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Sustainable Asset Valuation (SAVi) of Paterson Park's Building Infrastructure:

City of Johannesburg (South Africa)

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The **International Institute for Sustainable Development (IISD)** and **KnowlEdge Srl** have worked on integrating climate data from the Copernicus Climate Data Store (CDS) to improve the analysis of infrastructure projects performed with SAVi. The project serves to demonstrate the importance and usability of climate data generated through the CDS products in deploying sustainable infrastructure projects to contribute to a climate-resilient, low-carbon economy.

The assessment of the Paterson Park's Building Infrastructure is one of the use cases for demonstrating the value of integrating climate data of the Copernicus database into SAVi.

Acknowledgements

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About the Sustainable Asset Valuation (SAVi)

SAVi is a simulation service that helps governments and investors value the many risks and externalities that affect the performance of infrastructure projects.

The distinctive features of SAVi are:

- Valuation: SAVi values, in financial terms, the material environmental, social, and economic risks and externalities of infrastructure projects. These variables are ignored in traditional financial analyses.
- Simulation: SAVi combines the results of systems thinking and system dynamics simulation with project finance modelling. We engage with asset owners to identify the risks material to their infrastructure projects and then design appropriate simulation scenarios.
- Customization: SAVi is customized to individual infrastructure projects.

For more information on SAVi: www.iisd.org/savi

About Copernicus Climate Data Store

The European Commission has charged the European Centre for Medium-Range Weather Forecasts (ECMWF) to implement the Copernicus Climate Change Service (C3S). The main goal of C3S is to deliver high-quality data to support climate change adaptation and mitigation policies (ECMWF, 2017). One of the main features of C3S is the Climate Data Store (CDS), which delivers current, past, and future climate indicators. The CDS contains historical climate observations, Earth observation datasets, global and local climate projections, seasonal forecasts, and global and local climate analyses (ECMWF, 2017).

Data obtained from the CDS Toolbox include location-specific, historical, and future weather indicators, such as precipitation and temperature. Historical data (ECMWF Reanalysis 5th generation [ERA5]) and projections (Coupled Model Intercomparison Project Phase 5 [CMIP5]) are available for consultation and download in the CDS. Selected indicators are also accessible through a dedicated online app created to facilitate the exchange of information between the CDS and several SAVi models. The SAVi tool uses climate information to estimate damage resulting from extreme weather events and climate trends, establish the value addition resulting from improved adaptive capacity, and calculate the supply and demand of ecosystem services (Bassi et al., 2020). For example, through the integration of data on precipitation, evaporation, and crop water requirements into the SAVi model, it is possible to evaluate current and future water supply in a specific landscape and inform planning for irrigation infrastructure (Bassi et al., 2020).

The Integration of Climate Data into the SAVi Model (Bassi et al., 2020) outlines the integration of authoritative Copernicus climate data from the CDS into the SAVi tool. It describes how several climate indicators obtained from the CDS were integrated into SAVi and how its analysis has improved as a result. In light of this integration, the International Institute for Sustainable Development can generate sophisticated SAVi-derived analyses on the costs of climate-related risks and climate-related externalities.

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Executive Summary

The Paterson Park Precinct project is part of Johannesburg's Corridors of Freedom Initiative, which seeks to improve social cohesion within the urban environment. Buildings (social housing, sports facilities, and a recreational centre) are a core component of this project.

The project is also part of the Global Environment Facility (GEF) Sustainable Cities Impact Program, which promotes holistic urban planning to maximize environmental and social benefits and to avoid negative trade-offs.

The City of Johannesburg's Development Planning Department requested a comparison of the buildings of the Paterson Park project with greener and climate-resilient building designs.

The Sustainable Asset Valuation (SAVi) application includes an economic and financial valuation of the Paterson Park Project – Buildings, a comparative economic and financial valuation of a building with higher energy and water efficiency requirements, and a simulation of these values under different climate scenarios.

The Copernicus Climate Change Service (C3S) data that was used for this assessment includes precipitation patterns, temperature changes, and heating and cooling degree days.

Three messages arise from the results of the SAVi assessment:

- Over the life cycle of buildings, there are significant cost savings in energy and maintenance expenditures for green buildings.
- Climate change has the largest impact on the cost of energy expenditures, both under Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios. It also increases the cost of greenhouse gas emissions further under both climate scenarios, and this is the case in both the business-as-usual and green building scenarios.
- Solar power generates a positive return on investment and is a worthwhile investment for buildings in South Africa, especially taking into account the rising electricity prices.

Table ES1. How decision-makers can use this analysis

Stakeholder	Role in the project	How will the stakeholder use the results of the assessment with C3S data?
City of Johannesburg	Design and oversight of the precinct project.	• To make better decisions on urban planning and climate adaptation. • To inform the design of the next-generation (green) building standards. • To ensure future buildings are green, low carbon, and resilient to changing climates.
United Nations Environmental Programme (UNEP)	Coordinator and supervisor of several project components of a GEF-funded project, including the eco-district pilot in Paterson Park Precinct.	• To showcase the value of green buildings for reducing costs for the city and enhancing overall environmental regeneration and resilience. • To use the SAVi outputs as evidence to inform and design other urban projects. • To raise awareness on how climate data can be integrated into urban planning and the design of green and resilient buildings.
Global Environment Facility (GEF)	Main donor for the design, assessments, and implementation of several eco-districts in Johannesburg, including the Paterson Park Precinct.	• As quantitative evidence for the GEF that funding of green buildings is aligned with their objectives to promote environmental sustainability and climate change adaptation. The latter is implemented through the GEF's Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF). • To appreciate the valuations on low-carbon and resilient buildings. • To make a market for and build expertise on low-carbon and resilient cities by implementing eco-districts. • To define funding priorities for resilient cities.

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Glossary

Causal loop diagram: A schematic representation of key indicators and variables of the system under evaluation that shows the causal connections between them and contributes to the identification of feedback loops and policy entry points.

Discounting: A finance process to determine the present value of a future cash value.

Feedback loop: "A process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself" (Roberts et al., 1983).

Indicator: Parameters of interest to one or several stakeholders that provide information about the development of key variables in the system over time and trends that unfold under specific conditions (United Nations Environment Programme [UNEP], 2014).

Internal Rate of Return (IRR): An indicator of the profitability prospects of a potential investment. The IRR is the discount rate that makes the net present value of all cash flows from a particular project equal to zero. Cash flows net of financing give us the equity IRR.

Methodology: The theoretical approach(es) used for the development of different types of analysis tools and simulation models. This body of knowledge describes both the underlying assumptions used as well as qualitative and quantitative instruments for data collection and parameter estimation (UNEP, 2014).

Model transparency: The degree to which model structure and equations are accessible and make it possible to directly relate model behaviour (i.e., numerical results) to specific structural components of the model (UNEP, 2014).

Model validation: The process of assessing the degree to which model behaviour (i.e., numerical results) is consistent with behaviour observed in reality (i.e., national statistics, established databases) and the evaluation of whether the developed model structure (i.e., equations) is acceptable for capturing the mechanisms underlying the system under study (UNEP, 2014).

Net benefits: The cumulative amount of monetary benefits accrued across all sectors and actors over the lifetime of investments compared to the baseline, reported by the intervention scenario.

Net present value (NPV): The difference between the present value of cash inflows net of financing costs and the present value of cash outflows. It is used to analyze the profitability of a projected investment or project.

