared for response. (Jongman et al., in prep)." (Red Cross Red Crescent Climate Centre, 2015).		Environmental Management Department; Disaster Risk Management Centre; Media Office; Public Emergency Communication Centre 107	Budget for Disaster Risk Reduction; Efficacy of emergency facilities and services and efficacy of health care facilities and services in case of climatic disaster (5.6); Level of adequate shelter and food post disaster event; Effective disaster response plans and communication systems during disasters (2.15); Fine scale projections of climate Risk & Vulnerability (R&V) assessments available to all (2.1); Floodplains and flood-prone, exposed coastal zones are mapped and planned for (2.6)
Advocate for/incentivise national government to devolve management	Governance	Implement and facilitate devolution of management of harbours, ports, rail, dams to CCT (and other critical services), where constitutionally, legally and technically appropriate.	Devolved management of such critical infrastructure services will minimise the political economy barriers to effective service delivery and allow the City to mainstream climate resilient spatial and development planning	In general, devolved management is more cost effective: "Given the size of the difference in the costs of state and council management, this is unlikely to affect our	Corruption and lack of capacity could derail these efforts. No guarantee that devolving management will result in greater	Transport Department; Urban Integration Department; Property Management	Level of decentralisation of management of resources (2.3)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		Overall management of critical services should happen at the lowest level where they function as a complete system (i.e. rail at metro level, water at catchment level).	in the management of these functions. Improved management of these essential services will bring about a plethora of economic, social and potentially environmental benefits (Bahl and Bird, 2013; Leigh and Lee, 2019).	conclusion that substantial savings could be realized by decentralizing management. More generally, the findings suggest that decentralization deserves wider attention in conservation strategies in developing countries with limited financial resources." (Samanathan, Prabhakar, Mehta, 2009).	efficiency- very dependent in each decentralised management unit- could lead to huge discrepancies across areas and greater inequality as a result. Risks of political disconnects that might influence resource allocations and ultimately impact climate resilience building efforts.	Department; Budget Department; Department of Water and Sanitation; Catchment CMAs/ Water Boards	
Climate change and disaster risk school curricula	Behaviour	Include climate change and disaster risk reduction activities and modules in school curricula from a young age. Align with community-based Early Warning Systems and broader environmental outreach programs across the City with key partners such as Cape Nature, WESSA etc.	Help to pre-empt and build resilience through increasing understanding and awareness. Appropriate skills, knowledge and raised awareness will enable students to better understand and cope with DRR and climate change (CC) - improving community responses. Improve social cohesion and reduce impacts of extreme events, reduce economic losses and health impacts of floods/fires due to improved understanding of responses and possible triggers, improved mobilisation of community EWS. Job creation, children gain skills and education that is more relevant to future economy. Increased empowerment of children, a vulnerable group (Kagawa and	Depends on implementation - could be cost of new textbooks (cheapest but least effective), implementing pilot projects (more expensive but most effective in transferring necessary knowledge and skills) and many others (UNICEF, 2012). 1997 costs of public education in Seattle, Washington: (1) environmental education, including transportation costs for field visits (105 schools with four trips each) costing $46 500. Teacher training in environmental education programmes for $3 400 (EPA, 1997).		Department of Education; Environmental Management Department; Disaster Risk Management Centre; Media Office	Effective disaster response plans and communication systems during disasters (2.15)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
			Selby, 2012).				
Climate change coordination hub	Governance	Develop and implement a cross-cutting coordination hub for climate change in the City. This platform will act as a cross-department and directorate coordination hub to facilitate, plan and implement cross-cutting climate change adaptation and mitigation initiatives ranging from policy development to on-the-ground actions. High-level political buy-in and messaging about the importance of climate change and associated adaptation and mitigation actions such as maintaining and restoring ecosystems for climate resilience and sustainable development.	Improved coordination will result in greater mainstreaming of climate resilient development planning and climate change in general. This will improve the level of integrated planning and assist with 'de-siloing' of development planning. Moreover, this will improve the coordination of communication of risks and how these are managed by different departments in the City.			Environmental Management Department; City Manager; Office of the Executive Mayor; Media Office; Sustainable Energy Markets	Existence of climate resilience hub (6.1); Collaborative and cross sectoral policy design, planning and review (2.13)
Climate resilient sector and district plans	Planning	All relevant sector and district plans being revised or developed should include key risks related to climate change and propose relevant and adequate adaptation efforts and key research required to understand sector/district specific risks to people, economy and environment. District Plan review processes should be integrated across all relevant departments in the	Enhanced sector and district planning will facilitate improved climate resilience and improve the coordinated effort to address climate risks across sectors and districts. Importantly this will result in improved action to reduce risk and vulnerability through maximising available resources.			Environmental Management Department; City Manager; Office of the Executive Mayor; Budget Department; Urban Planning and Design; Development Management; Department of Water and	Existence of climate resilience hub (6.1); Collaborative and cross sectoral policy design, planning and review (2.13)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		City and feed into future department/sector plans in an integrated and iterative manner.				Sanitation	
Coastal erosion assessment, wind and swell modelling	Planning	Facilitate research focusing on numerical projections of the quantitative changes in wind, waves and swells (periodicities and amplitudes) under climate change and associated impacts (coastal erosion, sedimentation and operations) around Cape Town, with a focus on at risk coastal regions and harbours. The research needs to build on recent work done to determine coastal urban development setback lines and focus on integrating these findings into policy-making, district planning and budgeting processes. In addition to coastal flooding and erosion risks, flood-line analyses across the City should be regularly revised in response to the changing climate and urban space.	A detailed understanding of coastal dynamics will provide greater insight into the possible climate-related changes to the coastline to improve development planning and decision-making. The benefits of improved development planning will be focused on reduced risks to property and infrastructure relating to coastal erosion, sea-level rise and storm surge. This will translate into lower risk to human life Understanding the financial risk of these changes will allow for a strategic prioritisation of investment and addressing the trade-off of protecting existing assets vs. investing in new areas/infrastructure. Other key benefits related to improved economic productivity, reduced loss from extreme events etc.	Quantitative research is generally less expensive than qualitative research. Costs however would include wave monitoring equipment (beacons, buoys, etc), aerial photographs/ GIS mapping of coastal regions, as well as sampling of coastal waters for sediment levels. Previous research utilised Google maps, field observations, and questionnaire surveys - which would be a fairly cost effective research mechanism (Lin and Pusella, 2017) University Research: The National Research Fund (NRF) offers between R60 000 and R200 000 for a Honours, Masters or PhD student for marine and coastal research (NRF, 2018).		Environmental Management Department	Partnerships for climate science are established and capacitated (2.12); Floodplains and flood-prone, exposed coastal zones are mapped and planned for (2.6)
Community gardening and ecosystem management schemes	Behaviour	Sensitise and mobilise community owned ecosystem management and community gardening initiatives, this includes targeted community capacity building and engagement activities in vulnerable areas. Efforts should begin with existing	Improved social cohesion, resilient and diversified food source, improved management and security of local ecosystems, ecosystem services can be improved which will help to decrease impacts of drought and reduce flooding. Increased biodiversity, increase access to	A community garden's start-up costs R56 000- R112 500: including establishing the garden near a source of water, maintaining city fees, insurance and contractor wages. A large community garden can cost R450 000 (https://howtostartanllc.com/bu	Unsustainable gardening practices, displacement of people to use the land. Could potentially be in conflict with priority space being at a premium in urban	Enterprise and Investment Department; Social Development Department; Environmental Management Department;	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries (2.2); Existence of climate resilience hub (6.1); River and wetlands health (2.1); Ecosystem health (5.3); Water resources availability (2.2)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		activities and providing support to CBOs/NGOs/NPOs operational in this space.	healthy foods for low income households. Job creation, aesthetic improvements (Agustina and Beilin, 2011).	siness-ideas/community-garden). Land can be donated however. Soil analysis test: less than R300 per square meter. Prepping the land involves time spent on tilling and money (R6000 for 14 meters) for compost. Hand tool set can cost R300 but are often donated. Seeds (fruit and veg) not more than R50 a packet. May need water storage tank for water access and cost will depend on size (1000 litre tank less than R3000 while 10000 litre around R14 000) (price check.co.za)	spaces. There are risks associated with food safety and health standards as well as the need for watering.	Development Management Department; Media Office; Recreation and Parks Department; Urban Integration Department; Department of Education	
Densification sensitisation and mobilisation schemes	Behaviour	Sensitise and mobilise communities and the City at large to sustainable land use practices and increasingly densified living through community capacity building and outreach activities, as well as communications campaigns to facilitate the transition from urban sprawl to more sustainable, equitable and densified living around key transport and economic hubs.	Decrease risk through moving people off floodplains/risk-prone land. Increase resilience through densification sensitisation by increasing buy in to densification practices, which will increase societal value placed on these projects (leading to improved social cohesion). People live closer to place of work which decreases transport costs and emissions. improved neighbourhoods as urban sprawl is mitigated, decreased cost of providing infrastructure, more efficient use of operations and better economic access for all. Gill and Bhide (2012); Creutzig et al. (2012); CCT (2012)			Environmental Management Department; Media Office; Urban Planning and Design Department; Development Management Department	Budget for new climate resilient infrastructure (2.10); Urban density (2.5);

