Appendix

BURO HAPPOLD

Tucson Climate Adaptation and Action Plan

Greenhouse Gas Emissions and Forecast Analysis

July 2022

BURO HAPPOLD

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1 Context

In 2020, Tucson Mayor Regina Romero and the Tucson City Council (Mayor and Council, or M&C) committed to take decisive and equitable action on climate change and environmental sustainability, resulting in the declaration of a Climate Emergency and the establishment of a 2030 carbon neutrality goal (i.e., net zero greenhouse gas emissions) for City operations. In 2021, the M&C initiated multiple engagements with the Tucson community at large, including a community survey and multiple community listening and planning sessions, to identify community priorities for climate action.

In January 2022, the City contracted with a consultant team led by Buro Happold to develop and finalize a Climate Action and Adaptation Plan (CAAP) for the City of Tucson, to be completed by the end of calendar year 2022. In spring 2022, the climate action and adaptation plan re-titled, "*Tucson Resilient Together*."

1.1 Defining carbon neutrality

Carbon neutrality is measured as a balance of the GHGs that are actually emitted versus absorbed or sequestered from the atmosphere by trees or water bodies (also known as "carbon sinks"). In other words, if an entity theoretically emitted 100,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) in a year, it would be considered carbon neutral if it either completely eliminated those emissions, or if it countered those emissions using carbon insets (investing in an entity-owned project that sequesters emissions, like an urban forest) or carbon offsets (investing in a non-related project that reduces or sequesters emissions, like a large solar array).

For the purposes of Tucson's municipal and community-wide inventories, carbon neutrality accounts for Scope 1 and 2 emissions alone and excludes Scope 3 emissions. As a note, these inventories do not include any insets or offsets, and only include actual emissions.

2 Purpose

As part of its scope of work, Buro Happold was asked to complete a **Greenhouse Gas and Forecast Analysis** as an interim deliverable for *Tucson Resilient Together*. This assessment provides an overview of the City's operational and community-wide greenhouse gas (GHG) emissions, as well as business-as-usual and business-as-planned analyses for emissions out through 2030. The final emissions inventory and analyses will be included in the body and addendums to the Tucson climate action and adaptation plan.

The document is structured as follows:

- **Section 3: Methodology** – This section provides a brief overview of the methodology applied for assessing GHG emissions, especially with respect to 2030 business-as-usual and business-as-planned scenarios.
- **Section 4: Baseline Greenhouse Gas Emissions** – This section provides an overview of GHG emissions during the selected baseline year, 2019, detailing emissions sources across City operations and the Tucson community.

- **Section 5: Scenario Analyses** – This section details business-as-usual and business-as-planned analyses for City operations and community-wide GHG emissions. Assumptions regarding emissions through 2030 are explained.
- **Section 6: Conclusions** – This section provides some final, overarching takeaways from the analysis.

3 Methodology

This section summaries the methodological approach for assessing GHG emissions across City operations and the Tucson community, as well as for forecasting emissions out through 2030.

3.1 Measuring Greenhouse Gas Emissions

To understand how we measure GHG emissions, it is important to know how they are categorized. First, there is biogenic carbon, which is naturally emitted, absorbed, and stored by organic matter (e.g., trees, soil), and there is non-biogenic or anthropogenic carbon from human activity sources such as the combustion of fossil fuels (e.g., coal, oil, gas). When accounting for our GHG emissions, we are most concerned with quantifying and reducing anthropogenic GHG emissions, because they are the emissions for which we are most directly responsible, thus the ones which we can most effectively reduce or eliminate.

Typically, GHG emissions can be quantified by source, sector, or scope. In the case of source, emissions are quantified based on whether or not they come from stationary energy sources (e.g., homes, buildings, infrastructure), transportation (e.g., vehicles, airplanes), or waste (e.g., landfill). If measuring by sector, emissions are generally sorted into residential, commercial, industrial, or municipal emissions with some sub-categories. Finally, emissions can be measured by scope, which has to do with the direct or indirect control of activities contributing to emissions. There are three scopes of emissions that are internationally recognized and standardized:

- **Scope 1:** Direct emissions from owned or controlled sources. These can include on-site fuel combustion, emissions from owned vehicles, and fugitive (unintentionally leaked or discharged) emissions from refrigerants, fire suppression systems, and more.

- **Scope 2:** Indirect emissions from purchased electricity, steam, heating, and cooling.

- **Scope 3:** Indirect emissions from all other activities, which can include purchased goods/services, business travel, commuting, waste disposal, investments, leased assets, and more.

Sorting emissions into scopes is most commonly recognized and accepted because it provides direction to emitting entities with respect to where they can have the greatest impact or ownership of emissions and their mitigation. Conventionally, entities will report on and work towards reducing Scope 1 and 2 emissions, with some voluntarily action on Scope 3 emissions.

Finally, emissions are most typically measured in metric tons of carbon dioxide equivalent ($MTCO_2e$). This unit accounts for the fact that different GHGs have different global warming potentials, which refers to the magnitude of heat absorption of a given GHG. One unit of methane, for example, has approximately 30 times the global warming potential of carbon dioxide.

3.2 Baseline Year

For this analysis, and for the *Tucson Resilient Together* plan at large, a baseline year of 2019 is established for multiple reasons. First, 2019 is the most recent year for which emissions data is available from the City and the Pima Association of Governments (PAG).[1] Second, if more recent data were available, 2020 and 2021 emissions would have been substantively impacted by shifting operations due to the COVID-19 pandemic. As a result, these years would not have constituted meaningful indicators of the City or the community acting on a 'per-usual' basis.

3.3 Emissions Inventory Development and Review

Tucson's greenhouse gas emissions, both from City operations and community-wide activities, are measured on an annual basis and reported on a biennial basis through the PAG Regional Greenhouse Gas Inventory Report. Tucson Water also conducts and maintains a distinct GHG emissions inventory for its activities. In PAG's report, emissions are reported in a mixed fashion accounting for source, sector, and scope, whereas Tucson Water quantifies emissions by scope.

Buro Happold was neither scoped to develop a new GHG emissions inventory for the City of Tucson, nor to make substantive revisions to the existing inventories available from PAG. However, Buro Happold completed a high-level review of the emissions inventory and supplemental data provided by the City of Tucson and PAG, and noted inconsistencies to PAG for review. Where PAG clarified erroneous calculations or figures, Buro Happold substituted corrections.

Furthermore, Buro Happold was not scoped to complete an in-depth analysis of the City operations and communitywide processes for identifying, collecting, and calculating emissions from data. However, recommendations are included in the firm's *Existing Conditions Assessment* with respect to how the City can develop complete, accurate, and legible inventories, and that it institutes comprehensive data collection and management protocols to assure the integrity of Tucson's GHG emissions inventories. This assessment will briefly restate some of those findings.

Consequently, the inventory summaries and analyses included herein are based on our 2019 inventories as published in the most recent PAG report. However, emissions have been recategorized into Scopes 1-3 for the purposes of reporting and in alignment with best practices.

3.4 Business as Usual vs. Business as Planned

When conducting initial scenario analyses, Buro Happold typically prepares two 'business-as' scenarios that outline projected emissions out to a certain date: **business as usual (BAU)**, and **business as planned (BAP)**. In a BAU scenario, it is assumed that no additional actions are taken by the City to reduce greenhouse gas emissions apart from any existing or ongoing initiatives. Plans, proposed initiatives, and policies that have not yet been implemented are assumed to not be implemented during this timeframe. This approach is conservative, and assumes that activities will remain largely static.

[1] PAG is responsible for collecting data from the City of Tucson to calculate GHG emissions for city operations. PAG separately collects data for and calculates community-wide emissions. These emissions are published on a biennial basis by PAG, with the most recent publication being the *Regional Greenhouse Gas Inventory (2014-2019)*, issued in June 2021.