Optimization: A stream of modelling that aims to identify the policy or set of policies that deliver the best possible outcome from a set of alternatives, given a set of criteria (i.e., parameters to optimize) and/or constraints (i.e., available budget) (UNEP, 2014).

Representative Concentration Pathways (RCPs): "The Representative Concentration Pathways (RCPs) describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. The RCPs have been developed using Integrated Assessment Models (IAMs) as input to a wide range of climate model simulations to project their consequences for the climate system" (IPCC, 2020).

Scenarios: Expectations about possible future events used to analyze potential responses to these new and upcoming developments. Consequently, scenario analysis is a speculative exercise in which several future development alternatives are identified, explained, and analyzed for discussion on what may cause them and the consequences these future paths may have on our system (e.g., a country or a business).

Simulation model: Models can be regarded as systemic maps in that they are simplifications of reality that help to reduce complexity and describe, at their core, how the system works. Simulation models are quantitative by nature and can be built using one or several methodologies (UNEP, 2014).

Social cost of carbon: The economic cost caused by an additional tonne of carbon dioxide emissions or its equivalent through the carbon cycle (Nordhaus, 2017).

Stock and flow variables: "A *stock* variable represents accumulation and is measured at one specific time. A *flow* variable is the rate of change of the stock and is measured over an interval of time" (UNEP, 2014, p. 51).

System dynamics: A methodology developed by J. Forrester in the late 1950s (Forrester, 1961) to create descriptive models that represent the causal interconnections between key indicators and indicate their contribution to the dynamics exhibited by the system as well as to the issues being investigated. The core pillars of the system dynamics method are feedback loops, delays, and non-linearity emerging from the explicit capturing of stocks and flows (UNEP, 2014).

Vertical/horizontal disaggregation of models: Vertically disaggregated models contain a high level of detail on the sectoral level (i.e., energy), while horizontally disaggregated models focus on capturing the interconnections between several sectors and contain less detail on the sectoral level (UNEP, 2014).

List of Abbreviations

BAU	business as usual
C3S	Copernicus Climate Change Service
CBA	cost–benefit analysis
CDS	Climate Data Store
CLD	causal loop diagram
CMIP5	Coupled Model Intercomparison Project Phase 5
CO_2e	carbon dioxide equivalent
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	ECMWF Reanalysis 5th generation
GEF	Global Environment Facility
GHG	greenhouse gas
IRR	internal rate of return
NPV	net present value
O&M	operation and management
PV	photovoltaic
RCP	Representative Concentration Pathways
SAVi	Sustainable Asset Valuation tool
UNEP	United Nations Environment Programme

1 Introduction

Paterson Park Precinct is a master project that is part of the Johannesburg Corridors of Freedom. The upgrade of the area aims to create an urban environment that promotes social cohesion. The project consists of retrofitting old buildings, as well as building new facilities. The Paterson Park project is also part of the Global Environment Facility (GEF) Sustainable Cities program,[1] which promotes holistic urban planning to maximize environmental and social benefits, aiming to avoid negative trade-offs. The Paterson Park project includes two components:

- A stormwater facility and open space (link to other SAVi assessments).
- A buildings component consisting of a new library, swimming pool, sports facilities, and the retrofitting of a multi-purpose recreation centre.

This SAVi assessment focuses on the second component. The International Institute for Sustainable Development worked with the City of Johannesburg to evaluate and compare the current upgraded and new buildings with greener and more climate-resilient building designs.

The Copernicus climate data helps us understand how climate change impacts the City of Johannesburg and the building project. The data that were used for this assessment include precipitation, temperature change, and heating and cooling days.

The data and climate scenarios have been integrated into the customized SAVi model for the buildings of the Paterson Park project. The buildings assessed include an administrative building, a pool, a gym, and a library. The SAVi assessment evaluates the economic performance of the current buildings and compares it to a greener, more climate-resilient project under different climate scenarios.

[1] See more about the Sustainable Cities program here: https://www.thegef.org/topics/sustainable-cities

2 Methodology: SAVi Paterson Park – Buildings

2.1 Systems Thinking and System Dynamics

The underlying dynamics of the Paterson Park building project, including driving forces and key indicators, are summarized in the causal loop diagram (CLD) displayed in Figure 1. The CLD includes the main indicators analyzed during this SAVi assessment, their interconnections with other relevant variables, and the feedback loops they form.

The CLD illustrates the interconnections of the economy and environment while highlighting key dynamics and potential trade-offs emerging from different scenarios envisaged for the Paterson Park project. The CLD is the starting point for the development of the mathematical stock and flow model.

2.2 CLD

The SAVi Buildings model provides a blueprint for discussions on risks, benefits, and climate impacts of building projects (Bassi et al., 2017). For this assessment, we have adjusted and customized the CLD for the Paterson Park buildings. Figure 1 presents the CLD of the basic dynamics that underlie the analysis of the building project.

To design solution-oriented and effective interventions, CLDs need to capture the causal relations of a system correctly. Therefore, CLDs establish causal links between variables by linking them with arrows and attributing a sign to the arrow (either + or −) that indicates whether a change in one variable generates a positive or negative change in the other.

- “A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction.
- A causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction” (Bassi et al., 2016).

