Tucson
Resilient Together

City of Tucson
Cost-Benefit Analysis and Multi-Criteria Analysis of Key Climate Action and Adaptation Strategies
(Final Technical Memo)

Autocase

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About

Autocase^{TM} (created by Impact Infrastructure) is a team of professionals across North America that have developed best-practice cost-benefit analysis approaches and automated economic evaluation software tools while being involved in all facets of real estate, infrastructure development, and policy evaluation.

The firm has worked with corporations and all levels of government to support decision making, project prioritization, and stakeholder outreach. Our primary goal is to create a standardized suite of business case analysis tools to promote the development of more sustainable and resilient communities. The firm's professional economists conduct rigorous economic assessments to help decision makers prioritize worthy but competing projects based on maximum economic, environmental and community benefits.

This study is conducted in partnership with Buro Happold – integrated consulting engineers and advisors - who collaborated around the development of the decarbonization strategies, economic modeling assumptions and data parameters.

Acronym Glossary

AFLEET - Alternative Fuel Life-Cycle Environmental and Economic Transportation
BCR - Benefit-Cost Ratio
CAAP - Climate Action and Adaptation Plan
CAC - Criteria Air Contaminants
CBA - Cost-Benefit Analysis
CO2e - Carbon Dioxide Equivalent
DOE - U.S. Department of Energy
DOT - U.S. Department of Transportation
EASIUR - Estimating Air Pollution Social Impact Using Regression
EIA - U.S. Energy Information Administration
EPA - Environmental Protection Agency
ESCO - Energy Service Company
EUI - Energy Use Intensity
EV - Electric Vehicle
GHG - Greenhouse Gas
GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GWP - Global Warming Potential
ICE - Internal Combustion Engine
kWh - Kilowatt-Hour
LCCA - Life Cycle Cost Analysis
MCDA - Multi Criteria Decision Analysis
MMBtu - Million British Thermal Units
MSW - Municipal Solid Waste
MT - Metric Tonne
NEPA - National Environmental Policy
NOx - Nitrous Oxide
NPV - Net Present Value
O&M - Operations and maintenance
SOx - Sulfur Oxide
SSA - Solar Service Agreement
TEP - Tucson Electric Power
VMT - Vehicle Miles Traveled
VPPA - Virtual Power Purchase Agreement
VTPI - Victoria Transport Policy Institute
WARM - EPA Waste Reduction Model
WHO - World Health Organization

1. Background

1.1. Overview

This technical memo depicts the details of two distinct quantitative economic and business case analyses developed to complement the broader planning efforts supporting the Tucson Resilient Together Climate Action and Adaptation Plan (CAAP). Autocase Economic Advisory, in collaboration with Buro Happold, conducted a two-stage analytical approach to support the decision process around the CAAP implementation – a Multi-Criteria Development Analysis (MCDA) framework to help better understand the relative merits of the full list of CAAP strategies , and a more granular economic business case Cost Benefit Analysis (CBA) on a short-list of strategies to understand relative value in monetary terms. There are numerous innovative and practical strategies to help drive towards the CAAP goals; however, these options are not all created equal with varying costs, benefits, and impacts over a long-term period. These analyses are intended to provide additional insights into strategy outcomes.

1. Cost Benefit Analysis (CBA): this is an enhanced economic business case analysis conducted on a short-list of six decarbonization strategies (containing 20 actions) from the full list of strategies developed in the Tucson Resilient Together CAAP. The intent is to use a rigorous cost benefit analysis business case framework to quantify and monetize the incremental life cycle financial, social and environmental (triple bottom line) costs and benefits over a long-term study period. This allows for deeper understanding into the quantitative outcomes of the various climate strategies. As the City's implementation plan for these strategies becomes more developed, the evaluation process can support an iterative planning process if the City elects, which is not within the scope of this current project. The goal is to inform policy design, quantify community impacts, and understand trade-offs within the various options using a well-established framework with best-available scientific data, empirical evidence, and peer-reviewed literature. This sustainable business case for the actions aligns strategic environmental goals with economic value and offers Tucson the opportunity to understand the costs and benefits of climate actions beyond solely their accounting ledger of financial costs by measuring the intrinsic social and environmental performance. The CBA was conducted at an early stage in the capital planning process to implement the strategies and actions of the CAAP. As such there was limited quantitative information developed on the strategies and actions evaluated. The analysis is intended to speak to high-level projected outcomes, based on a series of underlying assumptions and information garnered from a variety of jurisdictions. As the City's efforts focus on implementation a more robust CBA could be iterated upon with more certainty and specificity around strategy designs and parameters, which is not within the scope of this current project.

2. Multi-Criteria Decision Analysis (MCDA): To support an evaluation of the full list of strategies at this stage of solution development, a MCDA was developed to incorporate a broader set of considerations in addition to cost-benefit analysis outcomes such as equity outcomes, community drivers, and other project characteristics. An MCDA is a decision-support process that allows stakeholders to identify the goals, objectives, and criteria for a project, as well as the associated metrics that may be used to score a project as a measure of compliance or project success. These quantitative and qualitative metrics are commonly weighted to identify the hierarchy of criteria or preferences, such that strategies that target the same broad objective can be compared against other criteria scores that are of most importance to stakeholders. The MCDA allows a broader ranking and prioritization among strategies, and achieves this by scoring, weighting, and ranking each strategy on a relative basis to each other based on a set of key criteria and sub-criteria. This formalized quantitative approach will help to prioritize proposed actions and strategies for implementation. The list of criteria, sub-criteria and quantitative scoring framework were developed specifically for this early stage of the capital planning process to implement the strategies, with limited quantitative information on the CAAP strategies. This MCDA could be iterated upon and supplemented as quantitative information on the strategies is more developed.

This technical memo is segmented into these two analyses, with each section outlining the key concepts, methodologies, assumptions, results, and data.

2. Cost Benefit Analysis - Analytical Framework

The City of Tucson initiated the development of this report to ensure a fact-based financial and economic assessment of a selection of possible decarbonization strategies. As part of this evaluation, Tucson can integrate these economic findings into the decision support and stakeholder engagement process. These analytical efforts can create an objective, defensible, and transparent screening process for both the financial and broader societal impacts of various integrated sustainability and resiliency planning, policy, and infrastructure options available.

When planning for climate mitigation and adaptation policies and projects, it is essential to consider, not only the upfront cost of a project or policy, but what benefits will society as a whole see from implementing those projects or policies.

Cost-Benefit Analysis (CBA) is an established economic approach for comparing the benefits and costs of a given project or activity. CBA involves identifying, quantifying, monetizing and summing in dollars, to the extent possible, the value of incremental costs and benefits over the life of a project. It provides a systematic evidence-based economic business case approach to quantify and attribute monetary values to the direct financial impacts, as well as broader social, environmental, and equity impacts resulting from an investment using empirical data and peer-reviewed literature. This analysis is comprised of a financial analysis - specifically a life cycle cost analysis (LCCA), depicting the estimated high-level costs over a long-term study period, including upfront capital costs, ongoing operations and maintenance, any avoided costs or revenues associated with the strategies and actions. The framework then adds the quantified and monetized social and environmental co-benefits or disbenefits, accounting for a broader set of non-financial impacts.

The importance of CBA for decision makers is that its results provide a quantitative measure of a project's worthiness. The analysis involves a comprehensive account of a project's benefits and costs over the entire project life cycle and a "side-by-side" comparison of net benefits for alternative investments. The analysis is depicted on an incremental comparative basis to a base case - in this analysis, the base case would be the status quo across the actions and strategies without these CAAP investments with the exception of the decarbonization of the existing grid (based on a 80% renewable by 2035 target for Tucson Electric Power (TEP) applied to the Western Electricity Coordinating Council / Southwest emission factors by the U.S. Energy Information Administration (EIA, 2022)).

CBA is an industry standard decision-support tool used to inform and improve public policy, programs and projects. Essentially, this approach helps prioritize projects in a standardized way, as well as provide insights as to the impacts on various project stakeholders. For example, the US, Europe, and the UK mandate legislative requirements to use CBA to evaluate policies and policy reforms, and CBA is required for a variety of merit-based federal grant funding programs. Additionally, the World Bank and other multilateral financial institutions, such as the Inter-American Development Bank and Asian Development Bank widely use CBA to help bring about a better allocation of resources, to provide insights into overall societal welfare gains, direct financial impacts, sustainability impacts, and assess project risks.

The methodological framework of CBA can be used as a screening-level lens in which to better understand the long-term trade-offs for greater upfront investment in climate mitigation and adaptation actions from a development and policy standpoint and the future implications to those investments. Results are presented to help prioritize projects and better understand trade-offs.

Strategies and Actions Evaluated

The climate action strategies evaluated within the plan are multi-faceted, and the underlying modeling to value the numerous economic impacts are complex. It is important to note that this is a high-level conceptual strategy evaluation - at an early implementation planning stage, where the minutiae of the quantitative effects and implementation has not yet been determined. The intent is to serve as an initial valuation to provide greater insight into the strategy outcomes at this stage.

These particular strategies were selected among the broader list of strategies for a few key reasons. First, these strategies were likely to have the most significant municipal emissions reduction potential given the 2030 carbon neutrality target, giving them some level of priority with respect to implementation. On a related note, some of these strategies could have significant community-wide emissions reductions, which would make significant dents in the newly set community-wide emissions goal. Second, these strategies were selected because of their potential co-benefits. Third, these strategies were selected because of the challenges and resources required to implement. The strategies selected for this analysis are more involved, so they merit examination to better inform the City's actions going forward. Fourth and finally, these were selected because they reflect some of the community's priorities.

The strategies and actions evaluated are listed in Table 1.

Table 1. Strategies / Actions Evaluated

Strategy	Action	Details
Decarbonize City-owned and operated buildings and facilities	E-1.1	Benchmark energy use of City buildings and facilities using EnergyStar Portfolio Manager
	E-1.2	Create an internal carbon tax for City departments that is informed by the City's emissions portfolio
	E-1.3	Implement ongoing weatherization and retro-commissioning (building tune-ups)
	E-1.4	Develop a net zero building framework for City-owned buildings and facilities, including but not limited to energy efficiency, electrification, and renewables
	E-1.5	Utilize an energy services company (ESCO) to rapidly but strategically implement energy efficiency measures and equipment in City-owned buildings, and ongoing energy management
Procure zero-emission electricity and decarbonize City and community power supply	E-3.2	Work with community advocates and other jurisdictions to co-form a community choice energy program or joint powers authority to procure 100% renewable power for Tucson
	E-3.4	Pursue solar service agreements (SSAs) or virtual power purchase agreements (VPPAs) to meet the City's power needs for municipal operations
Champion walking, cycling, and rolling as sustainable and climate resilient mobility options	T-1.1	Use various funding sources, including Prop 411, to implement bicycle, pedestrian, and other zero emission mobility projects identified in Move Tucson to create a transportation network aligned with the Complete Streets approach
	T-1.5	Increase safety for all road users, including pedestrians and bicyclists, by eliminating lanes on wide roads and creating public space, walkways, enhanced crossings and signals, and protected bike lanes
Invest in safe, comfortable, and convenient public transit as the backbone of a sustainable and resilient transportation system	T-2.1	Maintain and expand the Frequent Transit Network to increase Sun Tran service frequency and improve Sun Tran bus service

Transition public agency fleets to zero-emission and Near-zero-emission vehicles	T-5.1	Implement a fleet management plan that mandates all newly purchased City vehicles (including replacements) are zero-emission vehicles and implements fleet efficiency evaluations to ensure that the City does not own or use more vehicles than it needs at any time.
	T-5.2	Develop capital project plans to install charging stations to meet the projected demand of fleet vehicles
	T-5.3	Develop implementation plan for replacement of City-owned medium-to-heavy duty vehicles with zero and near zero emission vehicles
	T-5.5	Create a funding and purchase plan for battery electric buses, paratransit vehicles, and other zero emission vehicles across all public transportation services
Implement a Community-wide Zero Waste Plan and accompanying initiatives to achieve zero waste for City operations by 2030, and community-wide zero waste by 2050	RR-1.1	Complete a solid waste characterization study to understand how much metal, glass, plastics, food waste, and other materials are in Tucson's waste stream, in order to devise tactics to reduce waste and disposal costs
	RR-1.2	Implement Zero Waste Plan for community-wide solid waste diversion
	RR-1.3	Incorporate Zero Waste goals and objectives into the City's waste contracts and franchise agreements
Create a community-wide organics collection and treatment program	RR-2.1	Prioritize food waste reduction via food loss prevention, food rescue/donation, and organics composting
	RR-2.2	Coordinate with haulers to establish an organic waste curbside collection program across the City and provide residents with organic waste bins and education
	RR-2.3	Develop a comprehensive strategy to divert organic waste from Los Reales Landfill

Key Study Parameters

The study period is consistent for all strategies from 2023 to 2050. While each action underpinning each strategy may vary in implementation timing and duration, for sake of consistency and simplicity where project timing is not explicitly referenced, the models assume a 2023 implementation and 27 years of operation. Annual cash flows (benefits and costs) are accounted for throughout the entire study period. To discount the future cash flows into today's dollars, a discount rate of 3% was selected for the analysis. By utilizing the real discount rate across the economic analysis, annual cash flows are not required to be inflated as this discount rate is net of expected annual inflation. All values are reported in 2022 dollars ($2022) unless otherwise noted.

2.1. Interpreting Results

The section below outlines the results from the cost benefit analysis for the project. The results are segmented into two core cash flow components - financial and social/environmental impacts.

- Financial cash flows include the life cycle costs associated with the different scenarios such as upfront capital costs, ongoing operations and maintenance costs such as utilities, avoided costs, as well as any revenues. Given the limitations of the quantitative data available at this time for the implementation of the strategies, these are not probable cost estimates, more like rough order of magnitude approximations using data from relevant sources and programs in other jurisdictions. Certain actions may have been more challenging to source data with greater uncertainty underpinning estimates or missing data leading to incomplete costing development.

- Social/environmental impacts include the cash flows associated with reduced emissions from renewable energy generation, energy consumption, productivity from active transportation, enhanced roadway safety, among others. These reflect both market and non-market sources of value attributable to the CAAP actions.

Results are presented as Net Present Value (NPV) and Benefit Cost Ratio (BCR). Using the two metrics together, one can get a sense of the scale of the impact (NPV), as well as the value generated per unit invested (BCR).

NPV is the present value of benefits net costs over the project's useful life inclusive of financial, social, and environmental impacts. Future cash flows are discounted into current dollars at rates of 3%. NPV is the principal measure of an investment's economic worth:

- NPV > 0, means benefits are larger than costs.
- NPV < 0, means costs are larger than benefits.

BCR is estimated as the present value of benefits divided by the present value of costs from capital expenditures and/or operations and maintenance. BCR is intended to illustrate the benefits that are achieved for every dollar invested.

- 0 < TBL-BCR < 1, project delivers less than $1 in benefit for every $1 in costs.
- TBL-BCR > 1, project delivers more than $1 in benefits for every $1 in costs.

3. CBA Results Overview

3.1. CBA Results

This investigation reveals the net present value, benefit-cost ratio, carbon (referred to as carbon or carbon dioxide equivalents (CO_2e) throughout) emissions reduced, and NPV per metric ton of CO_2e of implementing each strategy, as shown in the tables and figures below.

Table 2 presents summary results for the CBA. Summing across the strategies returns $7.9 billion in net present value associated with 76 million metric tons of CO2e reduced over the study period of 2023 to 2050, and just over 1.3 million metric tons reduced in 2030. The NPV per mt CO2e reduced over the study period ranges from $6/mt CO2e to $8,500; this metric can aid decision making of which initiatives are more cost effective at reaching carbon neutrality.

With the adoption of Tucson Resilient Together, the City is committing to achieving carbon neutrality in municipal operations by 2030 and community-wide by 2045. However, 2050 was selected as the end of the study period to account for post-implementation costs and benefits, recognizing that climate action and adaptation efforts will need to be sustained beyond the target year

Table 3 presents the detailed present values by strategy. Tables 4 and 5 present the annual and cumulative CO2e per year for each action over the duration of the study period.

Table 2. Summary Results

	E-1.1, E-1.2, E-1.3, E-1.4, E-1.5 & E-3.4	E-3.2	T-1.1, T-1.5 & T-2.1	T-5.1, T-5.2, T-5.3 & T-5.5	RR-1	RR-2	Total
NPV	$12,794,000	$4,450,299,000	$2,615,893,000	$22,317,000	$802,897,000	$22,938,000	**$7,927,138,000**
BCR	1.11	2,303.28	452.17	1.15	n/a	1.21	**32.07**
mt CO2e Reduced (2023-2050)	2,020,437	53,952,570	308,112	291,353	17,295,150	2,494,504	**76,362,126**
NPV per mt CO2e Reduced	$6	$82	$8,490	$77	$46	$9	**$8,711**
mt CO2e Reduced in 2030	82,828	651,208	11,706	13,709	441,237	63,640	**1,264,329**

Key findings and drivers for each of the strategies are detailed below.

E-1.1, E-1.2, E-1.3, E-1.4, E-1.5 & E-3.4

- The City will face consultant and municipal staff costs along with the costs of building retro-commissioning, retrofitting, and electrification by the energy service company (ESCO), and increased costs from energy consumption.
- The electricity consumption in the base case is lower than in the design case due to electrification where natural gas consumption is converted to electricity consumption, even with energy savings from retrofitting and retro-commissioning. Even though this is the case, there are still air pollution and CO2e emissions reduction because the emission factors in the base case are greater than the design; emissions in the design are offset due to the City contracting VPPAs, and subsequently RECs, to cover its electricity consumption (action E-3.4).

- The increased consumption of electricity from electrification results in higher electricity costs to the City. This incremental electricity cost outweighs the avoided cost of natural gas from the elimination of natural gas consumption, and creates a negative financial NPV due to electrification.

E-3.2 & E-3.3

- The price of Community Choice Energy is assumed to be lower than the residential, commercial, industrial electricity prices and the model therefore returns a positive financial NPV. Additionally, the sheer scale of the impact - the entirety of Tucson - to which the price and avoided air pollution and CO2e emissions causes the magnitude of these impacts.

T-1.1, T-1.5 & T-2.1

- Based on current assumptions that a mode shift would grow at approximately 1% per year (with walking, cycling and rolling as ⅔ shift and ⅓ shift to public transit), this small percentage increase would lead to roughly 2x higher transit bus VMTs (each year), as compared to actual public transit VMTs reported in 2019. This has sizable implications on the results presented in T-1.1, T-1.5, and T-2.1. There are significant benefits from reducing a high proportion of VMTs, but also face high costs to hire sufficient bus drivers to meet such elevated demand. For example in T-2.1, it is estimated that just under 900 Sun Tran employees would need to be hired (each year) to meet the increased public ridership, as compared to the workforce of 420 drivers in 2019.
- The number of walking, cycling, and rolling commuters grows over time as an increasing percentage of commuters switch to sustainable modes of transportation. This ultimately leads to a higher annual benefit resulting from physical activity.
- Although the model factors in the increasing percentage of commuters that switch to sustainable modes of transportation, there is a parallel effect from population increases that causes the City's VMTs to increase over time, which results in an increasingly higher annual number of avoided crashes.
- The proposed road diet safety enhancements are expected to result in an average of three avoided fatal crashes and 18 avoided incapacitating injury crashes each year.
- Avoided fatality crashes account for 70% of the total avoided crash value and avoided incapacitating injury crashes account for the remaining 30%.

T-5.1, T-5.2, T-5.3 & T-5.5

- T-5.1
  - Light-duty trucks are the largest driver, accounting for 50% of the cash flows. Passenger cars are not far behind, responsible for 41% of cash flows, while motorcycles make up the remaining 9%.
  - The financial savings stemming from avoided fuel purchases are 1.65 times the projected amount spent on electricity to fuel electric vehicles.

    - The financial savings stemming from avoided maintenance costs are 2.3 times the projected amount spent on vehicle purchase costs.
- T-5.3
    - Heavy-duty trucks are the largest driver, accounting for 63% of the cash flows, while medium-duty trucks are responsible for 37%.
    - The financial savings stemming from avoided fuel purchases are 1.5 times the projected amount spent on electricity purchases.
    - The financial savings stemming from avoided maintenance costs are 2.5 times the projected amount spent on vehicle purchase costs.
- T-5.5
    - Sun Tran buses are the largest driver, accounting for 88% of the cash flows, while Sun Van vehicles only make up 12%.
    - The financial savings stemming from avoided fuel purchases are 1.2 times the projected amount spent on electricity purchases.
    - The financial savings stemming from avoided maintenance costs are 1.9 times the projected amount spent on vehicle purchase costs.

RR-1 & RR-2

- Recyclable waste accounts for 42% of Tucson's municipal solid waste (MSW). Mixed paper is the largest driver, accounting for 42% of recyclable waste. This is followed by mixed plastics (24%), dimensional lumber (15%) and mixed metals (9%)..
    - The recyclable waste with the largest effect on carbon emission reduction is mixed metal, which reduces 4.39 tonnes of CO2e per ton recycled. This is followed by mixed paper (3.55 tonnes of CO2e per ton recycled), dimensional lumber (2.66 tonnes of CO2e per ton recycled), carpet (2.38 tonnes of CO2e per ton recycled) and mixed plastics (0.93 tonnes of CO2e per ton recycled).
- Organic waste accounts for 43% of Tucson's municipal solid waste (MSW). Food waste is the largest driver, accounting for 66% of organic waste. Yard trimmings make up the remaining 34%.
    - The organic waste with the largest effect on carbon emission reduction is food waste, which reduces 0.12 tonnes of CO2e per ton composted, whereas yard trimmings reduce 0.05 tonnes of CO2e per ton composted. Therefore, food waste has a much stronger effect on carbon emission reduction, as a ton of composted food waste reduces 240% more CO2e than a ton of composted yard trimmings.
    - By implementing a community composting program, compost facilities can generate revenue through the sale of fertilizer and other soil amendments. It is estimated that Tucson can offset 17% of its compost program cost with this revenue source.

Table 3. Detailed Results

		E-1.1, E-1.2, E-1.3, E-1.4, E-1.5 & E-3.4	E-3.2 & E-3.3	T-1.1, T-1.5 & T-2.1	T-5.1, T-5.2, T-5.3 & T-5.5	RR-1	RR-2	**Total**
Financial	Municipal Staff Costs	-$9,664,000	-$1,933,000	-$5,798,000	-$5,798,000	-$1,933,000	-$1,933,000	**-$27,059,000**
Financial	Consultant Costs	-$200,000	$0	$0	$0	$0	$0	**-$200,000**
Financial	Transportation Capital Expenditures	$0	$0	$0	-$73,689,000	$0	$0	**-$73,689,000**
Financial	Transportation Operations and Maintenance	$0	$0	$292,610,000	$158,699,000	$0	$0	**$451,309,000**
Financial	Cost of Electricity &/or Natural Gas	-$58,789,000	$1,747,852,000	$0	-$71,737,000	$0	$0	**$1,617,326,000**
Financial	Cost of Municipal Building Retro-commissioning	-$17,220,000	$0	$0	$0	$0	$0	**-$17,220,000**
Financial	Cost of Municipal Waste Resource Recovery	$0	$0	$0	$0	$0	-$109,453,000	**-$109,453,000**
Financial	Cost of Municipal Retrofitting & Electrification by ESCO	-$27,490,000	$0	$0	$0	$0	$0	**-$27,490,000**
Financial	Revenues - Waste Resource Recovery	$0	$0	$0	$0	$0	$18,242,000	**$18,242,000**
Social & Environmental	Air Pollution Reductions - Electricity & Natural Gas	$29,039,000	$245,254,000	$0	$0	$0	$0	**$274,293,000**
Social & Environmental	Air Pollution Reductions - Transportation	$0	$0	$1,314,000	$770,000	$0	$0	**$2,084,000**
Social & Environmental	Avoided Accidents from Road Diet & Multimodal Safety Enhancements	$0	$0	$1,241,010,000	$0	$0	$0	**$1,241,010,000**
Social & Environmental	Carbon Emission Reductions - Electricity & Natural Gas	$97,118,000	$2,459,126,000	$0	$0	$0	$0	**$2,556,244,000**
Social & Environmental	Carbon Emission Reductions - Transportation	$0	$0	$771,000	$14,072,000	$0	$0	**$14,843,000**
Social & Environmental	Carbon Emission Reductions - Waste	$0	$0	$0	$0	$804,830,000	$116,082,000	**$920,912,000**

Social & Environmental	Productivity from Active Transportation	$0	$0	$869,363,000	$0	$0	$0	**$869,363,000**
Social & Environmental	Reduced Transportation Congestion	$0	$0	$212,084,000	$0	$0	$0	**$212,084,000**
Social & Environmental	Reduced Transportation Noise	$0	$0	$4,539,000	$0	$0	$0	**$4,539,000**

Financial NPV	-$113,363,000	$1,745,919,000	$286,812,000	$7,475,000	-$1,933,000	-$93,144,000	**$1,831,766,000**
Social & Environmental NPV	$126,157,000	$2,704,380,000	$2,329,081,000	$14,842,000	$804,830,000	$116,082,000	**$6,095,372,000**
NPV	$12,794,000	$4,450,299,000	$2,615,893,000	$22,317,000	$802,897,000	$22,938,000	**$7,927,138,000**
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NPV per mt CO2e Reduced	$6	$82	$8,490	$77	$46	$9	**$104**
mt CO2e Reduced in 2030	82,828	651,208	11,706	13,709	441,237	63,640	**1,264,329**

3.2. Carbon Emission Reductions

3.2.1. Carbon Neutrality by 2030 (BAP)

The proposed climate action strategies are expected to drive reductions in carbon emissions. To reach the City's goal of carbon neutrality across City operations by 2030 and carbon neutrality community-wide by 2045, a progressive and dynamic approach must be undertaken through targeted policy interventions identified in the CAAP. This section isolates the quantities of carbon equivalents (CO2e) for the strategies included in the CBA. Figure 1 presents the share of carbon mitigation between the City and Community, with the majority (95%) of carbon reductions occurring at the community-wide level.