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Design and implement a Payment for Ecosystem Services (PES) regulatory system	Governance	Payment for Ecosystem Services (PES) create an incentive for the provision of specific ecosystem services which are not provided in the absence of the payment. In many cases, PES are highly dependant on state funding, thus there's a need to regulate the use of public funds to ensure that funds are not being misallocated or allocated to wealthier participants (iied, 2013). There is also a need for regulation to ensure funds received by participants are actually being used for ecosystem services. PES programmes are generally not a single economic instrument, but rather a policy mix as there have to be multiple policy instruments which work together. There is a need to formalise PES rules via regulation to make sure the correct parties are being benefitted from the investment.	PES can promote ecosystem conservation and regeneration. benefits people directly, through direct payments and potentially new jobs, and indirectly, for instance by promoting healthier ecosystems. Better provision of ecosystem services are essential to improving resilience to climate change, as well as being inputs to agriculture, generation of hydroelectricity, and the ecotourism industry. In situations where there are high profits of alternate activities, PES only helps ecosystem/ environmental conservation when regulation is strongly enforced (iied, 2013).	The restoration of natural environments and sustainable land use management can bring strong economic returns (TIPS, 2012). Economically, watershed restoration can provide between R116 – R220 per hectare, while only costing R21 – R88 per hectare per year (Blignaut et al., (2010) Landowners and communities face opportunity costs in foregoing certain economic activities to preserve and restore natural environments and that compensation is necessary to make these costs acceptable, particularly for the poor (TIPS, 2012).	The viability of any PES is affected by the states ability to enforce regulation. For instance, if the state is trying to protect a specific areas ecosystem, there has to be an enforcement of regulations to prevent people abusing the land and still receiving the payment. If this enforcement falls short, the ecosystem may be harmed and funds will be lost (iied, 2013), with minimal environmental or social benefits being accrued.	Environmental Management; City Manager; Development Management; Urban Integration; Transport; Treasury; Revenue; Recreation & Parks; Water & Sanitation	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries (2.2); Existence of climate resilience hub (6.1); River and wetlands health (2.1); Ecosystem health (5.3); Water resources availability (2.2); Ecosystem/vegetation type protection level; Percentage of biodiversity priority area (2.4)
Design a programme and incentives for affordable, safe energy solutions in all Low Income Households	Governance	Currently low income households generally cannot afford electricity, and so rely on cheaper forms of energy such as firewood and paraffin. These sources however are more volatile and can lead to	Decrease the energy poverty of low income households. More affordable energy solutions will also allow these households to spend less money on energy, allowing income to be spent elsewhere.	LPG gas is one of the cheapest safe solutions and costs around R24 per litre (DOE, 2019). This is much greater than paraffin (R7 per litre), so incentives will have to subsidise these costs.		Media; Environmental Management; Electricity Gen & Distribution; Water & Sanitation;	Equitable resource Availability; Increased energy and water conservation; Increased off grid solutions

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		fires – thus there's a need for safe, affordable energy solutions in these households. Options could include gas for cooking and lighting.	Safer energy solutions will mean less household fires and less damage to communities from these fires. Solutions such as gas or renewable energy are cleaner and emit less emissions than fires, which will alleviate much of the air pollution in low income settlements, which has further health benefits on locals. Also as these solutions are cleaner it will curb the emissions of low income settlements, mitigating against climate change. Also educational benefits as children can study at night.	In 2018 a typical solar PV unit cost between R16 and R24 per watt generated (including all equipment and labour) (SALGA, 2018).		Sustainable Energy Markets; Revenue	
Energy and water conservation	Behaviour	Sensitise and mobilise community and city-wide energy and water conservation practices through targeted community capacity building and engagement activities in areas where there is big potential for saving, as well as city-wide communications around the need for sustainable use of resources. Build on existing and past water and energy saving campaigns. Efforts should begin with existing activities and providing support to CBOs/NGOs/NPOs operational in this space (e.g. Friends of the Liesbeek River etc.), through sub council	Decreased consumption decreases pressure on scarce resources, improves social cohesion and community engagement, increases resilience of entire system to energy and water scarcities, reduces household (HH) spending on resources (Hussey and Pittock, 2012).	"CAPE TOWN - The campaigning of Day Zero has cost the City of Cape Town more than a million rand." Palm (2018)	Energy-efficient technology reduces the cost of production, often leading to more production (and more energy used) (Tierney, 2011). Similarly, with water conservation technology.	Media Office; Environmental Management Department; Sustainable Energy Markets Department; Water & Sanitation Department;	Level of electricity consumption (3.5); Percentage of water reused (2.4); Leadership and administrative capabilities (2.14); Strengthening the cities institutional capacity in building resilient economies; Partnerships between cities and NGOs

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		representation and relevant information campaigns to heighten the importance of building climate resilience.					
Financial incentives for sustainable water, energy and land use	Planning	Develop and implement incremental and innovative incentives for sustainable uses of water, land and energy. Aligned with the need to decouple municipal revenue from resource risk, these incentives will enable the uptake of resource efficient technology, which will contribute towards long-term system resilience through improved diversification. Some financial incentives for sustainable water, energy and land use include standards, pricing, grants, taxes, subsidies and broader information disclosure. For example, subsidies to renewable energy production would incentivise renewable energy production.	Improved sustainability of water, energy and land-use will improve the availability of these resources to be more equitably shared and managed to improve resilience across the City. Other benefits for the City could be an increase in revenue from the financial incentives, as well as a broader stimulation of new and innovative business activities.	Evidence supports the efficacy of financial incentives. For instance, "Policy choices have profound and long-lasting impact on the regulated industry affecting economic rent distribution among suppliers, consumers, the grid operator and the government. A good policy not only balances the effectiveness of the program and the incurred transaction costs but also provides correct market signals for short-run operations and long-run investment and planning… It could further require a regulatory reform to revise tariff structures, resulting in daunting transaction costs… To efficiently regulate carbon emissions in the power sector, a program that expands beyond the local or the regional scope to cover the whole power market is needed." (Chen, Zhang & Takashima, 2019).	Financial incentives bring the risk of negative public perceptions and the possibility of financial burden falling on the non-target groups (vulnerable populations). Penalties/incentives can distort existing markets and will preference certain industries over others.	Environmental Management Department; Electricity Generation and Distribution Department; Water and Sanitation Department; Sustainable Energy Markets; Revenue Department; Treasury Department	Financial incentives for improved climate resilient initiatives