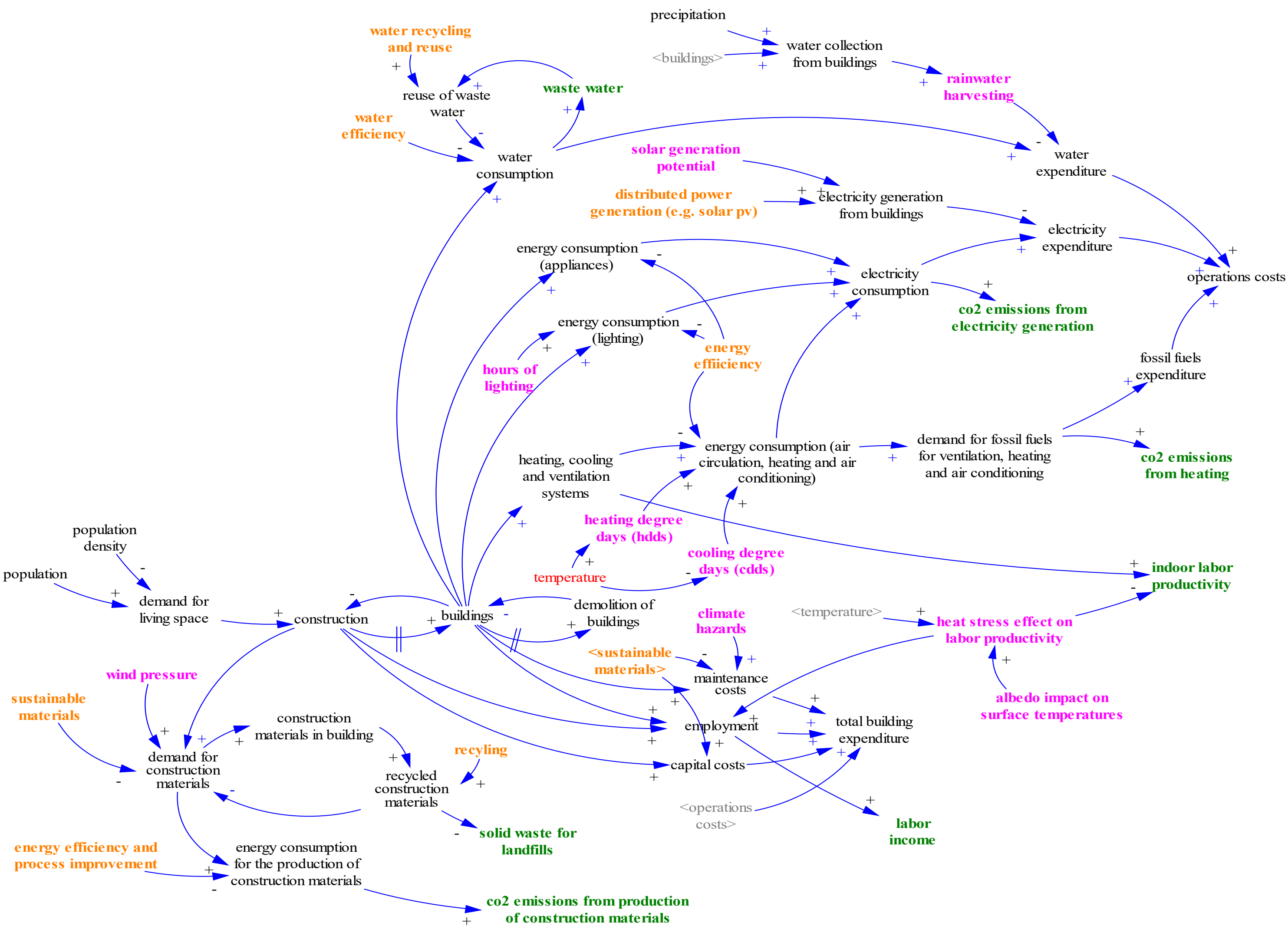
Table 1. Causal relations and polarity

Variable A	*Variable B*	*Sign*
↑	↑	+
↓	↓	+
↑	↓	-
↓	↑	-

Moreover, these causal interactions can form what is known as a positive or negative "feedback loop" (Forrester, 1961). In other words, an intervention made in that system can support the tendency toward an equilibrium within the overarching system, in which case this negative feedback loop is called a balancing loop. Alternatively, an intervention can reinforce the intervention's impact and hence create a positive feedback loop, which is called a reinforcing loop (Bassi, 2009; Forrester, 1961). What makes CLDs useful for decision-makers and other stakeholders is this feedback component, showing how the different elements within a system interact with each other and either exacerbate or ameliorate a given situation (The Economics of Ecosystems and Biodiversity, 2018). These mapped relationships may not necessarily indicate linear behaviour, and potential impacts may be delayed, which is why a CLD that captures the extent and complexity of this system is important. The interaction of feedback loops may also be where the source of a given policy problem lies, and therefore where decision-makers will need to direct their efforts for finding a solution—along with being aware of how this solution will affect the rest of the system (World Wildlife Fund, 2014).

We have applied the SAVi Buildings model to inform stakeholders of the risks, benefits, externalities, and climate impacts of the Paterson Park project. The assessment monetizes risks and externalities and provides information about social and environmental impacts on top of the conventional economic assessment. Figure 1 presents the CLD of the basic dynamics that underlie the analysis.

Figure 1. CLD of the Paterson Park buildings



Variables in black represent those that are conventionally considered when undertaking a building. The way they are interconnected in the CLD represents the basic dynamics of the system in which a building project is embedded. Building projects have a construction phase, an operation and maintenance (O&M) phase, and a demolition phase. The variables and dynamics of the system that are related to the building's construction phase are on the bottom left side of the diagram. The variables and dynamics related to the system's O&M phase are on the right-hand side of the diagram.

From the building's construction phase, we see that its construction depends positively on changes in population. Population growth generates demand for building construction, which leads to more buildings. This, in turn, generates demand for construction inputs such as construction materials and labour. The cost of these inputs is responsible for the building project's capital costs.

Continuing with the building system's basic dynamics, represented by black variables, the building's operational costs are attributable to water, electricity, and fossil fuel expenditure. These operational costs depend largely on water and energy consumption. Further, a building project's O&M phase generates costs in terms of maintenance and employment. These O&M costs, together with the capital costs incurred during the construction phase, determine total building expenditure.

The basic dynamics of the system and the outcomes of the project can be altered if additional investments or efforts are made in sustainability and efficiency. Thus, the orange variables are included to represent variables related to a green building scenario. During the construction phase, the project's outcomes can be altered with the use of sustainable materials, recycling, and changes in energy efficiency. During the building's O&M phase, outcomes can be altered with energy and water efficiency changes, the use of sustainable materials, and water reuse.

Green variables represent externalities, which are side effects of the project. Externalities are impacts of the building project that affect a third party in the system. Specifically, we see that construction practices lead to carbon dioxide (CO_2) emissions and generate waste, which ends up in landfills. Operation practices also lead to CO_2 emissions, produce wastewater, and can have an impact on labour productivity. These are negative side effects caused by the building project. A third party will have to incur the cost of these externalities during the project's lifetime. For example, CO_2 emissions are related to health risks. A third party will likely incur emissions-related health costs as a result.

On the other hand, building projects are also linked to positive externalities. Both the construction and O&M phases of the project generate employment. This employment leads to a positive externality in terms of labour income being generated.

Finally, pink variables represent climate effects that are incorporated into the model using the climate data from the Copernicus CDS. Climate change can have a notable effect on the project outcomes. These impacts will materialize as additional costs and thus must be considered as a part of the project's assessment. From the CLD, we see that an increase in wind pressure will lead to an increase in demand for construction materials. This is because increased wind intensity is likely to cause damage to buildings, which will require repair.

Climatic changes can also affect the amount of solar energy that is generated, the amount of energy for lighting that is demanded, and the amount of rainwater that is harvested. In addition, changes in temperature will affect energy consumption and labour productivity. Changes in the number of heating and cooling degree days a building requires will change as a result of temperature changes. This will impact the project's O&M costs. Increased temperature levels and albedo can also lead to heat stress, which has been shown to have a negative effect on labour productivity. All of these impacts can change the underlying dynamics of the system and the predicted outcomes of the project.

The CLD presented in Figure 1 shows the interconnectedness of socio-economic and environmental key indicators. It allows for a greater understanding of the potential impacts of sustainable investments and climate change and how these impacts would unfold through the system.

2.3 Climate Data

The Copernicus CDS provides data to forecast how different climate variables will change in Johannesburg over time. Figures 2 to 5 below show how air temperature and precipitation are changing in Johannesburg. Two climate scenarios are included:

- The Representative Concentration Pathways (RCP) 4.5 climate scenario assumes that emissions peak in 2040 and begin to decline thereafter.
- The RCP 8.5 scenario assumes that fossil fuel-intensive forms of energy generation continue to be used heavily through the remainder of the century.

The blue line represents the historical data (ECMWF Reanalysis 5th generation [ERA5] database), and the red line represents the climate projection (Coupled Model Intercomparison Project Phase 5 [CMIP5]) based on different datasets, with results from different global circulation models.