In order to compare the carbon reductions attributable to the strategies assessed in the CBA, a baseline must first be determined. Two baselines - a business as planned (BAP) and a business as usual (BAU) - are presented in this report for each the City and the Community perspective .

The BAP from Tucson Resilient Together is defined as assuming that plans, proposed initiatives, and policies not yet implemented are being implemented as planned. For the City these include: TEP will achieve its preferred portfolio of 70% renewable energy by 2035, the City successfully transitions its light-duty vehicle fleet to electric by 2030 (per commitments in the 2022 EV Readiness Roadmap), and that the City is on track to achieve zero waste by 2050. For the Community, the BAP from Tucson Resilient Together assumes that TEP achieves its preferred portfolio of 70% renewable energy, and that the City implements the full-build scenario from Move Tucson through 2045 (meaning that all planned transit and transportation projects are completed) with an accompanying increase in VMT (City of Tucson, 2023).

Modified City and Community BAPs are presented in this report for both the City and Community to avoid double counting as the BAPs from Tucson Resilient Together already incorporated some of the strategies considered in the CBA. The BAP for the City nets actions T-5.1. The BAP for the Community nets action T-1.1. Furthermore, the BAPs only reflect Scope 1 and 2 emissions, and therefore RR-1 and RR-2 emission reductions are not included in the strategy reductions derived from the CBA.

The carbon reductions derived from the strategies assessed in the CBA were subtracted from the BAP to derive CAAP pathways for both the City (actions E-1.3, E-1.5, T-5.3, and T-5.5) and the Community (action E-3.2); see Figures 2 and 4.

When the City is looking at its impact from the strategies in 2030, there is a reduction of nearly 94,000 mt CO2e that represents an abatement of 92% of its BAP emissions. Similarly, for the Community in 2030, there are 0.7 million mt CO2e reduced that represents an abatement of 9% of its BAP emissions.

It is important to note that the consultant team was not scoped to estimate the BAP or BAU for the Community past 2030, so Autocase was unable to compare the CBA strategies' carbon reductions against the Community's baseline emissions at year 2045. Communitywide climate action measures, even if implemented on a rapid timeframe, can take several years to be reflected in reduced greenhouse gas emissions at the communitywide scale, particularly for land use changes which influence long-term development patterns and major infrastructure projects that need to go through multiyear design, permitting, and procurement processes. Figures 8 to 11 illustrate the annual and cumulative reductions from 2023 - 2050, inclusive of 2045, and Table 4 and 5 present the quantified tonnes of carbon reduced in the year 2045.

Figure 1. City and Community Share of CO2e Abatement in 2030

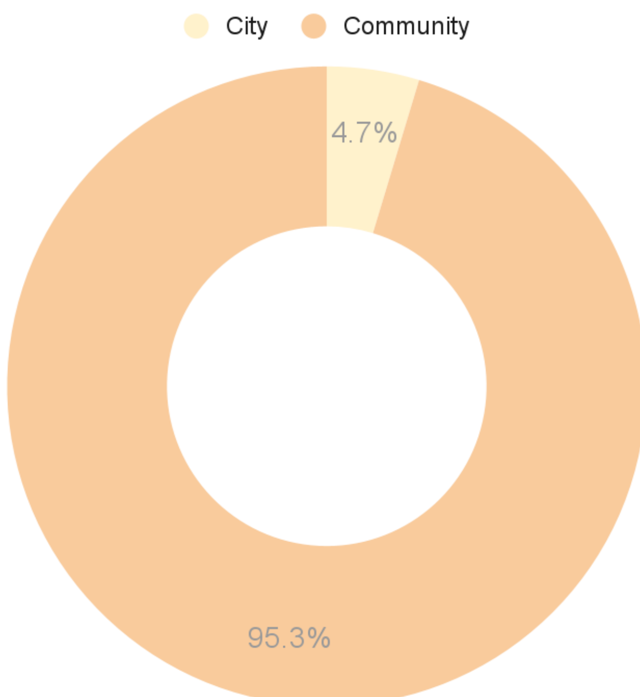


Figure 2. City BAP Pathways 2023 - 2030

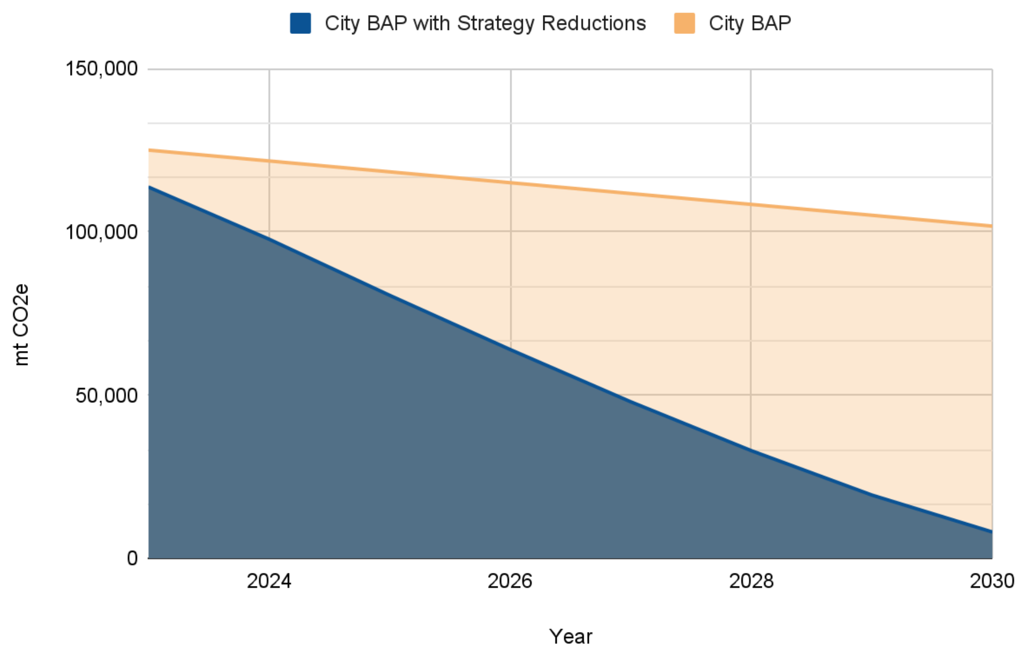
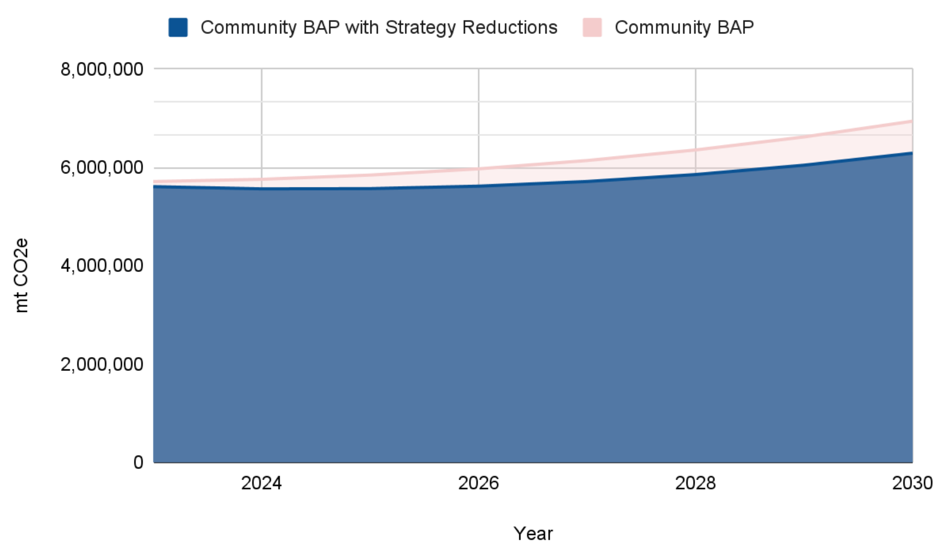


Figure 3. Community BAP Pathways 2023 - 2030



3.2.2. Carbon Neutrality by 2030 (BAU)

Similar to the BAP pathways, the abated CO2e from the strategies in the CBA are compared to the BAU, as presented in Tucson Resilient Together (City of Tucson, 2023); these BAUs only reflect Scope 1 and 2 emissions, and therefore RR-1 and RR-2 emission reductions are not included in the strategy reductions derived from the CBA.

The carbon reductions from the CBA for the City (actions E-1.3, E-1.5, T-5.1, T-5.3, and T-5.5) and for the Community (actions E-3.2 and T-1.1) were subtracted from the BAU to derive a CAAP pathway for both the City and the Community (see Figures 4 and 5).

When the City is looking at its impact from the strategies, there is a reduction of 50,000 mt CO2e for an abatement of 66% of its BAU emissions in 2030. Similarly, for the Community, there are 0.7 million mt CO2e for an abatement of 7% of its BAU emissions in 2030.

Figure 4. City BAU Pathways 2023 - 2030

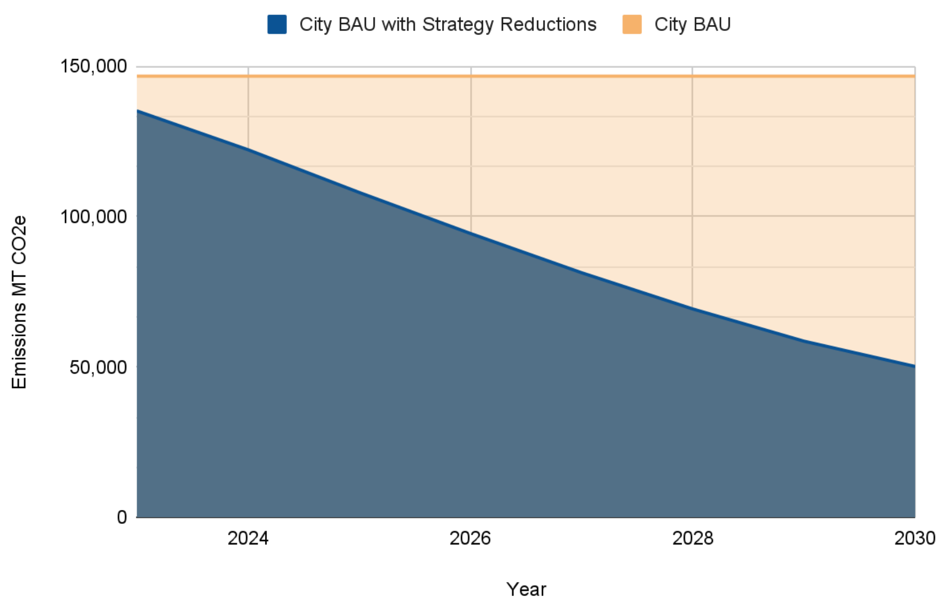
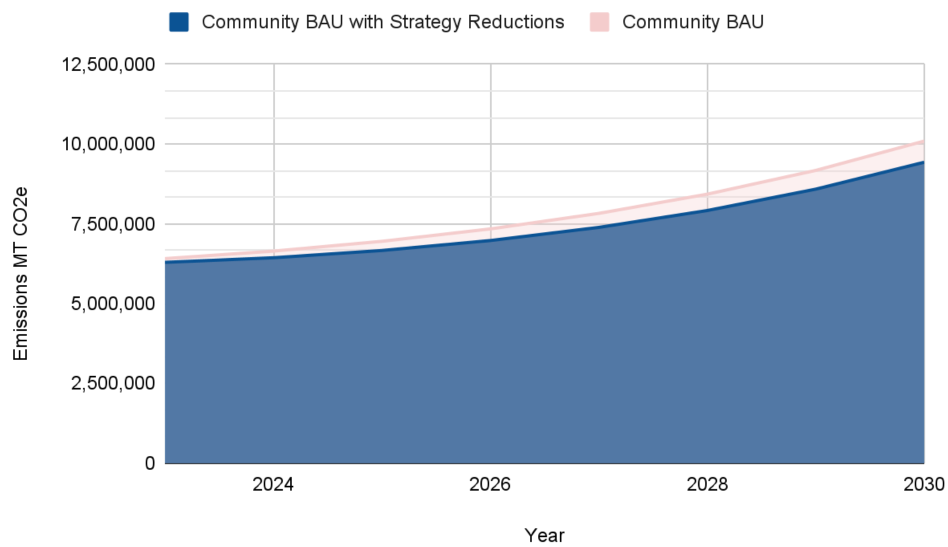


Figure 5. Community BAU Pathways 2023 - 2030



3.2.3. Annual and Cumulative Carbon Reductions

The actions included in the six strategies evaluated are expected to be implemented simultaneously. Annual CO2e reductions are expected to be 1.3 million metric tons in 2030, 4.7 million metric tons in 2045, and 5.2 million metric tons in 2050 (Figure 6, Tables 5).

These annual reductions translate into cumulative CO2e reductions of 5.8 million metric tons by 2030, 51 million metric tons by 2045, and 76 million metric tons by 2050, cumulatively (Figure 7, Table 4).

To better understand which actions have the greatest potential for GHG emissions reductions, the carbon reductions are segmented by each action within the figures below. Implementing action E-3.2 (community choice energy for all of Tucson) returns the greatest share of abated CO2e followed by implementing RR-1 (zero waste) due to the sheer scale of these applicable actions - the entirety of Tucson city population.

Figure 6. Annual CO2e Emissions Reduction – All Actions 2023 - 2050

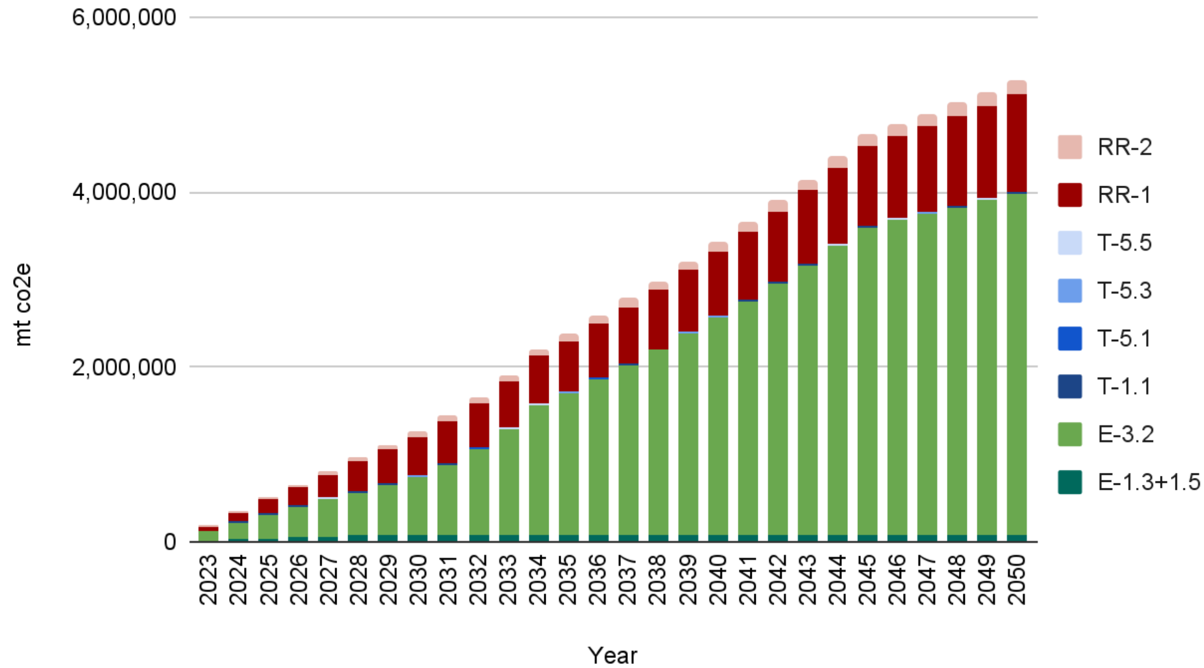
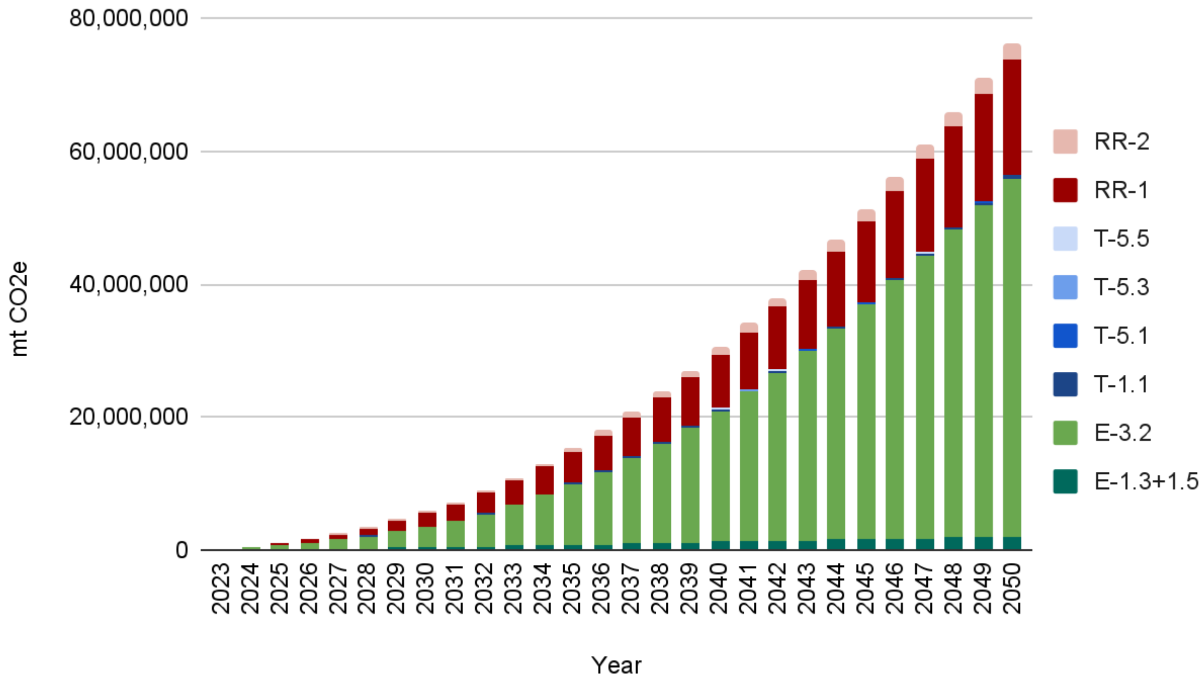


Figure 8. Cumulative CO2e Reductions by all Actions 2023 - 2050



The City has two distinct carbon neutrality targets - carbon neutrality across City operations by 2030 and carbon neutrality community-wide by 2045. Figures 9 and 10 below dissect the carbon emissions associated with each action into City or Community categories to help illustrate which actions contribute to meeting 2030 vs. 2045 carbon neutrality targets.

To help reach carbon neutrality across municipal operations by 2030, retro-commissioning, electrifying, and retrofitting municipal operations drive the greatest share of CO2e reductions (Figure 9). To help reach community-wide carbon neutrality by 2045, by far encouraging community choice energy along with waste diversion and composting provides opportunity to reach neutrality (Figure 10).

Figure 9. Annual CO2e Emissions Reductions - Actions for Municipal Carbon Neutrality 2030

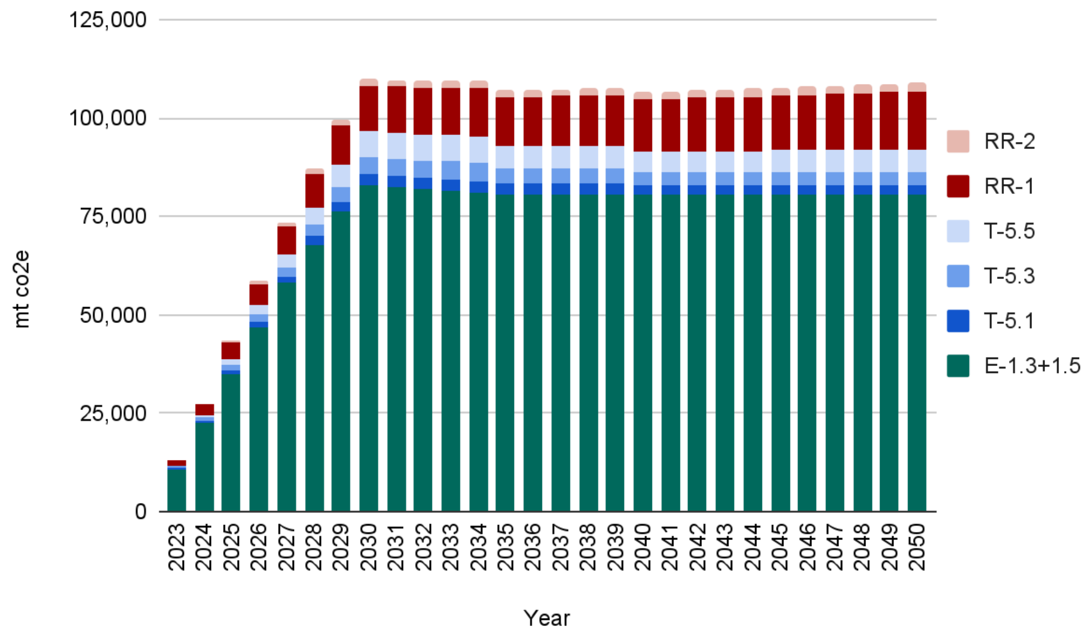


Figure 10. Annual CO2e Emissions Reductions - Actions for Community Carbon Neutrality 2045

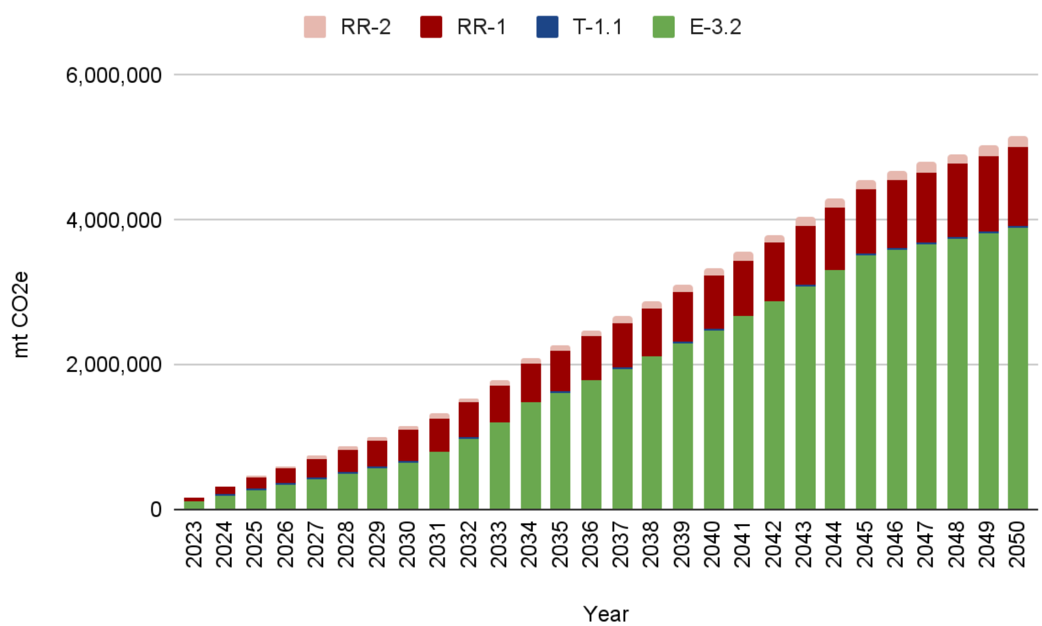


Table 4. Cumulative CO2e Reductions 2023 - 2050

Strategy	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
E-1.3+1.5	10,825	33,525	68,441	115,301	173,312	241,245	317,537	400,365	482,787	564,804	646,415	727,621	808,422	889,223
E-3.2	103,354	297,205	573,016	925,602	1,352,388	1,852,757	2,427,696	3,078,904	3,876,596	4,853,165	6,050,468	7,522,657	9,138,490	10,915,413
T-1.1	13,497	27,128	38,594	50,173	61,863	73,665	85,578	97,284	109,099	120,740	132,251	143,861	154,767	165,769
T-5.1	227	734	1,582	2,778	4,352	6,335	8,757	11,589	14,429	17,277	20,133	22,997	25,469	27,941
T-5.3	389	1,239	2,671	4,670	7,279	10,541	14,497	18,925	23,364	27,814	32,275	36,748	40,563	44,378
T-5.5	92	483	1,948	4,191	7,357	11,594	17,049	23,498	30,042	36,680	43,414	50,244	55,986	61,778
RR-1	50,736	153,498	309,566	520,155	786,524	1,109,938	1,491,631	1,932,868	2,401,184	2,897,170	3,421,427	3,974,566	4,557,210	5,169,991
RR-2	7,318	22,139	44,649	75,023	113,441	160,088	215,140	278,780	346,326	417,863	493,477	573,257	657,293	745,675
Total by year	186,438	535,951	1,040,468	1,697,893	2,506,516	3,466,162	4,577,885	5,842,214	7,283,828	8,935,513	10,839,860	13,051,951	15,438,199	18,020,168

