Nature Towns

AN ECONOMIC BUSINESS CASE EVALUATION OF A REGENERATIVE COMMUNITY

McMac CX

Advanced Analytics Power By:

Autocase
Economic Advisory

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NATURE TOWNS TRIPLE BOTTOM LINE COST BENEFIT ANALYSIS - FINAL TECHNICAL MEMO | 2

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PROJECT OVERVIEW

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INTRODUCTION

Nature Towns are compact communities surrounded by lush greenbelts. The towns are dense enough for most amenities to be accessible by walking while accommodating up to 2,880 people in 1,280 households, as well as 200 live-work retail buildings. Most of the greenbelt area around the towns operate as an agricultural farm that provides sustenance and revenue to the local community. These regenerative farms are also expected to provide other environmental benefits such as carbon sequestration and pollination, as well as infiltrate stormwater from rainfall events thereby reducing pollutant loads in runoff water. Nature Towns aims to holistically integrate communities with green infrastructure by promoting regenerative lifestyles with improved health outcomes, community cohesion, and overall sustainable living. This report outlines the economic analysis and methods used to conduct and evaluate the benefits and costs of Nature Towns project design along the lens of the triple bottom line – representing the financial, social, and environmental impacts using the Autocase software along with bespoke economic models developed by Autocase economists.

This enhanced business case analysis takes a combination of Autocase software analytics and custom exogenous models to evaluate the long-term costs and benefits of Nature Towns as compared to a typical/conventional residential development on the same size property, where the Nature Towns development has greater density, mixed-use property types, on-site amenities, food production, and various sustainability elements reducing energy and water consumption, increasing recreational opportunities, walkability, community cohesion, community health, and overall improved communal lifestyles. Triple Bottom Line - Cost Benefit Analysis (TBL-CBA) is a systematic evidence-based economic business case framework that uses best practice Life Cycle Cost Analysis (LCCA) and Cost Benefit Analysis (CBA) techniques to quantify and attribute monetary values to the Triple Bottom Line (TBL) impacts resulting from an investment. TBL-CBA expands the traditional financial reporting framework (such as capital, and operations and maintenance costs) to account for social and environmental performance. Both benefits and costs are expressed in monetary units, discounted to net present value (NPV) terms, which allows for an evaluation of different alternatives with a variety of attributes using a common measure.

The primary investments analyzed in this report are building specific features such energy efficiency measures, renewable energy production on site, and improved worker occupant well-being from access to quality views with vegetation. With Nature Towns' focus on green infrastructure, there are other co-benefits analyzed such as annual revenue from farms, recreational opportunities, and green space access that benefit the community and

INTRODUCTION

environment, providing opportunities for carbon sequestration, pollination, runoff water capture, and overall a lower ambient surrounding temperature. Nature Towns' layout and design also increases the community's walkability to most necessary amenities, thereby reducing dependencies on private vehicles for transportation.

The TBL-CBA impacts from Nature Towns innovative design are detailed in Table 1. The project parameters for this analysis assume an operating horizon of 40 years following a construction period from 2021 to 2027, thus capturing impacts from 2028 to 2068. This analysis also assumes a project discount rate of 3%.

Table 1: Impacts Assessed in the TBL-CBA

Impact		
Financial	Social	Environmental
• Capital Expenditures • Replacement Cost • Operations & Maintenance • Residual Value • Financial Savings from Electricity • Financial Savings from Natural Gas • Renewable Energy Revenue • Revenue from Produce & Farm	• Value of Reduced Accident Risk • Value of Reduced Private Vehicle Operations • Value of Reduced Commuter Time • Value of Reduced Road Maintenance • Employee Productivity • Reduced Employee Absenteeism • Recreational Value • Public Health (Exercise) • Urban Heat Island	• Noise Pollution Reduced from Reduced Miles Travelled • Air Pollution Reduced from Reduced Miles Travelled • Carbon Emission Reduced from Reduced Miles Travelled • Carbon Emissions Reduced from Energy Savings • Air Pollution Reduced from Energy Savings • Carbon Emissions Reduced by Vegetation • Air Pollution Emissions Reduced by Vegetation • Carbon Emissions Reduced from Waste Management • Water Quality • Pollination

TBL-CBA RESULTS

The TBL-NPV associated with the subset of investments made by Nature Towns is estimated to be at $856 million over the 40-year study period. The main driver of the results stem from social impacts, accruing to the Nature Towns community at-large. Social benefits account for nearly 70% of the total TBL-NPV results, followed by positive effects in both environmental and financial categories. This project shows significant social and environmental impacts, thereby showcasing a business case for Nature Towns that extends beyond financial implications. The project also generates substantial social and environmental benefits accrued from reduced vehicle miles travelled by community members from increased accessibility of amenities attributed to the innovative town layout centered around community well-being and nature.

Figure 1: TBL-NPV Breakdown by Impact Category

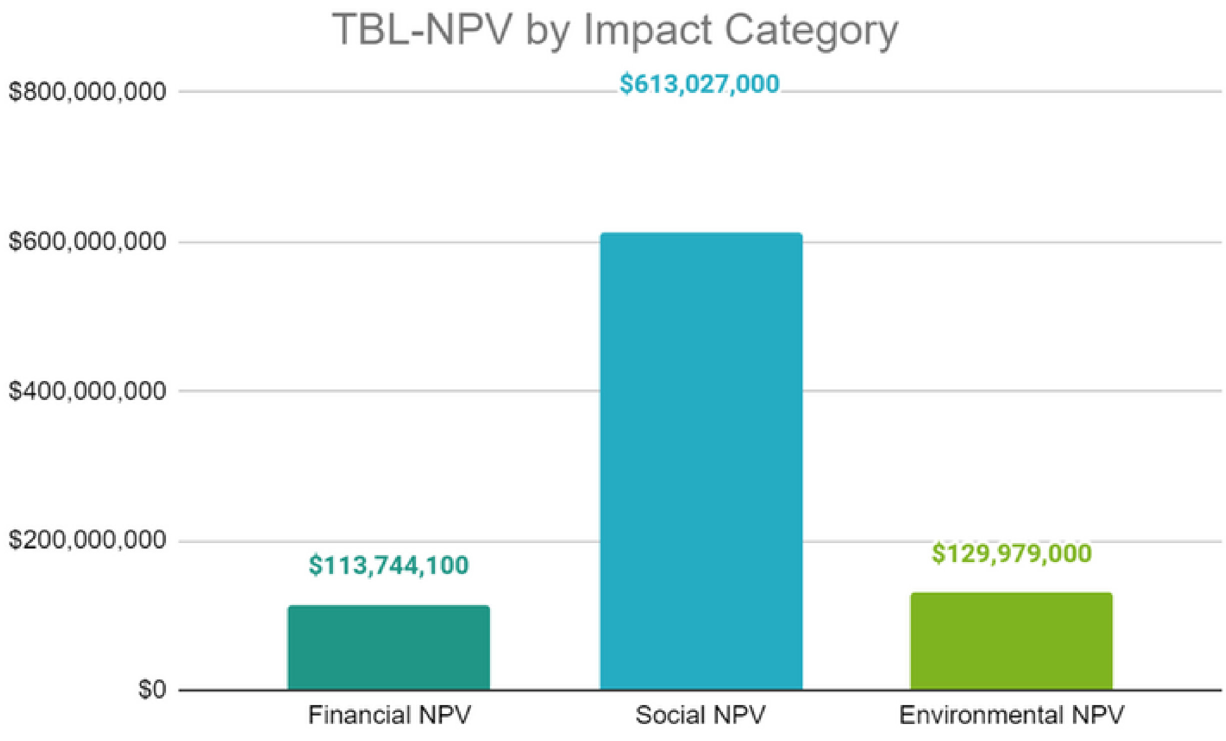
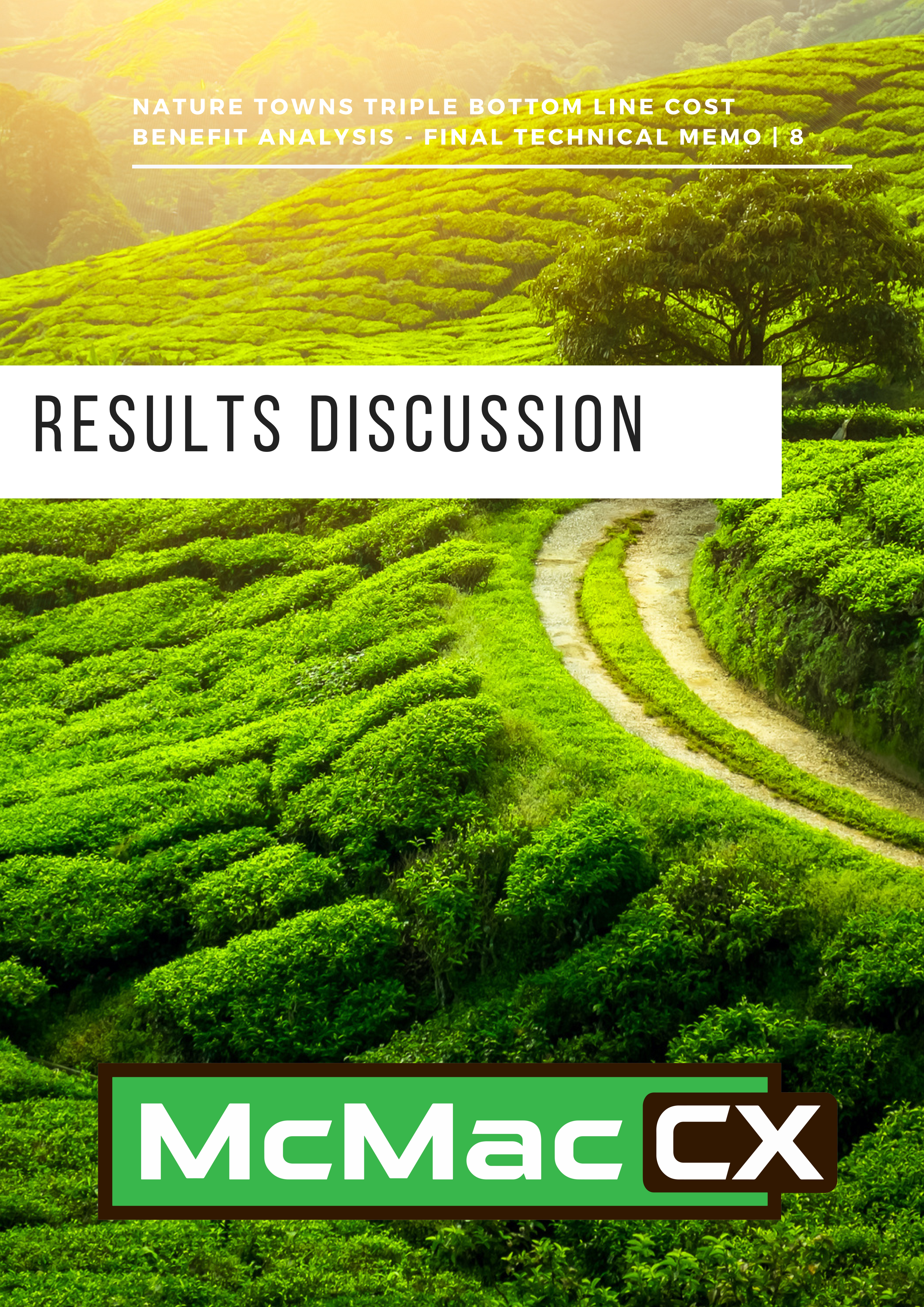