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
Health related impacts of climate change research	Planning	Facilitate targeted research into the potential health related impacts of climate related disasters/hazards, as well as gradual health impacts resulting from climate stressors. The impacts should be assessed in relation to existing housing and sanitation standards and relative levels of exposure to climate change impacts.	Understanding potential health risks of climate change will allow for more targeted health infrastructure and capacity development and knowledge dissemination. Leading to improved health outcomes and reduced risks of widespread negative human health impacts - through proactive planning and preparation. A technical understanding of these risks will provide leverage for further funding opportunities and the development of specific health-related interventions.	A broad range of data is needed to monitor the climate effects on health. Many variables are already recorded by existing systems, and thus may only require access and cross-referencing. For others, new systems or changes to existing systems may be necessary. There also needs to be a combined meteorology aspect with health research - to correlate health findings with climate change. All forms of monitoring require procedures for standardisation, training and quality assurance. Linkage of multiple data sets covering meteorology, health, intermediate stages (e.g. vectors, pathogens) and effect modifiers (land use, control programmes) also will be important (WHO, Chapter 10, 2003)		Environmental Management Department; City Health Department	Partnerships for climate science are established and capacitated (2.12); Reported cases of climate change-induced diseases (5.9)
Household disaster risk preparedness planning	Behaviour	Targeted disaster risk preparedness planning sessions at community level to equip households with the understanding and knowledge of how best to respond to different disasters and what tools (i.e. social media, CCT DRM contacts, etc.) may be available. Use existing Family Disaster Preparedness Guidelines and take	Households can better respond and recover from drought, fire, flooding etc. Decreased economic and social impacts of hazards, improved social cohesion and community safety. Job creation, increase in savings, improved community connectedness and communication (Levac et al., 2012).	Cost effective solution - cheaper than reactive response (Kelman, 2013).	Wasted resources as a result of stockpiling, fear-mongering, withdrawal from community through desire to protect those closest to you. Maladaptation through misunderstanding of what successful	Environmental Management Department; Disaster Risk Management Centre; Media Office	Effective disaster response plans and communication systems during disasters (2.15)

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		advantage of existing community newspapers and information dissemination avenues.			planning is and realistic conceptions of actual risk (Jones et al., 2010).		
Increase uptake of sustainable electrification	Governance	The increased uptake of sustainable electrification will provide cleaner energy, reducing the carbon footprint of the electricity sector. Sustainable electrification refers to low-carbon and low-impact generation, affordable and safe distribution, and reasonable usage practices amongst others. A key method of increasing this is through small-scale embedded generation (SSEG). SSEG provides rural communities and impoverished areas with the potential to generate sustainable electricity without the need of formalised energy structures (PWC, 2016).	Sustainable electrification will reduce the energy sectors carbon footprint, helping the mitigation efforts of the country against climate change. Sustainable electrification, particularly decentralised solutions, will provide accessible and affordable electricity access for people, particularly in rural or impoverished areas where they cannot access formalised energy through the grid (PWC, 2016). Expanding the grid to many rural areas is not feasible, and thus mini-grids and SSEG are much cheaper options (PWC, 2013). The costs of renewable energy are also constantly falling.	The costs of Solar PV SSEG are projected to decrease over the next 5 years. (SALGA, 2018). Costs of wind power have fallen by 60% since 2009 and lithium iron batteries costs are also falling at around 10% a year (KPMG, 2017) In 2018 a typical solar PV unit cost between R16 and R24 per watt generated (including all equipment and labour) (SALGA, 2018)	A rapid transition to more sustainable electrification options could have serious revenue implications for the City if the transition is not effectively planned for and managed. Especially SSEG options, which might permanently decrease the revenue generation potential of the municipality from energy sales. This could have a number of knock-on impacts for other vulnerable sectors and regions.	Media; Environmental Management; Electricity Gen & Distribution; Water & Sanitation; Sustainable Energy Markets; Revenue	Percentage of renewable energy capacity (3.1) (3.2); Level of electricity consumption (3.5);
Mobile flood protection products	Infrastructure	Barriers, walls and/or devices that can be transported to areas vulnerable to flooding in advance of heavy rainfall and/or flooding events.	Protection from flooding, reduction in economic losses from flooding, prevention of loss of life. Mobility provides greater flexibility for the highly dynamic urban development	Tube Wall takes 1 hour to install and costs £31 800. A 1 metre height filled sandbag costs £115 600. A 0.5 metre height flood stop barrier costs	Time-consuming to install and labour intensive-logistically challenging especially in poorly	Environmental Management Department; Disaster Risk Management	Floodplains and flood-prone, exposed coastal zones are mapped and planned for (2.6); Climate-smart infrastructure planning and the integration of green and grey

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			and settlement patterns in CCT. Bramley and Bowker (2002); Chen et al. (2018)	£15 000 and takes 2 hours to install. A watergate costs £18 750 (100m x 1m high). An Aquafence takes an hour to install and costs £47 000 (Ogunyoye, Stevens & Underwood, 2011).	equipped areas- can't always be reliably deployed and consequently, not fully operational in time (Ogunyoye, Stevens & Underwood, 2011). Might result in poor evacuation responses during flood events.	Centre; Water and Sanitation Department	infrastructure (2.7); Budget for Disaster Risk Reduction; Risk Financing
Partnerships for trade-offs	Governance	Implement, facilitate and develop partnerships and associated strategies for managing trade offs of sustainable urban development. This includes partnerships with and between private, public and non-governmental organisations who are stakeholders in or managers of different City functions that will change with a revised revenue and development approach. This includes partnerships (i.e. PPPs) for integrated resources management and conservation. Develop professional and technical relationships with universities (e.g. School of Public Governance at Stellenbosch University) to provide support into partnerships and broader governance issues.	Partnerships will lead to improved buy-in, social and institutional cohesion, transparency and trust within and across the City. Sharing of knowledge and expertise will improve decision-making around complex trade-offs and ultimately maximise the benefits and minimise the costs of building resilience in a more equitable manner. A key benefit could be increased transparency of governance and private sector activities as they relate to climate resilience.	Partnerships with the private sector bring cost efficiency: “In these public-private partnerships the design is very much driven by government which integrates private components to implement policies or provide resources. In this approach, private actors are brought in the policy-making process for cost-efficiency reasons or for effectiveness reasons.” (Marx, 2019).	Partnership building, especially PPPs, can be resource and time intensive. Moreover, PPPs are risky public investments with a myriad of potential negative social, environmental and economic outcomes if not implemented effectively (Gondard et al. 2018).	Environmental Management Department; City Manager; Enterprise and Investment; Office of the Executive Mayor; Urban Integration	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries (2.2); Partnerships for climate science are established and capacitated (2.12); Partnerships between cities and NGOs; Collaborative and cross sectoral policy design, planning and review (2.13); Agreements between municipality and private power producers for renewable energy