In a BAP scenario, it is assumed that these plans, proposed initiatives, and policies are being, or will be, implemented. Unless additional detail is provided by the implementer, their impacts are incorporated in a linear fashion (steady, equal progress each year until a designated endpoint).

In both the BAU and BAP scenarios, 2030 is the designated "target year" given the City's stated goal of achieving carbon neutrality for emissions from City operations by 2030. Since the City has not issued a target for community-wide emissions at the time of drafting, an endpoint of 2030 is also applied to that scenario analysis.

3.5 Limitations and Accuracy

Limitations in scope, data, and metrics-driven goals or actions vastly limit the granularity and definition of these analyses. Given that limitation, and that data and calculations are owned or shared by the City of Tucson and PAG, Buro Happold cannot guarantee or fully verify the accuracy and completeness of the GHG emissions inventories and the accompanying scenario analyses. However, despite these limitations, the forthcoming analysis provides sufficient information to guide the development of meaningful GHG emissions mitigation strategies for implementation within *Tucson Resilient Together*.

4 Baseline Greenhouse Gas Emissions

This section provides an overview of GHG emissions during the 2019 baseline year, differentiating between **City operations**, or emissions from City-owned assets or activities, and **community-wide emissions**, or emissions from non-government sectors (i.e., residential, commercial, and industrial).

4.1 City Operations Emissions

It is estimated that, in 2019, the City of Tucson emitted approximately 153,517 $MTCO_2e$ across its assets and activities under Scopes 1 and 2. Approximately 26% of municipal emissions were Scope 1 emissions, or from assets directly owned by the City, and the remaining 74% were Scope 2 emissions, or procured electricity. The overarching breakdown of emissions by source is shown below in Figure 1 and Table 1.

Figure 1. 2019 GHG Emissions from City Operations

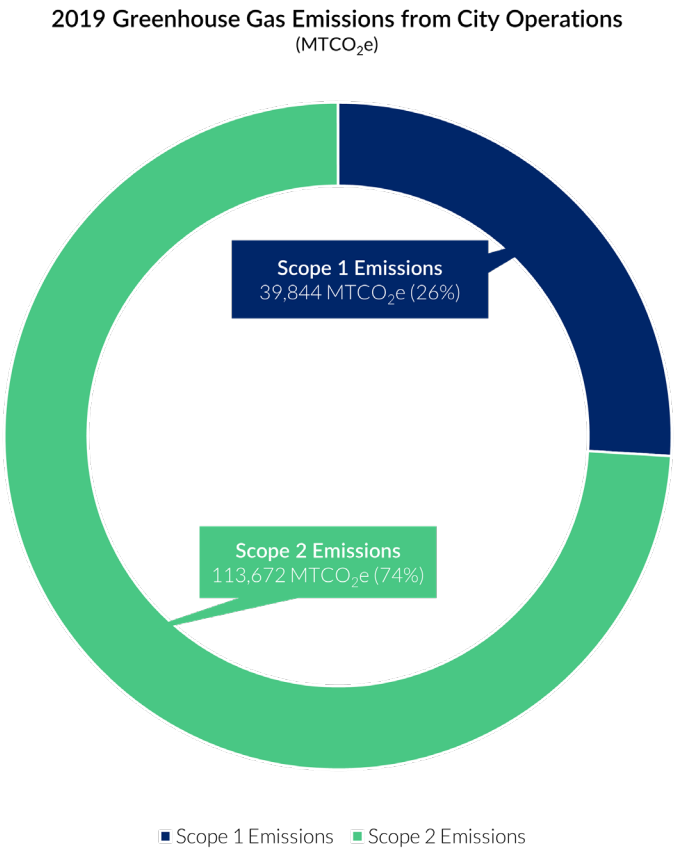


Table 1. 2019 GHG Emissions from City Operations by Source[2,3]

Source	GHG Emissions ($MTCO_2e$)
STATIONARY ENERGY	**143,348**
Facilities and Parks	**41,924**
Grid-supplied electricity	*36,329*
Fossil fuel consumption	*5,595*
Tucson Water	**90,414**
Grid-supplied electricity	*70,091*
Fossil fuel consumption	*20,323*
Fleet Facilities	**1,792**
Grid-supplied electricity	*1,792*
Street and Traffic Lighting	**5,460**
Grid-supplied electricity	*5,460*
District Energy	**3,758**
Fossil fuel consumption	*3,758*
TRANSPORTATION	**10,169**
City Fleet On-Road	**9,561**
City Fleet Off-Road	**608**
TOTAL	**153,517**

4.1.1 Gaps and Exclusions

The *Local Government Operations (LGO) Protocol*, available through ICLEI – Local Governments for Sustainability, provides guidance on the operational boundaries of a City emissions inventory. Most notably, this guidance indicates that emissions should be categorized more broadly under three scopes: Scope 1, or all direct GHG emissions; Scope 2, or indirect GHG emissions associated with the consumption of purchased or acquired electricity, steam, heating, or cooling; and Scope 3, or all other indirect emissions not covered in Scope 2. Apart from a brief designation of "Scope 3" emissions for employee commuting, the City does not report out on its emissions in this manner.[4] They have only been recategorized as such for the purposes of this report and the plan.

Most notably, fugitive emissions, from sources such as refrigerants or fire suppression emissions, are not included in the City's Scope 1 emissions. Calculations and data were also not available for this particular subset of emissions, which could constitute a significant number of emissions now and in the future.

[2] Numbers may not add up due to rounding.

[3] Discrepancies between values listed here and values listed in PAG's Regional Greenhouse Gas Inventory (2014-2019) are due to corrected values after clarification with PAG. These differences are considered immaterial (less than 5% difference).

[4] Tucson Water does report out its GHG emissions based on scopes (1-3).

In addition, the Central Arizona Project, employee commuting, and waste account for City emissions that can be considered as Scope 3. Other sources of Scope 3 emissions, which can include but are not limited to business travel, the extraction and production of purchased materials, are not included. While their reporting is not required per the LGO Protocol, the City may consider how to account for these other emissions while moving toward carbon neutrality by 2030.

4.2 Community-wide Emissions

It is estimated that, in 2019, the Tucson community emitted over 6.1 million $MTCO_2e$ across Scope 1 and 2 emissions. 44% of community-wide emissions are classified as Scope 1, including fossil fuel use across residential, commercial, and industrial sectors, as well as emissions from transportation. The remaining 56% come from Scope 2 emissions (procured electricity). The overarching breakdown of community-wide emissions by source is shown in Figure 2.

Figure 2. 2019 Community-wide GHG Emissions by Sector

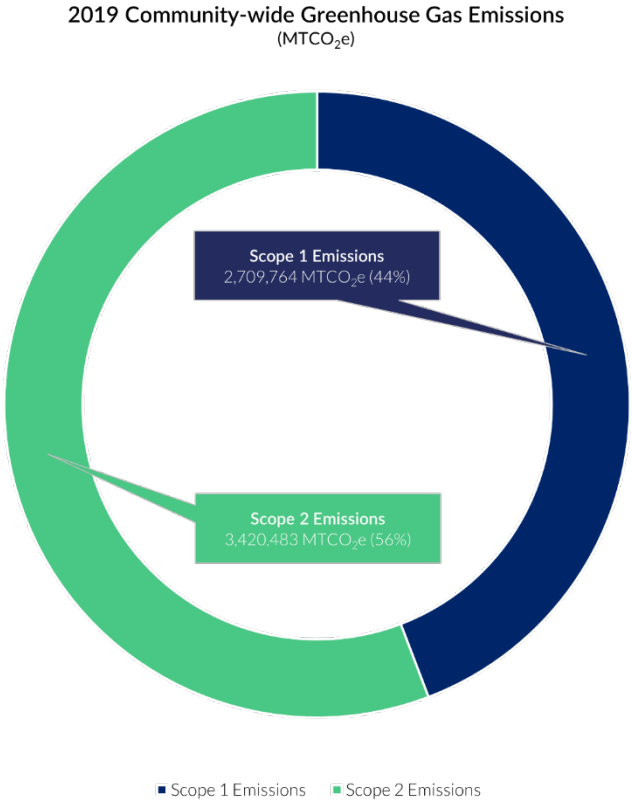


Table 2. 2019 Community-wide GHG Emissions by Source[5,6]