Figure 2. Change in air temperature under RCP 8.5

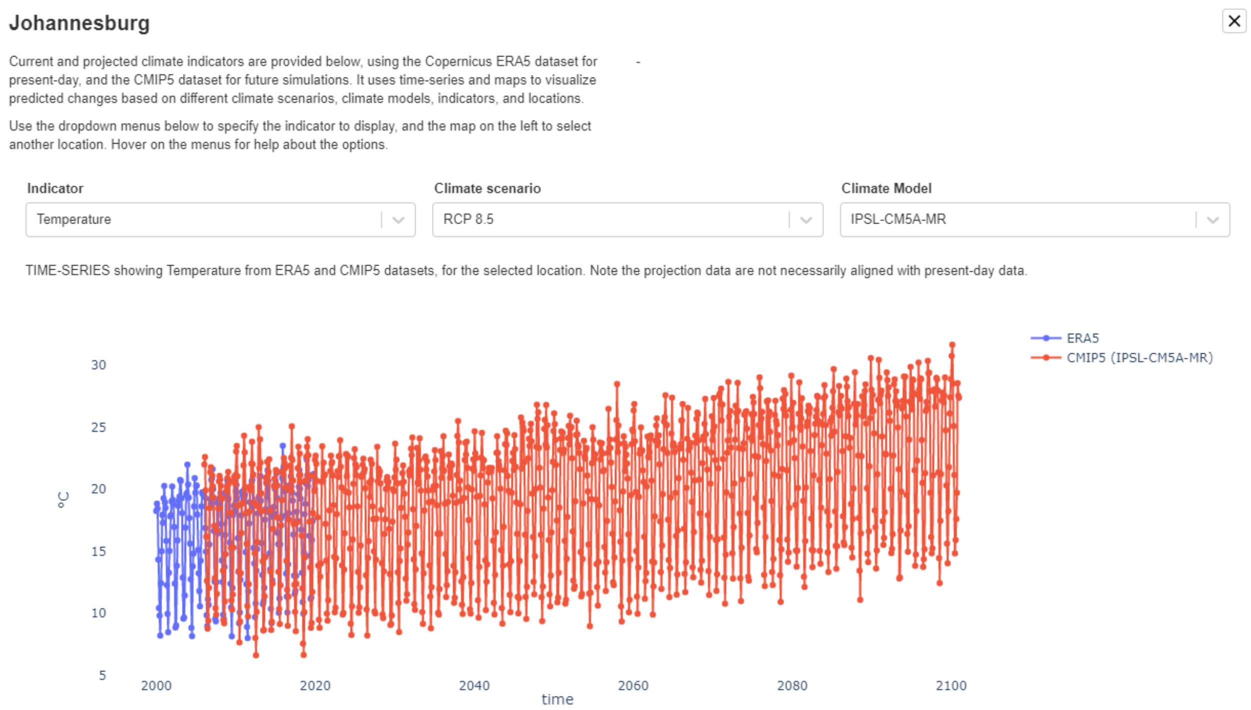


Figure 3. Change in air temperature under RCP 4.5

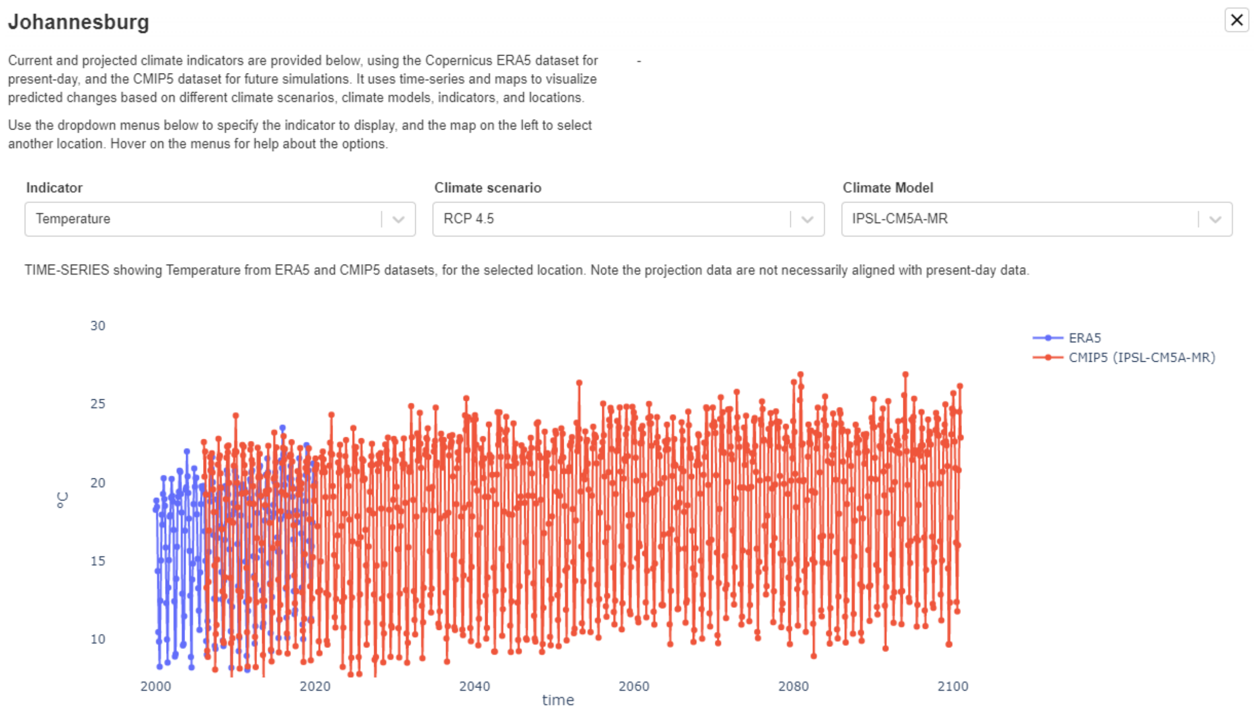


Figure 2 and Figure 3 show the predicted temperature changes in Johannesburg using the Copernicus CDS under the RCP 8.5 scenario and the RCP 4.5 scenario, respectively. Both figures show an increasing trend in air temperature; however, this increase is larger under the RCP 8.5 scenario.