Table 4. Cumulative CO2e Reductions 2023 - 2050 (continued)

Strategy	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
E-1.3+1.5	970,024	1,050,825	1,131,626	1,212,427	1,293,228	1,374,029	1,454,830	1,535,631	1,616,432	1,697,233	1,778,034	1,858,835	1,939,636	2,020,437
E-3.2	12,859,471	14,976,884	17,274,049	19,757,549	22,434,155	25,310,831	28,394,740	31,693,248	35,213,931	38,808,301	42,477,831	46,224,025	50,048,417	53,952,570
T-1.1	176,868	176,868	188,159	198,644	209,218	219,880	230,632	241,472	252,401	263,419	274,525	285,721	296,916	308,112
T-5.1	30,413	32,885	35,357	37,568	39,779	41,990	44,201	46,412	48,623	50,834	53,045	55,256	57,467	59,678
T-5.3	48,193	52,008	55,823	59,181	62,539	65,897	69,255	72,613	75,971	79,329	82,687	86,045	89,403	92,761
T-5.5	67,619	73,510	79,450	84,641	89,875	95,152	100,472	105,835	111,241	116,690	122,182	127,717	133,294	138,914
RR-1	5,813,554	6,488,554	7,195,657	7,935,541	8,708,896	9,516,425	10,358,840	11,236,867	12,151,246	13,102,727	14,092,074	15,120,065	16,187,489	17,295,150
RR-2	838,497	935,853	1,037,840	1,144,554	1,256,096	1,372,567	1,494,070	1,620,709	1,752,591	1,889,825	2,032,520	2,180,788	2,334,744	2,494,504
Total by year	20,804,639	23,787,387	26,997,961	30,430,105	34,093,786	37,996,771	42,147,039	46,552,787	51,222,436	56,008,357	60,912,898	65,938,451	71,087,366	76,362,126

Table 5. Annual CO2e Reductions 2023 - 2050

Strategy	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
E-1.3+1.5	10,825	22,700	34,916	46,860	58,011	67,933	76,292	**82,828**	82,422	82,017	81,611	81,206	80,801	80,801
E-3.2	103,354	193,851	275,811	352,586	426,786	500,369	574,939	**651,208**	797,692	976,569	1,197,303	1,472,189	1,615,833	1,776,923
T-1.1	13,497	13,631	11,467	11,578	11,690	11,802	11,914	**11,706**	11,815	11,641	11,510	11,610	10,906	11,002
T-5.1	227	507	848	1,196	1,574	1,983	2,422	**2,832**	2,840	2,848	2,856	2,864	2,472	2,472
T-5.3	389	850	1,432	1,999	2,609	3,262	3,956	**4,428**	4,439	4,450	4,461	4,473	3,815	3,815
T-5.5	92	391	1,465	2,243	3,166	4,237	5,455	**6,449**	6,544	6,638	6,734	6,830	5,742	5,792
RR-1	50,736	102,761	156,069	210,589	266,368	323,414	381,693	**441,237**	468,316	495,986	524,257	553,139	582,644	612,781
RR-2	7,318	14,821	22,510	30,374	38,419	46,646	55,052	**63,640**	67,546	71,537	75,614	79,780	84,036	88,382
Total by year	**186,438**	**349,513**	**504,517**	**657,425**	**808,623**	**959,646**	**1,111,723**	**1,264,329**	**1,441,614**	**1,651,686**	**1,904,347**	**2,212,091**	**2,386,248**	**2,581,969**

Table 5. Annual CO2e Reductions 2023 - 2050 (continued)

Strategy	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	Total
E-1.3+1.5	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	80,801	2,020,437
E-3.2	1,944,058	2,117,413	2,297,165	2,483,500	2,676,606	2,876,676	3,083,909	3,298,508	3,520,683	3,594,370	3,669,530	3,746,194	3,824,392	3,904,153	53,952,570
T-1.1	11,099	0	11,292	10,485	10,574	10,662	10,751	10,840	10,929	11,018	11,107	11,196	11,196	11,196	308,112
T-5.1	2,472	2,472	2,472	2,211	2,211	2,211	2,211	2,211	2,211	2,211	2,211	2,211	2,211	2,211	59,678
T-5.3	3,815	3,815	3,815	3,358	3,358	3,358	3,358	3,358	3,358	3,358	3,358	3,358	3,358	3,358	92,761
T-5.5	5,841	5,891	5,940	5,191	5,234	5,277	5,320	5,363	5,406	5,449	5,492	5,535	5,577	5,620	138,914
RR-1	643,563	675,000	707,103	739,884	773,355	807,528	842,415	878,028	914,379	951,481	989,347	1,027,991	1,067,424	1,107,662	17,295,150
RR-2	92,822	97,356	101,986	106,715	111,542	116,471	121,503	126,639	131,882	137,233	142,695	148,269	153,956	159,760	2,494,504
Total by	2,784,471	2,982,748	3,210,574	3,432,145	3,663,681	3,902,985	4,150,268	4,405,748	4,669,649	4,785,921	4,904,541	5,025,554	5,148,915	5,274,760	76,362,126

year																

3.3. Air Pollution Reductions

In addition to carbon emission reductions attributable to the strategies, there are also expected to be air pollutants - SOx, NOx, PM2.5, and VOC - emission reductions associated with reduced electricity and natural gas consumption by municipal buildings as well as reduced exhaust emissions from active transit and electric vehicles.

Table 6. Air Pollution Reductions by Strategy Assessed in the CBA (metric tons)

Air Pollutant	E-1.1, E-1.2, E-1.3, E-1.4, E-1.5 & E-3.4	E-3.2	T-1.1, T-1.5 & T-2.1	T-5.1, T-5.2, T-5.3 & T-5.5	Total (2023-2050)
SOx	763	86	2	-10	840
NOx	263	86	34	68	451
PM2.5	32	1	4	3	39
VOC	101	3	161	111	376

4. CBA Methodologies and Key Assumptions

This section provides an overview on the key steps and assumptions underpinning the evaluation of the strategies and individual actions included in this analysis. The intent is to speak to the key elements in each action's impacts and how they are calculated. Given the nature of this high-level analysis, many assumptions were used to approximate impacts and data sourced from alternative yet similar locations. As specific CAAP strategies and actions are implemented, more technical planning and engineering data could be used to supplement and override the assumptions developed for this stage of evaluation.

4.1. Common Methodologies

4.1.1. Carbon Emissions

Reducing electricity consumption from the grid and natural gas consumption is expected to reduce CO2e (Carbon, CH4, and N2O), thereby generating societal benefits. For each unit of energy produced and used, CO2e are released into the atmosphere, quantified using emission factors. The social benefit of reduced CO2e is monetized by applying the social cost of carbon to the amount of carbon dioxide equivalent emissions reduced.

Method

- Greenhouse gas - CO2, CH4, and N20 - emission factors are from TEP purchased and owned generation (Buro Happold, personal communication, 2022); see Table A.3 in the appendix.
- The base case assumes Tucson Electric Power (TEP) decarbonizes its portfolio by 80% by 2035 from transitioning 70% of its portfolio to wind and solar sources of energy (TEP, 2020). A straight line depreciation is applied between 2023 and 2035. For years 2035 to 2050 the emission factor remains constant.
- The design case for the City assumes that by 2045 the City procures VPPAs to cover its energy consumption needs with renewable energy certificates (RECs) exchanged in return (action E-3.4). A straight line depreciation is applied between 2023 and 2045. A simplifying assumption is made that the renewable energy generated by the projects that issued the RECs offset the base case energy, and subsequently the base case emissions.
- The design case emission factors for the Community assumes that the community co-forms a community choice energy program (referred to as a community choice agreement, CCA) to procure 100% renewable power for Tucson by 2045 (Action E-3.2).
- When emission factors are combined with energy consumption, the quantity of emissions is converted into CO2e using global warming potentials (GWP) sourced from the EPA (2022). CH4 has a GWP of 29.8 and N20 has a GWP of 273 (EPA, 2022).
- Emission factors for natural gas combustion are also sourced from the EIA (2022) and follow the same conversion process from CO2, CH4, and N20 to CO2e as described for electricity; see Table A.3 in the appendix.
- The environmental benefit of reduced GHGs is monetized by applying the social cost of carbon to the amount of carbon dioxide equivalent emissions reduced. Autocase applied the social cost of carbon in line with most recent US federal guidance (Executive Order 13990) from the Government's Interagency Working Group on Social Cost of Carbon (2021). The social cost of carbon is $57 per metric tonne of CO2e in 2023 and grows through the duration of the study period to reflect the increasing damages of climate change, see Table A.3 in the appendix.
- 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 economic cost of damages relating to 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 CO2e in the atmosphere.

4.1.2. Air Pollution

Reduced criteria air contaminants (CACs) stem from the following sources in this analysis: reducing electricity and natural gas consumption in buildings as well as reducing vehicle miles traveled by ICE vehicles. Reducing electricity consumption from the grid and natural gas consumption (in the design case compared to the base case) may generate environmental benefits from reduced air pollution being emitted. For each unit of energy produced and used, air pollution emissions are released into the atmosphere, quantified using emission factors. Reducing gasoline consumption in ICE vehicles also reduces air pollution. The social benefit from reducing air pollution emissions is monetized by applying the social cost of each air pollutant to the respective amount of that air pollutant reduced.

Method

- Autocase calculates the environmental benefit for the following air pollutants: NOx, SOx, PM2.5, and VOCs. Emission factors for NOx and SOx are sourced from TEP (2021). Emission factors for PM2.5, and VOCs are sourced from Ou & Cai (2020) for electricity. For natural gas consumption, Ou & Cai (2020) is sourced for NOx, SOx, PM2.5, and VOCs. Emission factors for ICE vehicles are sourced from GREET and detailed in Strategy T-5.
- Autocase uses social values for CACs to monetize the impacts of changes in outdoor air pollutant quantities derived from changes in operational energy use (see appendix Table A.6).
- Autocase uses the following sources to build a location specific valuation of CAC emissions: Estimating Air Pollution Social Impact Using Regression (EASIUR) (2015), Environmental Protection Agency (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.

4.1.3. Energy Prices

In order to monetize the quantified energy consumption, Autocase applies forecasted energy prices of gasoline, diesel, E85, propane, natural gas and electricity to consumption.

Method

- Prices of gasoline, diesel, E85, propane, natural gas and electricity were sourced from the EIA Annual Energy Outlook (AEO) (EIA, 2022). These values are projected out to the year 2050, representing anticipated changes to the nature of the energy supply and are localized to the WECC – Southwest region.

4.2. Strategy E-1: Decarbonize City-owned and operated buildings and facilities

4.2.1. E-1.1: Benchmark energy use of City buildings and facilities using EnergyStar Portfolio Manager

The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Impact in Results Table
- Municipal Staff Costs

4.2.2. E-1.2: Create an internal carbon tax for City departments that is informed by the City's emissions portfolio

The City expects to contract a consultant at a cost of $100,000. It is assumed the project begins and completes in 2023.

Impact in Results Table
- Consultant Costs

4.2.3. E-1.3: Implement ongoing weatherization and retro-commissioning (building tune-ups)

The City of Tucson is proposing retro-commissioning their municipal buildings to achieve energy savings, and ultimately reduce their municipal carbon emissions. The model assumption is that retro-commissioning will be completed in 10-year cycles, where 10% of municipal square footage is retro-commissioned annually. Since the approximate square footage of municipal facilities is 5,939,824, the assumption is that approximately 593,982 square feet are retro-commissioned each year.

Impacts in Results Table
- Cost of Electricity and/or Natural Gas
- Cost of Municipal Building Retro-commissioning
- Air Pollution Reductions - Electricity & Natural Gas
- Carbon Emission Reductions - Electricity & Natural Gas
- Municipal Staff Costs

Method

- Financial Costs of Retro-commissioning
  - Retro-commissioning costs per square foot were supplied by the City of Tucson, and multiplied by the number of square feet retro-commissioned each year to get an annual retro-commissioning cost.

- Financial Savings to Electricity and/or Natural Gas
  - Since retro-commissioning will result in a change in electricity and natural gas consumed, there will be a change in the cost associated with electricity and natural gas. To calculate the change in electricity costs, the change in kilowatt hour (kWh) from retro-commissioning was multiplied by the electricity cost. To calculate the change in natural gas costs, the change in million British thermal units (MMBtu) from retro-commissioning was multiplied by the cost of natural gas.

- Municipal Staff Costs
  - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

- Environmental Savings
  - The total emissions from CO2e and CACs from retro-commissioning are calculated by multiplying the emission factors by the 15% reduction in kWh and MMBtu from retro-commissioning (Energy Star).

Assumptions

- The CBA sources a blended electricity rate of $0.141 for the City, and applies an annual growth rate of 2% from 2023 to 2050 (City of Tucson, personal correspondence, 2023).
- The model does not include electricity use by the Central Arizona Project as it falls under Scope 3 emissions as indicated by Buro Happold.
- The model assumes 10% of gross floor area (GFA) is retro-commissioned each year (Buro Happold, personal communication, 2022).
- The model assumes that retro-commissioning will occur in 10 year cycles, which means 10% of the GFA is retro-commissioned annually. Once the cycle is over and the full area has been retro-commissioned, the cycle re-starts and 10% continues to be retro-commissioned annually. The first time an area is retro-commissioned, the area is assumed to see an EUI reduction of 15% (Energy Star, 2007), and every time thereafter, retro-commissioning will ensure the building maintains that 15% EUI reduction level from its pre-commissioning EUI level (Buro Happold, personal communication, 2022).

4.2.4. E-1.4: Develop a net zero building framework for City-owned buildings and facilities, including but not limited to energy efficiency, electrification, and renewables

The City expects to contract a consultant at a cost of $100,000. It is assumed the engagement begins and completes in 2023. The City also expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Impact in Results Table

- Consultant Costs
- Municipal Staff Costs

4.2.5. E-1.5: Utilize an energy services company (ESCO) to rapidly but strategically implement energy efficiency measures and equipment in City-owned buildings, and ongoing energy management

The City proposes to use an energy services company to implement energy efficiency measures, building electrification, and ongoing energy management. This is expected to reduce energy use intensity (EUI) of electricity and eliminate natural gas, causing a reduction in CO2e and CAC emissions due to the grid in the base case sourcing 20% of energy from fossil fuel sources from 2035 onwards. The model assumes the energy efficiency measures and electrification will start in 2023.

Impacts in Results Table

- Cost of Electricity &/or Natural Gas
- Cost of Municipal Retrofitting by ESCO
- Cost of Municipal Electrification
- Air Pollution Reductions - Electricity & Natural Gas
- Carbon Emission Reductions - Electricity & Natural Gas
- Municipal Staff Costs

Method

- Financial Costs
  - The costs used for retrofitting were taken from the Department of Energy and are assumed to be an average of standard and deep retrofitting. To determine the amount that the ESCO charges annually, the Total Measure Cost from the DOE Guide was divided by the time horizon.
  - Electrification costs were taken from the Cost Study of the Building Decarbonization Code, and then localized to Tucson using the RSMeans Cost Index. To calculate the total electrification cost to the City, the electrification cost per square foot was multiplied by the total municipal square footage.

- Financial Savings
    - There are two factors affecting electricity costs in this strategy. As electrification occurs, there will be an increase in electricity, and since retrofitting will result in a reduction in energy use. There will be a change in the cost associated with electricity. To calculate the case base electricity cost, the base case electricity use of kWh was multiplied by the cost associated with purchasing the power. The design case electricity cost was then calculated by multiplying the kWh purchased each year from VPPAs, by the estimated dollar cost per kWh in a VPPA agreement. The reduction in the cost of electricity was then calculated taking the design case cost of electricity by the base case cost of electricity.
    - As electrification occurs, natural gas will be eliminated by 2030.

- Municipal Staff Costs
    - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

- Environmental Savings
    - The model assumes a 25% energy reduction per square foot attributable to the ESCO (City of Tucson, personal communication, 2023).
    - To ensure 100% of municipal buildings undergo retrofitting and electrification by 2030, 12.5% of gross floor area must undergo retrofitting and electrification annuallyThe amount CO2e and CACs emitted are calculated based on the electrical grid emission factors.
    - The total emissions from CO2e and CACs reduced are calculated by multiplying the emission factors by the reduction in kWh from retrofitting.

Assumptions

- The model does not include electricity use by the Central Arizona Project as it falls under Scope 3 emissions as indicated by Buro Happold.
- The model assumes retrofitting occurs at the same time as retro-commissioning and electrification.
- ESCO cost is calculated by taking the average Total Measure Cost from standard and deep retrofits in the DOE Guide, and dividing it by the time horizon. The model assumes the ESCO profits 15% (City of Tucson, personal correspondence, 2023).
- Energy reductions from retrofitting is assumed to be 25% (City of Tucson, personal communication, 2023).
- The model assumes a 1:1 ratio of natural gas consumption to electricity when electrification is implemented. This inherently assumes the systems installed to electrify the City's assets have the same energy output efficiency as the replaced natural gas systems.

4.3. Strategy E-3: Procure zero-emission electricity and decarbonize City and community power supply

4.3.1. E-3.2: Work with community advocates and other jurisdictions to co-form a community choice energy program or joint powers authority to procure 100% renewable power for Tucson

Impacts in Results Table

- Cost of Electricity &/or Natural Gas
- Air Pollution Reductions - Electricity & Natural Gas
- Carbon Emission Reductions - Electricity & Natural Gas
- Municipal Staff Costs

Method

- Financial Savings
  - The model assumes the community of Tucson will have 100% renewable power by 2045 sourced through a community choice program. To achieve this the community will need to switch 12.5% of annual electricity consumption to electricity sourced from renewables each year until 2030.
  - To measure the amount of energy consumption that is now produced by renewables annually, the total community renewable electricity consumed (in kWh) is multiplied by the amount of electricity that needs to come from CCA to reach the 2045 goal.
  - The new total cost of electricity was calculated by multiplying the amount of electricity purchased from the grid by the cost of electricity, and then adding the amount of electricity produced from solar multiplied by the cost of electricity from VPPA.

- Municipal Staff Costs
  - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

- Environmental Savings
  - To calculate the emission factors for each year, the amount of electricity still being purchased from the grid was multiplied by the EIA emission factors. This produced the amount of CO2e being emitted each year, and this value was compared with the base case of using 100% grid electricity to demonstrate the difference between the base case and the design case.

Assumptions

- The model assumes a cost savings for a CCA to be 9% below TEP blended rates across residential, industrial, and commercial rates (Lowes, personal communication, 2023).
- The base case in the model uses January 2023 electricity prices for residential, industrial, and commercial (TEP). Notably these prices are expected to increase in the near future due to energy expansion costs, based on TEP's recent rate request which will be reviewed by the Arizona Corporation Commission (https://www.tep.com/rate-proposal/).
- The model assumes that annual energy consumption by the community increases from 2023 - 2030 by an average rate of 6% and then by 2% annually from 2031-2050 (City of Tucson, personal communication, 2023).

4.3.2. E-3.4: Pursue solar service agreements (SSAs) or virtual power purchase agreements (VPPAs) to meet the City's power needs for municipal operations

Embedded in E-1 - Commissioning, Electrification, Retrofitting. This strategy assumes in the design case that the City procures 100% of its electricity needs by renewable electricity via VPPAs by 2030. This action inherently underpins the actions valued under E-1 and T-5. Meaning, the price for VPPA-sourced renewable energy is used to price the electricity used in municipal buildings as well as to charge electric vehicles and electric fleets for municipal operations.

4.4. Strategy T-1 & T-2: Champion walking, cycling and rolling as sustainable and climate-resilient mobility options & Invest in safe, comfortable, and convenient public transit as the backbone of a sustainable and resilient transportation system

4.4.1. T-1.1: Use various funding sources, including Prop 411, to implement bicycle, pedestrian, and other zero-emission mobility projects identified in Move Tucson to create a transportation network aligned with the Complete Streets approach

Vehicle Miles Traveled (VMTs)

Strategy T1.1 outlines that the City of Tucson is assumed to have a gradual modal shift which would result in 40% of VMTs coming from walking, cycling, rolling, and public transportation by 2050. This is a considerable shift from the estimated combined rate of walking, cycling, rolling, and public transportation in 2019, which was assumed to be 10%. As a result of reducing VMTs, there will be a reduction in CO_2e and CACs, and environmental savings from the social cost attributed to those reductions.

Reducing VMTs also reduces nuisance 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 the prevalence of tinnitus, and increases annoyance levels by society.

Another impact of reducing VMTs is the increase in the speed of those roads (due to reduced congestion) allowing people to save time. Although the time saved for any individual driver will be small due to a reduction in vehicle miles, it has the potential to impact thousands of drivers, leading to a substantial amount of total time saved by such workers.

Transportation crashes, however small or large, impose real costs on society. This risk of crashes is heightened if there are more cars on the road. Some types of vehicles impose different types of risks to society. This analysis focuses on crashes that lead to fatalities and those that lead to incapacitating injuries.

Furthermore, reducing total VMTs reduces road infrastructure costs such as pavement damages due to reduced vehicle travel on roadways as well as vehicle operations costs for fuel and maintenance.

Impacts in Results Table

- Transportation Operations and Maintenance
- Air Pollution Reductions - Transportation
- Avoided Crashes from Road Diet & Multimodal Safety Enhancements
- Carbon Emission Reductions - Transportation
- Reduced Transportation Congestion
- Reduced Transportation Noise
- Municipal Staff Costs

Method

- VMTs
    - The modal shift will result in fewer VMTs, and it is assumed that the vehicle types impacted from the modal shift are motorcycles, passenger cars, and passenger trucks.
    - The annual reduction in VMTs is calculated by multiplying the modal shift percentage (sourced from BuroHappold) that represents the proportion of the population that will be walking, cycling, rolling, and taking public transportation for each year by the base case VMTs for the three types of vehicles.
- Financial Savings
    - A reduction in VMTs will result in a reduction in gasoline required for those vehicles. To calculate the gasoline cost savings, the fuel consumption per mile for each

vehicle type is taken from GREET, and multiplied by the annual VMTs, and then multiplied by the gasoline prices.

- Municipal Staff Costs
  - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.
- Environmental Savings
  - As a result of fewer VMTs, there will be a reduction in GHGs and CACs. The emission reductions are calculated by multiplying the GREET emission factors, which are on a gram per mile unit, for motorcycles, cars, and passenger trucks by the reduction in VMT annually from the modal shift.
  - Cost savings associated with reduction in GHGs and CACs are calculated by multiplying the emissions reduced by their respective social costs.
- Social Savings
  - A study by Essen et al. (2019), identified the noise reduction benefit per vehicle mile traveled and segmented the values by the type of vehicle, weight of the vehicle, time of day, congestion level, and whether the project is in an urban, suburban or rural area. This analysis uses the assumptions of a 100% urban , 95% day, and 50% occurring during peak times of the day. The noise benefit is multiplied by the annual VMTs to commute the total noise benefit for each year.
  - The marginal cost of reliability is calculated using a US DOT (2009) congestion study that estimates the relationship between congestion relief (average conditions) and reliability benefits (variable conditions). This marginal cost is multiplied by the annual VMTs to get cost savings from noise reduction.
  - Costs for pavement damages depend on the Highway Cost Allocation Study (2000), estimated at 0.1 cents per vehicular mile, which is multiplied by VMTs to get to the total annual cost.
  - These safety benefits of reducing vehicular miles 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 $0.30 per vehicle mile traveled, which is multiplied by annual VMTs to get the yearly savings.

Assumptions

- The City of Tucson will shift from walking, cycling, rolling, and public transportation making up 10% of total commuting methods, to 40% by the year 2050.
- The model makes a simplifying assumption that all passenger cars, motorcycles, and passenger trucks are gasoline only based on national level data that gasoline cars make up 91% of the stock of cars and gasoline light-duty trucks make up 84% of the stock of light-duty trucks (EIA, 2022).
- Vehicle emission factors (g/mile) are taken from GREET for passenger cars, motorcycles, and passenger trucks.

- Passenger truck emission factors from GREET are an average of emission factors from SUVs and pick-up trucks.
- The model assumes the roads are used 95% day, and 50% occurring during peak times of the day, and are 100% urban roads.
- The congestion calculation assumes the freeway makes up 26% of VMTs, which is taken from TRIP's American Interstate Highway Report.

Productivity from Active Transportation

Strategy T-1.1 encourages Tucsonans to shift their transportation habits from conventional internal combustion engines (ICE) vehicles to activate transit options such as walking, cycling, and rolling. When individuals shift behavior away from driving vehicles to active transportation, they increase their time spent exercising. Research indicates that individuals who exercise have lower absenteeism and presenteeism rates at their place of employment, which is a benefit to society (Boles et al., 2004).

Impact in Results Table

- Productivity from Active Transportation

Methodology

- GDP data (FRED, 2022) and population data (Census Bureau, 2022) are collected for Arizona. This is used to calculate per capita GDP.
- In Pima County, an average of 9% of trips (including commuting, going to school, shopping, social recreation, and transporting someone else) are by walking, 2% by cycling or rolling, and 5% by public transit (National Household Travel Survey, 2009). The proportion of the mode shift VMTs, with the mode shift beginning at 10% in 2019 and increasing annually to 40% in 2050, remains constant with 55% walking, 12% cycling or rolling, and 33% by public transportation.
- The number of employed persons in Tucson (Bureau of Labor Statistics, 2022) are multiplied by the proportion of the mode shift that walk, cycle, and roll to estimate the number of persons that participate in active transportation.
- Research indicates that exercise negates lost productivity due to absenteeism and presenteeism by about 4% (Boles et al., 2004). This is combined with per capita GDP in Arizona to determine the value of avoided cost of inactivity.
- 150 minutes per week per year are needed to avoid inactivity costs (CDC, 2022). The model combines this with the avoided cost of inactivity to derive the avoided cost of inactivity per minute.
- The average commute time in Tucson is 22.4 minutes (Move Tucson, 2021). The average time spent commuting is then multiplied by the avoided cost of inactivity per minute to estimate the benefit of total avoided cost of inactivity per year. This calculation is then applied throughout the study period and discounted into present value.