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
Pollution control taxes and subsidies	Planning	Develop and implement incremental and innovative incentives and subsidies to control pollution, with a focus on water pollution and effluent discharge. These should be strategically structured to limit the impact on business while maximising the savings to be made in terms of water treatment (and other types of environmental amelioration, i.e. air quality, soil contamination etc.), noting that the underperformance of water treatment in the City is a big issue. A strong focus should be placed on the enforcement of penalties and the strategic use of different media to communicate these efforts.	Pollution taxes and subsidies will incentivise businesses and people to either pollute less or clean up better, both having the effect of reducing water and air pollution. Decreased water pollution will have a number of benefits, soil quality will improve, agricultural productivity will improve, health of locals who rely on water resources will improve, easier to treat less polluted water, reducing water treatment costs. Decreased air pollution which will lead to improved air quality – significantly improving local peoples health.	Different incentives: 1) Emission charges - businesses are free to pollute but will be charged per downstream emissions. Requires effective monitoring - but would be fairly cheap to implement 2) Pollution control subsidies - would be more of a cost to government as the subsidy would have to incentivise business to change polluting behaviour	Business risk - small businesses will likely suffer the most, given the implicit costs. This could lead to crowding out and higher unemployment. Financial incentives bring the risk of negative public perceptions and the possibility of financial burden falling on the non-target groups (vulnerable populations). Penalties/incentives can distort existing markets and will preference certain industries over others.	Environmental Management Department; Water and Sanitation Department; Revenue Department; Treasury Department; Scientific Services	Percentage of compliant water samples tested (5.2); River and wetlands health (2.1); Air quality index level (5.1)
Propose alternate options/pathways for devolution of management from National to Local Government	Governance	Overall management of critical services should happen at the lowest level where they function as a complete system (i.e. rail at metro level, water at catchment level). Devolved management will ensure local decisions are what is best for local people.	Devolved management of such critical infrastructure services will minimise the political economy barriers to effective service delivery and allow the City to mainstream climate resilient spatial and development planning in the management of these functions. Improved management of these essential services will bring about a plethora of economic, social and potentially environmental benefits (Bahl and Bird, 2013; Leigh and Lee, 2019),		Corruption and lack of capacity could derail these efforts. No guarantee that devolving management will result in greater efficiency- very dependent in each decentralised management unit- could lead to huge discrepancies across areas and	Transport; Urban integration; Property Management; Budget	Level of decentralisation of management of resources (2.3)

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			that will reduce vulnerabilities throughout the City. Also provides a greater level of accountability as people can more easily access decision makers.		greater inequality as a result. Risks of political disconnects that might influence resource allocations and ultimately impact climate resilience building efforts.		
Redesign revenue structures to disincentivise urban sprawl and unsustainable urbanisation	Governance	Current revenue structures in terms of land use perpetuate urban sprawl. Incentives for increasingly densified housing and service delivery development need to come through revenue structures. Revenue structures which could incentivise densification include Tax rebates for compliant developments (CCT, 2012) Tax Increment Financing, Subsidies for building densified housing buildings, Rights Bonuses (Aurecon, 2017), service charge rebates etc.	Planned, rapidly advanced densification will minimise climate change impacts on critical infrastructure (Temmer and Venema, 2017). Thus, attracting greater investment and serving more people in closer proximity. Strategic densification, planned with ecosystem management and restoration, and human mobilisation and settlement strategies, will help improve the quality of green and natural spaces in CCT, to counteract risks associated with greater population densities. Myriad co-benefits are associated with densification: decreased carbon emissions, greater economic productivity, shorter commutes to work, increased availability of affordable urban housing, decreased pressure on land-resources and the environment, improved (centralised) provision of essential services.		Densification can increase risks of climate hazards, e,g, fires, floods (Landauer et al. 2018). When hard surfaces replace green cover, pluvial flooding is more likely (Douglas et al., 2010).	Environmental Management; Revenue; Treasury; Water & Sanitation; Electricity Gen & Distribution; Development Management; Urban Integration	Urban density (2.5);

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Regional systems coordination	Governance	Develop and implement a cross-cutting institution tasked with regional coordination and management of systems beyond the City boundaries; integrated and sustainable food systems management; integrated and cooperative water resources management / catchment management; in-migration; rural-urban integration etc.	Improved regional management, coordination, cooperation and integration (facilitated through active institutional engagement and partnerships) will improve the cooperative management of broader resource systems (e.g. food and water) in the region. In this way, the benefits and costs associated with generating these essential resources can be shared more equitably and reduce conflict. Moreover, up-to-date regional development information is essential to consider in the City's development planning processes, most notably with regards to the movement of people and the management of food, water and energy systems that extend beyond the municipal boundaries of the system. (Timmerman and Bernardini, 2009; Leigh and Lee, 2019).	"the pace and scale of urbanization, climate change and the development of decentralized treatment technologies may shake up the established model of a single municipal water and wastewater utility, with significant implications for the way the sector is structured and regulated. In the future, elements of adaptive policy-making such as defining triggers for policy review and processes to institutionalise learning (Walker, Rahman, and Cave 2001) may be usefully integrated into economic regulation in the water sector." (Jensen, 2019).	Will only prove to be effective so long as there is political will and vested interest. Blockages and conflict are likely to arise, which might inhibit climate resilience building action.	Environmental Management Department; City Manager; Office of the Executive Mayor; Water and Sanitation Department; Urban Integration Department; Development Management Department	Knowledge and enforcement of ecosystem management beyond city's administrative boundaries (2.2); Existence of climate resilience hub (6.1); River and wetlands health (2.1); Ecosystem health (5.3); Water resources availability (2.2)
Renewable energy/ clean energy transport options and smart grids	Infrastructure	Roll out affordable and safe energy solutions, such as solar PV small-scale embedded generation systems (SSEG), to all low income households.	Solar PV SSEG will provide some, if not all, of low-income household energy needs in the day (and at night depending on battery storage capabilities). This will allow many households to 1) gain access to electricity, 2) cut down their current spending on electricity – resulting in decreased overall energy poverty. Renewable solutions also mean that the risk of fire will be much reduced as volatile forms of energy such as firewood and paraffin can be	The costs of Solar PV SSEG are projected to decrease over the next 5 years. In 2018 a typical unit cost between R16 and R24 per watt (including all equipment and labour) (SALGA, 2018)	New technology - requires correct installation and maintenance to ensure reliability. RE is not necessarily cheaper than conventional electricity supply. This combination may lead households to still rely on centralised electricity grids,	Environmental Management Department; Electricity Generation and Distribution Department; Sustainable Energy Markets	Percentage of renewable energy capacity (3.1) (3.2); Level of electricity consumption (3.5); Budget for new climate resilient infrastructure (2.10)

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			replaced. This will also lessen the air pollution generated from these energy sources.		leaving RE technology as stranded assets (Phuangpornpitak and Tia, 2013).		
Resilient and adaptive land use action plan	Planning	Develop and implement a short to medium term resilient and adaptive land use action plan to implement strategies for mitigating increased land competition – e.g. flexible use and shared resources. Public transport upgrading and upscaling; Use City-owned land to influence mixed use growth (e.g. schools as social hubs); pedestrianisation; rapid land settlement to avoid 'no-go' development areas. Facilitate dialogue between stakeholders who participate in the City's development to begin the buy-in process and sensitisation for densification and broader changes in land use. Scope best areas for densified mixed use development on transport corridors and outside flood zones (to be determined in light of the changing climate and urban space).	Reducing conflict over land-resources is essential to improving climate resilience, most notably in relation to providing affordable housing and improving the integration of land-use types in a densified manner. Benefits of an action plan: provides specific interventions within a given timeline and budget; identifies who is responsible for coordinating and implementing, etc. A co-created action plan improves buy-in and enables sustainable settlement within the City; leads to improved land-use planning; a greater focus on pedestrianisation of mixed-use zones, thus increasing safety, decreasing noise pollution, carbon emissions, parking space, etc.. Increased face to face interaction, increased opportunity to increase permeable ground cover. Improved air quality, increased physical activity (Soni and Soni , 2016; Creutzig et al. 2012).			Environmental Management Department; City Manager; Development Management Department; Urban Integration Department; Transport Department; Recreation and Parks Department; Water and Sanitation Department	Urban density (2.5); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7); Urban planning informed by R&V assessments (2.8); Household expenditure on transport per quintile (3.6); Non-motorised transport (NMT) paths as a percentage of the total municipal road network length
Resource Poverty and Resilience Policy	Governance	Develop policy to promote resource conservation AND simultaneously increase consumption to reduce resource poverty. Promote water conservation for uses	Addressing resource poverty, improving overall conservation of resources (through decreased consumption) will increase human resilience and adaptive capacity. Most notably, access to water and	Costs, and payback periods, are difficult to quantify and will vary per intervention: "The expected costs for resource conservation and		Environmental Management Department; Electricity Generation and Distribution	Water resources availability (2.2); Percentage of renewable energy capacity (3.1); Percentage of water reused (2.4); Percentage of renewable electricity available (3.2); Water use in litres per capita (2.9);