Source	GHG Emissions ($MTCO_2e$)
STATIONARY ENERGY	**4,137,505**
Residential	**1,845,577**
Grid-supplied electricity	*1,493,843*
Fossil fuel consumption	*351,734*
Commercial	**1,283,403**
Grid-supplied electricity	*1,023,695*
Fossil fuel consumption	*259,707*
Industrial	**1,008,525**
Grid-supplied electricity	*902,944*
Fossil fuel consumption	*105,581*
TRANSPORTATION	**1,992,742**
Onroad Emissions, Private & Commercial	**1,694,471**
Onroad Emissions, Transit	**16,627**
Nonroad Emissions	**281,644**
TOTAL	**6,130,247**

4.2.1 Gaps and Exclusions

The *Global Protocol for Community-Scale Greenhouse Gas Inventories (Protocol)*, from the Greenhouse Gas Protocol, provides guidance with respect to the development of community-scale emissions inventories. As is often included in emissions accounting standards, community-wide emissions should be designated between scopes 1-3. In the case of Tucson's community-wide GHG emissions inventory, this is not the case, though it is presented as such in the chart above for the purposes of this document and the plan at large.

[5] Numbers may not add up due to rounding.

[6] Discrepancies between values listed here and values listed in PAG's Regional Greenhouse Gas Inventory (2014-2019) are due to corrected values after clarification with PAG. These differences are considered immaterial (less than 5% difference).

The *Protocol* also defines the inventory boundary and sources to be defined. Per the *Protocol*, these activities should be classified into six main sectors: stationary energy; transportation; waste; industrial processes and product use (IPPU); agricultural, forestry, and other land use (AFOLU); and any other emissions occurring outside the geographic boundary as a result of City activities (which can be reported separately). In the case of community-wide emissions for Tucson, stationary energy, transportation, and waste emissions are included, but specific emissions that would be captured under IPPU, AFOLU, or otherwise are not included.

In addition, within existing categories, not all possible sub-sectors of emissions are captured (or it is not clear if some are). Within stationary energy, it is likely that certain sources of emissions, including agriculture, forestry, and fishing activities, as well as fugitive emissions from mining, processing, storage, coal transportation, oil, and natural gas systems, are not being captured. In the case of transportation, on-road and off-road emissions are captured, but it does not appear that emissions from railways, aviation, or waterborne navigation (if applicable) are being captured. Finally, with respect to waste, solid waste disposal and wastewater reclamation are included, but it is not clear if activities related to the biological treatment of waste or incineration and open burning are being captured in the emissions inventory.

Each of these may constitute significant components of the Tucson community's actual emissions profile, but it is likely that these emissions have not been calculated due to either potential immateriality or due to insufficient data. While the City has not set a target for reducing community-wide emissions, determining where and how it can capture these additional emissions sources may support more focused strategies on emissions mitigation at the community scale out through 2030 and beyond.

5 Scenario Analyses

This section will show and explain BAU and BAP scenarios through 2030 both City operations and community-wide emissions. It will provide details with respect to some of the assumptions applied within each forecast, as well as some of the specific limitations within each scenario, where applicable (if not otherwise detailed in Section 3).

5.1 City Operations

5.1.1 2030 BAU Scenario

The 2030 BAU scenario for emissions from City operations, shown in Figure 3, is built on the 2019 emissions baseline presented in Section 4. In this scenario, it is assumed that:

- Consumption or related activities will remain consistent through 2030;[7]
- There will be no change in full-time-equivalent (FTE) staff or building/asset stock;
- There will be no change in the carbon intensity of procured electricity or fuels;

[7] This is a conservative approach. It is more likely than not that resource use increases over time, rather than stays static or decreases.

- Population change will have no bearing on City operations; and

Due to the lack of 2020 and 2021 emissions data, the commonly seen decline in emissions during those years due to the impact on operations from COVID-19 is not reflected.

5.1.2 2030 BAP Scenario

The 2030 BAP scenario for emissions from City operations, shown in Figure 4, is also built on the 2019 emissions baseline presented in Section 4. In this scenario, the assumptions applied for the BAU scenario still hold, but in addition, it is assumed that:

- Tucson Electric Power's goal or preferred portfolio of 70% renewable electricity by 2035 is implemented during this timeframe;[8]
- The goal laid out in the City's 2022 *EV Readiness Roadmap* to transition 90% of the City's light-duty vehicle fleet to electric by 2030 is achieved;
- The City's goal laid out in its Climate Emergency Declaration to be a "zero-waste" city by 2050 is in progress.[9]

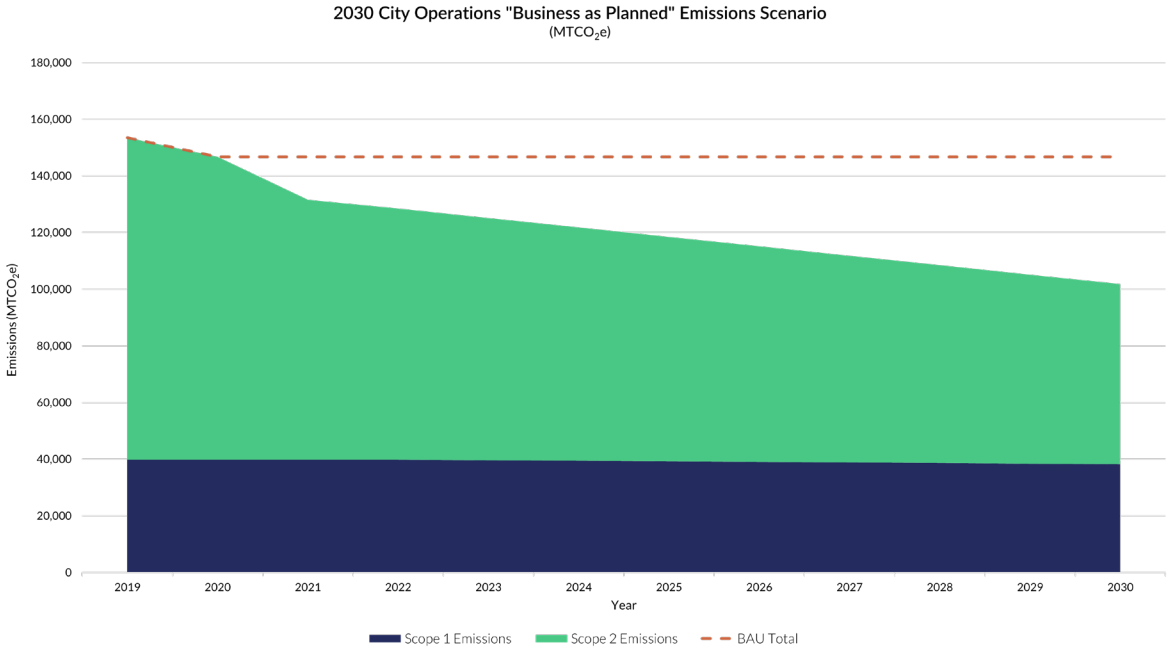
5.1.3 Project GHG Emissions from City Operations through 2030

Figure 3 below shows projected emissions from City operations through 2030. The BAP scenario is represented by the stacked area, whereas the BAU is overlaid as a dotted line.

[8] This approach assumes linear interpolation between the current carbon intensity of TEP electricity in 2019 and the reduced emissions intensity assumed in 2035 and is drawn from the TEP *2020 Integrated Resource Plan*. Electricity procured from other sources is assumed to stay the same with respect to carbon intensity through 2030.