Assumptions

- The model assumes that productivity benefits for employed persons from active transportation result from all trip types, not just active commuting.
- The model assumes that the average commute time for working persons in Tucson is equal to the average time spent walking, cycling, and rolling to work. Additionally, the average commute time is used as a proxy for average trip time for all trip types, supported by this study for Maricopa County that illustrates a similar distribution of trip lengths for work and non-work trips (Maricopa Association of Governments, 2018).
- The model assumes there are 260 working days per year, and thus that working persons commute for 260 days a year.
- The model assumes that 100% of walking, cycling, and rolling commuters are engaged in moderate or vigorous physical activity, as per CDC definitions (CDC, 2022).
- The model assumes that 100% of Tucson employment are within the working ages of 20 to 64 years old.

4.4.2. T-1.5: Increase safety for all road users, including pedestrians and cyclists, by eliminating lanes on wide roads and creating public space, walkways, enhanced crossings and signals, and protected bike lanes

As part of strategy T-1, which encourages Tucson residents to engage in sustainable modes of transportation, strategy T-1.5 aims to implement a variety of safety enhancements to Tucson's roadways. The City of Tucson follows a Complete Streets policy for road design, which means roads are designed and constructed for all users. One strategy used under a Complete Streets approach is called a road diet, in which a travel lane is eliminated to improve safety and provide road space to other user groups such as pedestrians and cyclists.

Impacts in Results Table

- Avoided Crashes from Road Diet & Multimodal Safety Enhancements
- Municipal Staff Costs

Methodology

- Avoided Crashes from Road Diet & Multimodal Safety Enhancements
    - The Pima Association of Governments Strategic Transportation Safety Plan publishes crash rates for vehicle crashes that result in incapacitating injuries or fatalities (PAG, 2016). These rates are applied to the yearly vehicle miles traveled (VMT) in Tucson to obtain the number of crashes.
    - The Federal Highway Administration (FHWA) reports that road diet measures reduce the likelihood of vehicle crashes by 29% (FHWA, 2014). The number of vehicle crashes avoided given a road diet program is calculated by applying this percentage to the yearly number of vehicle crashes.
    - The Department of Transportation's benefit-cost analysis guidance monetizes the values of vehicle crashes resulting in incapacitating injuries or fatalities (DOT, 2022). Incapacitating injury crash and fatality crash costs are multiplied by the number of

avoided crashes to obtain the yearly cost of avoided incapacitating injuries and fatalities. These yearly costs are then discounted into present value.

- Municipal Staff Costs
    - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Assumptions

- The model assumes Tucson's proposed safety enhancements affect passenger vehicles, namely motorcycles, passenger cars, passenger trucks and light commercial trucks.
- The model assumes that the proposed safety enhancements only affect 25% of Tucson's VMT to be conservative without knowing which specific roads will be impacted.

4.4.3. T-2.1: Maintain and expand the Frequent Transit Network to increase Sun Tran service frequency and improve Sun Tran bus service

The City of Tucson has proposed increasing the frequency of Sun Tran bus routes to allow for 15 minute frequency on all routes. This action will result in a financial cost to the City of paying additional bus drivers for the newly added routes. This model methodology only calculates the cost associated with hiring additional drivers, as this strategy assumes no additional buses will be purchased. This assumption of no additional bus purchases does not affect the change in VMTs estimated within this model, but it does underestimate the capital and ongoing operating costs of the initiative.In addition, the environmental and social impacts from the switch of VMTs to public transportation is included elsewhere in section T-1.1

Impact in Results Table

- Transportation Operations and Maintenance
- Municipal Staff Costs

Method

- Financial costs
    - To calculate the additional number of drivers required, the ratio of the 2019 number of Sun Tran drivers to the number of transit bus VMTs was created. This driver to VMT ratio was then multiplied by the additional public transit VMTs each year from the modal shift percent (sourced from Buro Happold) to calculate the additional required drivers each year.
    - The annual additional required drivers was then multiplied by the bus driver salary to determine the total financial cost of hiring additional bus drivers each year.
- Municipal Staff Costs
    - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Assumptions

- The model assumes bus drivers work 37.5 hours a week and 52 week per year
- Bus driver hourly rate is $17 (sourced from Indeed)
- The model assumes that no additional buses will be purchased as a results of this action
- The model assumes there are 434 Sun Tran drivers in 2022
- The model assumes that the modal shift percent (sourced from Buro Happold) includes the increased VMTs from this increase in bus frequency. Therefore, the social and environmental benefits of this VMT shift are calculated in the T-1.1 methodology

4.5. Strategy T-5: Transition public agency fleets to zero-emission and near zero-emission vehicles

Strategy T-5 aims to convert the City's vehicle fleet from internal combustion engine (ICE) vehicles to electric vehicles (EVs). Transportation shifts from ICEs to EVs are necessary for the City to achieve its carbon target. Although EVs do have emission factors associated with the energy use during battery charging cycles, the quantity of pollutants released into the atmosphere is dictated by how fossil fuel dependent the composition of the energy grid is. The forecasted vehicle miles traveled (VMTs) assigned to EVs that would otherwise have been completed by ICE vehicles without the proposed strategy were calculated to form a comparative case. This model uses estimates of future ICE and EV emission factors taken from the Argonne Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Technologies Model (GREET) to monetize carbon and air pollutant reduction benefits, as well as estimates of vehicle purchase and ownership costs taken from the Argonne Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool (AFLEET) to monetize lifecycle costs and benefits. It should be noted that the latest version of the AFLEET tool was published in 2020, and the reported vehicle purchase and maintenance costs were sourced pre-COVID-19 pandemic. Therefore, the AFLEET tool likely underestimates current vehicle purchase and maintenance costs. However, since these costs are applied over the duration of the study period, it is assumed the volatility in the automotive market is netted out.

Under the proposed strategy, the City would install EV charging infrastructure targeting City-owned vehicles and public transit. This study accounts for the installation of Level 2 chargers and Level 3 chargers, which are common workplace chargers. Charger installation costs and additional financial costs stemming from the required increase in electricity consumption, as well as financial savings from the avoided cost of fossil fuel purchases, are also calculated for the City's fleet vehicles converting from ICE to EV. Moreover, lifecycle ownership costs and benefits are calculated for the converted fleet vehicles.

4.5.1. T-5.1: Implement a fleet management plan that mandates all newly purchased City vehicles (including replacements) are zero-emission vehicles and implements fleet efficiency evaluations to ensure that the City does not own or use more vehicles than it needs at any time

Impacts in Results Table

- Transportation Capital Expenditures
- Transportation Operations and Maintenance
- Cost of Electricity &/or Natural Gas
- Air Pollution Reductions - Transportation
- Carbon Emission Reductions - Transportation
- Municipal Staff Costs

Methodology

- Passenger car, light-duty truck and motorcycle fleet
  - City fleet data received from the client has 2017 counts and VMTs by fuel vehicle type. This is mapped to the 2022 VMT data received from the client to estimate 2022 vehicle counts and yearly VMTs for each ICE vehicle combination.
  - The City fleet ICE vehicles are switched over from fossil fuel to electric at a constant yearly rate such that the City fleet is entirely electric by 2030.

- Electric vehicle charging stations costs
  - Yearly electric vehicle purchases for all vehicle types are projected until 2030. The number of required electric vehicle chargers is calculated using the vehicle to charger ratios provided by the City. The number of required electric vehicle chargers is multiplied by the unit cost of that vehicle type's respective electric charger.
  - Studies report that 30% of electric vehicle costs are related to operations, and 10% of the operation costs are attributed to maintenance (EVgo Fast Charging, 2020). Therefore, operations and maintenance (O&M) costs for the electric vehicle chargers are calculated as 3% of their installation cost. The O&M costs are cumulative and projected out until 2050.

- Financial savings
  - As the fleet switches to electric, increased electricity purchases are offset by reduced fossil fuel costs. Gasoline, diesel, E85, compressed natural gas and liquefied petroleum gas prices are collected for the Mountain region (EIA, 2022). Commercial electricity prices are provided by the City, with a 2% yearly growth rate (City of Tucson, personal communication, 2023).
  - For each fossil fuel vehicle combination, the vehicle's yearly miles traveled are multiplied by the vehicle's fuel use. This value is then multiplied by the yearly fuel price to obtain the yearly avoided cost of fuel.

  - For each electric vehicle type, the electric vehicle's fuel use is multiplied by the sum of the vehicle miles traveled by that vehicle and each fossil fuel. This value is then multiplied by the yearly commodity electricity price for the City to obtain the yearly consumption cost of electricity.

- Ownership costs
  - Vehicle purchase and maintenance costs are collected for each fuel vehicle combination (AFLEET, 2020).
  - Each fuel vehicle combination's fixed costs and maintenance costs are divided by the vehicle's total miles traveled over a 15-year planned ownership to obtain costs on a per-mile basis.
  - Fixed costs and maintenance costs for the respective electric vehicle are subtracted from the fixed costs and maintenance costs for each fossil fuel vehicle combination to create differential costs. These differential fixed costs and maintenance costs are then inflated to $2022.
  - Each fossil fuel vehicle combination's yearly miles traveled are multiplied by that fossil fuel vehicle combination's differential fixed cost and maintenance cost. This provides the yearly increased fixed cost and decreased maintenance cost of switching that fossil fuel vehicle combination to electric.

- Environmental impacts
  - Fossil fuel and electric emission factors are normalized on a per-mile basis (GREET, 2022). Each fossil fuel vehicle's emission factors are subtracted from the respective vehicle's electric emission factors to arrive at the differential emissions factors as a result of switching that fossil fuel vehicle to electric.
  - These yearly differential emissions factors are multiplied by the respective fossil fuel vehicle's yearly VMTs that are switched over to electric. This provides the annual pollutant reductions for each fossil fuel vehicle combination, which are monetized using social costs. This calculation is then applied throughout the study period and discounted into present value.

- Municipal Staff Costs
  - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Assumptions

- The model assumes that VMTs per vehicle and miles per gallon ratios are constant between the 2017 and 2022 data sets.
- Based on the most recent data available from the City as of 2017, the model states that the City does not have any electric light-duty vehicles in its current fleet.

- The model assumes that the City fleet vehicle counts remain constant throughout the analysis. An increase in VMTs corresponds to an increase in each vehicle's respective VMTs, and not to an increase in vehicles.
- The model assumes that the City will install electric vehicle charging stations at a ratio of four light-duty electric vehicles per electric vehicle charger (City of Tucson, personal communication, 2023).
- The model assumes that passenger cars, motorcycles and light-duty trucks will use Level 2 workplace chargers.
- Fleet inventory data provided by the City was only disaggregated to the vehicle type (e.g., light duty truck, heavy duty truck). Whereas the GREET data is refined to light-duty pick-up trucks and sport utility vehicles (SUV) within the light duty vehicle class. For the light duty truck vehicle type. Based on weights provided by the City, the model states the City's light-duty truck fleet consists of 57% light-duty pick-up trucks and 43% SUVs. Therefore, fuel use and emission factor projections for light-duty trucks are a weighted average between the fuel use and emission factor projections for light-duty pick-up trucks and SUVs.
- The model assumes that a motorcycle's purchase price is $33,627.41 (City of Tucson, personal communication, 2023) and that a motorcycle's annual mileage is 3,000 miles (PowerSportsGuide, 2023).
- The AFLEET tool does not include motorcycles. Therefore, gasoline motorcycle maintenance costs are estimated using the ratio of a motorcycle's purchase price to a car's purchase price, and electric motorcycle costs are estimated using the ratio of electric car costs to gasoline car costs.
- The GREET model does not include motorcycles. Therefore, the ratio of the average gasoline motorcycle's mile per gallon (MPG) to the average gasoline car's MPG is multiplied by the GREET model's gasoline car and electric car MPG values to estimate the MPG values for a gasoline motorcycle and electric motorcycle (AFDC, 2020).
- The GREET model does not include motorcycles. Therefore, the ratio of a motorcycle's CO2 emissions per mile to a passenger car's CO2 emissions per mile (Hernandez et al., 2019) is multiplied by the GREET model's gasoline passenger car CO2 emissions per mile to estimate the CO2 emissions per mile for a gasoline motorcycle.
- The model calculates the ratio of pollutant emissions per mile to CO2 emissions per mile for gasoline passenger cars and multiplies these values by the CO2 emissions per mile for gasoline motorcycles to estimate the pollutant emissions per mile for gasoline motorcycles.
- 2020 fuel use projections for motorcycles are projected forward every five years using the average five-year growth rate of the same fuel for passenger cars, light-duty pick-up trucks and SUVs.
- Emission factors projections for motorcycles are projected forward every five years using the growth rate of emission factors projections for the same fuel for passenger cars.
- The model applies electricity emission factors for GHGs and CACs and then straight-lined down to 100% reduction to account for the City of Tuscon's proposition in Strategy E-3.4 to

obtain all electricity from solar SSAs or VPPAs by 2030. Therefore, emission factors for the City's electric vehicles in 2030 and onwards are null.
- The model does not incorporate increases in electricity demand costs from increases in electric vehicle charging due to the availability of data such as understanding the City's peak demand schedule, charging behavior, and the City's demand pricing from its utility.

4.5.2. T-5.2: Develop capital project plans to install charging stations to meet the projected demand of fleet vehicles

The effects of T-5.2 are embedded within T-5.1 and the monetization pathway is detailed in that section.

4.5.3. T-5.3: Develop implementation plan for replacement of City-owned medium-to-heavy duty vehicles with zero and near zero emission vehicles

Impacts in Results Table
- Transportation Capital Expenditures
- Transportation Operations and Maintenance
- Cost of Electricity &/or Natural Gas
- Air Pollution Reductions - Transportation
- Carbon Emission Reductions - Transportation
- Municipal Staff Costs

Methodology
- Medium-duty & heavy-duty truck fleet
  - See Action T-5.1
- Electric vehicle charging stations costs
  - See Action T-5.1
- Financial savings
  - See Action T-5.1
- Ownership costs
  - See Action T-5.1
- Environmental impacts
  - See Action T-5.1
- Municipal Staff Costs
  - See Action T-5.1

Assumptions
- The model assumes that VMTs per vehicle and miles per gallon ratios are constant between the 2017 and 2022 data sets.

- Based on the most recent fleet inventory data available from the City as of 2017, the model states that the City does not already have any electric medium-duty or heavy-duty vehicles in its current fleet.
- The model assumes that the City fleet vehicle counts remain constant throughout the analysis. An increase in VMTs corresponds to an increase in each vehicle's respective VMTs, and not to an increase in vehicles.
- The model assumes that the City will install electric vehicle charging stations at a ratio of four medium-duty electric vehicles per electric vehicle charger and one heavy-duty electric vehicle per electric vehicle charger (City of Tucson, personal communication, 2023).
- The model assumes that medium-duty trucks will use Level 2 workplace chargers, and that heavy-duty trucks will use Level 3 chargers.
- The AFLEET tool does not include gasoline heavy-duty trucks. Therefore, gasoline heavy-duty truck costs are estimated using the ratio of gasoline medium-duty truck costs to diesel medium-duty truck costs.
- The model applies electricity emission factors for GHGs and CACs (EIA, 2023) and then straight-lined down to 100% reduction to account for the City of Tuscon's proposition in Strategy E-3 to obtain all electricity from solar SSAs or VPPAs by 2030. Therefore, emission factors for the City's electric vehicles in 2030 and onwards are null.
- The GREET model does not include gasoline heavy-duty trucks. Therefore, the model calculates the ratio of fuel use and emissions factors for gasoline heavy-duty pick-up trucks and vans to diesel heavy-duty pick-up trucks and vans and multiplies by the fuel use and emissions factors for diesel heavy-duty trucks to estimate the fuel use and emissions factors for gasoline heavy-duty trucks.
- 2020 fuel use and emission factors projections from the GREET model for medium-duty trucks and heavy-duty trucks are projected forward every five years using the average five-year growth rate of the same fuel for passenger cars, light-duty pick-up trucks and SUVs.
- Emission factors projections for medium-duty trucks and heavy-duty trucks are projected forward every five years using the growth rate of emission factors projections for the same fuel for light-duty trucks.
- Projections for CH4 emissions for diesel medium-duty trucks and diesel heavy-duty trucks are estimated using the CH4 growth rate for gasoline light-duty trucks.

4.5.4. T-5.5: Create a funding and purchase plan for battery electric buses, paratransit vehicles, and other zero emission vehicles across all public transportation services

Impacts in Results Table

- Transportation Capital Expenditures
- Transportation Operations and Maintenance
- Cost of Electricity &/or Natural Gas
- Air Pollution Reductions - Transportation
- Carbon Emission Reductions - Transportation

- Municipal Staff Costs

Methodology

- Transit bus and paratransit van fleet
  - The yearly Sun Tran and Sun Van VMTs are divided by the 2022 Sun Tran and Sun Van fleet vehicle counts (CPTDB, 2022) to calculate the annual average VMT per vehicle. This is multiplied by the number of respective vehicles to obtain the yearly VMTs for each ICE vehicle combination.
  - The Sun Tran and Sun Van ICE vehicles are switched over from fossil fuel to electric at a constant yearly rate such that the public transit fleet is entirely electric by 2030.
- Electric vehicle charging stations costs
  - See Action T-5.1
- Financial savings
  - See Action T-5.1
- Ownership costs
  - See Action T-5.1
- Environmental impacts
  - See Action T-5.1
- Municipal Staff Costs
  - See Action T-5.1

Assumptions

- In the data received from Buro Happold, Sun Tran and Sun Van VMTs are projected until 2030 using a 1% yearly growth rate. This growth rate is applied forward until 2050.
- The model assumes that the City already has six electric transit buses in its fleet (CPTDB, 2022). However, Action T-5.5 measures the incremental costs & benefits incurred from switching ICE transit buses to electric transit buses, and therefore these six pre-existing electric transit buses don't contribute to Action T-5.5's results.
- The model assumes that the public transit fleet vehicle counts remain constant throughout the analysis. An increase in VMTs corresponds to an increase in each vehicle's respective VMTs, and not to an increase in vehicles.
- The model assumes that the City will install electric vehicle charging stations at a ratio of one electric transit bus per electric vehicle charger and four electric paratransit vans per electric vehicle charger (City of Tucson, personal communication, 2023).
- The model assumes that Sun Van vehicles will use Level 2 workplace chargers, and that Sun Tran buses will use Level 3 chargers.
- The City provided updated purchase costs for transit buses and paratransit vans (City of Tucson, personal communication, 2023).
- The model applies electricity emission factors for GHGs and CACs (EIA, 2023) and then straight-lined down to 100% reduction to account for the City of Tuscon's proposition in Strategy E-3 to obtain all electricity from solar SSAs or VPPAs by 2030. Therefore, emission factors for the City's electric vehicles in 2030 and onwards are null.

- The GREET model does not include fuel use and pollutant emissions factors data for paratransit vans. Therefore, the model assumes that fuel use and pollutant emissions factors projections for paratransit vans are equal to those for SUVs.
- 2020 fuel use and emission factors projections from the GREET model for transit buses are projected forward every five years using the average five-year growth rate of the same fuel for passenger cars, light-duty pick-up trucks and SUVs.
- Emission factors projections for transit buses are projected forward every five years using the growth rate of emission factors projections for the same fuel for light-duty trucks.
- Projections for CH4 emissions for diesel transit buses and hybrid transit buses are estimated using the CH4 growth rate for gasoline light-duty trucks.

4.6. Strategy RR-1: Implement a Community-wide Zero Waste Plan and accompanying initiatives to achieve zero waste for City operations by 2030, and community-wide zero waste by 2050

The goal of Strategy RR is for Tucson to achieve Zero-Waste in its City operations by 2030, and Zero-Waste community-wide by 2050, with a 50% diversion rate by 2030. This is achieved by implementing a compost program for source-separated organics, and increasing municipal solid waste diversion from landfills to recycling and compost facilities. These environmental benefits are calculated using the Environmental Protection Agency's Waste Reduction Model (WARM) tool. The WARM tool calculates greenhouse gas emissions reductions from different waste management solutions.

Strategy RR-1 methods and assumptions apply to all actions within RR-1 taken as a combination.

Impacts in Results Table

- Carbon Emission Reductions - Waste
- Municipal Staff Costs

Methodology

- Carbon Emission Reductions - Waste
    - Waste characterization percentages for Tucson (City of Tucson, personal communication, 2023) were used to divide Tucson's summary waste data into various waste types. Construction and demolition waste was broken down into carpet, concrete, asphalt concrete, asphalt shingles, dimensional lumber, drywall & fly ash using weights from Fresno, California (CalRecycle, 2022). Fresno was selected since this breakdown was not available for Tucson, and Fresno and Tucson have similar populations.
    - The waste data received from the client was projected forward and mapped to the waste types included in the EPA's WARM model. Recyclable waste was increasingly diverted from landfill to recycling.

  - Reductions in CO_2e are quantified by using the WARM tool (EPA, 2022), which estimates the difference in emissions between the baseline and proposed design waste management policies. The environmental benefit of reduced CO_2e is monetized by applying the social cost of carbon to the amount of CO_2e emissions reduced to reflect the value to society. This environmental yearly benefit is then calculated throughout the study period and discounted into present value.
- Municipal Staff Costs
  - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Assumptions

- The model assumes a yearly population growth rate of 1% from 2030 to 2050. This is an average of the yearly population growth rates from 2023 to 2030 provided by the client. Yearly waste production is assumed to follow the same growth rate.
- Waste characterization of Fresno, California was used as a proxy for Tucson to divide construction and demolition waste data into various waste types.
- Tucson already has the required infrastructure for a recycling program. Therefore, the model assumes that increased recycling costs, such as tipping fees for recycling facilities, are offset by decreased landfill costs, such as tipping fees for landfills.
- This analysis was segmented into City operations waste diversion and Community-wide waste diversion. The community-wide waste data received from the City is from 2023 and indicates that 3% of community-wide waste stems from city operations. However, the city operations waste data received from the City is from 2019, and when projected forward to 2023 using population growth rates, it only accounts for 1.34% of community-wide waste. The supplied city operations waste data was used for the city operations waste diversion analysis, but the 1.66% difference should be noted. The city operations waste tonnage was subtracted from the community-wide waste tonnage for the community-wide waste diversion analysis.

4.7. Strategy RR-2: Create a community-wide organics collection and treatment program

Strategy RR-2 methods and assumptions apply to all actions within RR-2 taken as a combination.

Impacts in Results Table

- Carbon Emission Reductions - Waste
- Cost of Municipal Waste Resource Recovery
- Revenues - Waste Resource Recovery
- Municipal Staff Costs

Methodology

- Waste characterization percentages for Tucson (City of Tucson, personal communication, 2023) were used to divide Tucson's summary waste data into various waste types. Organic waste was broken down into food waste and yard trimmings using weights from Fresno, California (CalRecycle, 2022). Fresno was selected since this breakdown was not available for Tucson, and Fresno and Tucson have similar populations.
- The waste data received from the client was projected forward and mapped to the waste types included in the EPA's WARM model. Source-separated organic waste was diverted from landfill to composting.
- Reductions in CO2e are quantified by using the WARM tool (EPA, 2022), which estimates the difference in emissions between the baseline and proposed design waste management policies. The environmental benefit of reduced CO2e is monetized by applying the social cost of carbon to the amount of CO2e emissions reduced to reflect the value to society.
- The cost associated with this strategy is the cost of implementing a new compost program. The City of Tucson estimates this cost at $25.5/ton. This cost is multiplied by the yearly tonnage of waste diverted to the compost facility.
- Compost facilities generate revenue through the sale of fertilizer. A standard compost facility outputs around a third of the compost input (Citizens Business Commission, 2016). The City estimates the potential revenue stream of a compost program at 50% of its cost (City of Tucson, personal communication, 2023).Therefore, this fertilizer sells for $12.75/ton. This revenue is used to offset the cost of the compost program. The yearly environmental benefit, compost program cost and fertilizer sale revenue are then calculated throughout the study period and discounted into present value.
- Municipal Staff Costs
    - The City expects to hire a full time employee at a total cost of $100,000 per year including salary, benefits, and overhead. It is assumed they begin in 2023 and remain for the duration of the study period.

Assumptions

- The model assumes a yearly population growth rate of 1% from 2030 to 2050. This is an average of the yearly population growth rates from 2023 to 2030 provided by the client. Yearly waste production is assumed to follow the same growth rate.
- Waste characterization of Fresno, California was used as a proxy for Tucson to divide organic waste data into various waste types.
- This analysis was segmented into City operations waste diversion and Community-wide waste diversion. The community-wide waste data received from the City is from 2023 and indicates that 3% of community-wide waste stems from city operations. However, the city operations waste data received from the City is from 2019, and when projected forward to 2023 using population growth rates, it only accounts for 1.34% of community-wide waste. The supplied city operations waste data was used for the city operations waste diversion analysis, but the 1.66% difference should be noted. The city operations waste tonnage was subtracted from the community-wide waste tonnage for the community-wide waste diversion analysis.