Figure 4. Change in precipitation under RCP 8.5

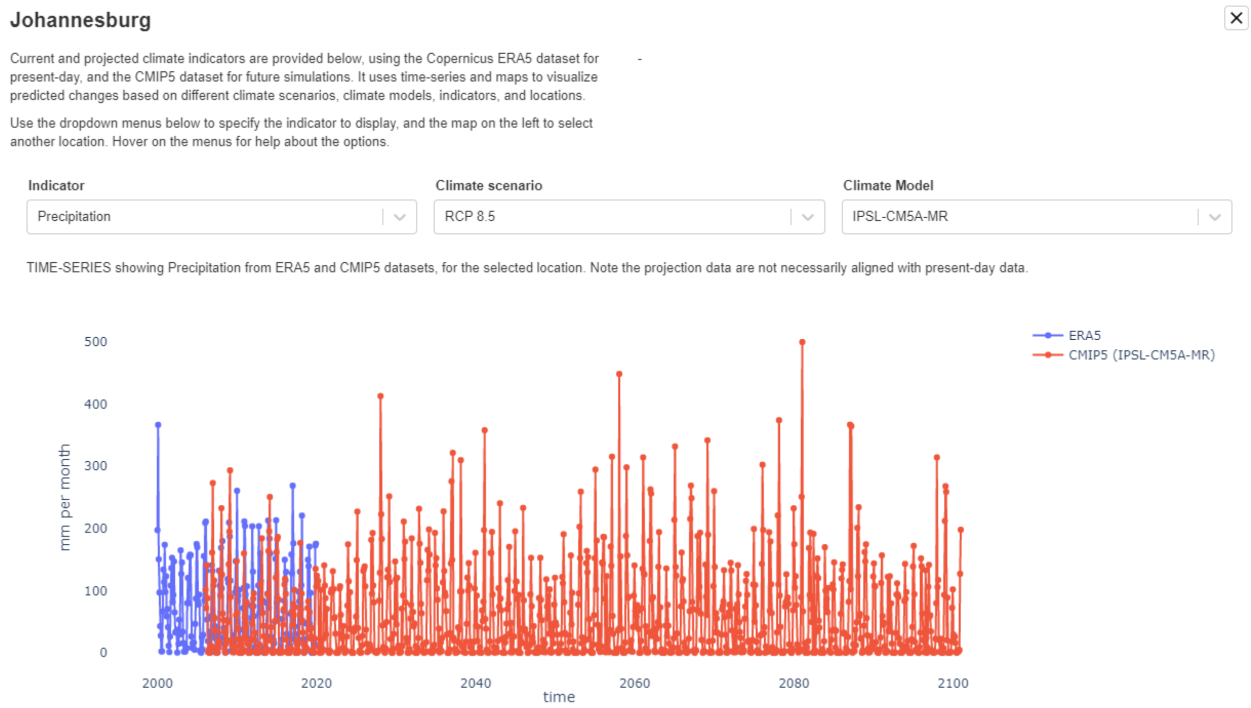


Figure 5. Change in precipitation under RCP 4.5

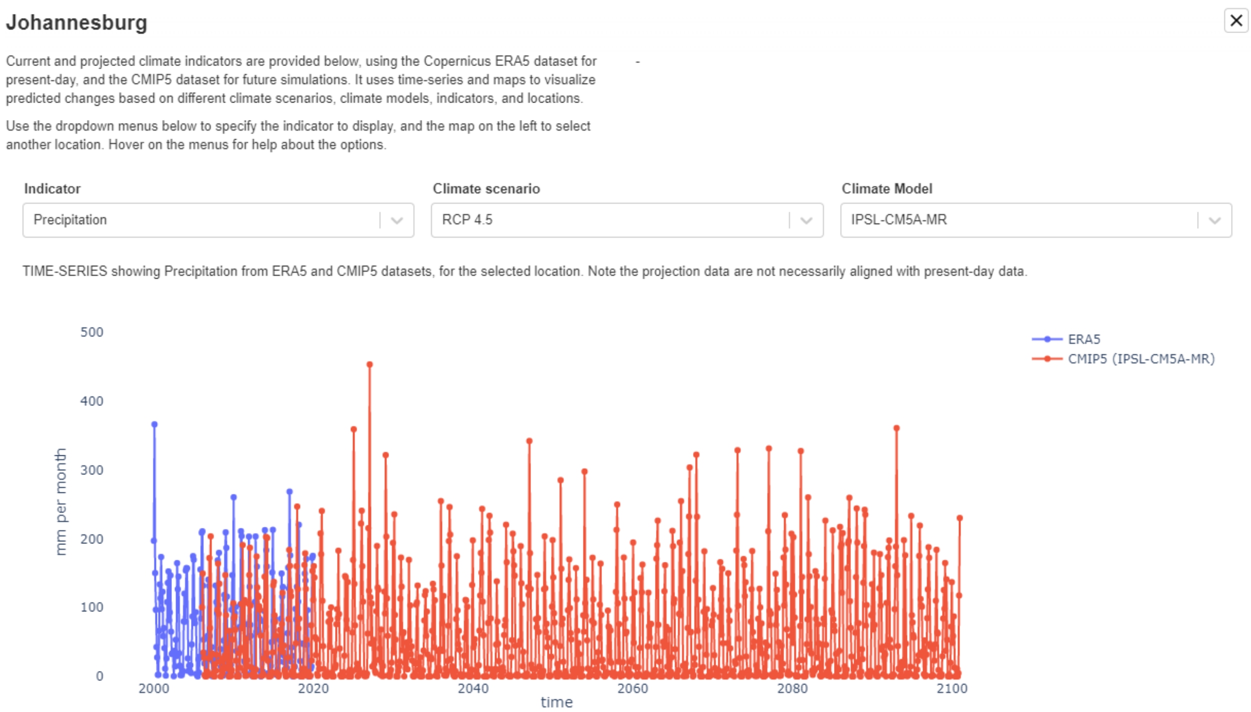


Figure 4 and Figure 5 show the predicted precipitation in Johannesburg under RCP 8.5 and RCP 4.5, respectively, using the data found in the Copernicus CDS. High precipitation events will be more frequent under both climate scenarios, but this is more evident under the emission-intensive RCP 8.5 climate scenario. The spikes in both figures represent events with high levels of precipitation. These spikes tend to become greater over time under the RCP 8.5 scenario.

2.4 Assumptions and Data Inputs for the SAVi Assessment

For this SAVi assessment, we compare a business-as-usual (BAU) scenario, which represents the Paterson Park buildings as they were upgraded and constructed today, with a green scenario, which includes greener features in relation to energy use (e.g., more efficient appliances and insulation). Further, we compare the performance of the green buildings to the conventional buildings under various climate scenarios.

Table 2. A comparison of building expenditures for the BAU and green scenarios

	BAU	**Green**
Capital and operational expenditures	In the BAU scenario, capital and operational expenditures are based on project-specific data.	For the green building scenario, it is assumed that capital expenditure is 2% less for conventional buildings when compared to green buildings (World Green Building Council, 2013). Additionally, in terms of operation costs, it is assumed that sustainable buildings are 40% more cost efficient than conventional buildings (Ping & Chen, 2016). These O&M costs cover wear and tear of wall painting, light, roofing and ceiling maintenance, as well as replacement and mechanical maintenance of energy and water systems. It does not include expenditures for energy or water usage.
Energy expenditure	Energy expenditure is calculated based on the energy requirements of the building and the cost of electricity. The building's energy requirements are based on project-specific data. The cost of electricity in the City of Johannesburg is set at ZAR 1.786/kWh (City Power Johannesburg (SOC) LTD., 2020). The total annual expenditure for electricity use is estimated at ZAR 257,200 per year. Additionally, cost savings from solar photovoltaic (PV) energy generation are based on project-specific data. This calculation assumes that the load factor of the installed capacity is 19% and that solar PV is responsible for energy substitution for 6 hours per day. The total amount of installed capacity is 180 kW. In	Changes in energy expenditures are based on project-specific assumptions about the differences in the energy usage of green buildings when compared to conventional buildings. The total annual expenditure for electricity use is estimated at ZAR 106,505 per year. The same cost savings for solar PV energy generation as in the BAU are assumed.