[9] Under this model, "zero waste" assumes that 90% of all solid waste is diverted from landfill, which aligns with assumptions and practices used in other cities and waste plans.

Figure 3. 2030 BAP Emissions Scenario for City Operations



In the BAP scenario, emissions decline by 34% by 2030 from 2019 levels, based on assumptions that Tucson Electric Power (TEP) will achieve its preferred portfolio of 70% renewable energy by 2035, that 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. The BAP scenario at 2030 is 31% lower than the BAU scenario during the same year.

5.2 Community-wide Emissions

5.2.1 2030 BAU Scenario

The 2030 BAU scenario for community-wide, shown in Figure 5, is built on the 2019 emissions baseline presented in Section 4. In this scenario, it is assumed that:

- Consumption or related activities will remain consistent per capita through 2030;[10]
- Population growth is assumed based on PAG's Urban/Suburban Mix scenario in the Technical Addendum to their *2045 Regional Mobility and Accessibility Plan*;
- Vehicle miles travelled (VMT) increases based on the "No Build" scenario presented in the City's *Move Tucson* plan through 2045;
- The fuel economy of passenger vehicles adjusts based on federally set standards through 2026 and;

[10] As with city operations, this is a conservative approach. It is more likely than not that resource use increases over time, rather than stays static or decreases.

- The loss of coal-powered energy from the Navajo Generation Station (NGS) for the Central Arizona Project is replaced with purchased electricity from the local/regional market.

Once again, the impact of COVID-19 is not reflected in 2020 and 2021 due to the lack of emissions data.

5.2.2 2030 BAP Scenario

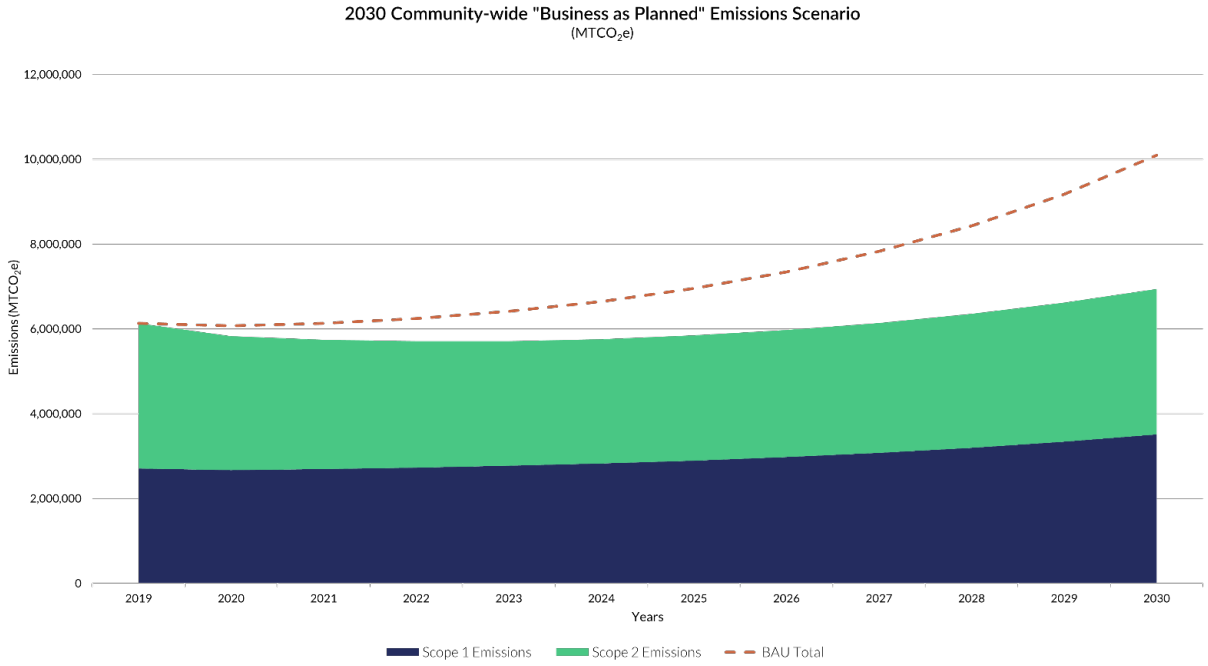
The 2030 BAP scenario for community-wide, shown in Figure 6, is also built on the 2019 emissions baseline presented in Section 4. In this scenario, the assumptions applied for the BAU scenario still hold, but in addition, it is assumed that:

- Tucson Electric Power's goal or preferred portfolio of 70% renewable electricity by 2035 is implemented during this timeframe; and
- VMT will grow based on the "Full Build" scenario in *Move Tucson* through 2045.

5.2.3 Project GHG Emissions Community-wide through 2030

As with City Operations, projected community-wide emissions through 2030 are shown in Figure 4 below that shows business-as-usual and business-as-planned scenarios.[11]

Figure 4. 2030 BAP Emissions Scenario Community-wide



[11] Projections are only shown through 2030, as these analyses pre-dated the establishment of a 2045 community-wide carbon neutrality goal.

Under the BAU scenario, community-wide emissions rise 65% by 2030 from 2019 levels, with emissions increasing across all sectors. However, in a BAP scenario, this diminishes to a 13% increase. The BAP scenario assumes once again that Tucson Electric Power 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 vehicle miles travelled (VMT). Both of these scenarios account for expected population growth across Tucson through 2030, as well as improving vehicle fuel economy standards. The largest emissions reductions in the BAP scenario occur in stationary energy due to the declining carbon intensity of the grid.

6 Conclusion

Through the inventory and scenario analyses, Buro Happold provides the following findings and takeaways:

- Across City operations and community-wide inventories, stationary energy makes up the largest share of emissions, but also present the greatest opportunity for reductions. Strategies will need to focus on building electrification and decarbonizing power supply, with considerations ranging from incentives and reach codes to community choice energy and municipalization.
- Transportation is a significant contributor to community-wide emissions. Working toward complete streets and transit-oriented development and forwarding the efforts initiated by *Move Tucson*, the *EV Readiness Roadmap*, and regional plans will promote mode shift to less carbon-intensive forms of transportation and contribute to reductions in VMT.
- Tucson's inventories for City operations and community-wide emissions will be critical to measuring progress and adapting policies and initiatives on the path to carbon neutrality. The City's mitigation strategy will need to be accompanied by support for monitoring and evaluation that solidifies inventories, provides support for their development on a regular basis, and enables the City to own their development and communication.
- Finally, as the City develops mitigation strategies, it should consider where strategies can yield co-benefits that cut across climate adaptation and resilience (e.g., passive design that creates shading and reduces cooling demand in buildings).

BURO HAPPOLD

Tucson Climate Adaptation and Action Plan

Climate Risk and Vulnerability Assessment

July 2022

BURO HAPPOLD

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1 Context

In 2020, Tucson Mayor Regina Romero and the Tucson City Council (Mayor and Council, or M&C) committed to take decisive and equitable action on climate change and environmental sustainability, resulting in the declaration of a Climate Emergency and the establishment of a 2030 carbon neutrality goal (i.e., net zero greenhouse gas emissions) for City operations. In 2021, the M&C initiated multiple engagements with the Tucson community, including a community survey and multiple community listening and planning sessions, to identify community priorities for climate action. In addition, the Mayor's Climate Action Advisory Council (CAAC), in partnership with the University Climate Change Coalition (UC3) at the University of Arizona, developed recommendations to scope a city-wide climate risk and vulnerability assessment.

In January 2022, the City contracted with a consultant team led by Buro Happold to develop and finalize a Climate Action and Adaptation Plan (CAAP) for the City of Tucson, to be completed by the end of calendar year 2022. In spring 2022, the climate action and adaptation plan re-titled, "*Tucson Resilient Together*."