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		and in areas where water use is least socially, economically and environmentally beneficial. Increase water and energy system buffers to reduce risk, and build resilience through systematic diversification of supply systems, off-grid solutions and consumption management; control point of sale consumption of municipally provided services (Smart metering).	energy services will provide people with a myriad of co-benefits (improved health and sanitation, opportunity for economic development and jobs, access to early warning systems, etc.). Combining improved access with an overall conservation approach will foster resource sharing within the available/sustainable supply of these resources, thus moving away from the notion that money is the chief determinant of access to basic services. Increasing the buffers of available supply will make systems more resilient to shocks and stressors.	recovery programs can vary widely and depend on the size, location, scope, and technologies used for each program. It can be difficult to develop reliable estimates of expected costs for broad resource conservation and recovery technologies and strategies. Similarly, payback periods for projects will depend on the regional market for recyclables or compost or, in the case of source reduction, the local government's current waste management costs." (U.S. Environmental Protection Agency, 2012).		Department; Water and Sanitation Department; Media Office; Sustainable Energy Markets; Revenue Department	Percentage of households without connection having access to a source of water less than 200m from the dwelling (2.10) (3.5); Level of decentralisation of management of resources (2.3)
Revenue model reform	Governance	Review of current financial models (subsidies and risks) - analysis of possible alternative and innovative revenue streams, their future sustainability and feasibility. The review should begin with the development of a new conceptual framework for revenue generation, collection and expenditure, with explicit targets for future sustainability, to address poverty, inequality and unemployment (e.g. petrol/ diesel cars phased out by 2050, replaced by public transport). Review of Inert gas generator (IGG) system, e.g. application of Local	Diversifying the revenue streams supporting City functions will improve the financial sustainability of the City through systematic de-risking of the revenue model. If revenue streams face lower risks and are more predictable, this will improve the credit worthiness of the City and the ability of the City to invest in its citizens and the necessary infrastructure to adapt to climate change (amongst the other essential services that the City provides). (Chernick et al. 2011)	The costing of revenue model reform is very difficult to quantify. It is, however, acknowledged that the process to develop innovative financing alternatives are complex, nuanced, multi-faceted and will require the engagement of a wide range of stakeholders and methodologies. (South African Cities Network, 2017).		Environmental Management Department; Revenue Department; Treasury Department; Water and Sanitation Department; Electricity Generation and Distribution Department	Collaborative and cross sectoral policy design, planning and review (2.13); Level of electricity consumption (3.5); Water use in litres (2.9)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		Government Equitable Share (LGES) for building climate resilience. Review application of the Municipal Finance Management Act (MFMA) / Public Finance Management Act (PFMA) to determine entry points for change. Political economy analysis of possible winners and losers (vested interests); trade-offs, possible synergies and conflicts from possible changes in municipal revenue model.					
Review all existing governance and planning models and processes to ensure they do not impede resilience building objectives	Governance	There is a need for greater political alignment to improve climate resilience objectives. The current governance structures contribute towards siloed decision-making. There needs to be a cross cutting governance mechanism which promotes climate resilience across all sectors. Also need to remove existing barriers which impede resilience building interventions. These barriers range from financial, institutional, legal, political to	There are multiple benefits in promoting climate resilience through reviewing governance models and structures. Removing barriers to resilience building activities will assist the City with attracting more investment to finance various initiatives and contribute towards an improved enabling environment. This will reduce the overall administrative transaction costs associated with implementing climate resilience building activities and contribute towards maximising the benefits from the limited resources available.		Changes to governance models are highly susceptible to creating unintended consequences such as the creation of rent-seeking opportunities. Vested interests might push for certain arrangements to achieve objectives that are not necessarily aligned with the overarching objectives of the review. Changes need to be made incrementally and analysed in depth alongside key decision-makers and	Environmental Management; Revenue; Treasury; Water & Sanitation; Electricity Gen & Distribution; Development Management; Urban Integration	Collaborative and cross sectoral policy design, planning and review (2.13);

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					stakeholders to understand the possible shortfalls of proposed governance arrangements equally to the possible benefits.		
Review of existing by-laws and regulations	Governance	Reviewing by-laws and regulations in line with the social contract to prevent human exposure. Prohibit developments within revised flood/coastal set back lines; maintenance, restoration and protection of green infrastructure (e.g. buffer zones, concrete coverage on developments); design standards for housing (e.g. heat and cold stress, fire risk, adaptive design - passive cooling/heating); resource efficiency requirements on new developments (i.e. RWH and solar panels); open space standards (i.e.50% of plot permeable); zoning schemes (i.e. new developments to be zoned with consideration of CC impacts). Damp and heat proofing ensures better insulation of houses, and less heat absorption from roads.	Regulating construction will ensure new developments are more sustainable and address climate change risks more directly, align with social and environmental targets and stimulate long-term (sustainable) economic growth. Such regulations will stimulate sustainable business development to support the construction and development sector, improve environmental conditions, reduce impacts of climate change (e.g. extreme heat and rainfall) and increase resource use efficiency of new developments. (Snow and Prasad, 2011)	Adaptive housing design: Costs of different passive cooling systems: PCM cooler at €500, Natural Circulation System at €5 000 and Forced Circulation for €10 000-20 000 (INTERTEC, 2019).	Possibly increase the short-term costs of construction and development; transition time and period could increase the costs of housing and building in general. This could reduce the potential rate of housing development needed to improve climate resilience.	Environmental Management Department; Development Management Department; Urban Integration	Urban density (2.5); Floodplains and flood-prone, exposed coastal zones are mapped and planned for (2.6); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7); Urban planning informed by R&V assessments (2.8); Budget for maintenance of infrastructure (2.11)