	addition, it is assumed that only 60% of the generation is available for own consumption (i.e., for reducing grid electricity use).	
Water expenditure	The cost of water use in buildings is based on the predicted water usage of the building and water price. Provided project-specific data on the hot water consumption of the building and total water usage is calculated assuming that hot water accounts for 30% of the share of water use in the building. The cost of water use is then calculated using the assumption that the water costs ZAR 0.02696/litre (Randburg Sun, 2017). The cost of water used for irrigation is based on an assumption from Peace Corps (1976) that each m^2 of irrigated surface requires 50 litres of water every month. Cost is then calculated using the assumption that water costs ZAR 0.0269/litre (Randburg Sun, 2017).	Water expenditure is assumed to be the same for the green building scenario and the BAU scenario.
Externalities – GHG emissions	The cost of greenhouse gas (GHG) emissions is calculated based on the social cost of carbon, which is assumed to be USD 31 per tonne of CO_2 equivalent (CO_2e) emissions (Nordhaus, 2017). Additionally, this calculation assumes a grid emissions factor of 0.00094 tonnes of CO_2e emissions per kWh of electricity generated and distributed by the electricity grid (National Business Initiative, 2016).	There are no additional assumptions for the externalities in the green building scenario. Differences in the value of externalities between the BAU scenario and the climate scenario are based on the changes in energy consumption between the two scenarios.
Externalities – Discretionary spending	The cost of discretionary spending is based on project-specific estimates of the employment required by the project. We assume 20 full-time equivalent positions involved in the construction phase of the Paterson Park buildings. Employment during the O&M phase is significantly lower. Over 2 years, the simulation model uses an average of six full-time equivalent positions. Additionally, this calculation assumes that the average annual salary of those employed for the project's construction, operation, and maintenance is ZAR 500,000 (Business Insider SA, 2019). It also assumes that the percentage of income that is used for discretionary spending is 24% (Numbeo, 2019).	There are no additional assumptions for the externalities in the green building scenario. Differences in the value of externalities between the BAU scenario and the climate scenario are based on the changes in energy consumption between the two scenarios.

3 Results: SAVi Paterson Park – Buildings

3.1 Integrated Cost–Benefit Analysis

Table 3 provides the summary results of the integrated cost–benefit analysis (CBA) that is provided in more detail in the section below. Under different climate scenarios and for the BAU versus green building design, the integrated life-cycle cost of buildings changes.

The BAU building scenario results in a cost between ZAR 461,367,293 and ZAR 462,000,596, depending on the climate scenario. This cost includes externalities such as the cost of GHG emissions and discretionary spending due to additional employment related to the project. The green building scenario results in a significantly lower cost over the life cycle of the project, ranging between ZAR 311,859,445 and ZAR 312,132,753.

Climate change increases the life-cycle cost of buildings for both the BAU and the greener design. Under the RCP 4.5 scenario, the cost of the BAU and green designs both increase 0.2%. Under the RCP 8.5 scenario, the cost of the green design increases by 2.1%. The cost of BAU under RCP 8.5 decreases by 1.2%, mainly because precipitation under that scenario increases to an extent that the cost for irrigation decreases.

It must be noted that we did not include a potential cost of flood damage should precipitation increase so much that the stormwater infrastructure of Paterson Park would not be able to absorb this. A separate SAVi assessment on the stormwater infrastructure of Paterson Park was conducted to assess flood damages. Nature-based stormwater infrastructure and green spaces contribute significantly to reduced flood risk and potential damages in the surrounding area. The results of the SAVi stormwater infrastructure assessment can be found here.

Table 3. Integrated life-cycle cost (40 years)

	BAU	Green	Difference relative to RCP 2.6	
RCP 2.6	ZAR 461,367,293	ZAR 311,859,445	**BAU**	**Green**
RCP 4.5	ZAR 462,083,129	ZAR 312,348,784	0.2 %	0.2 %
RCP 8.5	ZAR 462,000,596	ZAR 312,132,753	-1.2 %	2.1 %

Table 4 shows the detailed integrated CBA under the RCP 2.6 scenario. The net life-cycle cost, including the positive and negative externalities of the BAU scenario, amounts to ZAR 461,367,293, whereas the green scenario amounts to ZAR 311,859,445. There are significant cost savings because of energy expenditure, maintenance costs, and a significantly lower cost of GHG emissions over the 40-year life cycle of the buildings.

Table 4. Integrated CBA under the RCP 2.6 scenario

	RCP 2.6	
Integrated CBA (ZAR)	**BAU**	**Green**
Project-related investment and costs		
Capital investment	120,225,960	122,679,944
O&M cost	270,695,456	162,417,472
Energy expenditure	53,265,432	18,793,268
Baseline energy expenditure	*65,679,268*	*31,207,104*
Climate impacts on energy expenditure		
Cost savings from solar PV	*-12,413,836*	*-12,413,836*
Climate impacts on solar PV performance		
Water expenditure	6,056,209	6,056,209
Water expenditure from use in building	*2,632,364*	*2,632,364*
Irrigation water expenditure (outdoor)	*3,423,845*	*3,423,845*
Climate impacts on irrigation water expenditure		
Subtotal (1): Project-related investment and costs	**450,243,057**	**309,946,893**
Externalities		
Costs of GHG emissions	15,693,504	6,481,820
Baseline cost of GHG emissions	*15,693,504*	*6,481,820*
Climate impacts on cost of GHG emissions		
Discretionary spending	-4,569,268	-4,569,268
Costs of indoor air quality	0	0
Baseline costs of indoor air quality		
Cost of labour productivity lost due to heat stress		
Subtotal (2): Externalities	**11,124,237**	**1,912,552**
TOTAL net cost	**461,367,293**	**311,859,445**

Table 5 shows the detailed integrated CBA under the RCP 2.6 scenario. The impact of climate change is visible on energy and water expenditure, as well as on the cost of GHG emissions. The latter increases with ZAR 94,333 in the BAU and ZAR 59,025 in the green scenario because energy expenditure increases under the RCP 4.5 scenario.

The impact of climate change increases energy expenditure by ZAR 314,740 and reduces the cost savings from solar PV by ZAR 68,470 in the BAU. In the green scenario, the impact of climate change on energy expenditure is lower, up to ZAR 182,576.

Table 5. Integrated CBA under the RCP 4.5 scenario

	RCP 4.5	
Integrated CBA (ZAR)	**BAU**	**Green**
Project-related investment and costs		
Capital investment	120,225,960	122,679,944
O&M cost	270,695,456	162,417,472
Energy expenditure	65,994,008	31,389,680
Baseline energy expenditure	*65,679,268*	*31,207,104*
Climate impacts on energy expenditure	*314,740*	*182,576*
Cost savings from solar PV	*-12,413,836*	*-12,413,836*
Climate impacts on solar PV performance	*68,470*	*68,470*
Water expenditure	6,294,502	6,294,502
Water expenditure from use in building	*2,632,364*	*2,632,364*
Irrigation water expenditure (outdoor)	*3,423,845*	*3,423,845*
Climate impacts on irrigation water expenditure	*238,293*	*238,293*
Subtotal (1): Project-related investment and costs	**450,864,560**	**310,436,232**
Externalities		
Costs of GHG emissions	15,787,837	6,540,845
Baseline cost of GHG emissions	*15,693,504*	*6,481,820*
Climate impacts on cost of GHG emissions	*94,333*	*59,025*
Discretionary spending	-4,569,268	-4,569,268
Costs of indoor air quality	0	0
Baseline costs of indoor air quality		
Cost of labour productivity lost due to heat stress		
Subtotal (2): Externalities	**11,218,570**	**1,912,552**
TOTAL net cost	**462,083,129**	**312,348,784**

Table 6 shows the integrated CBA under the RCP 8.5 scenario. Similarly, as with the results of the RCP 4.5 scenario, the climate impact is primarily visible on energy and water expenditure, as well as the cost of GHG emissions. We also note a small impact on the cost of labour productivity due to heat stress.