2 Purpose

As part of its scope of work, Buro Happold was asked to complete a **Climate Risk and Vulnerability Assessment** to be a part of and inform *Tucson Resilient Together*. This Assessment identifies the city's social, physical, and natural vulnerabilities to climate change impacts and assesses the specific and collective risks posed by climate hazards that threaten Tucson. This Assessment addresses exposure and sensitivity across Tucson with respect to select, pertinent climate hazards, and provides an overview of the city's adaptive capacity given existing infrastructure, resources, policies, and programs.

Together with findings from a comprehensive community engagement process, accompanying greenhouse gas (GHG) emissions analyses, and Buro Happold's *Existing Conditions Assessment*, this Assessment will inform the development of climate adaptation and resilience strategies to be incorporated into *Tucson Resilient Together* and implemented by the City. The document is structured as follows:

- **Section 3: Global Climate Trends and Vulnerability** – Provides a brief overview of global climate trends and provides a definition of key terms pertaining to climate risk and vulnerability.
- **Section 4: Climate Risk and Vulnerability in Tucson** – Provides context with respect to major City- and community-led efforts to address climate risk and vulnerability across Tucson.
- **Section 5: Climate Hazards and Risk Assessment** – Provides an overview of the scope of hazards, projections, and models used to understand the impacts of climate change in Tucson and the specific hazards of greatest concern and risk to Tucson through mid- and late-century.
- **Section 6: Social Vulnerability Assessment** – Details the sensitivity and exposure of Tucson residents to the impacts of the climate hazards introduced in Section 5.
- **Section 7: Physical Vulnerability Assessment** – Details the susceptibility of physical infrastructure to climate hazards and extreme events.
- **Section 8: Adaptive Capacity** – Provides an overview of the ability of the natural and social environments of Tucson to adjust or adapt to the impacts of climate change.

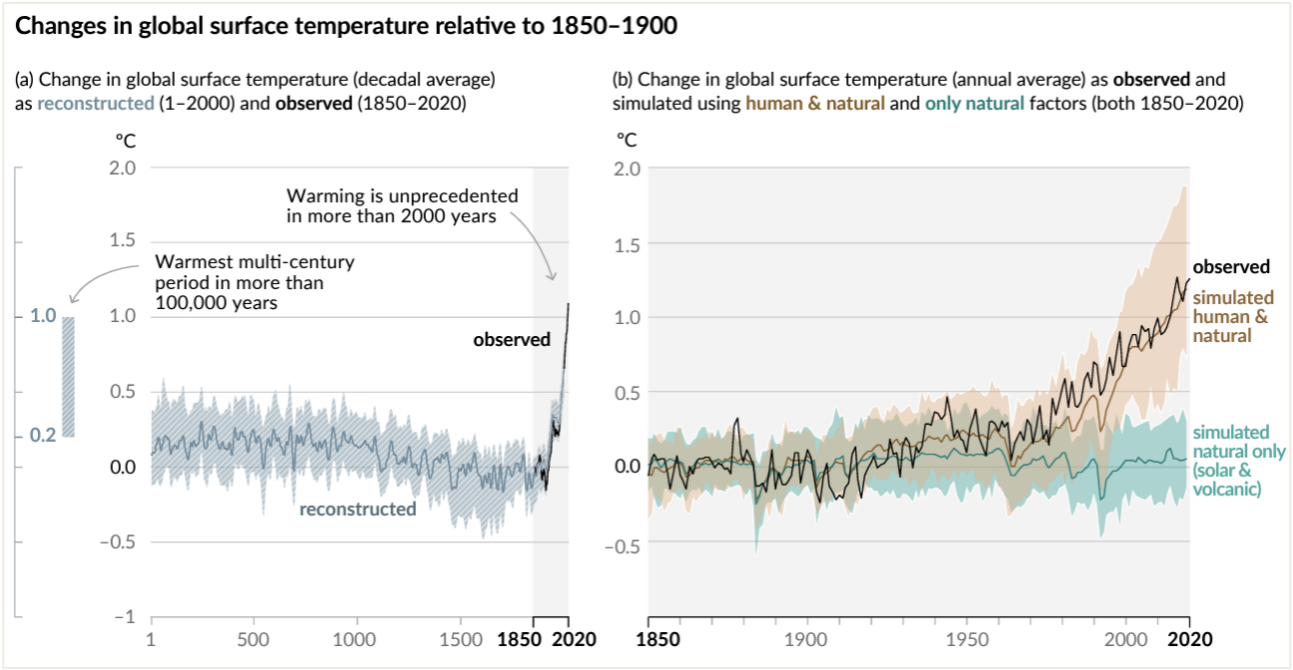
- **Section 9: Landscape and Ecosystem Vulnerability** – Provides an overview of natural resources susceptible to the adverse impacts of climate hazards.
- **Section 10: Conclusion** – Provides high-level takeaways and strategic pathways for the *Tucson Resilient Together* plan.

3 Global Climate Trends and Climate Vulnerability

3.1 Global Climate Trends

The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) describes human influence on climate as "unequivocal," explaining that global surface temperature has consistently risen over the last four decades. The impacts of anthropogenic climate change are far-reaching, from shifts in global precipitation patterns to oceanic warming to shifts in land biosphere and glacial retreat. Figure 1 below, pulled directly from the Summary for Policymakers of the Working Group I contribution to AR6, "Climate Change 2021: The Physical Science Basis," shows the "unprecedented" warming of the Earth's climate in the last 2000 years due to human influence.

Figure 1. History of global temperature change and causes of recent warming (IPCC AR6)[1]



[1] IPCC 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.3-32, doi: 10.1017/9781009157896.001.

Furthermore, the IPCC concludes that climate change is having observed impacts in "every inhabited region" around the world with respect to hot extremes, heavy precipitation, and agricultural and ecological drought. These observations, and their emergent concerns on behalf of the climate science community, have become increasingly stark over the last several IPCC reports, indicating not only that there is virtual certainty that humans are largely responsible for climate change, but that the projected impacts of climate change are being realized and becoming observable sooner than initially anticipated.

AR6 also provides a discussion of possible climate futures, based on climate models and projections with variable emissions outputs through mid- and end-of-century. The IPCC concludes that global surface temperature will continue rising through 2050 under all emissions scenarios, and that warming thresholds of 1.5°C and 2°C will be exceeded this century without substantive emissions reductions. These scenarios are discussed further in Section 5.

3.2 Climate Adaptation and Vulnerability

In Working Group II's contribution to AR6, "Climate Change 2022: Impacts, Adaptation, and Vulnerability," the IPCC assesses the impacts of climate change in the context of "ecosystems, biodiversity, and human communities at global and regional levels," examining specific vulnerabilities and the capacity of both human and natural environments to adapt as the climate changes. While the specific findings of this assessment are not covered in-depth here, the IPCC concludes that the adverse impacts of climate change have "caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability."[2] Furthermore, it explains that ecosystem and social vulnerability to climate change will differ among and within regions, and that "approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change."

Through this contribution, the IPCC also provides useful definitions that are critical to understanding the *Climate Risk and Vulnerability Assessment* for the City of Tucson. This Assessment adopts the definitions of these terms as defined by the IPCC in AR6.

- **Adaptation**: the "process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities."
- **Resilience**: the "capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or [reorganizing] in ways that maintain their essential function, identity, and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation."
- **Vulnerability**: the "propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity to susceptibility to harm and lack of capacity to cope and adapt."
- **Risk**: the "potential for adverse consequences for human or ecological systems, [recognizing] the diversity of values and objectives associated with such systems"

[2] IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press."

- **Hazard**: the "potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources."
- **Sensitivity**: the "degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)."
- **Exposure**: the "presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected."