Table 2 (below) provides a detailed breakdown of the numerous impacts analyzed in this report along with their respective category, and monetized impact in current dollars. Figure 2 demonstrates the breakdown of NPVs from each of the impacts using a waterfall chart to the show the cumulative net present value. In the context of this analysis, it is assumed that all residents within the Nature Towns community are expected to benefit from the sustainable designs, thereby estimating the beneficiaries at 2,880 individuals (1,280 households).

Table 2: Triple Bottom Line - Net Present Value (TBL-NPV) Per Impact (3% Discount Rate)

Stakeholder	Impact	Benefit/Cost	Expected
NT Community	Financial	Capital Expenditure	$30,275,500
NT Community	Financial	Replacement Cost	$22,775,900
NT Community	Financial	Operations and Maintenance	-$3,187,300
NT Community	Financial	Residual Value	-$7,252,500
Homeowners/ Tenants	Financial	Financial Savings from Electricity	$70,400,000
NT Community	Financial	Renewable Energy Revenue	$732,500
Homeowners/ Tenants	Social	Value of Reduced Accident Risk	$176,181,000
Homeowners/ Tenants	Social	Value of Reduced Private Vehicle Operations	$54,836,000
Homeowners/ Tenants	Social	Value of Reduced Commuter Time	$125,839,000
NT Community	Social	Value of Reduced Road Maintenance	$91,475,000
Homeowners/ Tenants	Social	Indoor Environment Quality - Productivity	$113,769,000
Homeowners/ Tenants	Social	Indoor Environment Quality - Absenteeism	$6,475,000
Homeowners/ Tenants	Social	Recreational Value	$39,538,000
NT Community	Social	Public Health (Exercise)	$2,794,000
NT Community	Social	Urban Heat Island	$2,120,000
Community at Large	Environmental	Noise Pollution Reduced from Reduced Miles Travelled	$26,590,000
Community at Large	Environmental	Air Pollution Reduced from Reduced Miles Travelled	$2,261,000
Community at Large	Environmental	Carbon Emission Reduced from Reduced Miles Travelled	$15,060,000
Community at Large	Environmental	Water Quality	$30,220,000
Community at Large	Environmental	Carbon Reduction from Energy Savings	$27,530,000
Community at Large	Environmental	Air Pollution Reduction from Energy Savings	$17,443,000
Community at Large	Environmental	Carbon Emissions Reduced by Vegetation	$2,019,000
Community at Large	Environmental	Air Pollution Reduced by Vegetation (features from ACS)	$326,000
Community at Large	Environmental	Biodiveristy	$3,331,000
Community at Large	Environmental	Pollination	$1,136,000
Financial NPV			**$113,744,100**
Social NPV			**$613,027,000**
Environmental NPV			**$124,780,000**
TBL-NPV			**$851,551,100**



RESULTS DISCUSSION

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This analysis considers a set of green infrastructure investments made by Nature Towns to promote sustainable living in Austin, Texas. The analysis reflects investment impacts of creating a community where daily and recreational amenities are within walking distance, properties are powered by efficient and renewable sources of energy, there is additional urban agriculture and green space, as well as measures for efficient waste management. The largest benefits of this TBL-CBA are sourced from the improved walkability within the town, generating a NPV of $500 million. Such impacts are derived from reduced accident risk, reduced private vehicle operations, reduced commuter time, reduced road maintenance, and reduced noise and pollutant emissions. This result is driven by the incremental assumption that each household within Nature Towns is expected to offset 25,400 miles per house per year of private vehicle use in favor of walking and virtual video conferencing. It is expected that the design scenario will include the usage of one electric car per family that is expected to contribute 12,000 miles per year. This reduction vehicle miles are attributed to the assumption that walkability in Nature Towns is expected to reduce dependency on private vehicles from 3 to 1 per household. An additional 8,000 miles are expected to be offset from the modal shift in favor of public transit available to riders in the community. Across 1,280 households, Nature Towns are expected to offset 47 million vehicle miles per year. Table 3 shows the reduction in air pollutants per year by reducing the vehicle miles travelled by private households.

Table 3: Detailed Annual Emission Reduction Breakdown (all households)

Pollutant Emissions Reductions Per Year	
Pollutant	**Reduction**
CO_2e (metric tons)	16,000
NO_x (lbs)	10,570
SO_2(lbs)	200
VOC_s (lbs)	10,500
$PM_{2.5}$ (lbs)	440
Total GHG Emissions (metric tons)	16,000
Total CAC Emissions (lbs)	22,000

Investing in renewable energy onsite is also expected to generate significant benefits to the community in terms of financial savings, reduced environmental damages from reduced pollutant emissions, and revenues from energy sold back to the utility grid. In aggregate energy savings are expected to generate total financial and environmental benefits of $116 million. Revenues from farm produce that are expected to be sold in the market are not included in this analysis.

Extensive investments into green space are expected to generate a variety of recreational opportunities for the community that are easily accessible across the Towns as compared to scarce amenities in the base case design alternative, thereby generating a net present value of $39.5 million. Besides substantial impacts in above categories, the site is also expected to generate social and environmental impacts from green space availability. Vegetative spaces are expected to have significant pollutant sequestering capacity as compared to hardscapes. The site is expected to sequester 60,000 tonnes of carbon over 40 years. Additionally, the green spaces are expected to capture runoff stormwater from increased infiltration capacity of the soil in the design case as compared to the baseline. Table 4 shows the average annual pollutant loads captured by green space land covers.