Table 6. Integrated CBA under the RCP 8.5 scenario

	RCP 8.5	
Integrated CBA (ZAR)	**BAU**	**Green**
Project-related investment and costs		
Capital investment	120,225,960	122,679,944
O&M cost	270,695,456	162,417,472
Energy expenditure	66,142,196	31,455,110
Baseline energy expenditure	*65,679,268*	*31,207,104*
Climate impacts on energy expenditure	*462,928.00*	*248,006.00*
Cost savings from solar PV	-12,302,214.00	-12,302,214.00
Climate impacts on solar PV performance	*-12,413,836*	*-12,413,836*
Water expenditure	*111,622.00*	*111,622.00*
Water expenditure from use in building	5,969,889	5,969,889
Irrigation water expenditure (outdoor)	*2,632,364*	*2,632,364*
Climate impacts on irrigation water expenditure	*3,423,845*	*3,423,845*
Subtotal (1): Project-related investment and costs	**450,731,287**	**310,220,201**
Externalities		
Costs of GHG emissions	15,833,897	6,564,789
Baseline cost of GHG emissions	*15,693,504*	*6,481,820*
Climate impacts on cost of GHG emissions	*140,393.00*	*82,969.00*
Discretionary spending	-4,569,268	-4,569,268
Costs of indoor air quality	4,679	0
Baseline costs of indoor air quality	*0*	*0*
Cost of labour productivity lost due to heat stress	*4,678.85*	*0.00*
Subtotal (2): Externalities	**11,269,308**	**1,912,552**
TOTAL net cost	**462,000,596**	**312,132,753**

Under the high-emission scenario (RCP 8.5), the cost of building infrastructure increases further. Green building design remains the cheaper option over the life cycle.

Table 7 and Figure 6 zoom in on the energy expenditure and how it changes due to climate impacts under RCP 4.5 and 8.5.

Figure 6. Energy expenditure (life cycle)

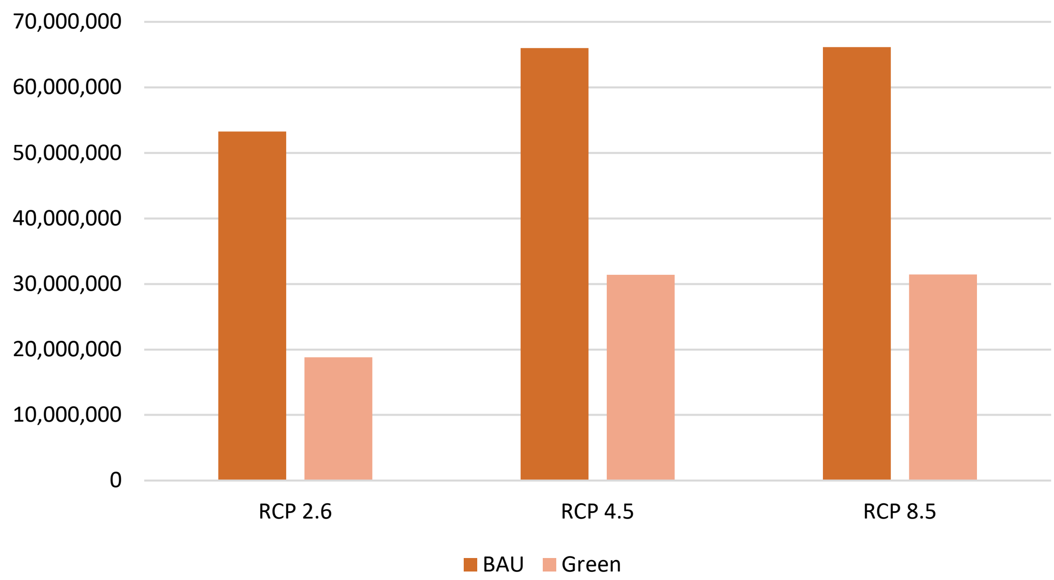


Table 7. Energy expenditure (life cycle)

Energy expenditure over the life cycle	**BAU**	**Green**
RCP 2.6	ZAR 53,265,432	ZAR 18,793,268
RCP 4.5	ZAR 65,994,008	ZAR 31,389,680
RCP 8.5	ZAR 66,142,196	ZAR 31,455,110

Figure 7 and Table 8 zoom in on the water expenditures across the different climate scenarios.

Figure 7. Water expenditure (life cycle)

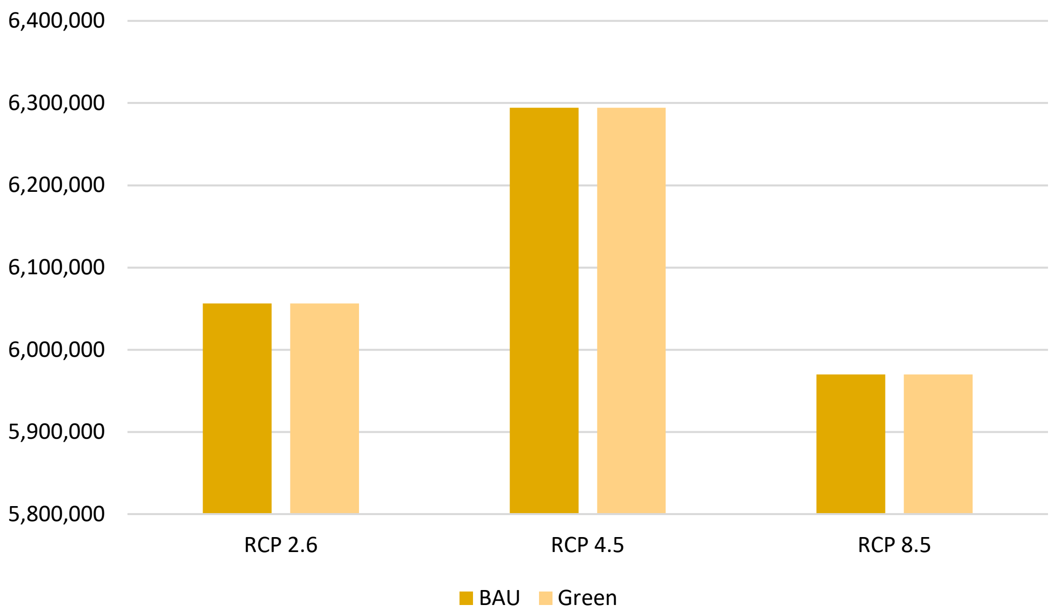


Table 8. Water expenditure (life cycle)

Water expenditure over the life cycle	BAU	Green
RCP 2.6	ZAR 6,056,209	ZAR 6,056,209
RCP 4.5	ZAR 6,294,502	ZAR 6,294,502
RCP 8.5	ZAR 5,969,889	ZAR 5,969,889

Water expenditure changes based on the amount of water required for irrigation when both (4.5 and 8.5) are compared to RCP 2.6. In-house water use is assumed to be the same across all scenarios, hence the same cost of water use. The RCP 8.5 scenario indicates a lower cost for irrigation and a higher cost for RCP 4.5, which is due to the differences in precipitation relative to the RCP 2.6 scenario. In the case of RCP 8.5, precipitation is on average higher, meaning less need for irrigation and therefore a cost saving. Precipitation is lower in the RCP 4.5 scenario compared to the RCP 2.6 scenario, leading to higher irrigation needs and thus costs.

A comparative table of all results per climate scenario for the integrated CBA as well as in cost per m^2 for the buildings can be found in the annex to this report.