4 Climate Risk and Vulnerability in Tucson

Tucson is considered a warm arid or semi-arid climate,[3] with average summer temperatures near or above 100°F and an average annual precipitation of 10.61 inches.[4] Tucson's annual average temperature high is 84°F, with the months of May through October having a higher long-term average, and the months of November through April having a lower long-term average. Spring and fall days tend to be mild with clear skies, although trends show higher temperatures that begin earlier in the year and end later.[5] Between 1991-2000, Tucson had an average of 68 days above 100°F.[6] Temperatures in Tucson are rising: the long-term average for Pima County is 66.8°F; however, almost every year since 1985 has had average annual temperatures exceeding that average. Projections show that average temperatures are likely to increase.[7]

Tucson has a dry spring and autumn, and a wet winter and summer. During the summer monsoon, Tucson receives southerly and south-easterly airflow from the Gulf of California and the Gulf of Mexico. This warm, moist air can trigger heavy, localized thunderstorms.[8] In 2008, the National Weather Service decided to consider June 15th through September 30th the official US Southwest monsoon.[9] Prior to that time however, the specific date of monsoon onset was defined by seasonal atmospheric patterns, specifically the average daily dewpoint temperature, which vary from year to year. Historically, the most common start date for the summer monsoon in Tucson was July 3rd, but it was documented to have started as early as June 17th (2000) and as late as July 25th (1987).[10] While Tucson receives the bulk of its precipitation in July and August, occasional tropical storms can move north from the Gulf of Mexico coast and bring rainfall in September.[11] Pima County has been in a drought since 1999,

[3] Peel, M.C., Finlayson, B.L., and McMahon, T.A. (2007). "Updated world map of the Koppen-Geiger climate classification." <https://hess.copernicus.org/articles/11/1633/2007/hess-11-1633-2007.pdf>.

[4] National Weather Service. (2022). "Tucson Monthly and Daily Normals (1991-2020)." <https://www.wrh.noaa.gov/twc/climate/tus.php>.

[5] Arizona State University and Arizona Department of Health Services. (2015). "Arizona Extreme Weather, Climate, and Health Profile Report."

[6] See Footnote #4.

[7] Meadow, A., LeRoy, S., Weiss, J., and Keith, L. (2019). "Climate Profile for The Highlands at Dove Mountain."

[8] See Footnote #5.

[9] Climate Assessment for the Southwest (CLIMAS). (n.d.). "Southwestern Monsoon." <https://climas.arizona.edu/sw-climate/monsoon>.

[10] National Weather Service. (2022). "Tucson Monsoon start date, occurrences by date (1946-2021)."<https://www.weather.gov/twc/monsoon>.

[11] See Footnote #5.

with almost every year since then experiencing a level of precipitation below the long-term average.[12] The drought has brought reduced winter precipitation and increased average winter temperatures.[13] However, precipitation in this area is naturally variable: while 2020 had the second-driest monsoon season on record, 2021 recorded the second-wettest.

Tucson has relatively light winds. However, during the monsoon, localized strong winds called microbursts can occur due to outflows from thunderstorms and straight-line winds. These winds can pick up and generate dust storms.[14]

5 Climate Hazards and Risk Assessment

This section first assesses climate hazards, identifying the climate hazards most pertinent to Tucson, as well as the present-day and projected changes in exposure to those hazards (where data are available). The hazards selected in this assessment include extreme heat, extreme precipitation, drought, wildfire, flooding, and other pertinent environmental conditions. Second, this section assesses risk by examining the specific probability and consequences of each hazard. Table 1 summarizes the hazards, variables, and projected change to be examined in this section.

Table 1. Climate hazards, variables, and projected change

	Climate Variables	Projected Change
Extreme Heat	Temperature	Warming
Wildfire	Temperature, Precipitation, Wind	Increasing
Drought	Temperature, Precipitation	Increasing
Precipitation	Precipitation	Variable
Flooding	Precipitation	Variable

5.1 Methodology

5.1.1 Climate Hazards and Concentration Pathways

Buro Happold selected the hazards included in this assessment based on findings from its *Existing Conditions Assessment*. The findings were drawn from reports already cited here, including the *Arizona Extreme Weather, Climate, and Health Profile Report* (2019) developed by Arizona State University (ASU) and the Arizona Department of Health Services (DHS) and the *Climate Profile for The Highlands at Dove Mountain* (2019), as well as the *Pima County Multi-*

[12] See Footnote #7.

[13] See Footnote #5.

[14] Ibid.

Jurisdictional Hazard Mitigation Plan (updated 2022) and the *Vulnerability and Risk Assessment: Recommendations* from the CAAC and UC3. Supplemental sources, detailed later in this Assessment and in the Addendum, include risk and resiliency assessments from Tucson Water and academic papers from the University of Arizona.

Climate hazards are assessed in the context of the Representative Concentration Pathways, or RCPs, which are IPCC-adopted GHG concentration trajectories. Like the Shared Socio-economic Pathways (or SSPs) covered in AR6, the RCPs indicate different, possible climate futures based on the volume of GHGs emitted in the coming decades. Four pathways were used in AR5, but they have since been expanded to include three additional pathways and are being considered together with the SSPs. In this Assessment, climate hazards are examined in historical (1971-2000), mid-century (2040-2069), and late-century (2070-2099) scenarios using the RCP 4.5 and RCP 8.5 scenarios. The former, RCP 4.5, is described by the IPCC as an intermediate moderate scenario, whereby emissions peak around 2040 and then decline. The latter, RCP 8.5, is a very high emissions scenario that indicates increases in GHG emissions through the 21st century. There are minimal differences between the two scenarios through 2050, but these two pathways side-by-side allow planners and policymakers to consider a moderate scenario, or RCP 4.5, side-by-side with a worst-case scenario, or RCP 8.5. It is important to note that these are still modelled, hypothetical scenarios, and that the speed and frequency of change in each scenario across all hazards will depend on how quickly and drastically emissions are mitigated in the short-term.

5.1.2 Risk Assessment

The risk assessment utilizes an approach developed by Buro Happold using the Global Covenant of Mayors for Climate & Energy (GCoM) Reporting Framework as a guide,[15] whereby a risk level is assigned to each hazard based on its probability (the likelihood of its occurrence) and its consequence (the outcome, impact, and/or gravity of the hazard), using the best available data and information. This included probability scoring from the Pima County Multi-Jurisdictional Hazard Mitigation Plan. This approach assesses each hazard's qualifying impacts, looking at their past impacts; their intensity, frequency, and timescale; anticipated future impacts; and vulnerable groups. Consequences are evaluated based on the consequences of past climate events and an understanding of social and physical sensitivity in Tucson. The outcomes of this Risk Assessment inform this and later sections of this report.

5.2 Extreme Heat

Extreme heat is the leading cause of weather-related mortality in the United States, even though most heat-related deaths are preventable through outreach and adaptation interventions.[16] In Climate Listening Sessions conducted in through 2021 and 2022 by the Mayor's Office, Tucson residents communicated that extreme heat was their top climate concern.[17] Tucson, like many other southwestern cities, saw rapid growth and development in the post-war era. Land cover change and waste heat

[15] Global Covenant of Mayors for Climate & Energy. (2019). "Guidance Note: Explanatory note accompanying the Global Covenant of Mayors Common Reporting Framework." <https://www.globalcovenantofmayors.org/wp-content/uploads/2019/08/Data-TWG_Reporting-Framework_GUIDENCE-NOTE_FINAL.pdf>.

[16] U.S. Environmental Protection Agency. (2021). "Climate Change Indicators: Heat-Related Deaths." <https://www.epa.gov/climate-indicators/climate-change-indicators-heat-related-deaths>.