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Revised Urban Densification Policy	Governance	Revise/extend the 2012 Densification Strategy: formalise & implement long-term approach to guide climate-resilient densification; promote mixed-use high densities in convenient walking distance of all high-capacity transport systems (except land for protecting ecological assets, agriculture, river/wetland corridors). Plan for human mobilisation, migration and development (in line with MSDF, BEPP) to facilitate rapid land settlement in suitable predefined locations; plan for future relocations to more sustainable locations. Prioritise settlements within 500m of work centres; or 1km where transport is good; integrate with service delivery functions. Increase rate of formal housing provision: create policy environment where urban poor can house themselves incrementally in densified areas, easily serviced.	Climate risk in CCT is largely a function of poor adaptive capacity and low resilience (e.g. poverty, inequality, lack of access to resources & services). Thus, planned, rapidly-advanced densification will minimise climate change impacts on critical infrastructure (Temmer and Venema, 2017), thus attracting greater investment, serving more people, in closer proximity. Strategic densification, planned with ecosystem management and restoration, and human mobilisation and settlement strategies, will help improve the quality of green and natural spaces in CCT, to counteract risks associated with greater population densities. Myriad co-benefits are associated with densification: decreased carbon emissions, greater economic productivity, shorter commutes to work, increased availability of affordable urban housing, decreased pressure on land-resources and the environment, improved (centralised) provision of essential services.	More densified cities are more cost effective, according to the Financial & Fiscal Commission (the Commission): "Using data from Johannesburg, eThekwini and Cape Town, the Commission constructed a model of a hypothetical city, which was used to compare the costs of a compact (or denser) city with the current reality. The study concluded that compact cities are considerably more efficient than the current sprawling form of South African cities, with savings to the state, households and environment. Over 10 years, a sprawling city will cost R57 billion more than a compact city, equal to 1.4% of projected GDP." (Financial and Fiscal Commission, 2011).	Densification can increase risks of climate hazards, e,g, fires, floods (Landauer et al. 2018). When hard surfaces replace green cover, pluvial flooding is more likely (Douglas et al., 2010). Increased pollution. Poorly-maintained low-income housing has potential to lead to high-rise slums, leaving people potentially more vulnerable to climate shocks and stressors. Low-income households could be forced to move away from transport nodes as household prices increase (forced resettlement far from employment; evictions without compensation) (Reckien et al. 2017).	Environmental Management Department; City Manager; Development Management Department; Urban Integration Department; Urban Planning and Design Department; Transport Department; Recreation and Parks Department; Solid Waste Management Department; Water and Sanitation Department; Electricity Generation and Distribution Department	Urban density (2.5); Household expenditure on transport per quintile (3.6); Percentage of commuters (city-wide) using private motorised transport (3.8); Percentage of households without connection having access to a source of water less than 200m from the dwelling (2.10); Percent of households with access to sanitation services (5.8); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7)
Risk insurance mechanisms	Governance	Policy to enable and facilitate re-insurance mechanisms (combined state and private). Includes research and assessment into possible	Insurance against climate risks will improve the adaptive capacity of insured populations and sectors, improving the ease of doing business and reducing investment	Costs associated with risk make premiums high: "… catastrophe cover can be exceptionally expensive since micro-insurers offering cover	Over time, adverse effects of climate change could threaten economic resilience and	Environmental Management Department; Treasury Department	Level of insurance cover; Number of cities major economic drivers/ commodities at risk; Risk financing

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		insurance options and quanta of risk related to climate change impacts across the City. Collaboration between private and public sector in managing climate risk is required, which includes the development of data sharing and communication channels between risk management sectors and CCT (partnerships).	risks. This will facilitate the growth of industries at high risk to climate change and mitigate the loss of jobs and business revenue due to climate change impacts. (Schaefer et al. 2016)	for co-variant risks face large, stochastic losses and thus must hold expensive capital reserves, diversify, or purchase reinsurance, all of which "load" or add to the premium. Moreover, providing insurance at a small scale can involve high transaction costs for reaching clients, estimating risks and handling claims. Because of these costs, and the return anticipated by insurers for entering high-risk markets, the premium on micro-insurance products and sovereign insurance instruments can greatly exceed expected losses." (Linnerooth-Bayer, J. & Hochrainer-Stigler, S, 2015).	financial stability [and] insurers are currently at the forefront – could result in lack of response & uninsurability. Additionally, too much money targeted towards climate impacts, will decrease funds targeted towards building resilience and could make insurance options too expensive for many people (Carrington, 2016).		
Riverine and wetland restoration	Infrastructure	Includes a variety of ecological, physical, spatial and management measures and practices such as river widening, weir removal, development of fish passes, restoration of natural vegetation, removal of artificial canalisation, etc. These are aimed at restoring the natural state and functioning of the river system (including wetlands) in support of biodiversity, recreation, flood management and landscape development. These efforts need to align with, build on	Contribution to sustainable regional development and tourism; carbon storage and climate regulation; Improved supply of fresh water (impact on human health and sustainable livelihoods); income generation; reduced vulnerabilities and improved nutrition from restored fish populations. Cost savings, e.g. from mitigated flood damage. Upstream wetland restoration and managed realignment to help increase water storage, planting of riparian trees to reduce water temperature. Can support key ecosystem services e.g.	Wetlands can be constructed, or natural. Costs are associated with restoration and maintenance. Restoring coastal wetlands is costly and sometimes impossible. Costs of a constructed wetland vary depending on drainage area treated and site constraints. Median cost approximately $3 000-$10 000 per impervious acre treated (EPA, 2012). As natural ecosystem services are cheaper than human-made systems, wetland restoration can be cost-effective (Alexander &	Can potentially increase existing stressors, e.g. actions that may lead to reduced water availability downstream may place further stress on already degraded water ecosystems (Barnett and O'Neill, 2010). Clearing and maintaining of green spaces along riverine corridors might promote dumping, land	Environmental Management Department; Water and Sanitation Department; Recreation and Parks department	River and wetlands health (2.1); Ecosystem health (5.3); Water resources availability (2.2); Ecosystem/vegetation type protection level; Percentage of biodiversity priority area (2.4)

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		and scale up existing activities such as CCT's various corridor management programs (CMPs) stemming from the sustainable Urban Drainage System (SUDS) strategy, as well as similar objectives outlined in the CCT resilience strategy.	flood/drought risk mitigation, aquifer recharge, nutrient retention; erosion prevention, air quality regulation, soil fertility and formation. Golfieri et al., (2017); Alexander and McInees (2012) Powell et. al. (2010); (Kabish et al. 2017) For temperature control; reduced human heat stress; benefits to biodiversity through mobility and habitat access; reduced air pollution. Recreational and well-being benefits; reduced demand for indoor climate controls (energy savings); preservation and creation of wildlife habitat. Kazmierczak and Carter (2010); CBD (2018)	McInnes, 2012). These are cost-effective approaches to urban challenges, because of multi-functionality, value and relatively low costs of implementation and maintenance. Other costs: Admin costs (e.g. surveys, research, consultation, planning); capital costs (e.g. land purchase, compensation payments, ongoing operational costs (McNeil & Rayment, 2015).	invasion and/or pollutant runoff.		
Rural-to-urban migration research and forecasting	Planning	Facilitate targeted research into the impact of rural-urban migration and forecasting to inform spatial planning, densification and rapid settlement planning.	A more detailed understanding of the current and future regional and local migration patterns will assist development and settlement planning to maximise the benefits of investment in development. This will have numerous benefits relating to improved standards of living, access to services/ resources etc.	“By 2055 estimates indicate that 75 percent of the world population will live in urban areas, highlighting the importance of promoting low cost policy decisions providing greatest environmental benefit, with short implementation timescale.” “Results from the study also identified appropriate policies to improve sustainability of each settlement. Policies which this study identified as generally applicable to enhance small and medium Irish settlement sustainability,		Urban Integration Department; Urban Planning and Design Department; Office of the Executive Mayor; Urban Integration	Partnerships for climate science are established and capacitated (2.12); Percentage of newly subsidised housing units in brownfield development (6.2)