Table 4: Detailed Pollutant Load Reductions

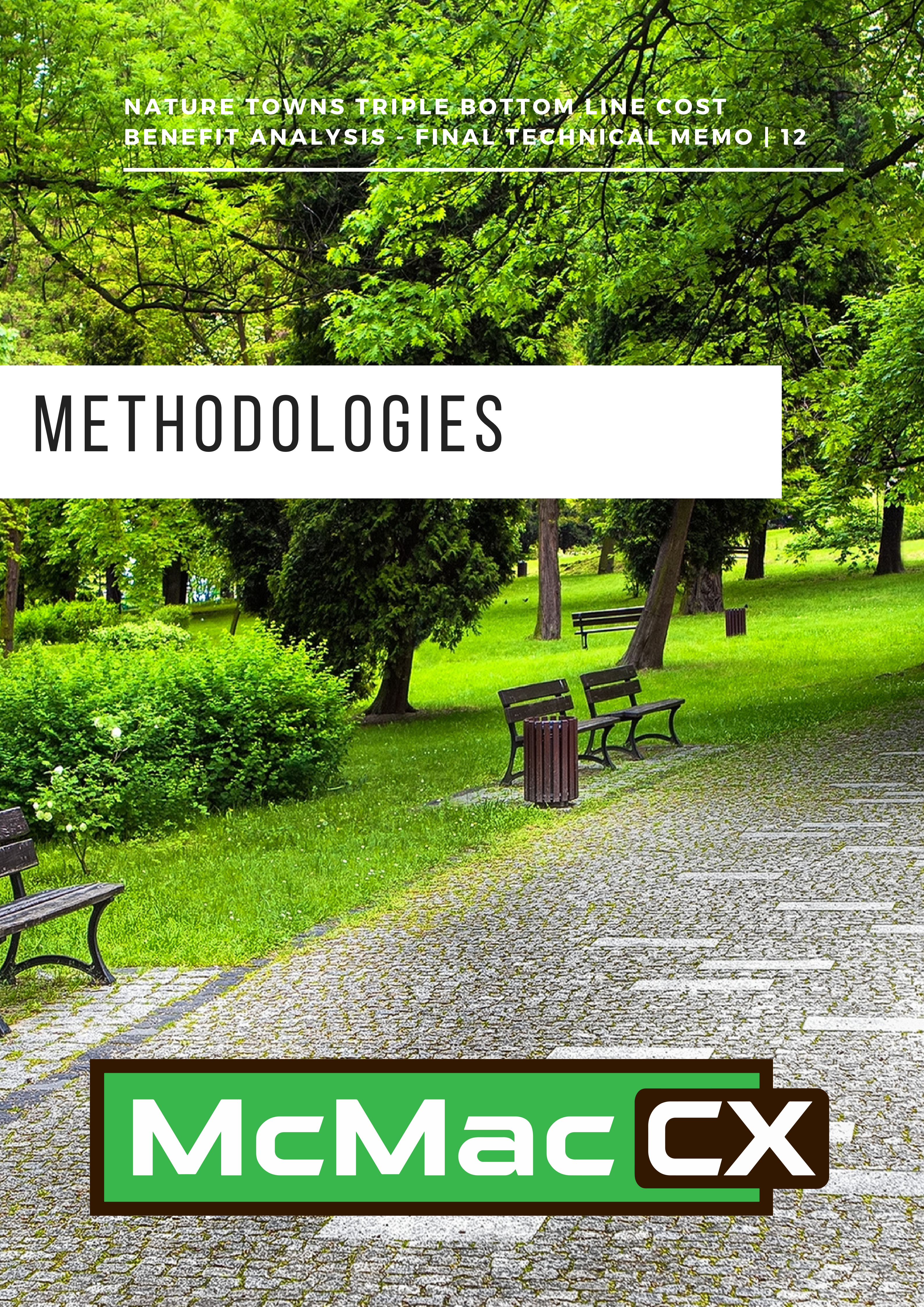
Pollutant Load Reductions (lbs) from Stormwater Capture per Year	
Pollutant	**Reduction**
Nitrogen	3,000
Phosphorus	1,100
Total Suspended Solids	642,000
Copper	96,200
Zinc	610,100
Lead	216,400

Besides sequestering carbon and capturing water, vegetative spaces are also expected to generate environmental benefits by creating opportunities for insect pollination. These are expected to generate an annual benefit of $60,000 across 191 acres of incremental green space added between the design and baseline. Green spaces are also responsible for reducing ambient temperature, thereby heat island impacts such as reducing the risk of heat-stress related mortality. Reductions in Urban Heat Island (UHI) is expected to generate benefits to the community, monetized at a total of $2.2 million across 40 years.

The LCCA for the project also shows a net positive NPV over the project life cycle from installation more cost-effective landcovers in the design over traditional landscapes. Capital expenditures in the design case are expected to be lower than the baseline, as hardscapes such as asphalt and concrete are more expensive upfront and require costly replacements over their useful lives; both of which can be mitigated through green infrastructure. Over the project life cycle, the operations and maintenance of green infrastructure is expected to outweigh that of hardscapes, thereby generating a negative net present value at -$3 million, reflecting the greater net costs of regularly maintaining green landscapes over impervious surfaces. Additionally, since the green infrastructure has lower capital costs as compared to grey infrastructure, at the end of the asset life, the Nature Towns scenario also generates a lower residual value, thereby giving a negative present value.

However, the LCCA (excluding utility cost savings) as a whole is expected to generate a positive NPV at $42.6 million derived from avoided upfront capital and replacement related expenditures.

METHODOLOGIES



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LIFE CYCLE COST ANALYSIS (LCCA)

LCCA evaluates the total cost of ownership over the life of a project to compare the cost-effectiveness of sustainable design options over that of conventional practices. It is usually conducted in the early design phase of a project, as it offers an opportunity to optimize designs to reduce life cycle costs. A comprehensive list of cost data used, and assumptions are listed in Table 6 LCCA considers all upfront, maintenance, and replacement costs, as well as any residual value of the project's assets remaining at the end of the analysis duration, and explained in further detail in the sections below.

Capital Expenditures

Upfront capital costs are the initial costs incurred during the construction period. Cost items can include the purchase of assets, systems, and any other materials during construction, including labor costs for installation. Upfront capital costs in each design case are compared to the base case. Positive incremental upfront capital cost in the results implies that the design was less costly than the base case. For this project, capital costs provided by the project team are supplemented with Autocase estimates from best available research.

Replacement Cost

Replacement costs refer to the costs required to replace an asset or piece of infrastructure after its useful life if the study period of the project is expected to exceed the useful life of assets. An asset may be replaced multiple times over the study period. The replacement cost may cost more, less, or the same as the upfront capital costs of the asset, this is estimated by Autocase using the best available guidance on components of green and grey infrastructure that would need to be replaces at the end of the asset's useful life.

Operations & Maintenance

Non-utility operations and maintenance (O&M) costs include all costs associated with operating, repairing, upgrading and/or recommissioning investments over the course of an investment's useful life but exclude any costs from utilities. These costs include preventative measures and anticipated repairs to extend the useful life of materials and equipment. Annual O&M costs are incurred each year during the life of the building (or study period) and may escalate if real costs increase over the study period. Escalation rates are capture growth beyond general inflation (i.e., costs increase every year by the rate of inflation; these cost increases should not be included). This analysis uses operations and maintenance cost estimates

LIFE CYCLE COST ANALYSIS (LCCA)

available from the project team, as well as those supplemented by Autocase research.

Residual Value

The residual value of an asset or investment refers to the financial benefit arising at the end of the life of a building or study period, for any assets with a remaining useful life. Autocase calculates residual values using straight-line depreciation.

ENERGY EFFICIENCY & RENEWABLE ENERGY

Financial Savings from Utility Savings

Lower dependency on energy in the design case generates financial benefits due to cost savings. The baseline is expected to have an electricity consumption of 11,484,000 kWh per year. In the design case, the site is expected use an additional 5.17 million kWh per year from electric vehicle fuel consumption. It is also expected to generate 20,294 MWh of energy onsite which is expected to offset electricity consumption onsite by over time, while also accounting for an annual degradation of equipment at 0.18% per year throughout the study period. Autocase estimates the financial savings from avoided dependency on utility-based electricity using local utility prices from the Energy Information Administration (EIA, 2019b) for Austin, Texas. Autocase forecasts energy prices from the U.S. Energy Information Administration (EIA, 2019b). The EIA provides energy price forecasts up to the year 2050 across a variety of high and low macroeconomic conditions such as fluctuating oil prices, economic growth, and technological progress.

Renewable Energy Revenue

On-site renewable energy production may not only be used on-site, but also sold to the grid. The revenue received from selling renewable energy is calculated a wholesale estimate of 0.03 $/kWh provided by the project team.