5. Multi Criteria Decision Analysis:

Multi Criteria Decision Analysis (MCDA) is a decision-support process that allows stakeholders to identify the goals, objectives, and criteria for a project, as well as the associated metrics that may be used to score a project as a measure of compliance or project success. It also assesses the trade-offs between those objectives as prescribed in different project designs.

These quantitative and qualitative metrics are commonly weighted to identify the hierarchy of criteria or preferences, such that project designs which target the same broad objective can be compared against other criteria scores that are of most importance to stakeholders. The scale of preference also lends to the scalability of criteria and sub-criteria scores as the strategies comply with different levels of achievement that fulfill each corresponding criteria. Within this project, City of Tucson seeks to assess strategies across 5 categories within their Climate Action Plan and use a scale of sustainability-based ranking system to prioritize investments.

This formalized quantitative approach will help to prioritize proposed specific implementation actions within strategies as they highlight key areas of the MCDA that have received high scores. The list of criteria, sub-criteria and quantitative scoring framework were developed specifically for this early stage of capital planning, with limited quantitative information available on the CAAP strategies. This MCDA could be iterated upon and supplemented as strategies are more fully developed. As more specific information on strategies and actions becomes available, more specific criteria and sub-criteria can supplement the high-level list currently implemented, along with more quantitative scoring attribution.

This MCDA highlights the relative merits of the full list of CAAP Strategies based on the qualitative descriptions provided as a part of each of the Action items highlighted under each Strategy. The criteria and sub criteria evaluate the strategies across key indicators that are important to the success of a strategy and action plan. The ranking system is expected to be used to identify strategies that best meet the City's objectives from an environmental, implementability, and community impact standpoint. The ranking system is shown in terms of a weighted score that reflects preferences of most to least important criteria.

Overall, the MCDA approach identifies sets of qualitative, high-level goals, objectives, preferences and trade-offs between those objectives as prescribed in different project designs.
There are three key steps that will be involved in setting up the MCDA:

- Setting up the broad criteria and sub-criteria
- Setting up weights per criteria and sub-criteria
- Scoring each strategy.

Within the MCDA approach, the above descriptions of the sub-criteria are expected to be used to define the inputs that would be needed to fill out the MCDA framework. The levels of compliance within each of the project criteria by each strategy will enable us to formulate a ranking score. Overall, the responses to these input questions will be segmented into categories:

- Yes/No Questions that suggest qualitative impacts that are to be expected from measures such as broadly integrating sustainability within the action plan. The scoring framework used here will be yes = 30, No = 10. Therefore, yes would indicate complete criteria fulfillment. We include these qualitative questions as a means to expand the criteria against which the strategy is assessed even if detailed action items may not be available at this time.
- Detailed scoring questions which have a tier of levels ranging from 1-3 may be selected for each project. Each level will be scored in multiples of 10. The levels between 1 and 3 are used to indicate partial fulfillment of criteria.

5.1. Broad Criteria Chart

The broad criteria are applied to every category of strategies. The broad criteria are kept consistent between strategies, however the sub-criterias are more specific to the sets of strategies and actions for each category.

Table 5. Energy Criteria Chart

Category	Criteria	Sub-criteria	Scoring Methodology
Energy	Carbon goals & emissions	Carbon neutrality / decarbonization	Targets from 0-100%
		Target timeline for strategy goal	Target timeline from nothing set to 2050
	Co-benefits and impacts	Who bears the majority of the strategy's benefits/ savings	Is it borne singularly by city community or a joint cost?
		Who bears the majority of the strategy's costs	Is it borne singularly by city community or a joint cost?
		Community (including underserved communities) participates in renewable energy access and production	Yes/No
		Strategy expects to improve affordability for community	Yes/No
		Scale of impact	Number of stakeholders affected (homeowners, businesses and commercial spaces, community-wide spaces, city-buildings and assets etc.)
	Implementation, Feasibility, Readiness	Expected implementation date	Target timeline from nothing set to immediate
		Ease of implementation	Level of effort, time, resources for the city

Table 6. Transportation Criteria Chart

Category	Criteria	Sub-criteria	Scoring Methodology
Transportation	Carbon goals & emissions	Monitoring and tracking of strategy outcomes for efficiency and progress toward sustainable modes	Yes/No
		Net zero / decarbonization targets	Targets from 0-100%
		Target timeline for strategy goal	Target timeline from nothing set to 2050
		Increased measures for electrification of fleet / promote modal shift towards EV vehicles/fleet by providing easy to access infrastructure	Yes/No
	Co-benefits and impacts	Strategy expects to increase transit accessibility to the community	Yes/No
		Strategy expects to improve affordability for community	Yes/No
		Strategy expects to increase transit-related safety to the community	Yes/No
		Who bears the majority of the strategy's benefits/ savings	Is it borne singularly by city community or a joint cost?
		Who bears the majority of the strategy's costs	Is it borne singularly by city community or a joint cost?
		Scale of increase in sustainable mode of transportation	Selection between cycling and/or walking and/or rolling, and/or other amenities
		Scale of impact	Number of stakeholders affected (homeowners, businesses and commercial spaces, community-wide spaces, city-buildings and assets etc.)
	Implementation, Feasibility, Readiness	Ease of implementation	Level of effort, time, resources for the city
		Efforts to increase programs that promote sustainable mode shift	Yes/No
		Measures that promote employer programs to incentivize employees to choose sustainable modes of commute	Yes/No
		Expected implementation date	Target timeline from nothing set to immediate

Table 7. Resource Recovery Criteria Chart

Category	Criteria	Sub-criteria	Scoring methodology
Resource Recovery	Carbon goals & emissions	Net zero waste target	Targets from 0-100%
		Timeline for strategy goal	Target timeline from nothing set to 2050
		Scale of zero-waste / decarbonization	Selection between community wide / complete diversion / strategies for diversion + food waste reduction, organic waste treatment + policies and programs to divert, source reduce and address waste management
		Monitoring and tracking of strategy outcomes for efficiency and progress	Yes/No
	Co-benefits and impacts	Scale of impact	Number of stakeholders affected (homeowners, businesses and commercial spaces, community-wide spaces, city-buildings and assets etc.)
		Who bears the majority of the strategy's benefits/ savings	Is it borne singularly by city community or a joint cost?
		Who bears the majority of the strategy's costs	Is it borne singularly by city community or a joint cost?
	Implementation, Feasibility, Readiness	Expected implementation date	Target timeline from nothing set to immediate
		Ease of implementation	Level of effort, time, resources for the city
		Policies and programs to help overcome cost-financing-implementation based barriers due to small-scale of business/waste creation	Yes/No

Table 8. Governance & Leadership Criteria Chart

Category	Criteria	Sub-criteria	Scoring Methodology
Governance & Leadership	Carbon goals & emissions	Does the strategy directly mitigate or abate emissions?	Yes/No
	Co-benefits and impacts	Who bears the majority of the strategy's benefits/ savings	Is it borne singularly by city community or a joint cost?

		Who bears the majority of the strategy's costs	Is it borne singularly by city community or a joint cost?
	Implementation, Feasibility, Readiness	Incorporation and/or continued tracking of climate action and resilience performance objectives?	Yes/No
		Scale of collaboration with the community and key stakeholders	List of community ambassadors, organizational, employers, local business groups
		Partnership potential within the community and neighborhoods for public engagement	Yes/No
		Ease of implementation	Level of effort, time, resources for the city
		Expected implementation date	Target timeline from nothing set to immediate

Table 9. Community Resilience Criteria Chart

Category	Criteria	Sub-criteria	Units
Community Resilience	Carbon goals & emissions	Target timeline for strategy goal	Target timeline from nothing set to 2050
		Strategy mitigates climate-related events (e.g., extreme heat)	Yes/No
	Co-benefits and impacts	Who bears the majority of the strategy's benefits	Selection between city and/or community
		Who bears the majority of the strategy's costs	Selection between city and/or community
		Strategy improves the quality of natural areas / green spaces in the City for the Community	Yes/No
		Scale of resilient grey infrastructure	List of features invested: Pilot high-albedo (or light-color and heat-reflective) surfaces on buildings, roadways, sidewalks and paths, and parking lots at City-owned properties
		Scale of resilient green infrastructure investments	Selection of feature: shade equity, urban greening, shade canopies, shade trees, splash pads, native and contextually appropriate tree species, tree equity, and water conservation, urban tree inventory, an urban forest master plan , green roofs, pollinator gardens, and rain gardens with a focus on Ward offices, parks, and greenways
		Strategy helps to mitigate / address climate-related events/ heat related illnesses & incidents (e.g., extreme	Yes/No

		heat	
	Implementation, Feasibility, Readiness	Scale of communities, organizations involved in the strategy	Schools, community organizations / neighborhood associations, faith based institutions, homeowners, municipal departments
		Incorporate community activities for improved risk mitigation, enhanced safety, and access to more resources	Yes/No
		Strategy to supports enhanced emergency and crises responses by the City	Yes/No
		Expected implementation date	Target timeline from nothing set to immediate
		Ease of implementation	Level of effort, time, resources for the city

Within the MCDA approach, the above scoring methodology is used to gather site qualitative data and information on resources expended towards fulfilling each of the criteria. The degree to which efforts have been expended by each strategy per category are reflected in the scores obtained across each sub-criteria. Overall, the responses to each of the sub-criteria for each site are segmented into three levels of scoring (Level 1 - Level 3), where level 3 represents complete fulfillment (and a score of 20-30), level 1 represents minimum or no fulfillment (and a score of 0-10), and the levels in between showing varying degrees of partial fulfillment (and scored of 10-20).

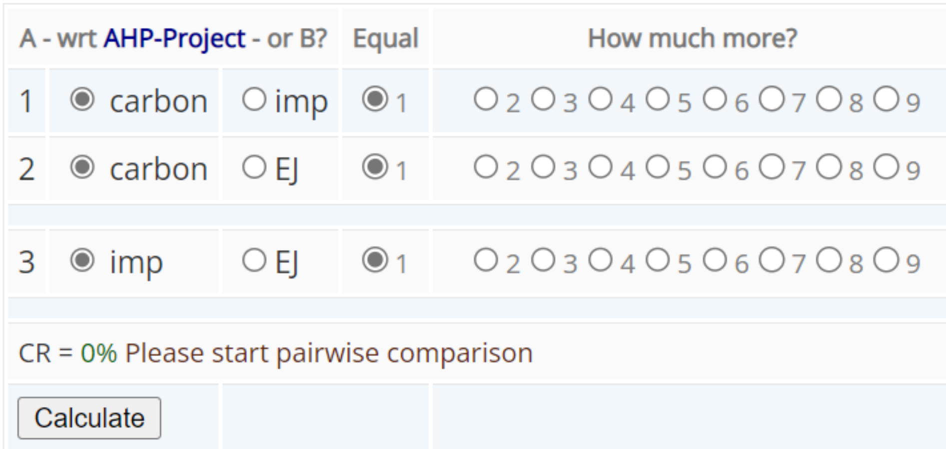
5.2. Analytic Hierarchy Process

We use the Analytic Hierarchy Process (AHP) approach to analyze the relative preferences between the broad and sub criteria and thereby set up the weights that are used for scoring. This includes making a series of simple comparisons, called Pairwise Comparisons between the different criteria and sub-criteria within the MCDA analysis. The comparisons are carried out by including a ranking system of the relative importance of each criteria on a scale of 1-9, with 5 clear groups of importance:

- Rank 1 - Equally important
- Rank 3 - Moderately more important
- Rank 5 - Strongly more important
- Rank 7 - Very strongly more important
- Rank 9 - Extremely more important

The rankings in between these five sections (2,4,6,8) represent in-between levels that may be used if the relative importance does not fall within these five distinct sections. The results of the AHP simulation are provided below. The AHP arranges the criteria and sub-criteria into a hierarchical structure similar to a family tree.

Weights are therefore applied within two layers: firstly within the broad criteria to lend weight to the criteria that are of most importance to the stakeholders, and then also within the sub-criteria levels to place emphasis on the drivers of each of the broad criteria. In this study, the sub-criteria have been allocated equal weights within each criteria to maintain simplicity.



As seen in the above figure, if Carbon goals & emissions is ranked as equally important as Co-benefits, environmental justice, and impacts, a rank of 1 can be selected. If it is more important, then a degree of importance may be selected across levels 2-9. The results of the simulation have been shown below to show criteria, sub-criteria specific weights, and the aggregate importance in terms of an MCDA Global Weight.

Table 9. Decision Hierarchy Structure

Decision Hierarchy					
Level 0	Level 1	Broad Weights	Level 2	Sub Criteria Weights	MCDA Global Weights
Energy	Carbon goals & emissions	29.50%	Carbon neutrality / decarbonization	50.00%	14.75%
			Target timeline for strategy goal	50.00%	14.75%
	Implementation, Feasibility, Readiness	26.80%	Who bears the majority of the strategy's benefits	20%	5.36%
			Who bears the majority of the strategy's costs	20%	5.36%
			Community (including underserved communities) participates in renewable energy access and production	20%	5.36%
			Strategy expects to improve affordability for community	20%	5.36%
			Scale of impact	20%	5.36%

	Co-benefits and impacts	43.60%	Expected implementation date	50.00%	21.80%
			Ease of implementation	50.00%	21.80%
				Total:	100%
Level 0	Level 1	Broad Weights	Level 2	Sub Criteria Weights	MCDA Global Weights
Transportation	Carbon goals & emissions	29.50%	Monitoring and tracking of strategy outcomes for efficiency and progress toward sustainable modes	25.00%	7.38%
			Net zero / decarbonization targets	25.00%	7.38%
			Target timeline for strategy goal	25.00%	7.38%
			Increased measures for electrification of fleet / promote modal shift towards EV vehicles/fleet by providing easy to access infrastructure	25.00%	7.38%
	Implementation, Feasibility, Readiness	26.80%	Strategy expects to increase transit accessibility to the community	14%	3.75%
			Strategy expects to improve affordability for community	14%	3.75%
			Strategy expects to increase transit-related safety to the community	14%	3.75%
			Who bears the majority of the strategy's benefits	14%	3.75%
			Who bears the majority of the strategy's costs	14%	3.75%
			Scale of increase in sustainable mode of transportation	14%	3.75%
			Scale of impact	14%	3.75%
	Co-benefits and impacts	43.60%	Ease of implementation	25.00%	10.90%
			Efforts to increase programs that promote sustainable mode shift	25.00%	10.90%
			Measures that promote employer programs to incentivize employees to choose sustainable modes of commute	25.00%	10.90%
			Expected implementation date	25.00%	10.90%

				Total:	100%
Level 0	Level 1	Broad Weights	Level 2		
Resource Recovery	Carbon goals & emissions	29.50%	Net zero waste target	25%	7.38%
			Timeline for strategy goal	25%	7.38%
			Scale of zero-waste / decarbonization	25%	7.38%
			Monitoring and tracking of strategy outcomes for efficiency and progress	25%	7.38%
	Implementation, Feasibility, Readiness	26.80%	Scale of impact	33%	8.84%
			Who bears the majority of the strategy's benefits	33%	8.84%
			Who bears the majority of the strategy's costs	33%	8.84%
	Co-benefits and impacts	43.60%	Expected implementation date	33%	14.39%
			Ease of implementation	33%	14.39%
			Policies and programs to help overcome cost-financing-implementation based barriers due to small-scale of business/waste creation	33%	14.39%

				Total:	100%
Level 0	Level 1	Broad Weights	Level 2		
Governance & Leadership	Carbon goals & emissions	29.50%	Does the strategy directly mitigate or abate emissions?	100%	29.50%
	Implementation, Feasibility, Readiness	26.80%	Incorporation and/or continued tracking of climate action and resilience performance objectives?	20%	5.36%
			Scale of collaboration with the community and key stakeholders	20%	5.36%
			Partnership potential within the community and neighborhoods for public engagement	20%	5.36%
			Ease of implementation	20%	5.36%
			Expected implementation date	20%	5.36%
	Co-benefits and	43.60%	Who bears the majority of the strategy's benefits	50%	21.80%

Level 0	Level 1	Broad Weights	Level 2		
	impacts		Who bears the majority of the strategy's costs	50%	21.80%
				Total:	100%
Level 0	Level 1	Broad Weights	Level 2		
Community Resilience	Carbon goals & emissions	29.50%	Target timeline for strategy goal	50%	14.75%
			Strategy mitigates climate-related events (e.g., extreme heat)	50%	14.75%
	Implementation, Feasibility, Readiness	26.80%	Scale of communities, organizations involved in the strategy	20%	5.36%
			Incorporate community activities for improved risk mitigation, enhanced safety, and access to more resources	20%	5.36%
			Strategy to supports enhanced emergency and crises responses by the City	20%	5.36%
			Expected implementation date	20%	5.36%
			Ease of implementation	20%	5.36%
	Co-benefits and impacts	43.60%	Who bears the majority of the strategy's benefits	17%	7.41%
			Who bears the majority of the strategy's costs	17%	7.41%
			Strategy improves the quality of natural areas / green spaces in the City for the Community	17%	7.41%
			Scale of resilient grey infrastructure	17%	7.41%
			Scale of resilient green infrastructure investments	17%	7.41%
			Strategy helps to mitigate / address climate-related events/ heat related illnesses & incidents (e.g., extreme heat	17%	7.41%
				Total:	100%

5.3. Results

The pairwise comparisons have shown that most strategies score between Level 2 and 3, thereby generating a relatively higher score. This has been seen in particular with the strategies within the Governance & Leadership category wherein the strategies are expected to directly mitigate emissions, produce benefits that are most applicable to the City and Community, and use a collaborative approach that involves different key members of the Community. Similarly, community resilience scores highly across the second and third strategy that has a focus on green-grey infrastructure that mitigate climate related heat island, flooding and other events. The robust scale of features specified as a part of the actions are responsible for the higher score attributed to these strategies. In the table below, each of the strategies per category have been assigned a weighted score to demonstrate the level of compliance with the scoring framework.

Detailed results have been provided per category as well to demonstrate the sub-criteria scoring as well. A key takeaway of the results includes answering the question of relative importance versus score. Strategies with low weights and relative importance may score very highly giving a medium score and vice-versa. This can be used by the City as a check on the strategies and underlying actions that are most effective but may not have been given enough attention / financial investment and vice-versa.

Table 10. MCDA Strategy Scores

Category/ Strategy	Strategy Description	Score (0-30)
Energy		
E4	Install and promote distributed energy resources (DERs) such as rooftop solar to provide local renewable energy and enhance energy resilience	23
E2	Support the electrification and decarbonization of existing and new residential and commercial buildings	22
E1	Decarbonize City owned and operated buildings and facilities	19
E3	Procure zero-emission electricity and decarbonize City and community power supply	19
E5	Pursue additional local sources of renewable energy, including resource recovery and heat exchange	17
Transportation		
T3	Adopt a "smart growth" approach that supports car-free and car-lite living and concentrates public services and infrastructure investments in existing neighborhoods	20
T4	For unavoidable vehicular trips, promote electric vehicles via charging infrastructure expansion, building codes, partnerships, and advocacy	19
T1	Champion walking, cycling, and rolling as sustainable and climate-resilient mobility options	19
T6	Encourage City employees to reduce the carbon footprint of their commuting and work-related travel	17
T2	Invest in safe, comfortable, and convenient public transit as the backbone of a sustainable and resilient transportation system	16
T5	Transition public agency fleets to zero-emission and near-zero-emission vehicles	15
Resource Recovery		
R1	Implement a Community-wide Zero Waste Plan and accompanying initiatives to achieve zero waste (90% diversion or greater) for City operations by 2030, and community-wide zero waste by 2050	19
R2	Create a community-wide organics collection and treatment program	19
R4	Use new technologies and partnerships to divert waste from landfill	17
R3	Develop a Sustainable Procurement Policy for City operations	17
R5	Encourage green infrastructure	16
Governance & Leadership		

G1	Formalize climate action and resilience priorities in City operations, budgeting, processes, performance monitoring, and investments	27
G4	Monitor and report emissions performance to adapt decarbonization strategies	26
G2	Accelerate climate action, adaptation, and resilience strategies through community and regional partnerships	25
G3	Develop educational, communications, and outreach resources and assets promoting climate action and adaptation	25
Community Resilience		
CR2	Bolster the City's heat mitigation resources to reduce the urban heat island effect and protect vulnerable individuals and communities	22
CR3	Deploy and maintain equitable nature-based solutions that reduce or sequester emissions, improve ecosystem health, and bolster climate resilience	21
CR4	Bolster community and regional networks to improve community-wide emergency response and resource-sharing	17
CR1	Establish accessible resilience hubs across all Wards to provide information and resources related to climate preparedness and response	15

5.3.1. Detailed Results

Table 11. Detailed Strategy Scores for Energy

Energy

Category Score	Sub-Criteria Score					Weighted Score				
	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5
Carbon goals & emissions	20	20	15	10	10	18	20	17	18	13
Co-benefits and impacts	18	24	16	28	14					
Implementation, Feasibility, Readiness	15	15	20	10	15					

Carbon Goals & Emissions					
	E1	E2	E3	E4	E5
Carbon neutrality / decarbonization	30	30	10	10	10

Target timeline for strategy goal	10	10	20	10	10

Co-benefits and Impacts					
	E1	E2	E3	E4	E5
Who bears the majority of the strategy's benefits	30	30	30	30	20
Who bears the majority of the strategy's costs	30	30	30	30	30
Community (including underserved communities) participates in renewable energy access and production	10	30	10	20	10
Strategy expects to improve affordability for community	10	10	10	30	10
Scale of impact	10	20	10	30	10

Implementation, Feasibility, Readiness					
	E1	E2	E3	E4	E5
Expected implementation date	10	10	20	10	10
Ease of implementation	20	20	20	10	20

Legend	Tier 1	Tier 2	Tier 3
	21-30	11-20	0-10

Figure 3. Multidimensional Visualization of Energy Scoring

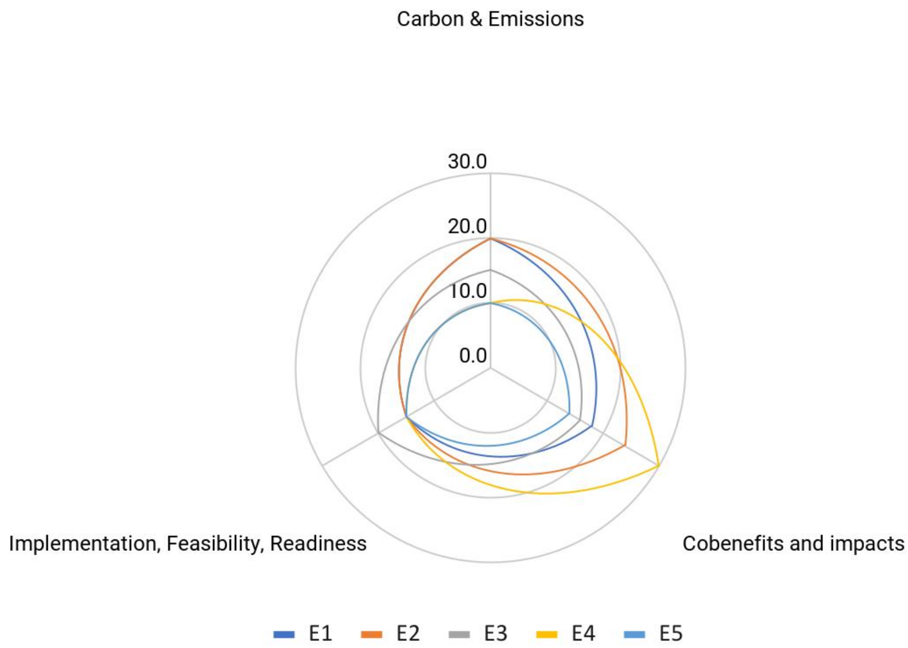


Figure 4: Bar Chart of Energy Scores By Strategy & Category

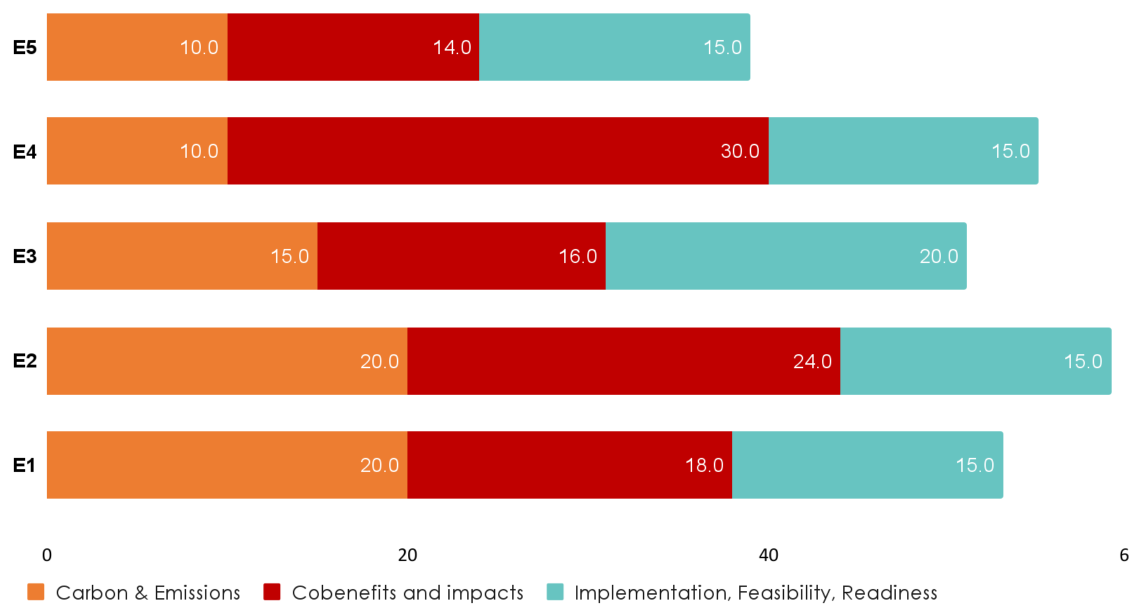


Table 12. Detailed Strategy Scores for Transportation

Transportation

Category Score	Sub-Criteria Score						Weighted Score					
	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6
Carbon goals & emissions	10	15	18	20	18	15	19	16	20	19	15	17
Co-benefits and impacts	23	20	21	19	13	17						
Implementation, Feasibility, Readiness	23	13	20	23	18	18						