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				in a low cost and timely manner are: Eco-driver training provision, Reduction in standby energy use, Enhanced solar water heating technology uptake, Waste prevention campaign organization, Higher rates of low water use fixtures." (Fitzgerald, O'Doherty, Moles and O' Regan, 2014).			
Social Media Campaign & EWS	Behaviour	Develop EWS with communities to educate and sensitise citizens to forecasted hazardous events, to improve community and system disaster response. Social media platforms can be used to educate people to increase climate change awareness and provide targeted EWS to improve disaster response.	People are able to access targeted adaptation information through social media, which increases awareness of risks. People are able to access disaster related information timeously and directly through their phones. This enables quick and efficient action in response to disasters. Improves social cohesion and combined disaster response efforts. EWS has the potential for disaster detection as well as warning, Can be used to develop real time crisis maps, damage detection and help to better understand of impact which canhelp emergency services to locate people in real-time. Chatfield and Brajawidagda (2012); Sakaki et al. (2010); Middleton, Middleton and Modafferi (2010); Avvenuti et al. (2016).	Using social media is a cost effective solution for disaster response and early warning for disasters, in comparison to large-scale systems (Chatfield and Brajawidagda, 2012; Middleton, Middleton and Modafferi, 2010). As a form of communication, social media has very few costs and the potential to reach a very large audience. It is also remarkable in its ability to create communities, or networks, of people with shared interests and a common purpose (Berry & Weigeldt, 2012).	Crowd sourcing information spread provides an opportunity for misinformation to spread (Chatfield and Brajawidagda, 2012). Uncertainty in climate forecasting might lead to distrust of institutional warnings and loss of credibility, meaning less people will respond to early warning messaging.	Environmental Management Department; Disaster Risk Management Centre; Media Office	Effective disaster response plans and communication systems during disasters (2.15)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
Solid Waste Management	Infrastructure	All parts of the City need to be 'clean and green', implying vastly improved waste reduction. Reduce waste inputs. Increase levels of recycling. Reuse. Waste-energy conversion. Reduce wet waste disposal. Institute incentives and disincentives for poor waste handling and production. This involves a variety of modalities ranging from waste collection, storage and processing infrastructure all the way to community driven clean-ups.	Clean environment. Lower health challenges and therefore costs. Lower disease potential (in the face of rising temperatures), I.e. outbreaks of diarrhoea in high temperature months when fly infestations cause infections, esp. in areas of poor sanitation and hygiene. 'Clean and green' is revenue positive; an attractive city is city with rising property rates. Tourist potential increases as the city is preferentially seen as a clean environment.	Costs of improved solid waste management vary significantly in relation to the modality of implementation. Large waste management facilities, including anerobic/aeobic digesters that convert waste to energy etc. together with waste collection trucks are generally very expensive investments to roll out over a short period of time. However, community pollution/waste management schemes and activities can have no costs.	There is little risk of maladaptation with regards to improving solid waste management.	Solid Waste Management Department; Environmental Management Department; Recreation and Parks Department; Budget Department; Treasury Department	Ecosystem health (5.3); river and wetlands health (2.1), water resources availability (2.2),
Sustainable and equitable densification incentives	Planning	Develop and implement incremental and innovative incentives for sustainable and equitable urban compaction and housing development. Aligned with revised by-laws and broader City business incentives (e.g. building on incentives such as the National Urban Development Zone Tax Incentive Scheme), these should focus on incentivising mixed use development, along key transportation corridors (aligned with MSDF) and to provide low income housing through incremental densification. These should be structured in a way to disincentivise settlement and/or development within	Various incentives for sustainable and equitable densification will increase the rate of change towards a densified development model and spur new business opportunities relating to sustainable development and construction. These interventions may bring in alternative revenue for the City and help to limit settlement on uninhabitable land, amongst others. The multiple indirect benefits associated with the resulting changes in behaviour and/or infrastructure development patterns will create a long-term sustainability dividend for the City (Grieg-Gran, 2002), which will limit impacts of climate change in the long-run by improving living standards, the ease of doing business, etc.	Social housing/ development is unattractive to investors, so government financial support/ incentives would be needed (Central Densification Plan 3A, eThekwini, 2017).	Could decrease business interest in housing development. Socio-cultural standards and norms associated with low-income housing expectations in South Africa might be in conflict with urban compaction incentives (despite these being 'pro-poor' in nature as they advocate for increased low-income housing development and mixed-use development). Social and industrial	Environmental Management Department; City Manager; Development Management Department; Urban Integration Department; Transport Department; Recreation and Parks Department; Budget Department; Treasury Department	Financial incentives for improved climate resilient initiatives; Percentage of renewable energy capacity (3.1); Percentage of water reused (2.4); Urban density (2.5); Income distribution (6.7)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
		flood lines and hazardous areas. Some incentives include standards, pricing, grants, taxes, subsidies and broader information disclosure.			action might inhibit urban compaction and low-income housing development, leaving people vulnerable to climate risks.		
Sustainable Urban Drainage Systems (SUDS)	Infrastructure	A collection of water management practices that align modern drainage systems with natural hydrological processes. Includes permeable paving, retention ponds, artificial and natural wetlands, bioswales and green roofs. Moreover, current drainage systems need to be maintained to limit and prevent blockages (closely linked to solid waste management).	In addition to attenuating flood peaks, SUDS contribute towards improved groundwater infiltration and provide recreational benefits, emergency water supplies for firefighting, improved control of system drainage / runoff, opportunity to use stormwater productively in a decentralised manner. Scholz and Grabowiecki (2007), Davis and Naumann (2017). Stormwater management -(green roofs can reduce peak runoff by up to 65%, and 90% for storms less than one inch). Wetlands can create natural habitats; Green roofs reduce energy use and costs (reduced emissions); mitigate urban heat island effect; can cut building electricity consumption by 2-6% for summer cooling . Green roofs can limit noise pollution and increase property values. Both white and green roofs make cities more comfortable (social benefits).. Can create a more aesthetically pleasing urban landscape;. Indigenous vegetation.	Installation of permeable pavement: $0.10-$6/square foot, with a service life of 7-35 years (Foster, Lowe & Winkelman, 2011). Retention ponds: construction and land acquisition costs vary. Creating a retention basin typically costs $0.50-$1/cubic foot. Constructed wetlands assumed to be 25% more expensive. Erosion and sediment control represents 5% of construction cost (EPA, 1997). Green Roofs: More expensive to install than conventional roof. Potential benefits and costs increase with a thicker soil layer Sproul et al. (2014); Mahdiyar et al., (2016). Green roofs can be either intensive or extensive, with different costs. Annual maintenance costs vary, but generally 2-3% of construction per year after vegetation established (Foster, Lowe & Winkelman, 2011). Green Walling: high design,	Stormwater ponds - routing runoff contaminated with road salts to stormwater ponds can result in highly contaminated groundwater moving from the ponds to streams. Constructed wetlands are susceptible to disease and predators - have lifespan limits and are costly to maintain (Virginia Tech, 2017). If SUDS are designed to try and manage stormwater from other sites instead of replacing impervious areas, this may result in excess runoff volumes.	Environmental Management Department; Development Management Department; Water and Sanitation Department	Budget for new climate resilient infrastructure (2.10); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7);

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			Sproul et al. (2014); CBD (2018)	construction, operation and maintenance costs (iWater Toolsheet). Average cost of installation with plants: $195-$265/square foot (Architek, 2019).			
Sustainable urban green spaces	Infrastructure	Equitably distributed and sustainably managed green spaces across the City, including nature reserves, green belts, parks, vegetation buffer zones, etc. Includes the restoration of polluted or hazardous land through indigenous re-vegetation and other bioremediation and clean-up activities.	Strong benefits in terms of increasing City aesthetics and broader liveability. Mitigate urban heat island, balancing water flows, runoff and groundwater recharge, carbon sequestration and storage. Mitigate environmental degradation caused by urbanisation. Reducing energy costs of cooling nearby buildings, improve local quality of life, create environments for biodiversity and recreation areas. Roy, Byrne and Pickering (2012); Haq (2011); Orru et al. (2014)	Costs: acquisition, development (design, construction) and maintenance. Will vary depending on characteristics, e.g. size, location, ownership, etc. (Tempesta, 2015). In general, maintenance costs are 85-95% of total cost (McPherson et al., 2005). One study found maintenance costs of, on average, 1.10 Euro per m^2 in Veneto region (Venice). In 15 UK parks, the average maintenance cost was 0.28 - 1.34 Euro per m^2 (Tempesta, 2015). <u>Revegetation:</u> Australian case studies: (1) revegetation of 0.25 hectares over two years: $150.50 per m^2. Costs include labour (seed collecting, planting, weeding), buying seedlings, use of equipment. (2) Rehabilitating 100 m^2 of riverbank cost $4 638, for labour, equipment and seedling costs (Taman, 1999).	Can lead to increased housing costs and property values - which can lead to gentrification and the displacement of local residents to less resilient locations (including informal settlements etc.). May impose health costs (such as asthma, allergies) and can create hazards (windthrow). Clearing and maintaining of green spaces might promote dumping, land invasion, crime and/or pollutant runoff. Wolch, Byrne and Newell (2014) Roy, Byrne and Pickering (2012)	Environmental Management Department; Recreation and Parks Department; Urban Integration Department; Development Management Department	Ecosystem health (5.3); Ecosystem/vegetation type protection level; Percentage of biodiversity priority area (2.4); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7)