CARBON AND CRITERIA AIR CONTAMINANT EMISSION

Reduction from Energy Savings

Reducing electricity and natural gas consumption from the grid (in the design case compared to the base case) generates environmental benefits from reduced carbon and air pollution being emitted. For each unit of energy produced and used, carbon and air pollution emissions are released into the atmosphere, quantified using emission factors. The social benefit from reducing air pollution emissions is monetized by applying the social cost of carbon and each air pollutant to the respective amount of that air pollutant reduced. Autocase calculates the environmental benefit for the following air pollutants: CO2e, NOx , SO2, PM2.5 , and VOC. Non-baseload, location-specific emission factors per unit of electricity are gathered from National Emissions Inventory in the U.S (EPA, 2014) and eGRID (EPA, 2020c). Emission factors for natural gas combustion for U.S. are gathered from the United States Environmental Protection Agency (1998). Emission factors and social values for each pollutant have been listed in the Inputs and Data section.

Social Value of Carbon

The environmental benefit of reduced GHGs is monetized by applying the social cost of carbon to the amount of carbon dioxide equivalent emissions reduced. The social cost of carbon is estimated at $51.94 / metric ton in the U.S is taken from the Government's Interagency Working Group on the Social Cost of Carbon (2016). The social cost of carbon is a conservative estimate of the negative effects of climate change. The cost of carbon pollution is an estimate of the damages - of the economic cost of the health, agricultural losses, property flooding and the value of ecosystem services. The estimates, and there are many estimates, are conservative because they do not yet capture all the identified impacts of rising levels of CO2 in the atmosphere.

Social Value of Criteria Air Contaminants

Autocase uses social values for criteria air contaminant (CACs) to monetize the impacts of changes in outdoor air pollutant quantities derived from changes in operational energy use. Autocase uses federal guidance from the Environment Protection Agency (EPA), Federal Aviation Administration (FAA), National Environmental Policy Act (NEPA), ExternE, World Health Organization (WHO) Air Quality Guidelines, and federal, regional departments of transportation to assess the pollutants of interest.

CARBON AND CRITERIA AIR CONTAMINANT EMISSION

The pollutants analyzed by Autocase are:

- NOx
- SO2
- PM2.5
- VOCs

Autocase uses the following sources to build a location specific valuation of CAC emissions: Estimating Air Pollution Social Impact Using Regression (EASIUR) (2015), EPA (2012), Muller et al. (2007), Rabl & Spadaro (2000), RWDI (2005), Sawyer et al. (2007), Transportation Research Board (2002), U.S. Department of Transportation (2017), Victoria Transport Policy Institute (VTPI) (2011) and Wang et al. (1994). Each of these sources value reduced emissions on four key fronts: health, ecology, visibility, and the built environment. Health outcomes may be divided into mortality (loss of life) and morbidity (negative quality of life due to diseases or illness).

EASIUR is a regression tool used by Autocase that simulates location-specific public health costs per grid, where each grid covers 36x36 square kilometers. Public health costs by EASIUR are calculated in terms of a change in mortality rate and years of life lost (YOLL) per death, monetized using a Value of Statistical Life (VSL). The other sources described above, specifically U.S. Department of Transportation, VTPI, EPA extend the analysis to include other human health impacts such as chronic bronchitis, emergency room visits, lower and upper respiratory symptoms, and restricted activity days). These health impacts are monetized using a combination of avoided damage-costs and a willingness to pay (WTP) to avoid negative health outcomes. Additionally, other impacts also accounted for are changes in crop yields, changes in visibility, and structural damage. For instance, Sawyer et al. (2007) uses Environment Canada's Visibility Impacts Estimator of Welfare (VIEW) model to monetize marginal changes in visibility attributable to increased particulate matter emissions.

VEHICLE MILES TRAVELLED

A key feature of the Nature Towns design layout is the improved walkability to amenities within the community. Using assumptions provided by the project team, it is assumed that Nature Towns will simulate a modal shift in private vehicle usage such that each household is expected to reduce the number of cars from 3 per household to 1 per household. Further, it is also expected that with improved walkability, each car is expected to cover only 12,000 miles per year and shift to using electric vehicles which gets a mileage of 100 MPGe. In incremental terms, it is expected that each household then has a reduction in vehicle miles travelled at 45,500 miles per year. Additionally, a modal shift is expected wherein, an increased dependency is expected on public transit, further reducing total vehicle miles travelled by 8,000 miles per year. Overall, across 1,280 households the project is expected to benefit from 47 million vehicle miles reduced per year. This is expected to generate social and environmental benefits of to include operations cost for cars, noise, road infrastructure, safety, and environmental carbon and criteria air contaminant reductions.

Value of Reduced Accident Risk

Reducing vehicle miles reduces the risk of car accident, injury, or death. These safety benefits are estimated with 2014 to 2018 NHTSA (2019) average of US crash statistics involving cars, and rating injury costing (USDOT, 2018). This results in a safety benefit of $0.28 per vehicle mile travelled.

Value of Reduced Private Vehicle Operations

Reducing vehicle miles reduces annual operating costs. Operation costs estimated for this benefit include maintenance cost of cars per year, as estimated by the US Department of Transportation (2020) at $0.09 per mile.

Value of Reduced Commuter Time

Reducing vehicle miles reduces the congestion of cars on road. The avoided cost of congestion is computed using data from the US Department of Transportation (2008) at $0.21 per vehicle mile.

Carbon and Criteria Air Contaminant Emissions Reduction

Reducing vehicle miles are a major source of carbon equivalent and criteria air contaminant emissions as community members are expected to travel shorter distances. This allows for reduced negative impacts to the ecosystem and the climate. Reduced emission levels are calculated using GREET and

VEHICLE MILES TRAVELLED

monetized using social values for each pollutant from sources such as Interagency Working Group (2016) on the Social Cost of Carbon, and a wide range of sources for criteria contaminants, listed in detail under Energy Efficiency & Renewable Energy above.

Noise Pollution Reduction

Reducing vehicle miles reduces noise, which generates value to the community. Noise pollution of roadways manifests as unwanted sounds and vibrations, with personal and financial implications. Noise directly impacts the health of people as it increases cardiovascular disease risk, decreases cognitive ability, increases sleep disturbance, increases prevalence of tinnitus, and increases annoyance levels. A study by Essen et al. (2019), identified the noise reduction benefit per vehicle mile travelled and segmented the values by type of vehicle, time of day, congestion level. The study also accounts for projects located in an urban, suburban, and rural areas. Considering a 50% suburban and 50% rural mileage, the value per vehicle mile travelled is multiplied by the total vehicle travel miles reduced to obtain the noise reduction social value.

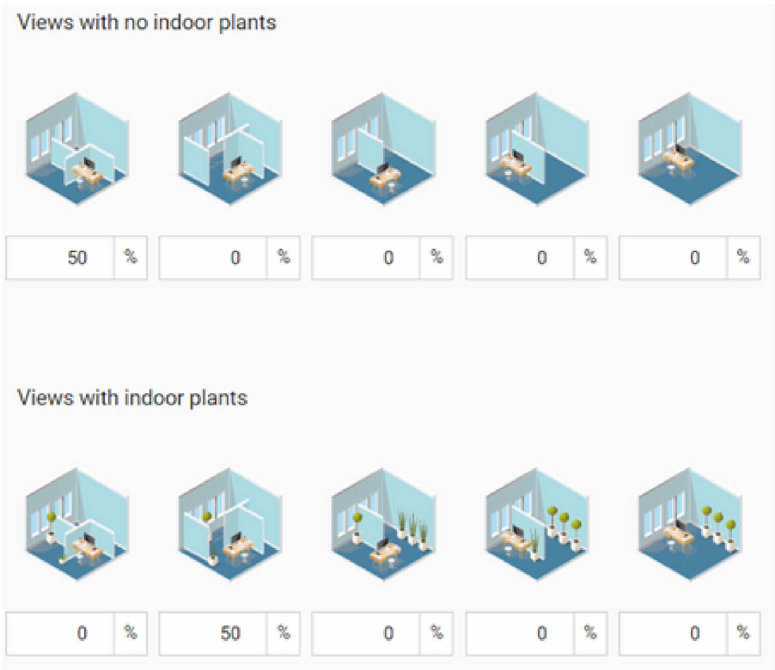
INDOOR ENVIRONMENT QUALITY: QUALITY VIEWS

Building sight lines can lead to effects on occupant's productivity and absenteeism through improved views. As a part of the Nature Towns project, views with plants are expected to increase in the design case as compared to the baseline. As a project evaluation of the entire community, it is assumed that all community occupants are expected to benefit from views of plants from their office buildings within the community.