[17] Tucson Mayor's Office. (2022). "Climate Listening Sessions Report."

emissions associated with this growth contributes to urban heat island effect and exacerbates extreme heat, particularly in low vegetated areas of the city.[18]

Prolonged exposure to heat can cause heat cramps, heat stroke, heat exhaustion, and death.[19] Heat can exacerbate symptoms associated with pre-existing health conditions, such as asthma and cardiovascular disease.[20] In addition to those with pre-existing health conditions, older adults, children, and outdoor workers are particularly vulnerable to the health consequences of extreme heat.[21] On average, there are 298 emergency room visits and 67 inpatient hospitalizations related to heat each year in Pima County.[22] It is important to note that these are documented cases of heat-related illness, as a greater number of cases go untreated.

Climate models indicate that the frequency, severity, and duration of Tucson's high heat days are projected to increase through mid- and late century, as shown in Figure 2. The annual average maximum temperature (AAMT) in Tucson between 1971 and 2000 was 85.6°F.[23] Under the RCP 4.5 scenario, the AAMT is projected to rise to 88.9°F by mid-century, and 90.7°F by late century. Under RCP 8.5, the AAMT is projected to rise to 90.8°F by mid-century, and 94.8°F by late century.

[18] Comrie, A.C. (2000). "Mapping a Wind-Modified Urban Heat Island in Tucson, Arizona." Bulletin of the American Meteorological Society, 81(10), 2417-2432. <https://doi.org/10.1175/1520-0477(2000)081<2417:MAWMUH>2.3.CO;2>.

[19] World Health Organization. (2018). "Heat and Health." <https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health>.

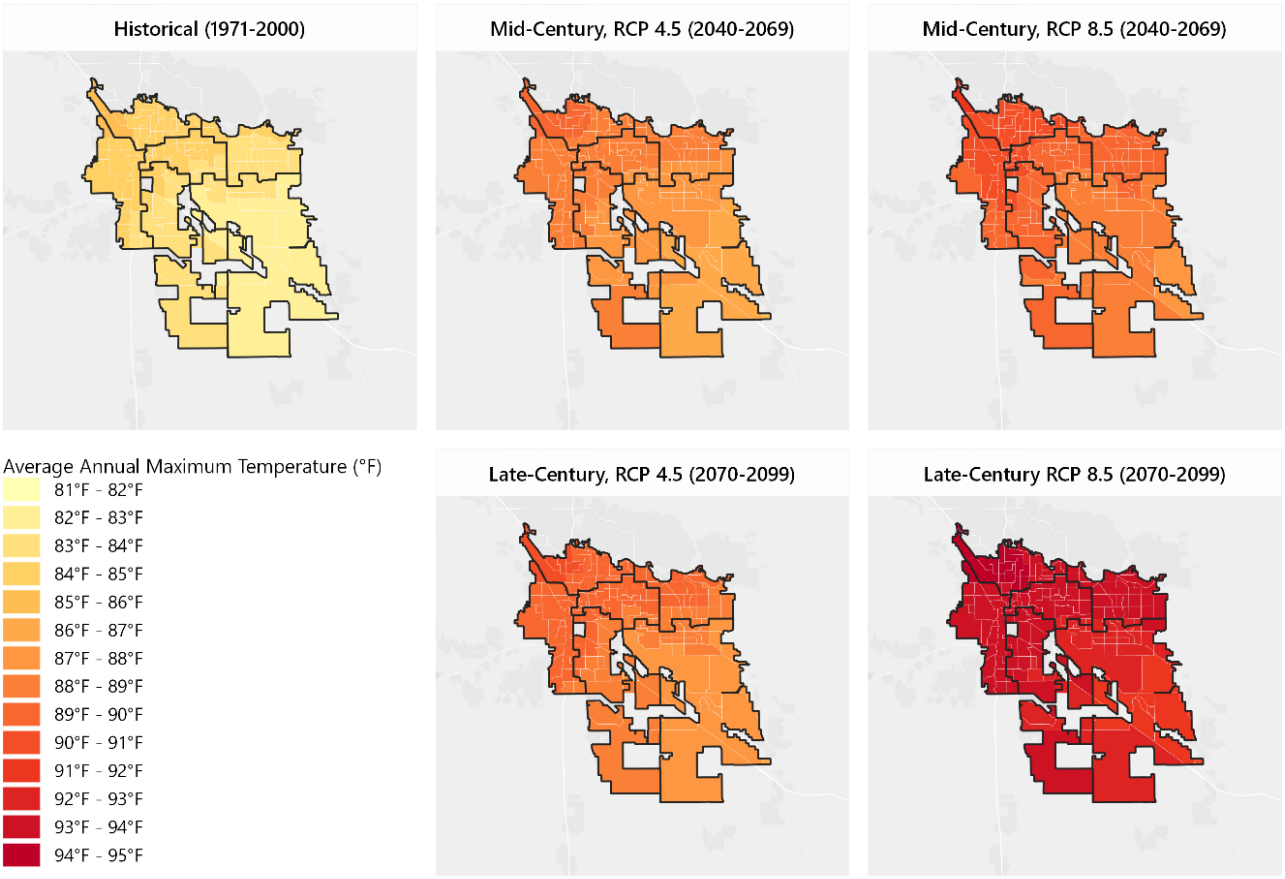
[20] U.S. Environmental Protection Agency. (2016). "Climate Change and the Health of People with Existing Medical Conditions." <http://www.cmu.edu/steinbrenner/ EPA%20Factsheets/existing-conditions-health-climate-change.pdf>.

[21] See Footnote #16.

[22] Arizona Department of Health Services. (2021). "Pima County Implementation and Monitoring Strategy (IMS) For: Heat-Related Illness." <https://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/extreme-weather/pubs/pima-county-heat-related-ilness.pdf>.

[23] Abatzoglou, J.T. and Brown, T.J. (2012). "A comparison of statistical downscaling methods suited for wildfire applications." International Journal of Climatology, 32, 772-780.

Figure 2. Average annual maximum temperature by area-weighted Census tract in Tucson



Data Source: Abatzoglou J.T. and Brown T.J. (2012). "A comparison of statistical downscaling methods suited for wildfire applications". International Journal of Climatology. With funding from the Regional Approaches to Climate Change, the Climate Impacts Research Consortium and the Northwest/SouthEast Climate Science Centers.

Recent record-breaking heat waves show that Tucson has experienced these changes to the climate. In June 2016, Tucson set its longest-ever streak of days of 115°F or higher, reaching 115°F on June 19th, 120°F on June 20th, and 115°F again on June 21st.[24] In September 2020, Tucson broke its record for the most days reaching or exceeding 100°F in a single year (108), breaking the previous record (99) set in 1994.