Carbon Goals & Emissions	T1	T2	T3	T4	T5	T6
Monitoring and tracking of strategy outcomes for efficiency and progress toward sustainable modes	10	30	10	10	10	10
Net zero / decarbonization targets	10	10	30	30	20	10
Target timeline for strategy goal	10	10	20	10	10	10
Increased measures for electrification of fleet / promote modal shift towards EV vehicles/fleet by providing easy to access infrastructure	10	10	10	30	30	30

Co-benefits and impacts	T1	T2	T3	T4	T5	T6
Strategy expects to increase transit accessibility to the community	30	30	30	10	10	10
Strategy expects to improve affordability for community	10	30	10	30	10	10
Strategy expects to increase transit-related safety to the community	30	10	10	10	10	10
Who bears the majority of the strategy's benefits	20	20	20	30	10	30
Who bears the majority of the strategy's costs	30	30	30	20	30	30
Scale of increase in sustainable mode of transportation	30	10	30	10	10	10
Scale of impact	10	10	20	20	10	20

Implementation, Feasibility, Readiness						
	T1	T2	T3	T4	T5	T6
Ease of implementation	20	20	20	20	20	20
Efforts to increase programs that promote sustainable mode shift	30	10	30	30	30	10
Measures that promote employer programs to incentivize employees to choose sustainable modes of commute	30	10	10	30	10	30
Expected implementation date	10	10	20	10	10	10

Legend	Tier 1	Tier 2	Tier 3
	21-30	11-20	0-10

Figure 5. Multidimensional Visualization of Transportation Scoring

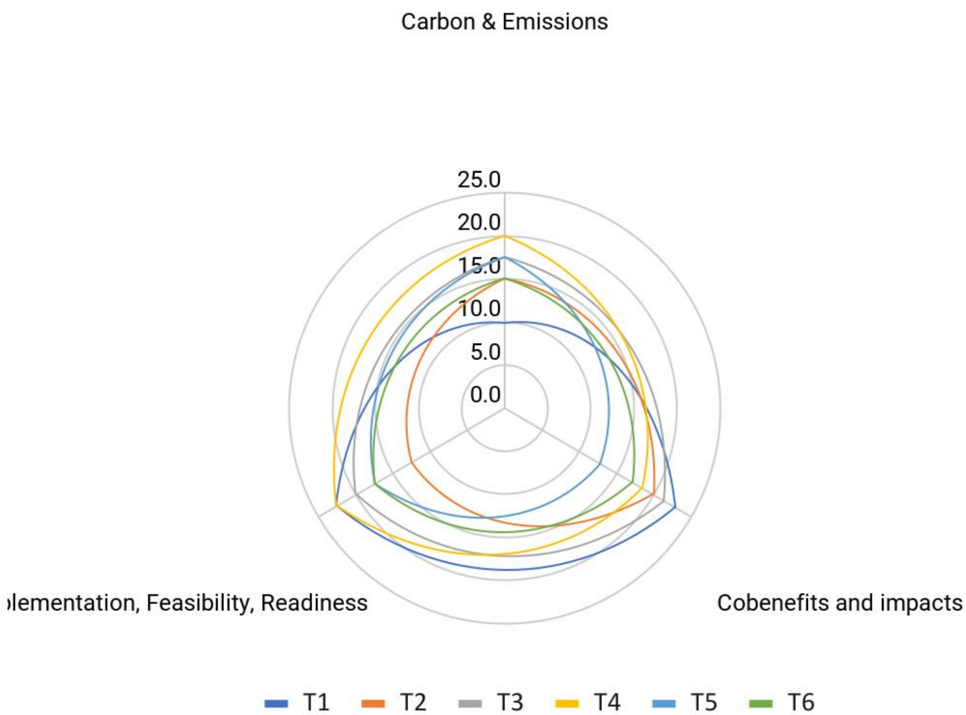


Figure 5. Bar Chart of Transportation Scores By Strategy & Category

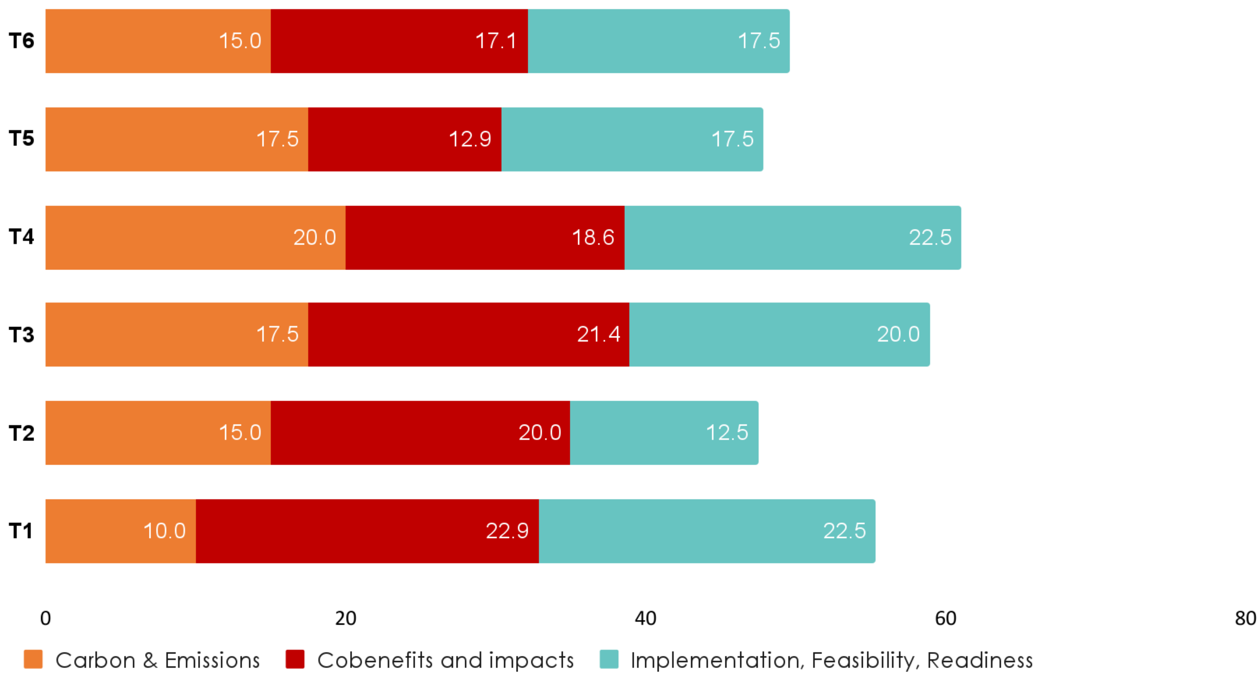

T6
15.0
17.1
17.5
T5
17.5
12.9
17.5
T4
20.0
18.6
22.5
T3
17.5
21.4
20.0
T2
15.0
20.0
12.5
T1
10.0
22.9
22.5
0
20
40
60
80
Carbon & Emissions
Cobenefits and impacts
Implementation, Feasibility, Readiness

Table 13. Detailed Strategy Scores for Resource Recovery

Resource Recovery

Category Score	Sub-Criteria Score					Weighted Score				
	RR1	RR2	RR3	RR4	RR5	RR1	RR2	RR3	RR4	RR5
Carbon goals & emissions	18	18	20	15	10	19	19	17	17	16
Co-benefits and impacts	23	23	17	17	17					
Implementation, Feasibility, Readiness	13	13	13	20	20					

Carbon goals & emissions	RR1	RR2	RR3	RR4	RR5
Net zero waste target	30	20	20	20	10
Timeline for strategy goal	10	10	10	10	10
Scale of zero-waste / decarbonization	20	30	20	20	10
Monitoring and tracking of strategy outcomes for efficiency and progress	10	10	30	10	10

Co-benefits and Impacts	RR1	RR2	RR3	RR4	RR5
Scale of impact	20	20	10	20	20
Who bears the majority of the strategy's benefits	20	20	10	20	20
Who bears the majority of the strategy's costs	30	30	30	10	10

Implementation, Feasibility, Readiness	RR1	RR2	RR3	RR4	RR5
Expected implementation date	10	10	10	10	10
Ease of implementation	20	20	20	20	20

Policies and programs to help overcome cost-financing-implementation based barriers due to small-scale of business/waste creation	10	10	10	30	30

Legend	Tier 1	Tier 2	Tier 3
	21-30	11-20	0-10

Figure 7. Multidimensional Visualization of Resource Recovery Scoring

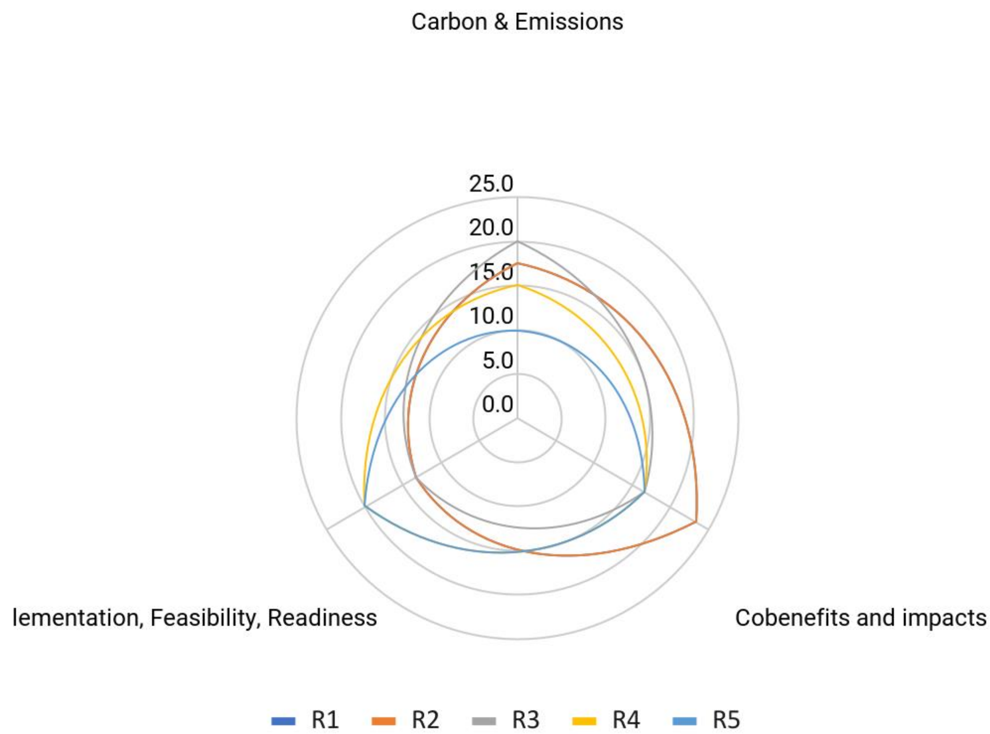


Figure 8: Bar Chart of Resource Recovery Scores By Strategy & Category

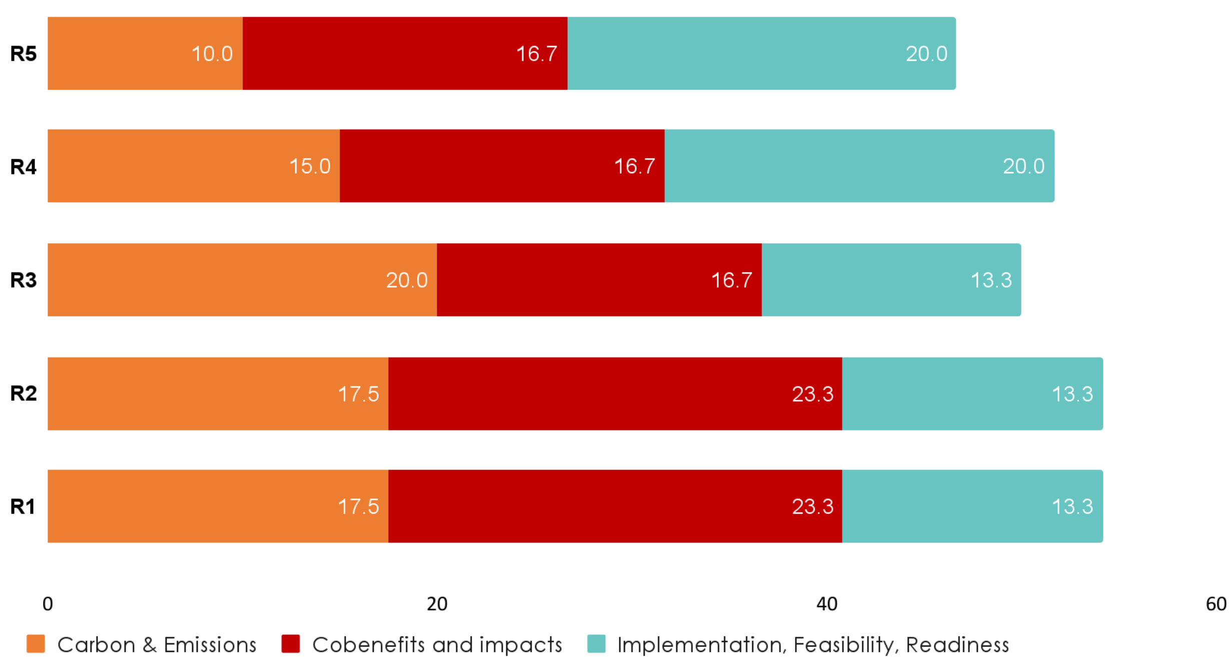


Table 14. Detailed Strategy Scores for Governance & Leadership

Governance & Leadership

Category Score	Sub-Criteria Score				Weighted Score			
	GL1	GL2	GL3	GL4	GL1	GL2	GL3	GL4
Carbon goals & emissions	30	30	30	30	27	25	25	26
Co-benefits and impacts	30	25	25	30				
Implementation, Feasibility, Readiness	20	20	20	16				

Carbon Goals & Emissions	GL1	GL2	GL3	GL4
Does the strategy directly mitigate or abate emissions?	30	30	30	30

Co-benefits and Impacts	GL1	GL2	GL3	GL4
Who bears the majority of the strategy's benefits	30	30	20	30
Who bears the majority of the strategy's costs	30	20	30	30

Implementation, Feasibility, Readiness	GL1	GL2	GL3	GL4
Incorporation and/or continued tracking of climate action and resilience performance objectives?	30	10	10	30
Scale of collaboration with the community and key stakeholders	10	30	30	10
Partnership potential within the community and neighborhoods for public engagement	30	30	30	10
Ease of implementation	20	20	20	20
Expected implementation date	10	10	10	10

Legend	Tier 1	Tier 2	Tier 3
	21-30	11-20	0-10

Figure 9. Multidimensional Visualization of Governance & Leadership Scoring

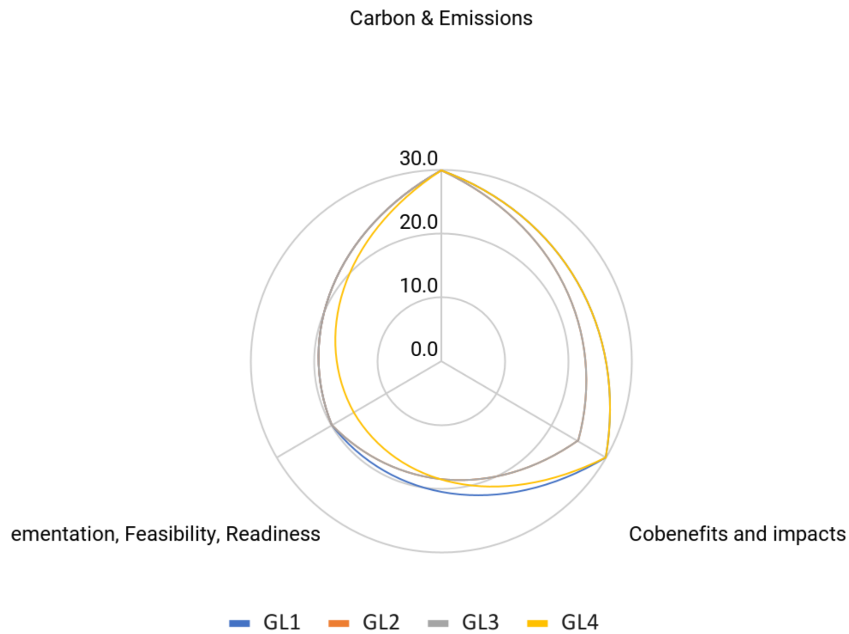


Figure 10: Bar Chart of Governance & Leadership Scores By Strategy & Category

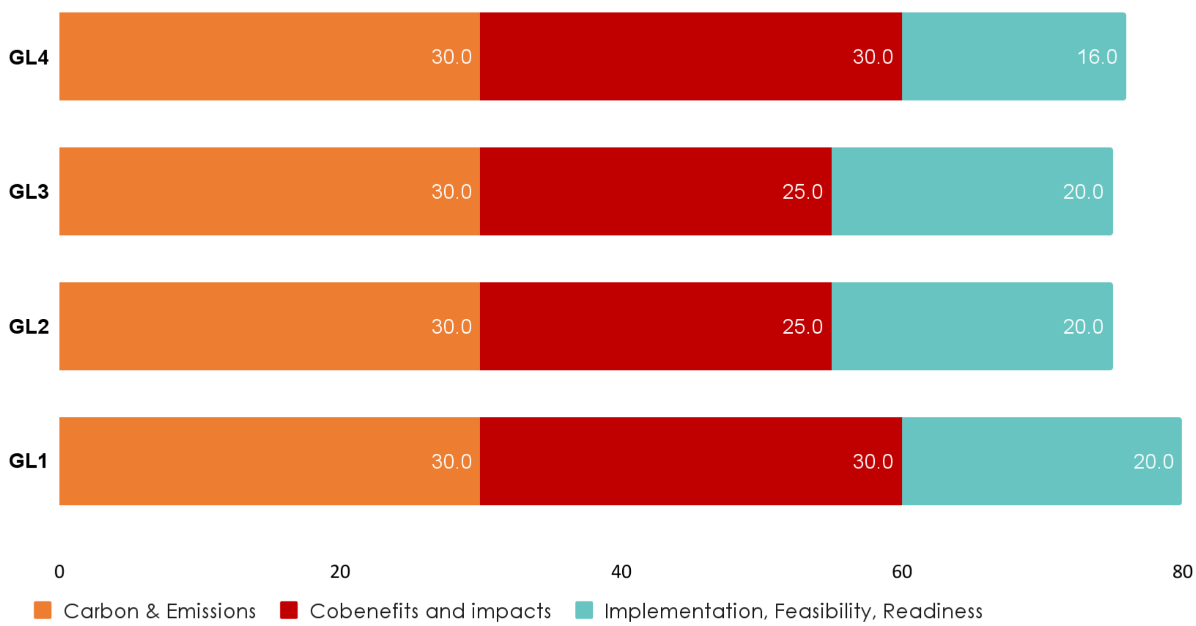


Table 15. Detailed Strategy Scores for Community & Resilience

Community Resilience

Category Score	Sub-Criteria Score				Weighted Score			
Energy	CR1	CR2	CR3	CR4	CR1	CR2	CR3	CR4
Carbon goals & emissions	10	20	20	10	15	22	21	17
Co-benefits and impacts	15	28	25	18				
Implementation, Feasibility, Readiness	22	14	16	24				

Carbon Goals & Emissions				
	RR1	RR2	RR3	RR4
Target timeline for strategy goal	10	10	10	10
Strategy mitigates climate-related events (e.g., extreme heat)	10	30	30	10

Co-benefits and Impacts				
	RR1	RR2	RR3	RR4
Who bears the majority of the strategy's benefits	20	20	30	30
Who bears the majority of the strategy's costs	30	30	20	20
Strategy improves the quality of natural areas / green spaces in the City for the Community	10	30	30	10
Scale of resilient grey infrastructure	10	30	10	10
Scale of resilient green infrastructure investments	10	30	30	10
Strategy helps to mitigate / address climate-related events/ heat related illnesses & incidents (e.g., extreme heat	10	30	30	30

Implementation, Feasibility, Readiness				
	RR1	RR2	RR3	RR4
Scale of communities, organizations involved in the strategy	20	20	10	30
Incorporate community activities for improved risk mitigation, enhanced safety, and access to more resources	30	10	30	30

Strategy to support enhanced emergency and crisis response by the City	30	10	10	30
Expected implementation date	10	10	10	10
Ease of implementation	20	20	20	20

Legend	Tier 1	Tier 2	Tier 3
	21-30	11-20	0-10

Figure 11. Multidimensional Visualization of Community Resilience Scoring

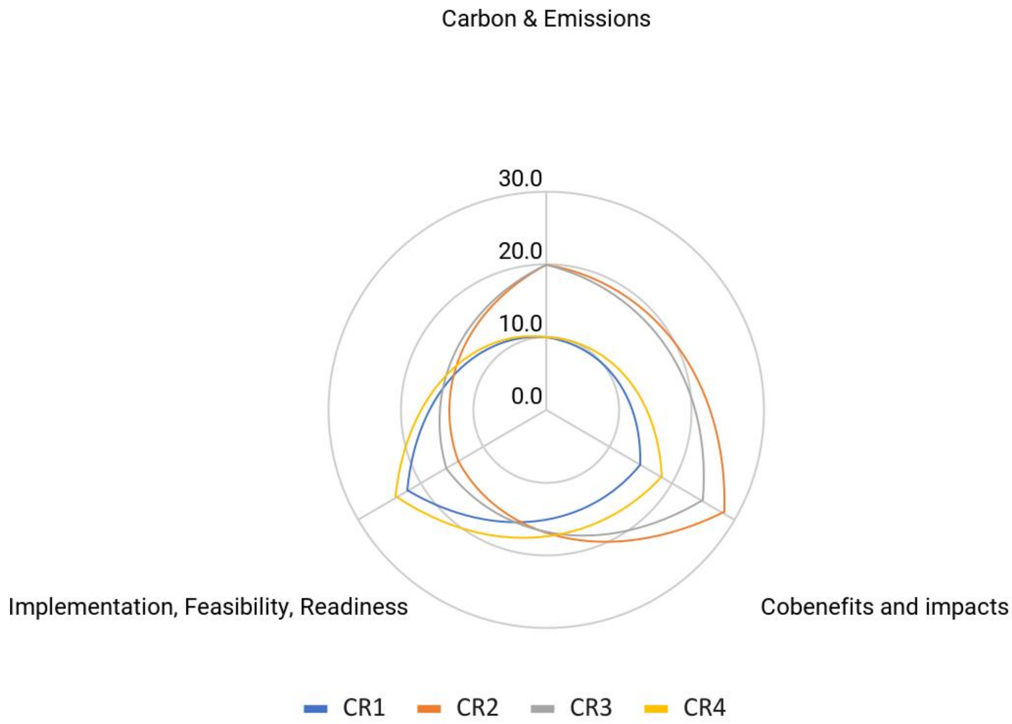
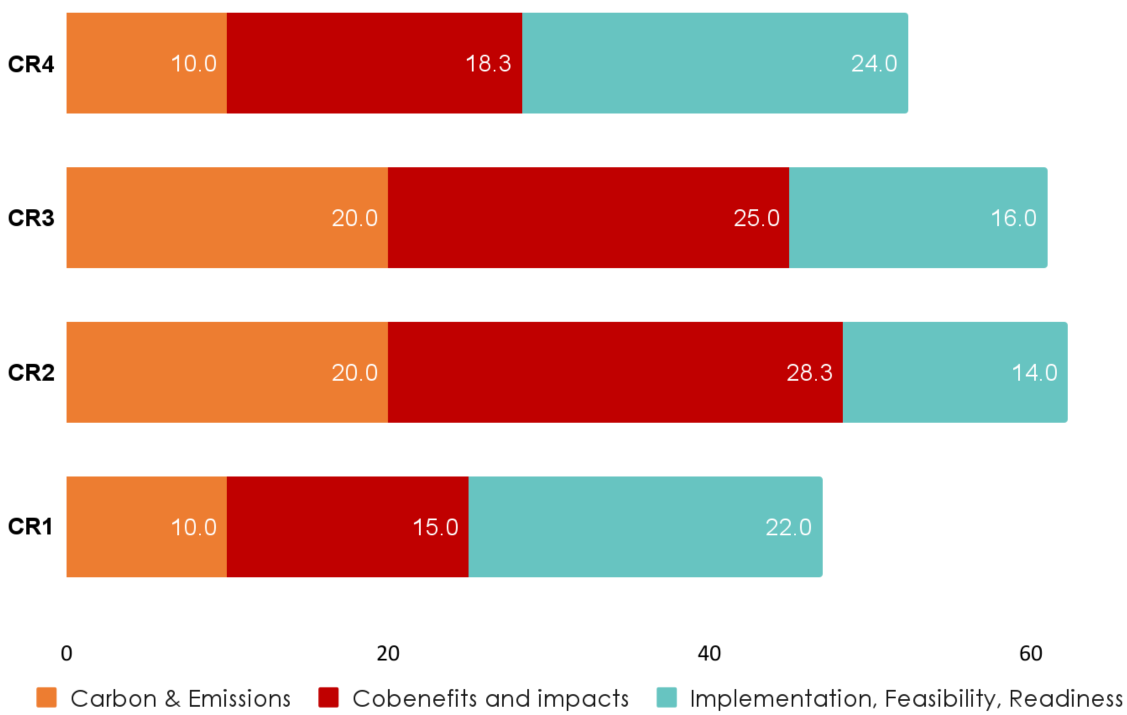