Productivity

Increasing green spaces within the employees' sightline can increase productivity up to 13.5%, for the best view rating (Heschong & Mahone, 2003). In this project, it is assumed that 50% of the community has access to a View Rating of 2 with plants. This is shown in the figure below, where there is partial view of plants for employees at their desks. Autocase uses an average office building wage for Texas to monetize the increase in productive work hours.

Figure 3: View Ratings in Autocase for Buildings Software



Absenteeism

Increasing green spaces within the employees' sightline can reduce up to 11.0 sick hours annually (Elzeyadi, 2011). Autocase uses this relationship and an average office building wage rate to estimate the change in absenteeism and therein, the change in productive work hours.

RECREATION

Nature Towns is expected to make significant investments into recreational amenities across the project sites. Recreational activities in open spaces are typically free of charge, but the direct use value can still be estimated. The recreation model uses two papers from The Trust for Public Land's Center for City Park Excellence (2008a; 2008b) that estimate the direct use value for recreational activities in Boston and Philadelphia. These studies surveyed community members on how much they would pay in the marketplace (a direct value per activity). For instance, researchers would use the price paid at commercial facilities with admission fees to participate in similar recreational activities, to derive a direct use value per activity. Using a project location of Austin Texas, we apply a cost of living index (Numbeo, 2018) to transfer the direct use values from Boston and Philadelphia to the project location.

A key input for this model is the number of visits by the community per year. The breakup for visitors to each amenity were provided by the project team and listed in the Inputs and Data section. Further, a baseline assumption has been made that in the absence of Nature Town designs, the community would only have recreational space within private home backyards, and no comparable public spaces. Autocase's research therefore applies a scarcity premium of low public space availability in the baseline to the direct use values (based on literature from the U.S. Army Corps of Engineers (2017)). The scarcity premium enables the model to account for communities that lack access to open space, increasing the value of an activity for areas that lack such amenities. Combining the direct value and scarcity premium, Autocase estimates the annual total value (benefit or cost) of recreation applied through the operations duration.

PUBLIC HEALTH

Low impact developments (LID), parks, and green space are attractive locations for exercise. The economic benefits of improved health from engaging in regular physical activity can be valued as the avoided reduction in productivity (from reduced presenteeism at work). Therefore, lost economic output from people being out of work or not engaged while at work represents the social cost in this model. The social cost of inactivity is estimated at $0.09 per minute of exercise (M., Pelletier, B., Lynch, W. [2004]; United States Census Bureau [2016]).

The number of visitors to these green spaces include those visiting fitness pads, sports pads, walking trails, jogging trails – a cumulative of 1,678 visitors per day. The amount of time spent per activity is estimated at 30 minutes on average – as suggested by the American Heart Association (2015) recommendations for exercise routines. According to the American Health Association, on average, only 48% of individuals engaged in exercise meet a minimum 150 minutes of aerobic activity (Cohen et al., 2011). Autocase thereby calculates a proportional public health benefit from exercise to represent the avoided loss of productivity from reduced presenteeism at work.

URBAN HEAT ISLAND

Heat waves are an increasing danger across North America, sometimes resulting in large numbers of premature heat-related deaths. These events may be more frequent and severe in the future due to climate change. Investing in a green space can reduce the severity of extreme heat events by creating shade and reducing the amount of heat absorbed hardscapes, i.e. affect the ambient temperature. Even a small cooling effect can be enough to reduce heat stress-related fatalities during extreme heat wave events. Nature Towns is expected to have urban heat island benefits from the incremental acres of green space in the design case as well as investments into denser vegetation in the design case as compared to the baseline turf and hardscapes.

Location specific (mapped to 25 square km cells) temperature forecasts are used from the CanESM2 model by the Canadian Centre for Climate Modelling (CCCma, 2017). The CanESM2 model represents the Canadian contribution to the IPCC Fifth Assessment Report (AR5). Data is extracted for RCP scenarios 4.5 to estimate the change in expected mortality from heat-stress related events over the project period. Using literature from Guo, et al. (2014), a Minimum Mortality Threshold (MMT) is set to identify the monthly number of days that have temperature exceeding this threshold above which the risk of heat-exposure related mortality increases.

The change in ambient temperature for hardscapes are estimated using solar reflectance indexes (SRI), and from green covers using heat fluxes (Watts/m2) and thermal conductivity (Watts/m2 K) (Alchapar et al., 2014; Madhumathi et al., 2018; Radhi et al., 2014; Santamouris et al., 2011; Tran et al., 2009; Uzarowski et al., 2018; Sharma et al (2016); Parshall et al (2016); Sailor & Hagos (2011)). These parameters inform the incremental change in surface temperature between different ground covers. A change in surface temperature is converted to a change in ambient temperature using literature from Guan (2011). The incremental change in ambient temperature between the base and design case informs the change in mortality. The value of statistical life (VSL) is used to monetize the change in mortality to calculate a benefit of investing in cool or green roofs for the user.

CARBON SEQUESTRATION & CRITERIA AIR CONTAMINANT DEPOSITION

Vegetated ground cover is associated with the benefits of carbon sequestration and pollutant deposition. Nature Towns is expected to have green cover that extends to 198 acres in the design case as compared to 178 acres of turf in the baseline. Plants sequester carbon by accumulating carbon in plant biomass that is above and below ground, as well as in the soil beneath the vegetation in the form of soil organic carbon. The rate at which carbon is sequestered depends on the type of vegetation. Larger plants sequester more carbon as they have more above and below ground biomass, both of which store carbon. Plants are also responsible for dry deposition of criteria air contaminants such as particulate matter, nitrous oxides, and sulphur dioxide. Total carbon sequestered is estimated at 60,000 tonnes over 40 years.

The best available scientific evidence has shown a variation in sequestration and deposition between vegetation that is managed or unmanaged, with unmanaged vegetation having higher sequestration rates owing to the energy emissions from vegetation maintenance. To account for differences of climate in different regions, Autocase uses the length of the local growing season. The length of the growing season is estimated following the US EPA procedure of determining the last frost day of the spring and the first frost day of the fall, with the number of days in between defining the growing season (US EPA, 2016). This scales the amount of the year in which plants will grow and carbon will be sequestered, accounting for regional climatic differences. Carbon and other pollutant sequestration rates (Getter et al., 2009; Gopalakrishnan et al., 2018; Kuronuma et al., 2018; Liebig et al., 2008; Qian et al., 2010; Selhorst & Lal 2012; Whittinghill et al., 2014; Zirkle et al., 2011) are monetized using the social cost of carbon and air pollutants.

CARBON EMISSIONS REDUCED FROM WASTE MANAGEMENT

Nature Towns is engaged in waste management practices to increase the tons of solid waste recycled and composted per year. According to documentation provided, we expect to recycle 1049 tons, and compost 312 tons of waste per year. Autocase uses the WARM tool v15 (2020) by the EPA to estimate the reduced carbon emissions by recycling and composting. In total, we expect a reduction in 2,700 metric tonnes of carbon per year. Autocase monetizes this reduction in carbon emissions using the social cost of carbon.

As a part of reduced waste incineration, the tool also generates a reduced need for electricity, estimated at 27,966 Million BTU per year. This reduced energy consumption is combined with energy efficiencies on site to generate additional financial savings to the community, as well as reduced greenhouse gas and criteria air contaminant emissions.