3.3 Project Finance Indicators (Solar Panels)

The project finance model for the Paterson Park project focused on the performance of investment in solar panels. We simulated different scenarios with and without inflation on the cost of electricity (8% per year) and with the impact of the different climate scenarios. The results are in Table 9.

Both the internal rate of return (IRR) and net present value (NPV) indicate that under all scenarios, solar panel installations are a worthwhile investment because they generate a sufficiently avoided cost of electricity that would otherwise need to be purchased. This avoided cost becomes larger in the scenarios that take into account inflation and make solar panels an even more profitable investment. Finally, we note that there is a minor impact of climate change on the performance of solar panels, resulting in a lower IRR and NPV in the RCP 4.5 and RCP 8.5 scenarios compared to the BAU.

Table 9. IRR and NPV for solar panels on buildings

	IRR	NPV
BAU	21.30%	3.97
BAU (no inflation)	13.26%	1.17
RCP 4.5	21.22%	3.93
RCP 4.5 (no inflation)	13.19%	1.16
RCP 8.5	21.19%	3.91
RCP 8.5 (no inflation)	13.16%	1.15

Table 10. The assumptions used for the project finance model

Capital expenditure: cost of solar panels, including installation	ZAR 11/Wp; for a 150 kWp system as in Paterson Park, ZAR 1,650,000
Lifetime of solar panels	20 years
Energy generation	174 MWh
Cost of electricity	ZAR 1.786/kWh, with 8% inflation per year. We included a scenario with and without this inflation.

4 Conclusion

The SAVi analysis on the Paterson Park Precinct – Buildings project demonstrates the economic and financial attractiveness of retrofitting and constructing new buildings in accordance with high green building standards. Over the life cycle of these projects, significant cost savings materialize in comparison to buildings with lower environmental building standards. Further, the SAVi analysis also demonstrates that the integration of climate data and running climate scenarios on infrastructure projects helps to better plan expenditures, in particular in relation to water and energy in this case.

The assessment provides insight for the City of Johannesburg's Development Planning Department for future urban planning, as well as for advocating for next generation of green building standards. The assessment also showcases for stakeholders in the GEF Sustainable Cities program that quantitative evidence on cost reductions and externalities in relation to building projects can indeed be generated and used as input to inform and design other urban projects.

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Annex 1

Table A1. Integrated CBA (life cycle: 40 years)

	RCP 2.6		RCP 4.5		RCP 8.5	
Integrated CBA (ZAR)	**BAU**	**Green**	**BAU**	**Green**	**BAU**	**Green**
Project-related investment and costs						
Capital investment	120,225,960	122,679,944	120,225,960	122,679,944	120,225,960	122,679,944
Operation & maintenance cost	270,695,456	162,417,472	270,695,456	162,417,472	270,695,456	162,417,472
Energy expenditure	53,265,432	18,793,268	65,994,008	31,389,680	66,142,196	31,455,110
Baseline energy expenditure	*65,679,268*	*31,207,104*	*65,679,268*	*31,207,104*	*65,679,268*	*31,207,104*
Climate impacts on energy expenditure			*314,740.00*	*182,576.00*	*462,928.00*	*248,006.00*
Cost savings from solar PV	*-12,413,836*	*-12,413,836*	*-12,413,836*	*-12,413,836*	-12,302,214.00	-12,302,214.00
Climate impacts on solar PV performance			*68,470.00*	*68,470.00*	*-12,413,836*	*-12,413,836*
Water expenditure	6,056,209	6,056,209	6,294,502	6,294,502	*111,622.00*	*111,622.00*
Water expenditure from use in building	*2,632,364*	*2,632,364*	*2,632,364*	*2,632,364*	5,969,889	5,969,889
Irrigation water expenditure (outdoor)	*3,423,845*	*3,423,845*	*3,423,845*	*3,423,845*	*2,632,364*	*2,632,364*
Climate impacts on irrigation water expenditure			*238,293.25*	*238,293.25*	*3,423,845*	*3,423,845*
Subtotal (1): Project-related investment and costs	**450,243,057**	**309,946,893**	**450,864,560**	**310,436,232**	**450,731,287**	**310,220,201**
Externalities						
Costs of GHG emissions	15,693,504	6,481,820	15,787,837	6,540,845	15,833,897	6,564,789
Baseline cost of GHG emissions	*15,693,504*	*6,481,820*	*15,693,504*	*6,481,820*	*15,693,504*	*6,481,820*
Climate impacts on cost of GHG emissions			*94,333.00*	*59,025.00*	*140,393.00*	*82,969.00*
Discretionary spending	-4,569,268	-4,569,268	-4,569,268	-4,569,268	-4,569,268	-4,569,268

Costs of indoor air quality	0	0	0	0	4,679	0
Baseline costs of indoor air quality					*0*	*0*
Cost of labour productivity lost due to heat stress					*4,678.85*	*0.00*
Subtotal (2): Externalities	**11,124,237**	**1,912,552**	**11,218,570**	**1,912,552**	**11,269,308**	**1,912,552**
TOTAL net cost	**461,367,293**	**311,859,445**	**462,083,129**	**312,348,784**	**462,000,596**	**312,132,753**

Table A2. Cost per m² (ZAR)

	RCP 2.6		RCP 4.5		RCP 8.5	
Cost/m² (ZAR)	**BAU**	**Green**	**BAU**	**Green**	**BAU**	**Green**
Project-related investment and costs						
Capital investment	847.96	865.27	847.96	865.27	847.96	865.27
Operation & maintenance cost	1,730	1,038	1,730	1,038	1,730	1,038
Energy expenditure	329.33	108.87	418.69	197.40	419.77	197.90
Baseline energy expenditure	*416.88*	*196.42*	*329.33*	*108.87*	*329.33*	*108.87*
Climate impacts on energy expenditure			*89.37*	*88.54*	*90.44*	*89.03*
Cost savings from solar PV	*-87.55*	*-87.55*	*-87.55*	*-87.55*	*-87.55*	*-87.55*
Climate impacts on solar PV performance			*0.49*	*0.49*	*0.80*	*0.80*
Water expenditure	23.01	23.01	47.08	47.08	44.69	44.69
Water expenditure from use in building	*0.43*	*0.43*	*23.01*	*23.01*	*23.01*	*23.01*
Irrigation water expenditure (outdoor)	*22.58*	*22.58*	*22.58*	*22.58*	*22.58*	*22.58*
Climate impacts on irrigation water expenditure			*1.49*	*1.49*	*-0.90*	*-0.90*
Subtotal (1): Project-related investment and costs	**2,930.30**	**2,035.14**	**2,956.67**	**2,060.69**	**2,955.67**	**2,059.11**
Externalities						
Costs of GHG emissions	98.30	39.39	98.86	39.72	99.19	39.90
Baseline cost of GHG emissions	*98.30*	*39.39*	*98.30*	*39.39*	*98.30*	*39.39*
Climate impacts on cost of GHG emissions			*0.56*	*0.34*	*0.89*	*0.52*
Discretionary spending	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24
Costs of indoor air quality	0	0	0.03	0.00	0.03	0.00

Baseline costs of indoor air quality			*0.00*	*0.00*	*0.00*	*0.00*
Cost of labour productivity lost due to heat stress			*0.03*	*0.00*	*0.03*	*0.00*
Subtotal (2): Externalities	**70.06**	39.39	**70.65**	**11.49**	**70.98**	**11.67**
TOTAL net cost	**3,000**	**2,046**	**3,027**	**2,072**	**3,027**	**2,071**

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