Figure 12: Bar Chart of Community Resilience Scores By Strategy & Category



6. Appendix - Model Data - Cost Benefit Analysis

6.1. General inputs

Input	Unit	Value	Notes	Source
Discount rate	%	3%		U.S. Environmental Protection Agency (U.S. EPA). (2010)
Commercial electricity price	$2022/kWh	See Table A.1	Inflated to $2022 using CPI	U.S. Energy Information Administration: Annual Energy Outlook 2022 Table 54. Electric Power Projections by Electricity Market Module Region Case: Reference Case, Region: Western Electricity Coordinating Council / Southwest https://www.eia.gov/outlooks/aeo/data/browser/#/?id=62-AEO2022
Commercial natural gas price	$2022/MMBtu	See Table A.2	Inflated to $2022 using CPI	U.S. Energy Information Administration: Annual Energy Outlook 2022 Table 3: Energy Prices by Sector and Source Case: Reference Case, Region: Mountain https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2022
Transportation gasoline price	$2022/MMBtu		Inflated to $2022 using CPI	
Transportation diesel price	$2022/MMBtu		Inflated to $2022 using CPI	
Transportation E85 price	$2022/MMBtu		Inflated to $2022 using CPI	
Transportation natural gas price	$2022/MMBtu		Inflated to $2022 using CPI	
Transportation propane price	$2022/MMBtu		Inflated to $2022 using CPI	
Electrical grid emission factors	tonne/kWh	See Table A.3		-Tucson Electric Power (TEP) Electric Company ESG/Sustainability Quantitative Information https://docs.tep.com/wp-content/uploads/TEP-EEI-AGA-ESG-2021.pdf -Department of Energy: Office of Scientific and Technical Information
Natural gas emission factors	tonne/MMBtu	See Table A.4		

				Update of Emission Factors of Greenhouse Gases and Criteria Air Pollutants, and Generation Efficiencies of the U.S. Electricity Generation Sector https://www.osti.gov/biblio/1660468
Social cost of CO2	$2022/tonne	See Table A.5		Interagency Working Group on Social Cost of Greenhouse Gases Technical Support Document: Social Cost of Carbon and Nitrous Oxide Interim Estimates under Executive Order 13990 https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.
Social cost of CACs	$2022/tonne	See Table A.6		Estimating Air Pollution Social Impact Using Regression (EASIUR) https://barney.ce.cmu.edu/~jinhyok/easiur/

Table A.1: Electricity prices

Input	Unit	2022 Value	Growth Rate applied annually from 2023-2050	
Municipal blended electricity price	$2022/kWh	$0.141	2%	City of Tucson, persona
Residential electricity price	$2022/kWh	$0.130	2%	Tucson Electric Power (https://docs.tep.com/wp-
Commercial and industrial electricity price	$2022/kWh	$0.130	2%	Due to the wide range o sizes and demand profil electricity price for purpo industrial. C&I customer

Table A.2: Energy prices

Series name	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Commercial natural gas price	$2022/MMBtu	$8.56070	$8.39614	$8.10069	$7.96453	$7.98224	$8.15530	$8.32601	$8.53862	$8.64160	$8.72698	$8.77817	$8.88241	$8.94253
Transportation propane price	$2022/MMBtu	$19.20932	$17.62242	$17.62638	$17.52233	$17.65992	$18.02457	$18.52110	$18.84142	$19.17916	$19.47825	$19.72212	$19.95733	$20.09753
Transportation E85 price	$2022/MMBtu	$29.03439	$27.52784	$27.11651	$26.76375	$27.04924	$27.38378	$27.69269	$27.91202	$28.67268	$29.05186	$29.45435	$29.55998	$29.97218

Transportation gasoline price	$2022/MMBtu	$25.97226	$22.93502	$22.59231	$22.29841	$22.53627	$22.81499	$23.07236	$23.25510	$23.88885	$24.20476	$24.48075	$24.62811	$24.85103
Transportation diesel price	$2022/MMBtu	$24.51942	$23.56237	$24.32555	$24.22540	$24.10877	$24.07872	$24.26704	$24.41287	$24.35449	$24.67350	$24.78688	$24.82405	$24.85815
Transportation natural gas price	$2022/MMBtu	$15.60630	$15.01385	$14.44823	$13.83364	$13.29627	$12.89035	$12.57383	$12.29960	$12.04900	$11.83361	$11.62526	$11.50605	$11.38798

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
$8.93131	$8.97222	$9.02100	$9.05367	$9.09888	$9.13809	$9.19462	$9.20492	$9.22828	$9.23010	$9.24578	$9.26921	$9.30503	$9.32670	$9.35941	$9.38838
$20.19259	$20.32497	$20.49495	$20.64970	$20.72507	$20.97799	$21.12547	$21.13771	$21.29555	$21.48351	$21.50980	$21.60335	$21.66555	$21.69747	$21.67938	$21.65942
$30.09685	$30.30515	$30.51130	$30.95933	$31.11352	$31.12307	$31.47254	$31.67526	$32.21093	$32.57814	$32.71554	$33.02572	$33.12809	$33.04550	$33.08401	$33.12657
$24.95439	$25.18788	$25.42070	$25.75499	$25.92244	$25.93041	$26.22157	$26.39046	$26.83676	$27.14271	$27.25718	$27.51561	$27.60090	$27.53209	$27.56418	$27.59964
$25.00865	$25.22616	$25.47793	$25.64314	$25.75854	$25.93086	$26.07563	$26.11840	$26.45836	$26.79095	$26.94779	$27.13886	$27.22422	$27.19111	$27.17993	$27.11817
$11.23070	$11.15473	$11.06868	$10.99902	$10.94195	$10.91382	$10.89325	$10.83184	$10.80967	$10.76602	$10.74228	$10.73042	$10.73316	$10.73090	$10.72866	$10.72622

Table A.3: Electricity grid emission factors (tonne/kWh)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
CO2	0.0005130600	0.0004823900	0.0004520800	0.0004221200	0.0003925200	0.0003632200	0.0003343300	0.0003057800	0.0003037300	0.0003016800	0.0002996200	0.0002975700	0.0002955200	0.0002955200
NOx	0.0000001511	0.0000001514	0.0000001317	0.0000001251	0.0000001292	0.0000001336	0.0000001360	0.0000001370	0.0000001346	0.0000000952	0.0000000757	0.0000000676	0.0000000624	0.0000000614
SOx	0.0000001586	0.0000001614	0.0000001431	0.0000001354	0.0000001430	0.0000001487	0.0000001523	0.0000001555	0.0000001480	0.0000000905	0.0000000622	0.0000000503	0.0000000436	0.0000000435
PM2.5	0.0000000158	0.0000000156	0.0000000134	0.0000000127	0.0000000129	0.0000000132	0.0000000134	0.0000000133	0.0000000135	0.0000000108	0.0000000094	0.0000000089	0.0000000084	0.0000000083
VOC	0.0000000042	0.0000000041	0.0000000035	0.0000000033	0.0000000033	0.0000000034	0.0000000034	0.0000000034	0.0000000035	0.0000000030	0.0000000027	0.0000000026	0.0000000025	0.0000000024

2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200	0.0002955200
0.0000000613	0.0000000607	0.0000000606	0.0000000607	0.0000000609	0.0000000602	0.0000000571	0.0000000565	0.0000000569	0.0000000499	0.0000000480	0.0000000483	0.0000000472	0.0000000442

0.0000000427	0.0000000431	0.0000000416	0.0000000405	0.0000000404	0.0000000386	0.0000000381	0.0000000357	0.0000000352	0.0000000268	0.0000000243	0.0000000239	0.0000000239	0.0000000234
0.0000000083	0.0000000082	0.0000000083	0.0000000084	0.0000000085	0.0000000085	0.0000000079	0.0000000080	0.0000000081	0.0000000075	0.0000000073	0.0000000074	0.0000000072	0.0000000067
0.0000000025	0.0000000024	0.0000000025	0.0000000025	0.0000000025	0.0000000025	0.0000000023	0.0000000024	0.0000000024	0.0000000023	0.0000000022	0.0000000023	0.0000000022	0.0000000020

Table A.4: Natural gas emission factors (tonne/MMBtu)

CO2	0.0529099181
NOx	0.0000300185
SOx	0.0000020823
PM2.5	0.0000057488
VOC	0.0000018693

Table A.5: Social cost of CO2 ($2022/tonne)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
CO2	$57.15	$58.21	$59.26	$60.53	$61.80	$63.07	$64.34	$65.61	$66.67	$67.73	$68.79	$69.85	$70.90	$72.17

Table A.6: Social cost of CACs ($2022/tonne)

NOx	$10,412.02
SOx	$24,883.16
PM2.5	$237,197.71
VOC	$2,421.37

6.2. Transportation inputs

Input	Unit	Value	Notes	Source

Arizona population (2021)	#	7,264,877		Census Bureau Quick Facts: Arizona https://www.census.gov/quickfacts/fact/table/AZ
Arizona GDP (2021)	$2022 million	$443,110	Inflated to $2022 using CPI	Federal Reserve Bank of St. Louis Real Gross Domestic Product: All Industry Total in Arizona https://fred.stlouisfed.org/series/AZRQGSP#0
Tucson employment population	#	471,900		Bureau of Labor Statistics Economy at a Glance: Tucson, AZ https://www.bls.gov/eag/eag.az_tucson_msa.htm
Lost productivity due to absenteeism	%	1.11%		Boles et al. The Relationship between Health Risks and Work Productivity http://www.bdmscmeonline.com/common/documents/Health_&_Productivity_Management_(HPM)/Boles%202004%20the_relationship_between_health%20risks%20and%20work%20productivity.pdf
Lost productivity due to presenteeism	%	2.74%		
Average commute time	Minutes	22.4		Move Tucson: Delivering Mobility Choices Figure 5: Tucson's travel patterns documented in the U.S. Census, 2017 American Community Survey https://movetucson.org/wp-content/uploads/2021/11/MoveTucson_Plan_Fall2021.pdf
Walking mode split rate	%	5.47%	Average across all trip types	2009 National Household Travel Survey
Cycling mode split rate	%	1.19%	Average across all trip types	
Transit mode shift rate	%	3.35%	Average across all trip types	
Average hourly wage of Sun Tran Drivers	$	$17.00		Indeed https://www.indeed.com/q-Sun-Tran-l-Tucson,-AZ-jobs.html?vjk=f55b27eb2e954091
Number of Sun Tran Drivers	#	420	As of 2019	Sun Tran: FY2019 Annual Report https://www.suntran.com/wp-content/uploads/2021/07/ST-SL-SV-Annual-Report-19.pdf

% of VMT on freeways of total roads	%	26%		TRIP: America's Interstate Highway System at 65 https://tripnet.org/wp-content/uploads/2021/06/TRIP_Interstate_Report_June_2021.pdf
Pavement cost (urban)	$2022/mile	$0.0017	Inflated to $2022 using CPI	Federal Highway Administration (FHA): Highway Cost Allocation Study (HCAS) 1997 Federal Highway Cost Allocation Study Final Report https://rosap.ntl.bts.gov/view/dot/13475
Auto crash risk monetized value	$2022/mile	$0.3273	Inflated to $2022 using CPI	U.S. Department of Transportation: Benefit-Cost Analysis Guidance for Discretionary Grant Programs https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf
Congestion cost	$2022/mile	$0.2670	Inflated to $2022 using CPI	U.S. Department of Transportation: Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing Them through Pricing https://www.transportation.gov/office-policy/transportation-policy/assessing-full-costs-congestion-surface-transportation-systems
Noise cost for auto for indicated traffic mix	$2022/mile	$0.0057	Inflated to $2022 using CPI	European Commission: Handbook on the external costs of transport https://www.cedelft.eu/assets/upload/file/Rapporten/2019/CE_Delft_4K83_Handbook_on_the_external_costs_of_transport_Final.pdf.
Operational cost	$2022/mile	$0.1019	Inflated to $2022 using CPI	US Department of Transportation. Bureau of Transportation Statistics Average Cost of Owning and Operating an Automobile https://www.bts.gov/content/average-cost-owning-and-operating-automobilea-assuming-15000-vehicle-miles-year
Fatal crash value	$2022	$14,512,960	Inflated to $2022 using CPI	U.S. Department of Transportation: Benefit-Cost Analysis Guidance for Discretionary Grant Programs Table A-1: Value of Reduced Fatalities and Injuries https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf
Incapacitating injury crash value	$2022	$903,187	Inflated to $2022 using CPI	

Fatal crash rate	Crashes per 100 mil VMT	0.78		Pima Association of Governments Strategic Transportation Safety Plan 14 Appendix B: Crash Data By Severity https://pagregion.com/wp-content/docs/pag/2022/02/PAGSTSP-Final-Report-June2016.pdf
Incapacitating injury crash rate	Crashes per 100 mil VMT	5.49		
Crash reduction rate	%	29%		U.S. Department of Transportation: Federal Highway Administration Road Diet Informational Guide https://safety.fhwa.dot.gov/road_diets/guidance/info_guide/ch1.cfm
Level 2 charger installation costs	$2022	$3,500		City of Tucson, personal communication, 2023
Level 3 charger installation costs	$2022	$75,000		
Ratio of light-duty, medium-duty & paratransit van EVs to electric vehicle charger	Ratio	4:1		
Ratio of heavy-duty & transit bus EVs to electric vehicle charger	Ratio	1:1		
EV charger O&M costs	% of charger installation costs	3%		EVgo Fast Charging: The Costs of EV Fast Charging Infrastructure and Economic Benefits to Rapid Scale Figure 10: Visual Summary of DCFC Costs Figure 13: Visual Summary of DCFC Operations Costs https://a.storyblok.com/f/78437/x/f28386ed92/2020-05-18_evgo-whitepaper_dcfc-cost-and-policy.pdf
Community-wide VMTs	Vehicle miles traveled	See Table A.7		Buro Happold
Mode shift schedule	%	See Table A.8		
City fleet - VMTs	Vehicle miles traveled	See Table A.9		

City fleet - Count	#	See Table A.10	Values interpolated from projected VMTs	
Public transit fleet - VMTs	Vehicle miles traveled	See Table A.11		
Public transit fleet - Count	#	See Table A.12		Canadian Public Transit Discussion Board: Sun Tran https://cptdb.ca/wiki/index.php/Sun_Tran
City fleet - Fuel use	Btu/mile	See Table A.13		Argonne National Laboratory: Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET) https://greet.es.anl.gov/index.php
City fleet - Emission factors	grams/mile	See Table A.14		
Public transit fleet - Fuel use	Btu/mile	See Table A.15		
Public transit fleet - Emission factors	grams/mile	See Table A.16		
City fleet - Vehicle costs	$2022	See Table A.17	Inflated to $2022 using CPI	Argonne National Laboratory: Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool (AFLEET) https://greet.es.anl.gov/afleet
Public transit fleet - Vehicle costs	$2022	See Table A.18		City of Tucson, personal communication, 2023

Table A.7: Community-wide VMTs

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Motorcycle	11,237,500	11,349,875	11,462,250	11,574,625	11,687,000	11,799,375	11,911,750	12,024,125	12,136,500	12,248,875
Passenger car	3,061,460,000	3,092,074,600	3,122,689,200	3,153,303,800	3,183,918,400	3,214,533,000	3,245,147,600	3,275,762,200	3,306,376,800	3,336,991,400
Passenger truck	721,879,000	729,097,790	736,316,580	743,535,370	750,754,160	757,972,950	765,191,740	772,410,530	779,629,320	786,848,110
Light commercial truck	183,036,000	184,866,360	186,696,720	188,527,080	190,357,440	192,187,800	194,018,160	195,848,520	197,678,880	199,509,240
Intercity bus	3,201,810	3,233,828	3,265,846	3,297,864	3,329,882	3,361,901	3,393,919	3,425,937	3,457,955	3,489,973

Transit bus	5,921,720	5,980,937	6,040,154	6,099,372	6,158,589	6,217,806	6,277,023	6,336,240	6,395,458	6,454,675
School bus	17,765,300	17,942,953	18,120,606	18,298,259	18,475,912	18,653,565	18,831,218	19,008,871	19,186,524	19,364,177
Refuse truck	2,304,090	2,327,131	2,350,172	2,373,213	2,396,254	2,419,295	2,442,335	2,465,376	2,488,417	2,511,458
Single unit short-haul truck	51,026,600	51,536,866	52,047,132	52,557,398	53,067,664	53,577,930	54,088,196	54,598,462	55,108,728	55,618,994
Single unit long-haul truck	3,024,530	3,054,775	3,085,021	3,115,266	3,145,511	3,175,757	3,206,002	3,236,247	3,266,492	3,296,738
Motor home	2,392,940	2,416,869	2,440,799	2,464,728	2,488,658	2,512,587	2,536,516	2,560,446	2,584,375	2,608,305
Combination short-haul truck	22,026,800	22,247,068	22,467,336	22,687,604	22,907,872	23,128,140	23,348,408	23,568,676	23,788,944	24,009,212
Combination long-haul truck	58,989,500	59,579,395	60,169,290	60,759,185	61,349,080	61,938,975	62,528,870	63,118,765	63,708,660	64,298,555

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
12,361,250	12,473,625	12,586,000	12,698,375	12,810,750	12,923,125	13,035,500	13,147,875	13,260,250	13,372,625	13,485,000
3,367,606,000	3,398,220,600	3,428,835,200	3,459,449,800	3,490,064,400	3,520,679,000	3,551,293,600	3,581,908,200	3,612,522,800	3,643,137,400	3,673,752,000
794,066,900	801,285,690	808,504,480	815,723,270	822,942,060	830,160,850	837,379,640	844,598,430	851,817,220	859,036,010	866,254,800
201,339,600	203,169,960	205,000,320	206,830,680	208,661,040	210,491,400	212,321,760	214,152,120	215,982,480	217,812,840	219,643,200
3,521,991	3,554,009	3,586,027	3,618,045	3,650,063	3,682,082	3,714,100	3,746,118	3,778,136	3,810,154	3,842,172
6,513,892	6,573,109	6,632,326	6,691,544	6,750,761	6,809,978	6,869,195	6,928,412	6,987,630	7,046,847	7,106,064
19,541,830	19,719,483	19,897,136	20,074,789	20,252,442	20,430,095	20,607,748	20,785,401	20,963,054	21,140,707	21,318,360
2,534,499	2,557,540	2,580,581	2,603,622	2,626,663	2,649,704	2,672,744	2,695,785	2,718,826	2,741,867	2,764,908
56,129,260	56,639,526	57,149,792	57,660,058	58,170,324	58,680,590	59,190,856	59,701,122	60,211,388	60,721,654	61,231,920
3,326,983	3,357,228	3,387,474	3,417,719	3,447,964	3,478,210	3,508,455	3,538,700	3,568,945	3,599,191	3,629,436
2,632,234	2,656,163	2,680,093	2,704,022	2,727,952	2,751,881	2,775,810	2,799,740	2,823,669	2,847,599	2,871,528
24,229,480	24,449,748	24,670,016	24,890,284	25,110,552	25,330,820	25,551,088	25,771,356	25,991,624	26,211,892	26,432,160
64,888,450	65,478,345	66,068,240	66,658,135	67,248,030	67,837,925	68,427,820	69,017,715	69,607,610	70,197,505	70,787,400

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
13,597,375	13,709,750	13,822,125	13,934,500	14,046,875	14,159,250	14,159,250	14,159,250	14,159,250	14,159,250	14,159,250
3,704,366,600	3,734,981,200	3,765,595,800	3,796,210,400	3,826,825,000	3,857,439,600	3,857,439,600	3,857,439,600	3,857,439,600	3,857,439,600	3,857,439,600
873,473,590	880,692,380	887,911,170	895,129,960	902,348,750	909,567,540	909,567,540	909,567,540	909,567,540	909,567,540	909,567,540
221,473,560	223,303,920	225,134,280	226,964,640	228,795,000	230,625,360	230,625,360	230,625,360	230,625,360	230,625,360	230,625,360
3,874,190	3,906,208	3,938,226	3,970,244	4,002,263	4,034,281	4,034,281	4,034,281	4,034,281	4,034,281	4,034,281
7,165,281	7,224,498	7,283,716	7,342,933	7,402,150	7,461,367	7,461,367	7,461,367	7,461,367	7,461,367	7,461,367
21,496,013	21,673,666	21,851,319	22,028,972	22,206,625	22,384,278	22,384,278	22,384,278	22,384,278	22,384,278	22,384,278
2,787,949	2,810,990	2,834,031	2,857,072	2,880,113	2,903,153	2,903,153	2,903,153	2,903,153	2,903,153	2,903,153
61,742,186	62,252,452	62,762,718	63,272,984	63,783,250	64,293,516	64,293,516	64,293,516	64,293,516	64,293,516	64,293,516
3,659,681	3,689,927	3,720,172	3,750,417	3,780,663	3,810,908	3,810,908	3,810,908	3,810,908	3,810,908	3,810,908
2,895,457	2,919,387	2,943,316	2,967,246	2,991,175	3,015,104	3,015,104	3,015,104	3,015,104	3,015,104	3,015,104
26,652,428	26,872,696	27,092,964	27,313,232	27,533,500	27,753,768	27,753,768	27,753,768	27,753,768	27,753,768	27,753,768
71,377,295	71,967,190	72,557,085	73,146,980	73,736,875	74,326,770	74,326,770	74,326,770	74,326,770	74,326,770	74,326,770

Table A.8: Mode shift schedule

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%

Table A.9: City fleet - VMTs

Vehicle type	Fuel type	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Passenger car	E85	155,683	133,442	111,202	88,962	66,721	44,481	22,240	0	0	0	0	0
	Gasoline	4,615,039	3,955,748	3,296,456	2,637,165	1,977,874	1,318,583	659,291	0	0	0	0	0
	Electric	681,532	1,363,063	2,044,595	2,726,127	3,407,658	4,089,190	4,770,722	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253
Motorcycle	Gasoline	269,012	230,582	192,151	153,721	115,291	76,861	38,430	0	0	0	0	0
	Electric	38,430	76,861	115,291	153,721	192,151	230,582	269,012	307,442	307,442	307,442	307,442	307,442
Light-duty truck (composite of light-duty pick-up trucks & SUVs)	CNG	7,118	6,101	5,084	4,067	3,051	2,034	1,017	0	0	0	0	0
	Diesel	43,256	37,077	30,897	24,718	18,538	12,359	6,179	0	0	0	0	0
	E85	200,041	171,463	142,886	114,309	85,732	57,154	28,577	0	0	0	0	0
	Gasoline	5,891,161	5,049,566	4,207,972	3,366,377	2,524,783	1,683,189	841,594	0	0	0	0	0
	Electric	877,368	1,754,736	2,632,104	3,509,472	4,386,840	5,264,208	6,141,576	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944
Medium-duty truck	Diesel	314,526	269,594	224,662	179,729	134,797	89,865	44,932	0	0	0	0	0
	LPG	6,239	5,348	4,456	3,565	2,674	1,783	891	0	0	0	0	0
	Gasoline	1,123,995	963,424	802,854	642,283	481,712	321,141	160,571	0	0	0	0	0
	Electric	206,394	412,789	619,183	825,577	1,031,972	1,238,366	1,444,760	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154
Heavy-duty truck	CNG	1,444,980	1,238,555	1,032,129	825,703	619,277	412,852	206,426	0	0	0	0	0
	Diesel	1,026,531	879,884	733,236	586,589	439,942	293,295	146,647	0	0	0	0	0
	Gasoline	6,221	5,332	4,443	3,555	2,666	1,777	889	0	0	0	0	0

	Electric	353,962	707,923	1,061,885	1,415,847	1,769,809	2,123,770	2,477,732	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253	5,452,253
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442	307,442
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944	7,018,944
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154	1,651,154
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694	2,831,694

Table A.10: City fleet - Count (interpolated from 2022 City VMTs)

Vehicle type	Fuel type	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Passenger car	E85	14	12	10	8	6	4	2	0	0	0	0	0	0
	Gasoline	663	569	474	379	284	190	95	0	0	0	0	0	0
	Electric	97	193	290	387	484	580	677	774	774	774	774	774	774
Motorcycle	Gasoline	40	35	29	23	17	12	6	0	0	0	0	0	0
	Electric	6	12	17	23	29	35	40	46	46	46	46	46	46
Light-duty truck (composite of light-duty pick-up trucks & SUVs)	CNG	1	1	1	1	1	0	0	0	0	0	0	0	0
	Diesel	13	11	9	7	6	4	2	0	0	0	0	0	0
	E85	22	19	16	13	10	6	3	0	0	0	0	0	0
	Gasoline	906	777	647	518	388	259	129	0	0	0	0	0	0
	Electric	135	269	404	539	673	808	943	1,077	1,077	1,077	1,077	1,077	1,077
Medium-duty truck	Diesel	36	31	26	21	16	10	5	0	0	0	0	0	0
	LPG	1	1	1	1	0	0	0	0	0	0	0	0	0
	Gasoline	191	164	137	109	82	55	27	0	0	0	0	0	0
	Electric	33	65	98	131	163	196	229	261	261	261	261	261	261
Heavy-duty truck	CNG	92	79	66	52	39	26	13	0	0	0	0	0	0
	Diesel	114	97	81	65	49	32	16	0	0	0	0	0	0
	Gasoline	5	5	4	3	2	2	1	0	0	0	0	0	0