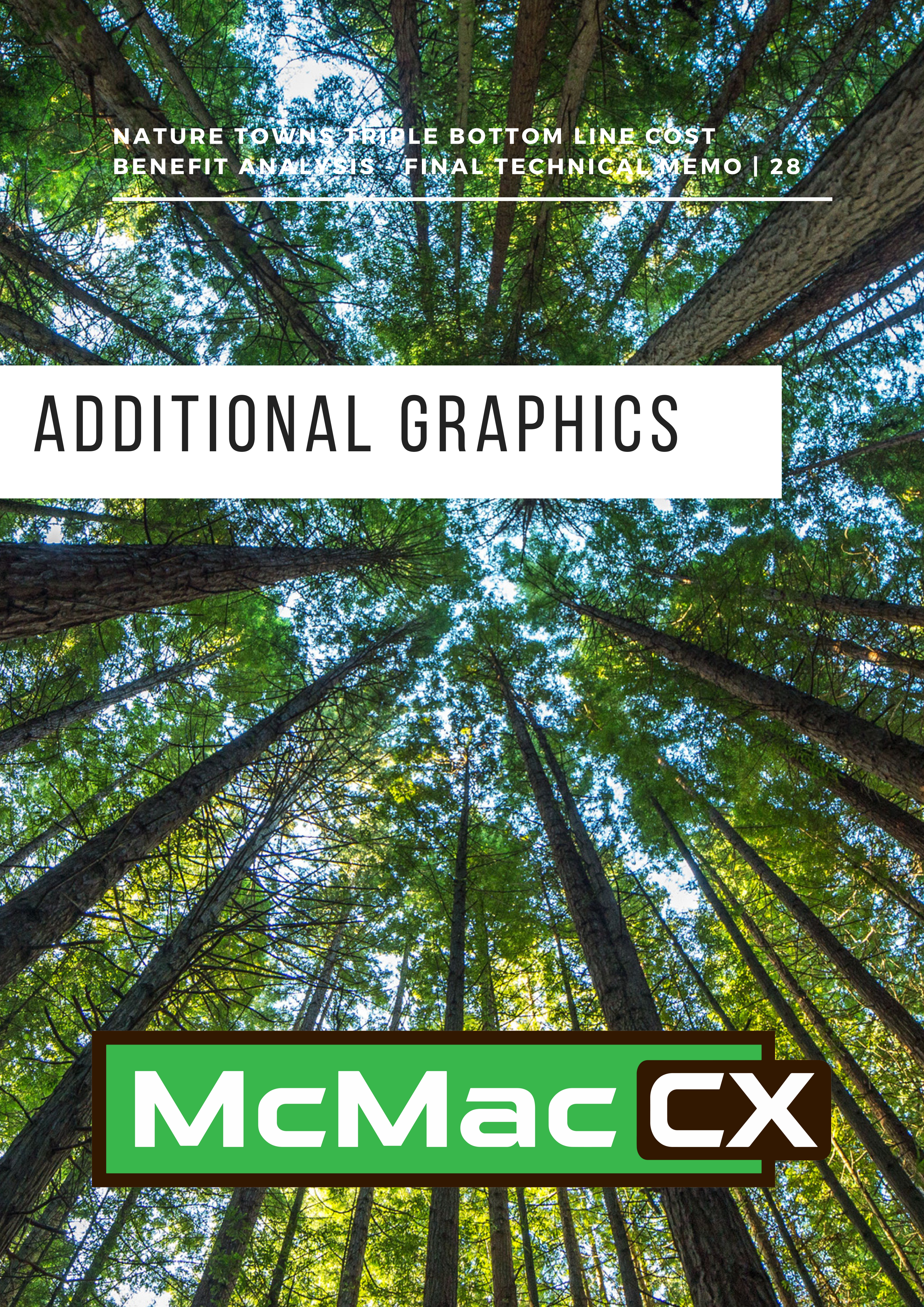
WATER QUALITY

Increased acres of vegetation, including low vegetation such as turf, medium vegetation such as shrubberies and trees are responsible for improving the water quality in downstream water in local areas by reducing runoff. Autocase uses location specific (mapped to 25 square km cells) precipitation forecasts are used from the CanESM2 model by the Canadian Centre for Climate Modelling (CCCma, 2017) to estimate the level of runoff between the baseline and design case. Information provided by the project team suggest a change in infiltration between the base and design case from a Type A soil to a Type D soil to account for engineered soil that has a higher level of infiltration capacity. Further, the design case is also expected to convert impervious hardscapes into green infrastructure such as detention ponds, and constructed wetlands, that are expected to capture additional runoff from nearby impervious surfaces.

This reduction in onsite runoff is expected to reduce the level of pollutant loads downstream, and thereby reduce negative impacts of water contamination. Autocase uses pollutant loading estimates to calculate the levels of Nitrogen, Phosphorus, Total Suspended Solids, and heavy metals such as Copper, Lead, and Zinc that are captured on site. Autocase values the changes in pollutant loads by applying a social cost of water pollutants. This social value is estimated using best available scientific research from Hernandez-Sancho et al. (2015) that uses wastewater treatment costs, and level of pollutant loads in runoff water at the study site to assign a shadow price to each pollutant type (Nitrogen, Phosphorus, Total Suspended Solids). The social value for heavy metals is estimated using research from the CE Delft Handbook (2019) that assesses the marginal damages of heavy metals in runoff water in terms of ecotoxicity.

POLLINATION

Urban farms act as a positive influence on pollination. Given Nature Towns significant investment into urban agriculture and green space, pollination is expected as an environmental benefit as compared to hardscapes under baseline conditions. The value of pollination is derived from FEMA (2013) guidance geared specifically towards the inclusion of environmental benefits within cost benefit analysis conducted for newly constructed green open space and riparian land use. These values are generated in terms of the ecosystem services provided by green space such as aesthetic value, quality, biological control, climate regulation, pollination, recreation etc. FEMA values the benefits of pollination at roughly $321 per acre.