Adaptation Option	Type	Description	Benefits and Co-Benefits	Costs	Maladaptation Potential	Potential Actors	Relevant Indicators
Tree planting and implementation of Nature Based Solutions such as water sensitive urban planning	Infrastructure	Strategically targeted planting of trees throughout the City, at scale, and prioritised in areas with less green infrastructure. The most applicable tree species will not be indigenous to the Fynbos biome, thus it is essential to ensure sound planning and research in advance to minimise any biodiversity or invasion threats to the Fynbos biome and the natural green spaces around the City.	Trees moderate temperatures (reduce urban heat island effects), windspeeds at ground level and contribute towards storm water control. Other benefits/co-benefits: Job creation, improved City aesthetics and related property prices, air pollution reduction, habitat for biodiversity, carbon storage and sequestration, water quality amelioration and improved groundwater recharge (Pramova et al., 2012; Kabish et al. 2017).	Primary costs of planting and maintaining include purchasing seeds/saplings, pruning, pest and disease control and watering. Costs will vary depending on species, location and climate zone. Chicago case study estimates $50-$500 per tree to establish. Five-city case study estimates $15-%65 per tree maintenance costs (Foster, Lowe & Winkelman, 2011).	Possibility of increasing risks from fires and wind/storms if not managed (trees can blow over/ catch alight). Health impacts from pollen dispersion. (Salmond et al, 2016). Planting trees alien to the area will require vast amounts of water. Trees can fall over and damage property/harm people.	Environmental Management Department; Water & Sanitation; Development Management; Recreation and Parks Department	Ecosystem health (5.3); Percentage of biodiversity priority area (2.4); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7)
Uptake of decentralised renewable energy and water supply systems	Behaviour	Sensitise people to, and mobilise the uptake of, decentralised renewable energy and water supply systems such as household rainwater harvesting systems, solar panels, wind energy. Includes all points of use, point of entry and small scale systems. Educational and communication campaigns, information and knowledge products, etc. Continue where the work left off at the end of the Western Cape drought (2015-2017), with a renewed focus on long-term sustainable	Decreases grid consumption and dependence on grid, increases resilience, increases total supply. Creates jobs, increased engagement with source of energy/water which increases value placed on service, relieves some supply constraints on centralised resource provision. Energy and greenhouse gas (GHG) emissions (decentralised water) through decreasing runoff. Energy: systems are modular and can respond to different contexts, innovations in technology are easily adopted incrementally, less path dependency. Sharma et al. (2013);	Renewable energy is increasingly cost competitive as a service, especially in comparison to nuclear and coal (Hermanus, 2017).	Risks of increased costs - reduced trust in government and City institutions - poor economies of scale and financial feasibility. Ineffective installation could disadvantage low income households as they are unable to afford maintenance. In event of disaster, inequality increases as the rich have better access to	Environmental Management Department; Electricity Generation and Distribution Department; Water and Sanitation Department; Media Office; Sustainable Energy Markets; Revenue Department	Percentage of renewable energy capacity (3.1), river and wetlands health (2.1), water resources availability (2.2), New businesses are created in secondary economic hubs/nodes to promote decentralisation (4.4), Agreements between municipality and private power producers for renewable energy

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		consumption.	Pain (2019); Spatari et al. (2011) Hermanus (2017)		these services. Over-abstraction of ground water from solar PV-based pumping systems. Quezada et al. (2014) IRENA (2014)		
Valuation of ecosystem services research	Planning	Facilitate further research into the economic valuation of key ecosystem services, as aligned with the ongoing Green Infrastructure Planning work. Through this, the aim should be to identify innovative and benefit-enhancing/cost-minimising investments in ecosystem restoration, maintenance and protection that complement ongoing efforts. A strong focus of this work needs to be on integrating existing and new research into policy-making and budgeting processes.	Having an integrated/extensive understanding of the value of ecosystem services in relation to alternative methods of providing these services will facilitate improved planning and decision making that can maximise the benefits (and minimise the costs) of balancing green and grey infrastructure development.	While research indicates net benefits, our results provide only partial estimates of benefits at one point in time and reflect the lower limit of the welfare benefits of ecosystem restoration because both scarcity of, and demand for ecosystem services is increasing and new benefits of natural ecosystems and biological diversity are being discovered. Nonetheless, despite incomplete information, the majority of the restoration projects we analysed provided net benefits and should be considered not only as profitable but also as high-yielding investments." (De Groot, et al, 2013).	Political and business interests could inhibit and skew investment into strategic (and not necessarily optimal) ecosystem services, resulting in suboptimal outcomes. Outcomes for this intervention, and which ecosystems will be targeted, are also dependent on who undertakes this research, as bias is inherent.	Environmental Management Department; Treasury Department	Partnerships for climate science are established and capacitated (2.12); Ecosystem health (5.3); Ecosystem/vegetation type protection level
Wastewater reuse and stormwater harvesting	Infrastructure	Construct new and retrofit existing wastewater reuse and recycling systems for improved performance of water treatment and reuse. Improvement of stormwater harvesting infrastructure from collection systems to storage,	Improves drought resilience through overall increase in water availability in the system (i.e. system augmentation), reduced water pollution and improved quality, improved environmental conditions, positive health impacts, potential to provide natural	<u>Wastewater Reuse:</u> Treatment system using a constructed wetland: about $5/gallon of capacity; i.e. roughly half the cost of conventional facilities (Foster, Lowe & Winkelman, 2011). The Greenfields Scheme cost	Incorrect water treatment of harvested stormwater can lead to unintended consequences and polluted water sources - e.g.	Environmental Management Department; Water and Sanitation Department; Development Management	Budget for new climate resilient infrastructure (2.10); Climate-smart infrastructure planning and the integration of green and grey infrastructure (2.7); Percentage of water reused (2.4)

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		treatment and redistribution. Should be aligned with practices outlined in the 2019 CCT Water Strategy (including key aspects such as managed aquifer recharge).	habitats and open spaces for communities. Possibility of large-scale impacts such as increased investor confidence and business activity due to decreased drought risk. Luthy et al. (2019); Rohre and Armitage (2017)	£2 million (grey water recycling with low-flush toilets, water efficient taps, underground rainwater storage) (Shaw, Colley & Connell, 2007). Stormwater harvesting: Water treatment costs; low cost treatment devices can be used e.g. slow sand filters; underground storage relatively more expensive than equivalent above-ground storage (Rohre & Armitage, 2017). Capital costs of creating a stormwater wetland: $1-$2/ cubic foot of storage provided (NOAA). Community resource centre, London: £3 million, stores storm water as irrigation system (Shaw, Colley & Connell, 2007).	chlorination as a method of disinfection can have harmful effects on plants if the water is used for irrigation purposes (Rohre and Armitage, 2017).	Department	