	Electric	30	60	90	121	151	181	211	241	241	241	241	241	241

2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
774	774	774	774	774	774	774	774	774	774	774	774	774	774	774
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
261	261	261	261	261	261	261	261	261	261	261	261	261	261	261
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
241	241	241	241	241	241	241	241	241	241	241	241	241	241	241

Table A.11: Public transit fleet - VMTs

Vehicle type	Fuel type	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SunTran	Diesel	3,462,858	2,996,704	2,521,037	2,035,856	1,541,162	1,036,955	523,234	0	0	0	0	0	0
	CNG	3,248,344	2,811,067	2,364,866	1,909,741	1,445,692	972,719	490,821	0	0	0	0	0	0
	Hybrid	337,092	291,715	245,411	198,181	150,025	100,942	50,934	0	0	0	0	0	0
	Electric	1,217,035	2,245,318	3,292,965	4,359,975	5,446,348	6,552,085	7,677,186	8,821,650	8,901,124	8,980,598	9,060,072	9,139,547	9,219,021
Sun Van	Gasoline	3,666,581	3,173,003	2,669,352	2,155,627	1,631,830	1,097,960	554,016	0	0	0	0	0	0
	Electric	523,797	1,057,668	1,601,611	2,155,627	2,719,717	3,293,879	3,878,115	4,472,423	4,512,715	4,553,007	4,593,299	4,633,592	4,673,884

2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9,298,495	9,377,970	9,457,444	9,536,918	9,616,393	9,695,867	9,775,341	9,854,816	9,934,290	10,013,764	10,093,239	10,172,713	10,252,187	10,331,662	10,411,136
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4,714,176	4,754,468	4,794,760	4,835,052	4,875,344	4,915,636	4,955,928	4,996,220	5,036,513	5,076,805	5,117,097	5,157,389	5,197,681	5,237,973	5,278,265

Table A.12: Public transit fleet - Count

Vehicle type	Fuel type	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Sun Tran	Diesel	99	85	71	57	42	28	14	0	0	0	0	0	0
	CNG	93	80	66	53	40	27	13	0	0	0	0	0	0
	Hybrid	10	8	7	6	4	3	1	0	0	0	0	0	0

	Electric	35	64	92	121	150	179	207	236	236	236	236	236	236
Sun Van	Gasoline	127	109	91	73	54	36	18	0	0	0	0	0	0
	Electric	18	36	54	73	91	109	127	145	145	145	145	145	145

2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
145	145	145	145	145	145	145	145	145	145	145	145	145	145	145

Table A.13: City fleet - Fuel use (Btu/mile)

Vehicle type	Fuel type	2020	2025	2030	2035	2040	2045	2050
Passenger car	Gasoline	4,289	3,655	3,563	3,167	2,931	2,931	2,931
	E85	4,289	3,655	3,563	3,167	2,931	2,931	2,931
	Electric	1,283	903	845	827	799	799	799
Light-duty pickup truck	Gasoline	6,827	5,360	5,068	4,565	4,134	4,134	4,134
	Diesel	5,389	4,830	4,673	4,073	3,628	3,628	3,628
	E85	6,827	5,360	5,068	4,565	4,134	4,134	4,134
	Compressed natural gas	7,186	5,840	5,143	4,604	4,194	4,194	4,194

	Electric	2,406	1,489	1,383	1,350	1,274	1,274	1,274
Sport utility vehicle (SUV)	Gasoline	5,594	4,081	3,983	3,560	3,221	3,221	3,221
	Diesel	4,393	3,662	3,669	3,213	2,884	2,884	2,884
	E85	5,594	4,081	3,983	3,560	3,221	3,221	3,221
	Compressed natural gas	5,889	4,478	4,064	3,617	3,299	3,299	3,299
	Electric	1,865	1,110	1,044	1,019	971	971	971
Motorcycle	Gasoline	2,528	1,995	1,926	1,722	1,571	1,571	1,571
	Electric	756	483	452	442	421	421	421
Medium-duty truck	Gasoline	11,810	9,317	8,996	8,046	7,338	7,338	7,338
	Diesel	20,016	17,311	17,046	14,891	13,316	13,316	13,316
	Liquefied petroleum gas	11,810	8,944	8,593	7,710	6,979	6,979	6,979
	Electric	4,970	3,176	2,971	2,902	2,768	2,768	2,768
Heavy-duty truck	Gasoline	16,172	12,759	12,318	11,018	10,048	10,048	10,048
	Diesel	30,205	26,123	25,723	22,472	20,094	20,094	20,094
	Compressed natural gas	33,561	26,399	23,603	21,067	19,202	19,202	19,202
	Electric	8,145	5,205	4,869	4,756	4,537	4,537	4,537

Table A.14: City fleet - Emission factors (grams/mile)

Vehicle type	Fuel type	Pollutant	2020	2025	2030	2035	2040	2045	2050

Passenger car	Gasoline	CO2	323.958	277.561	271.317	240.947	222.859	222.859	222.859
		CH4	0.015	0.008	0.005	0.005	0.005	0.005	0.005
		N2O	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		SOx	0.002	0.002	0.002	0.001	0.001	0.001	0.001
		NOx	0.082	0.039	0.021	0.021	0.021	0.021	0.021
		PM 2.5	0.003	0.004	0.004	0.003	0.003	0.003	0.003
		VOCs	0.230	0.153	0.130	0.128	0.127	0.127	0.127
	E85	CO2	318.290	272.720	266.593	236.752	218.980	218.980	218.980
		CH4	0.015	0.008	0.005	0.005	0.005	0.005	0.005
		N2O	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		SOx	0.001	0.001	0.001	0.000	0.000	0.000	0.000
		NOx	0.082	0.039	0.021	0.021	0.021	0.021	0.021
		PM 2.5	0.003	0.004	0.004	0.003	0.003	0.003	0.003
		VOCs	0.206	0.136	0.115	0.113	0.112	0.112	0.112
	Electric	CO2	31.703	13.937	0	0	0	0	0
		CH4	0.012	0.005	0	0	0	0	0
		N2O	0.002	0.001	0	0	0	0	0

		SOx	0.068	0.030	0	0	0	0	0
		NOx	0.063	0.028	0	0	0	0	0
		PM 2.5	0.006	0.003	0	0	0	0	0
		VOCs	0.002	0.001	0	0	0	0	0
Light-duty truck (composite of light-duty pick-up trucks & SUVs)	Gasoline	CO2	471.306	359.297	345.235	309.730	280.198	280.198	280.198
		CH4	0.016	0.009	0.006	0.006	0.006	0.006	0.006
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.003	0.002	0.002	0.002	0.002	0.002	0.002
		NOx	0.098	0.048	0.025	0.025	0.025	0.025	0.025
		PM 2.5	0.005	0.005	0.004	0.004	0.004	0.004	0.004
		VOCs	0.213	0.147	0.124	0.123	0.122	0.122	0.122
	Diesel	CO2	378.557	331.387	327.029	285.267	254.673	254.673	254.673
		CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		N2O	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		SOx	0.003	0.002	0.002	0.002	0.002	0.002	0.002
		NOx	0.082	0.032	0.013	0.013	0.013	0.013	0.013
		PM 2.5	0.003	0.003	0.002	0.002	0.002	0.002	0.002

		VOCs	0.222	0.152	0.123	0.123	0.123	0.123	0.123
	E85	CO2	463.054	353.023	339.218	304.332	275.315	275.315	275.315
		CH4	0.016	0.009	0.006	0.006	0.006	0.006	0.006
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		NOx	0.098	0.048	0.025	0.025	0.025	0.025	0.025
		PM 2.5	0.005	0.005	0.004	0.004	0.004	0.004	0.004
		VOCs	0.193	0.132	0.110	0.109	0.109	0.109	0.109
	CNG	CO2	383.335	303.786	271.743	242.439	220.799	220.799	220.799
		CH4	0.158	0.089	0.057	0.057	0.057	0.057	0.057
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.002	0.001	0.001	0.001	0.001	0.001	0.001
		NOx	0.098	0.048	0.025	0.025	0.025	0.025	0.025
		PM 2.5	0.005	0.005	0.004	0.004	0.004	0.004	0.004
		VOCs	0.075	0.045	0.032	0.032	0.032	0.032	0.032
	Electric	CO2	52.760	20.064	0	0	0	0	0
		CH4	0.021	0.008	0	0	0	0	0

		N2O	0.003	0.001	0	0	0	0	0
		SOx	0.114	0.043	0	0	0	0	0
		NOx	0.104	0.040	0	0	0	0	0
		PM 2.5	0.011	0.004	0	0	0	0	0
		VOCs	0.003	0.001	0	0	0	0	0
Motorcycle	Gasoline	CO2	301.425	258.256	252.446	224.187	207.358	207.358	207.358
		CH4	0.014	0.007	0.005	0.005	0.005	0.005	0.005
		N2O	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		SOx	0.002	0.002	0.002	0.001	0.001	0.001	0.001
		NOx	0.077	0.037	0.020	0.020	0.019	0.019	0.019
		PM 2.5	0.003	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.214	0.143	0.121	0.119	0.118	0.118	0.118
	Electric	CO2	18.687	7.464	0	0	0	0	0
		CH4	0.007	0.003	0	0	0	0	0
		N2O	0.001	0.000	0	0	0	0	0
		SOx	0.040	0.016	0	0	0	0	0
		NOx	0.037	0.015	0	0	0	0	0

		PM 2.5	0.004	0.001	0	0	0	0	0
		VOCs	0.001	0.000	0	0	0	0	0
Medium-duty truck	Gasoline	CO2	870.000	663.240	637.281	571.741	517.227	517.227	517.227
		CH4	0.082	0.046	0.030	0.030	0.030	0.030	0.030
		N2O	0.027	0.027	0.027	0.027	0.027	0.027	0.027
		SOx	0.005	0.004	0.004	0.003	0.003	0.003	0.003
		NOx	0.409	0.200	0.105	0.105	0.105	0.105	0.105
		PM 2.5	0.024	0.024	0.018	0.018	0.018	0.018	0.018
		VOCs	1.710	1.179	0.993	0.984	0.978	0.978	0.978
	Diesel	CO2	1,579.000	1,382.252	1,364.073	1,189.877	1,062.269	1,062.269	1,062.269
		CH4	0.042	0.024	0.015	0.015	0.015	0.015	0.015
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.011	0.010	0.009	0.008	0.007	0.007	0.007
		NOx	1.105	0.437	0.169	0.169	0.170	0.170	0.170
		PM 2.5	0.010	0.010	0.008	0.008	0.008	0.008	0.008
		VOCs	0.195	0.134	0.108	0.108	0.108	0.108	0.108
	LPG	CO2	772.000	588.732	565.820	507.636	459.242	459.242	459.242

		CH4	0.082	0.046	0.031	0.031	0.031	0.031	0.031
		N2O	0.027	0.027	0.027	0.027	0.027	0.027	0.027
		SOx	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		NOx	0.409	0.200	0.104	0.104	0.104	0.104	0.104
		PM 2.5	0.024	0.024	0.019	0.019	0.019	0.019	0.019
		VOCs	0.476	0.288	0.204	0.204	0.204	0.204	0.204
	Electric	CO2	122.781	49.043	0	0	0	0	0
		CH4	0.048	0.019	0	0	0	0	0
		N2O	0.007	0.003	0	0	0	0	0
		SOx	0.264	0.106	0	0	0	0	0
		NOx	0.243	0.097	0	0	0	0	0
		PM 2.5	0.025	0.010	0	0	0	0	0
		VOCs	0.006	0.003	0	0	0	0	0
Heavy-duty truck	Gasoline	CO2	1,232.029	939.230	902.470	809.657	732.459	732.459	732.459
		CH4	0.047	0.026	0.017	0.017	0.017	0.017	0.017
		N2O	0.018	0.018	0.018	0.018	0.018	0.018	0.018
		SOx	0.008	0.006	0.006	0.005	0.005	0.005	0.005

		NOx	0.674	0.329	0.172	0.173	0.173	0.173	0.173
		PM 2.5	0.029	0.029	0.022	0.022	0.022	0.022	0.022
		VOCs	0.771	0.532	0.448	0.444	0.441	0.441	0.441
	Diesel	CO2	2,381.000	2,084.321	2,056.908	1,794.235	1,601.813	1,601.813	1,601.813
		CH4	0.049	0.028	0.018	0.018	0.018	0.018	0.018
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.016	0.014	0.014	0.012	0.011	0.011	0.011
		NOx	2.386	0.943	0.366	0.366	0.367	0.367	0.367
		PM 2.5	0.004	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.241	0.165	0.133	0.133	0.134	0.134	0.134
	CNG	CO2	1,976.000	1,565.943	1,400.773	1,249.715	1,138.169	1,138.169	1,138.169
		CH4	1.584	0.892	0.570	0.571	0.572	0.572	0.572
		N2O	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		SOx	0.009	0.007	0.006	0.006	0.005	0.005	0.005
		NOx	0.050	0.024	0.013	0.013	0.013	0.013	0.013
		PM 2.5	0.004	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.213	0.128	0.091	0.091	0.091	0.091	0.091

	Electric	CO2	201.218	80.374	0	0	0	0	0
		CH4	0.078	0.031	0	0	0	0	0
		N2O	0.011	0.005	0	0	0	0	0
		SOx	0.433	0.173	0	0	0	0	0
		NOx	0.398	0.159	0	0	0	0	0
		PM 2.5	0.040	0.016	0	0	0	0	0
		VOCs	0.010	0.004	0	0	0	0	0

Table A.15: Public transit fleet - Fuel use (Btu/mile)

Vehicle type	Fuel type	2020	2025	2030	2035	2040	2045	2050
Transit bus	Diesel	20,478	17,711	17,439	15,235	13,623	13,623	13,623
	Compressed natural gas	24,091	21,549	19,651	19,651	19,651	19,651	19,651
	Hybrid	16,910	17,711	17,439	15,235	13,623	13,623	13,623
	Electric	8,076	5,161	4,828	4,716	4,499	4,499	4,499
Paratransit van	Gasoline	5,594	4,081	3,983	3,560	3,221	3,221	3,221
	Electric	1,865	1,110	1,044	1,019	971	971	971

Table A.16: Public transit fleet - Emission factors (grams/mile)

Vehicle type	Fuel type	Pollutant	2020	2025	2030	2035	2040	2045	2050

Sun Tran	Diesel	CO2	1,612.000	1,411.140	1,392.581	1,214.745	1,084.470	1,084.470	1,084.470
		CH4	0.019	0.011	0.007	0.007	0.007	0.007	0.007
		N2O	0.003	0.003	0.003	0.003	0.003	0.003	0.003
		SOx	0.011	0.010	0.009	0.008	0.007	0.007	0.007
		NOx	2.016	0.797	0.309	0.309	0.310	0.310	0.310
		PM 2.5	0.004	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.155	0.106	0.086	0.086	0.086	0.086	0.086
	CNG	CO2	1,387.000	1,099.172	983.235	877.203	798.907	798.907	798.907
		CH4	2.787	1.569	1.003	1.004	1.006	1.006	1.006
		N2O	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		SOx	0.006	0.005	0.004	0.004	0.003	0.003	0.003
		NOx	0.070	0.034	0.018	0.018	0.018	0.018	0.018
		PM 2.5	0.004	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.106	0.064	0.045	0.045	0.045	0.045	0.045
	Hybrid	CO2	1,333.000	1,166.904	1,151.557	1,004.501	896.773	896.773	896.773
		CH4	0.019	0.011	0.007	0.007	0.007	0.007	0.007
		N2O	0.003	0.003	0.003	0.003	0.003	0.003	0.003

		SOx	0.009	0.008	0.008	0.007	0.006	0.006	0.006
		NOx	2.016	0.797	0.309	0.309	0.310	0.310	0.310
		PM 2.5	0.004	0.004	0.003	0.003	0.003	0.003	0.003
		VOCs	0.155	0.106	0.086	0.086	0.086	0.086	0.086
	Electric	CO2	199.513	79.693	0	0	0	0	0
		CH4	0.078	0.031	0	0	0	0	0
		N2O	0.011	0.005	0	0	0	0	0
		SOx	0.430	0.172	0	0	0	0	0
		NOx	0.395	0.158	0	0	0	0	0
		PM 2.5	0.040	0.016	0	0	0	0	0
		VOCs	0.010	0.004	0	0	0	0	0
Sun Van	Gasoline	CO2	423.968	310.205	303.667	271.211	245.191	245.191	245.191
		CH4	0.016	0.009	0.006	0.006	0.006	0.006	0.006
		N2O	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		SOx	0.003	0.002	0.002	0.002	0.001	0.001	0.001
		NOx	0.103	0.050	0.025	0.025	0.025	0.025	0.025
		PM 2.5	0.005	0.005	0.004	0.004	0.004	0.004	0.004

		VOCs	0.190	0.129	0.107	0.106	0.105	0.105	0.105
	Electric	CO2	138.200	63.007	0	0	0	0	0
		CH4	0.054	0.025	0	0	0	0	0
		N2O	0.008	0.004	0	0	0	0	0
		SOx	0.298	0.136	0	0	0	0	0
		NOx	0.274	0.125	0	0	0	0	0
		PM 2.5	0.028	0.013	0	0	0	0	0
		VOCs	0.007	0.003	0	0	0	0	0

Table A.17: City fleet - Vehicle costs ($2022)

Vehicle type	Fuel type	Purchase	Maintenance and Repair
Passenger car	Gasoline	$22,610	$39,309
	E85	$22,610	$39,309
	Electric	$41,829	$24,783
Light-duty pickup truck	Gasoline	$41,829	$42,915
	Diesel	$32,785	$42,499
	E85	$49,743	$63,466
	Compressed natural gas	$40,699	$62,850

	Electric	$41,829	$42,915
Sport utility vehicle (SUV)	Gasoline	$32,785	$42,499
	Diesel	$54,830	$42,915
	E85	$46,917	$42,499
	Compressed natural gas	$87,050	$27,057
	Electric	$52,004	$26,795
Motorcycle	Gasoline	$33,627	$66,094
	Electric	$70,331	$41,670
Medium-duty truck	Gasoline	$47,482	$129,576
	Diesel	$59,918	$191,629
	Liquefied petroleum gas	$56,526	$129,576
	Electric	$105,139	$81,694
Heavy-duty truck	Gasoline	$62,712	$56,353
	Diesel	$79,137	$83,340
	Compressed natural gas	$124,357	$88,315
	Electric	$169,578	$57,935

Table A.18: Public transit fleet - Vehicle costs ($2022)

Vehicle type	Fuel type	Purchase	Maintenance and Repair
Transit bus	Diesel	$570,000	$1,162,500
	Compressed natural gas	$625,000	$547,500
	Hybrid	$825,000	$966,000
	Electric	$1,025,000	$625,940
Paratransit van	Gasoline	$138,000	$363,720
	Electric	$325,000	$363,720

6.3. Energy inputs

Input	Unit	Value	Notes	Source
VPPA contract price premium over electricity price	$2022/kWh	$0.01	This value is added to the blended municipal electricity price each year	City of Tucson, personal communication, 2023
Retrofit site EUI reduction	%	25%		City of Tucson, personal communication, 2023
Total retrofit cost	$2022/sq foot	$4.19	Average of Standard retrofit and Deep retrofit, inflated to $2022 using CPI	Department of Energy: Pacific Northwest National Laboratory Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance: Office Buildings https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20761.pdf
Electrification Cost	$2022	$0.2984	Localized to Tucson	Cost of Study of the Building Decarbonization Code. https://newbuildings.org/wp-content/uploads/2022/04/BuildingDecarbCostStudy.pdf RSMeans.

				https://www.rsmeans.com/media/wysiwyg/quarterly_updates/2021-CCI-LocationFactors-V2.pdf
ESCO Profit %	%	15%		City of Tucson, personal communication, 2023
Commissioning site EUI reduction	%	15%		Energy Star: 5. Retro-commissioning https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH5_RetroComm.pdf
Commissioning cost	$2022/sqft	$1.50		City of Tucson, personal communication, 2023
Municipal building square footage	Square feet	5,939,824		Buro Happold
Municipal grid-supplied electricity	kWh	See Table A.19		
Municipal fossil fuel consumption	Therms	See Table A.20		
Community-wide grid-supplied electricity	kWh	See Table A.21		

Table A.19: Municipal grid-supplied electricity (kWh)

	2020	2025	2030	2035	2040	2045	2050
Facilities and parks (TEP)	54,548,628	54,548,628	54,548,628	54,548,628	54,548,628	54,548,628	54,548,628
Tucson Water (Potable and Reclaimed), TEP	64,988,623	64,988,623	64,988,623	64,988,623	64,988,623	64,988,623	64,988,623
Tucson Water (Potable and Reclaimed), Trico	42,173,656	42,173,656	42,173,656	42,173,656	42,173,656	42,173,656	42,173,656
Tucson Water (Potable and Reclaimed), BIA	8,065	8,065	8,065	8,065	8,065	8,065	8,065
Fleet Facilities	2,690,513	2,690,513	2,690,513	2,690,513	2,690,513	2,690,513	2,690,513

Street and Traffic Lighting	8,198,177	8,198,177	8,198,177	8,198,177	8,198,177	8,198,177	8,198,177

Table A.20: Municipal fossil fuel consumption (Therms)

	2020	2025	2030	2035	2040	2045	2050
Facilities and parks	1,055,628	1,055,628	1,055,628	1,055,628	1,055,628	1,055,628	1,055,628
Tucson Water (Potable and Reclaimed)	3,834,448	3,834,448	3,834,448	3,834,448	3,834,448	3,834,448	3,834,448
District Energy	709,070	709,070	709,070	709,070	709,070	709,070	709,070

Table A.21: Community-wide grid-supplied electricity (kWh)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Residential	2,251,558	2,246,466	2,270,929	2,325,522	2,412,009	2,533,433	2,694,285	2,899,848	3,158,223	3,480,058	3,879,247	4,373,895	4,373,895	4,373,895	4,373,895
Commercial	1,537,530	1,534,053	1,550,758	1,588,038	1,647,098	1,730,015	1,839,857	1,980,230	2,156,668	2,376,440	2,649,036	2,986,818	2,986,818	2,986,818	2,986,818
Industrial	1,355,772	1,352,706	1,367,436	1,400,309	1,452,388	1,525,503	1,622,360	1,746,139	1,901,719	2,095,511	2,335,882	2,633,734	2,633,734	2,633,734	2,633,734

2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895	4,373,895
2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818	2,986,818
2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734	2,633,734

6.4. Waste inputs

Input	Unit	Value	Notes	Source
2019 city operations refuse waste	Tons	7,065		Buro Happold
2019 city operations rolloff	Tons	2,778		

waste				
2023 community-wide waste	Tons	764,106		City of Tucson, personal communication, 2023
Compost program implementation cost	$2022/ton	$25.5		
Fertilizer sale revenue	$2022/ton	$12.75		
Fertilizer production from compost	%	33.33%		Citizens Budget Commission: Can We Have Our Cake and Compost It Too? An Analysis of Organic Waste Diversion in New York City https://cbcny.org/research/can-we-have-our-cake-and-compost-it-too
Population growth rate	%	See Table A.22		Buro Happold
Waste characterization	%	See Table A.23		CalRecycle: Business Group Waste Stream by Material Type https://www2.calrecycle.ca.gov/WasteCharacterization/MaterialTypeStreams
Recyclable waste emission factors	tonne CO2e/ton	See Table A.24		U.S. Environmental Protection Agency: Waste Reduction Model (WARM) https://www.epa.gov/warm
Organic waste emission factors	tonne CO2e/ton	See Table A.25		

Table A.22: Population growth rate

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Population	559,716	566,903	574,091	581,279	588,277	595,276	602,274	609,272	616,271	623,731	631,281	638,923	646,657
Yearly growth rate		1.28%	1.27%	1.25%	1.20%	1.19%	1.18%	1.16%	1.15%	1.21%	1.21%	1.21%	1.21%

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
654,484	662,407	670,425	678,541	686,755	695,068	703,481	711,997	720,616	729,339	738,167	747,103	756,147	765,300	774,564	783,940
1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%	1.21%

Table A.23: Waste characterization

Waste type	%
Paper	17.90%
Plastic	10.10%
Glass	2.00%
Metal	3.83%
Construction and demolition waste	8.40%
Carpet	0.66%
Concrete	0.46%
Asphalt Concrete	0.11%
Asphalt Shingles	0.19%
Dimensional Lumber	6.47%
Drywall	0.40%
Fly Ash	0.10%
Organic	42.53%
Food waste	27.92%
Yard trimmings	14.61%
Household hazardous waste (HHW)	0.63%
Other materials	14.61%

Table A.24: Recyclable waste emission factors (tonne CO2e/ton)

	Carpet	Concrete	Asphalt Concrete	Asphalt Shingles	Dimensional Lumber	Drywall	Fly Ash	Mixed Paper (general)	Glass	Mixed Metals	Mixed Electronics	Mixed Plastics	Tires
Landfill	0.02	0.02	0.02	0.02	-0.92	-0.06	0.02	0.07	0.02	0.02	0.02	0.02	0.02

Recycling	-2.38	-0.01	-0.08	-0.09	-2.66	0.03	-0.87	-3.55	-0.28	-4.39	-0.79	-0.93	-0.38

Table A.25: Organic waste emission factors (tonne CO2e/ton)

	Food Waste	Yard Trimmings
Landfill	0.5	-0.2
Compost	-0.12	-0.05

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