ADDITIONAL GRAPHICS

Figure 3: TBL-NPV Breakdown by Impact Category

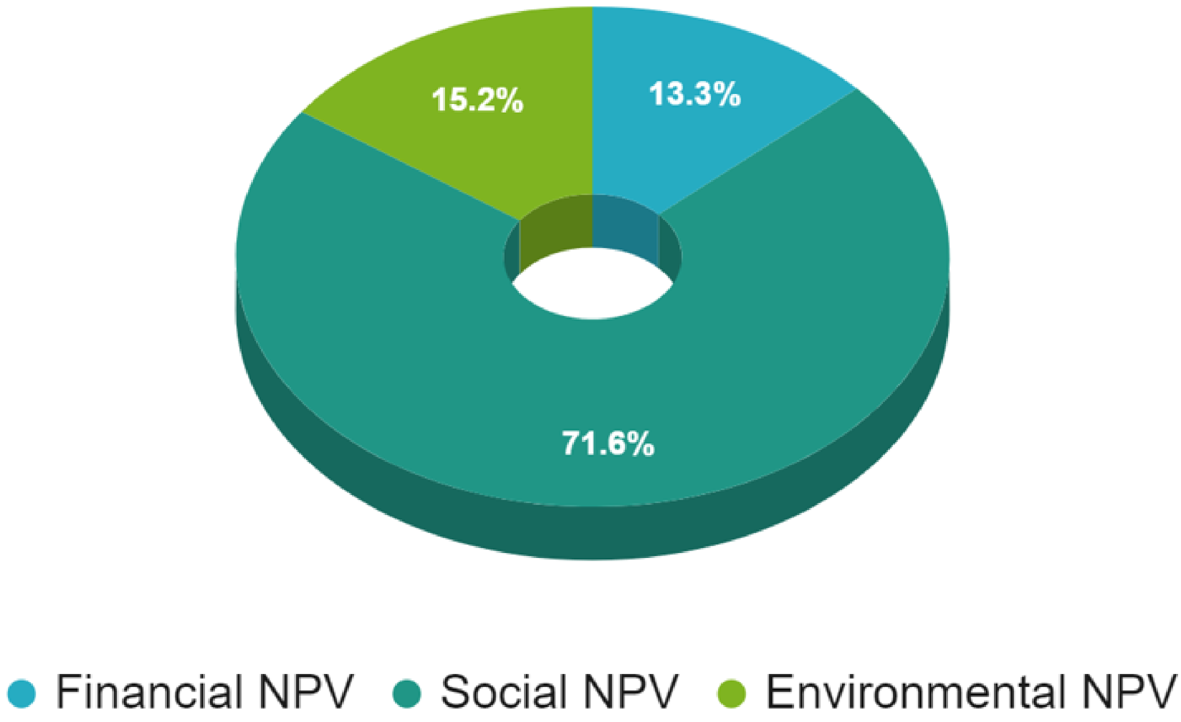


Figure 4: Financial Net Present Values by Impact Category

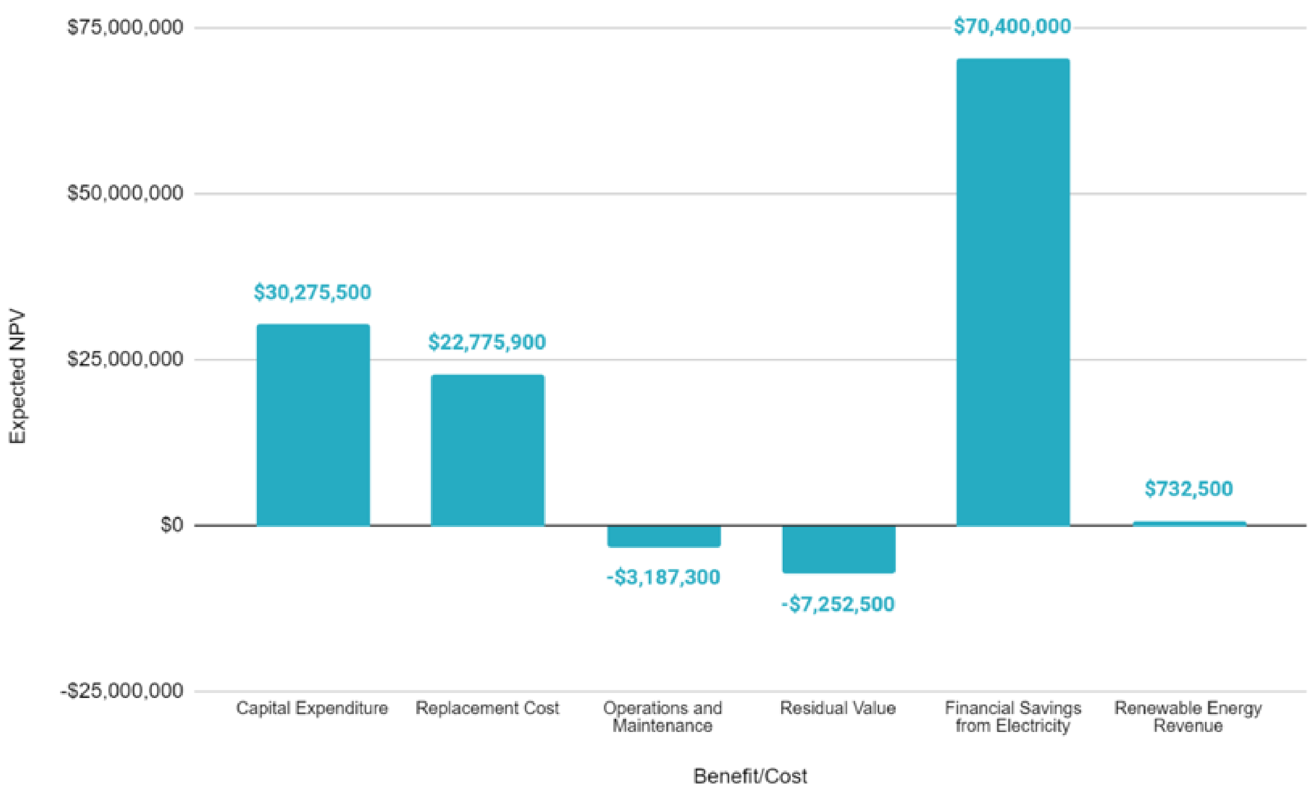


Figure 5: Social Net Present Values by Impact Category

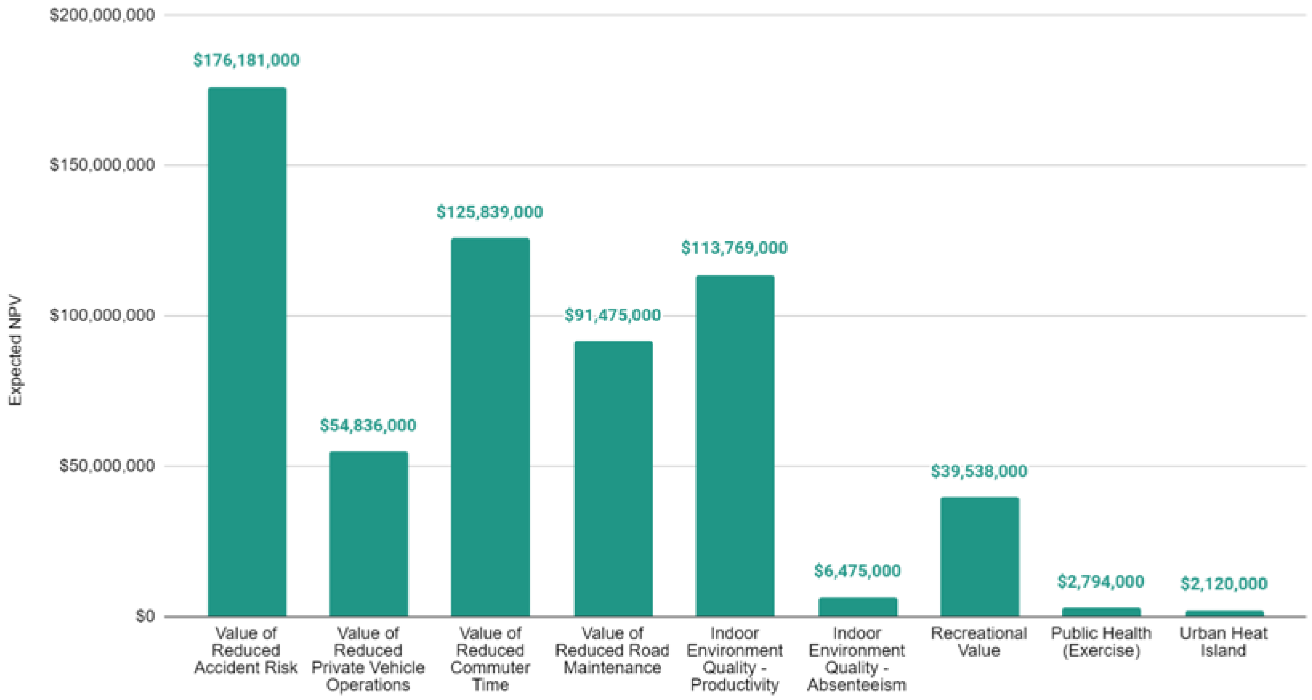
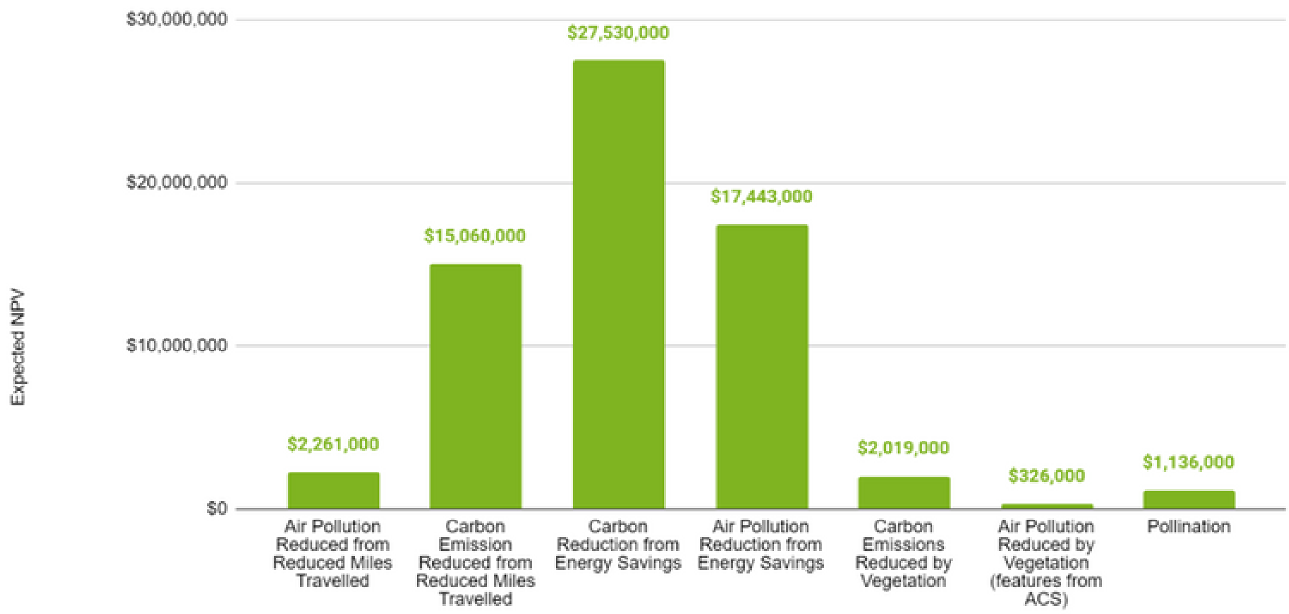


Figure 6: Environment Net Present Values by Impact Category (Air Pollutant and Carbon Emissions Reduction)



INPUTS AND DATA

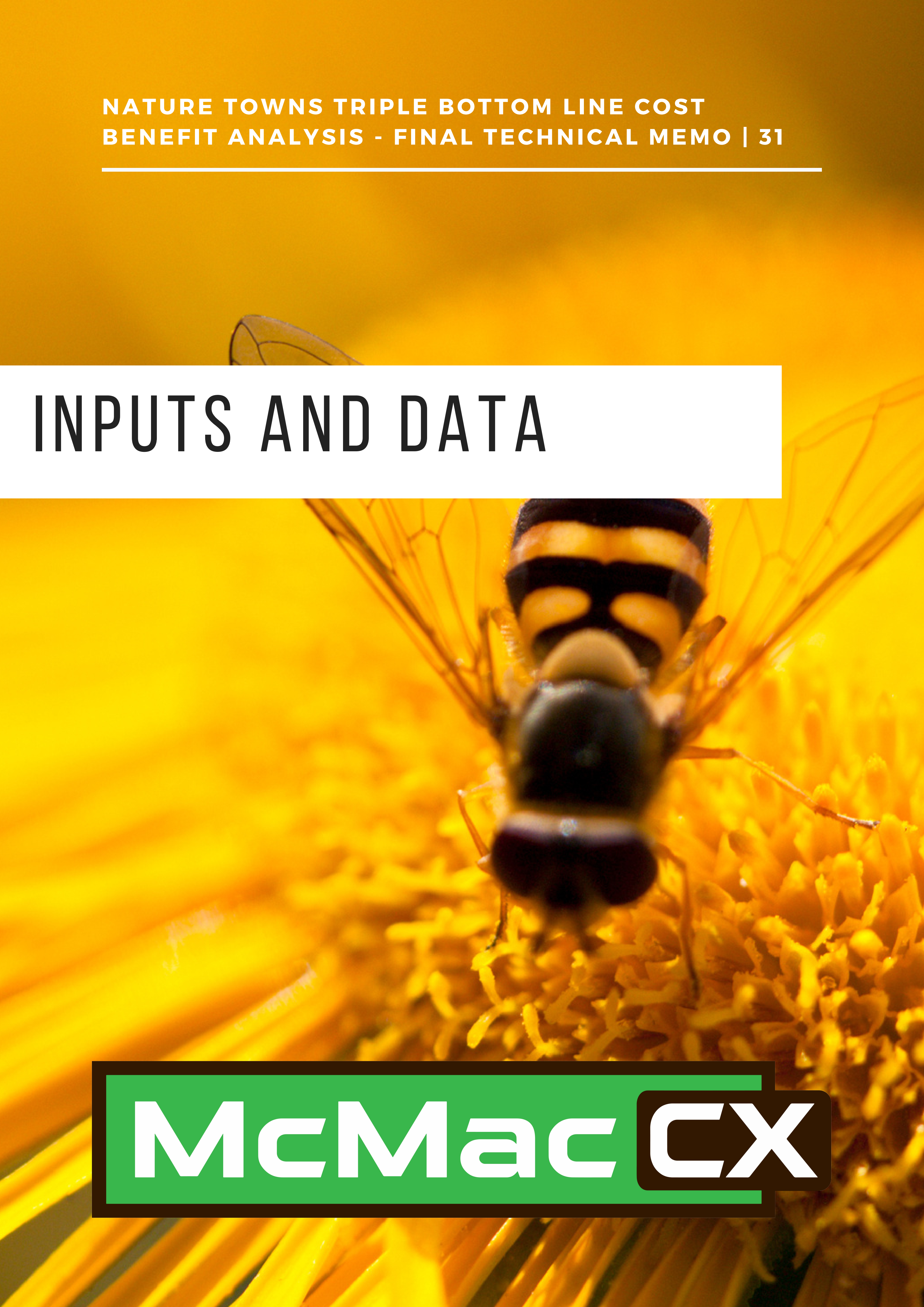


Table 5: Project Parameters

Project Inputs	Units	Values
General Inputs		
Site Area	acres	320 (191 acres green in design)
Population	#	2,880
Number of households	#	1,280
Construction Duration	Years	7
Operations Duration	Years	40
Financial Inputs		
Project Discount Rate	%	3%
Electricity Cost	$/kWh	$0.0831
Electricity Price Forecasts Growth	%/year	1.03%
Natural Gas Cost	$/MMbtu	$6.8316
Natural Gas Price Forecasts Growth	%/year	1.08%
Electricity Emissions Factors		
Carbon Dioxide Equivalents	Metric tonnes/Million MWh	535,693
Nitrous Oxide	Metric tonnes/Million MWh	361
Sulphur Dioxide	Metric tonnes/Million MWh	494
VOCs	Metric tonnes/Million MWh	6
Particulate Matter (2.5)	Metric tonnes/Million MWh	26
Natural Gas Emissions Factors		
Carbon Dioxide Equivalents	Metric tonnes/Million MMBtu	53,363
Nitrous Oxide	Metric tonnes/Million MMBtu	54
Sulphur Dioxide	Metric tonnes/Million MMBtu	0.26
VOCs	Metric tonnes/Million MMBtu	2
Particulate Matter (2.5)	Metric tonnes/Million MMBtu	2
Social values - Pollutants		
Carbon Dioxide Equivalents	$/ metric tonne	$51.94
Nitrous Oxide	$/ metric tonne	$10,751.47
Sulphur Dioxide	$/ metric tonne	$33,957.46
VOCs	$/ metric tonne	$2,262.6
Particulate Matter (2.5)	$/ metric tonne	$217,824.4
Social values – transit		
Noise	$/mile	0.47
Congestion	$/mile	0.20
Road Maintenance	$/mile	0.14
Accident Risk	$/mile	0.28
Vehicle Maintenance	$/mile	0.08
Climate		
RCP (Representative Concentration Pathway) Scenario		RCP 4.5

Table 6: Life Cycle Cost Analysis Data Inputs

Life Cycle Cost Analysis Inputs				
Feature Type	**Capital Costs**	**Operations & Maintenance**	**Size of LID (sf)**	**Source**
Base case				
Asphalt	$8.9/sf	$6.24/sf	3,828,480	Autocase
Concrete	$7.99/sf	$1.32/sf	288,000	Autocase
Managed Turf	$3.92/sf	$9.46/sf	7,764,480	Autocase
Design Case				
Asphalt	$8.9/sf	$6.24/sf	295,261	Autocase
Concrete	$7.99/sf	$1.32/sf	699,805	Autocase
Retention Ponds	$2.29/sf	$0.06/sf	827,640	Project Team
Dry Detention Pond	$2.29/sf	$0.06/sf	479,160	Project Team
Piping	$2.58/ft	-	41,392 (ft)	Project Team
Grass Pavers	$6.88/sf	$10.86/sf	733,750	Project Team
Porous Concrete	$6.54/sf	$9.79/sf	779,750	Project Team
Trees	$0.12/sf	$0.00054/sf	840,022	Project Team
Shrubs	$0.22/sf	$0.01/sf	6,969,600	Project Team
Constructed Wetland	$1.2/sf	$0.05/sf	87,120	Project team

Table 7: Input and data variables for other models

Input Variable	Units	Values
Vehicle Miles Travelled Model		
Base case (3 cars)	Annual miles per household	37,400
Design case (1 car)	Annual miles per household	12,000
Modal Shift to Transit	Annual miles	8,000
Pollination		
Incremental green space area	Acres	191
FEMA – Environmental Value	$/acre	$320
Biodiveristy		
FEMA Habitat Value	$/acre	927
Sequestration		
Low vegetation rate	Kg/sq meter / year	0.14
Medium – High vegetation rate	Kg/sq meter / year	0.25
Farm – sequestration	Kg/sq meter / year	2.65
Waste Management		
Recycled paper	Tons / year	593
Recycled metals	Tons / year	34
Recycled mixed plastics	Tons / year	314
Recycled glass	Tons / year	108
Composted food waste	Tons / year	556
Composted yard trimmings	Tons / year	312
Energy Efficiency		
Baseline energy consumption reduction	kWh/year	11,484,000 +(5,176,329 kWh EV)
Design renewable energy production	kWh/year	17,226,000
Percent of electricity offsetting electricity	%	100%
Useful life of system	Years	20
Degradation rate (annualized)	%	0.18% / year
Renewable energy sold back to the grid	kWh	4,263,701
Wholesale price for renewable energy sold back into the grid	$/kWh	0.03
Indoor Environment Quality – Quality Views		
Baseline views	-	View rating 1 – 100%
Design case views	-	View rating 1 – 50%; view rating 2 with plants – 50%

*Revenues have been sourced from the farm's projections from 2021-2028 revenues from tree fruit, vine fruit, and vegetables. Since Cost-benefit analysis does not attribute revenue benefits within the construction duration, the first year of revenues is assumed to be 2028.

Table 8: Recreational Visitors per Amenity per Day

Recreational amenities	Visitors / amenity / day
Dog Parks	793
Fitness Pad (Team Sports)	394
Meditation Garden (Birdwatching / Nature)	627
Sports Pad (Team Sports / Tennis)	300
Social (Festivals or Performances Picnic, bench-Sitting)	631
Children / Kids (Playground)	287
Gardens	710
Walking Trails	643
Jogging Trails (Running Track)	344
Miscellaneous	348

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