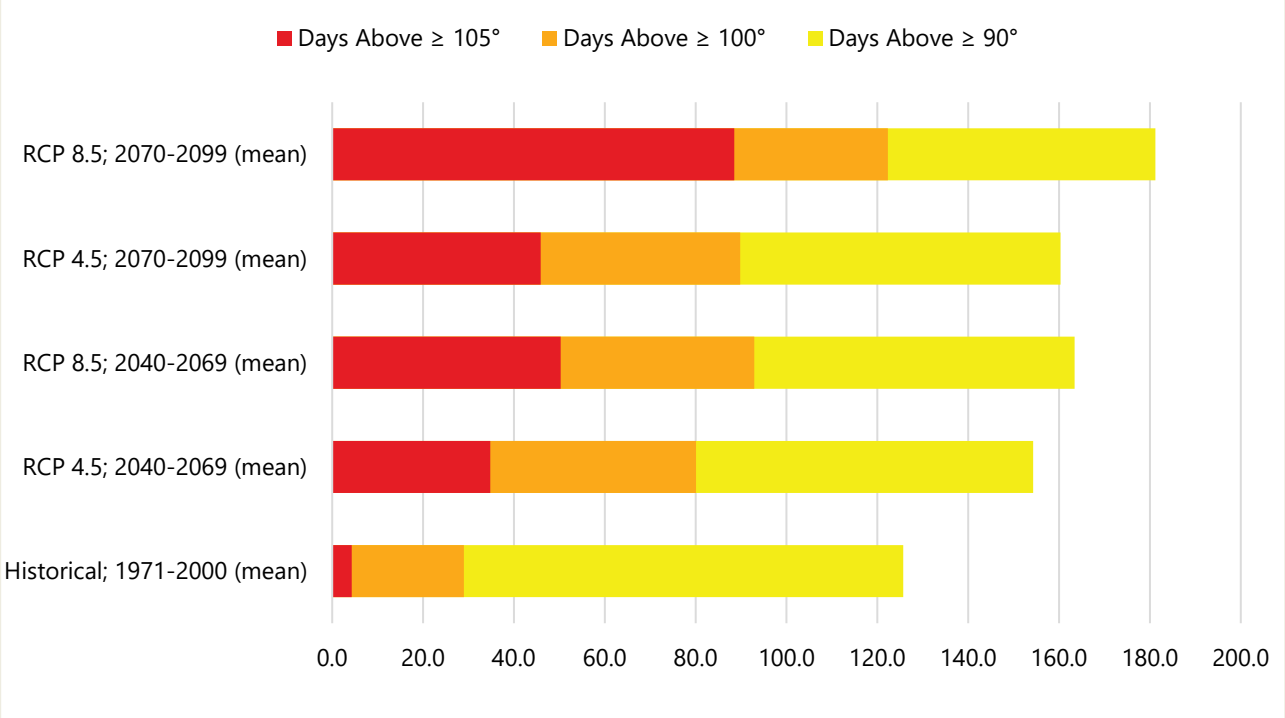
The National Weather Service defines an Excessive Heat Warning as when the maximum heat index temperature is expected to be 105°F or higher for at least two days, while night-time air temperatures do not drop below 75°F.[25] The mean number of days over 105°F between 1971 and 2000 was 4.3 days.[26] Under an RCP 4.5 scenario, this figure rises to 34.8 days by mid-century and 45.9 days by late century. Under RCP 8.5, the mean number of days rises to 50.3 by mid-century, and 88.5 days by late century.

[24] Pima County. (2017). "Pima County Multi-Jurisdictional Hazard Mitigation Plan."

[25] National Weather Service. (n.d.). "Heat Watch vs. Heat Warning. <https://www.weather.gov/safety/heat-ww>.

[26] Hegewisch, K.C., Abatzoglou, J.T., Chegwidden,O., and Nijssen, B. (2022). "Climate Mapper web tool." Climate Toolbox. <https://climatetoolbox.org>.

Figure 3. Historical and projected heat index in Tucson



5.3 Extreme Precipitation

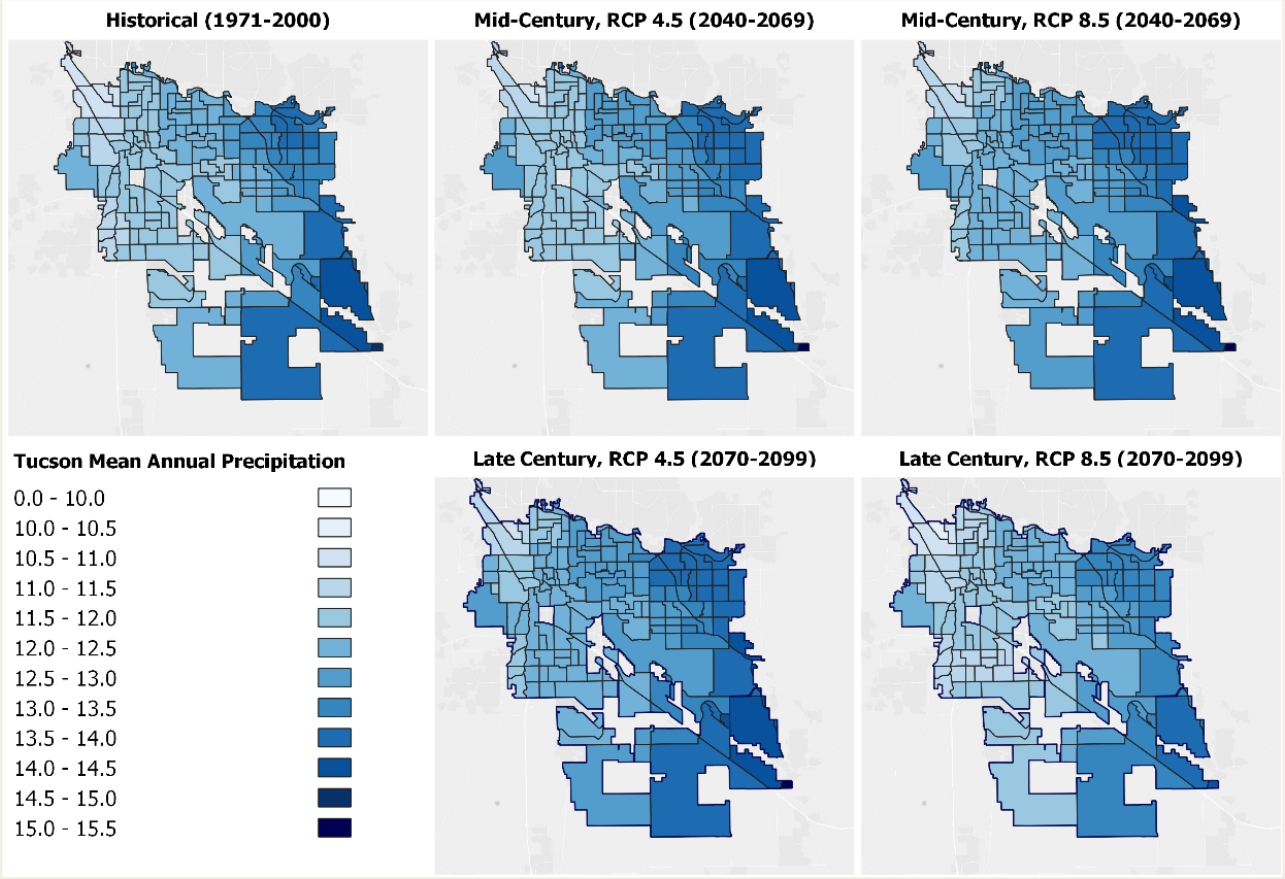
Even though Arizona's climate is classified as arid or semi-arid, the region's exposure to moisture surges from the Gulf of California and Gulf of Mexico, as well as to Eastern Pacific tropical systems, results in precipitation events during the summer monsoon from July through September. This contradictory climate pattern within the region has led to significant seasonal variability in extreme storm events, with up to 30% of annual precipitation being recorded in the months of July and August alone, while barely any rain falls between April and late June.[27]

As climate change progresses, the seasonal variability in rainfall will increase in severity at both extremes. This means Tucson is expected to experience both wetter storm events and more severe drought periods. In Tucson, the maximum annual precipitation depth (MAPD) between 1971 and 2000 was 14.88 inches with a median of 12.15.[28] Under RCP 4.5, the MAPD increases to 15.10 inches by mid-century and 15.24 inches by late century. Under RCP 8.5, the projected MAPD slightly increases to 14.90 inches by mid-century but decreases to 14.50 inches by late century.

[27] Arizona Department of Water Resources (2013). "Probable Maximum Precipitation Study for Arizona." <https://new.azwater.gov/sites/default/files/ArizonaPMPStudyFinalReport.pdf>.

[28] Climatology Lab (n.d.). "Multivariate Adaptive Constructed Analog (MACA) Dataset." <https://www.climatologylab.org/maca.html>.

Figure 4. Historical and projected annual precipitation in Tucson by Census tract[29]



With a standard deviation of 0.25, the historical and projected annual precipitation values do not vary greatly. However, it should be noted that annual precipitation values do not adequately capture the frequency and degree of extreme weather events, from very dry periods to severe storm events.

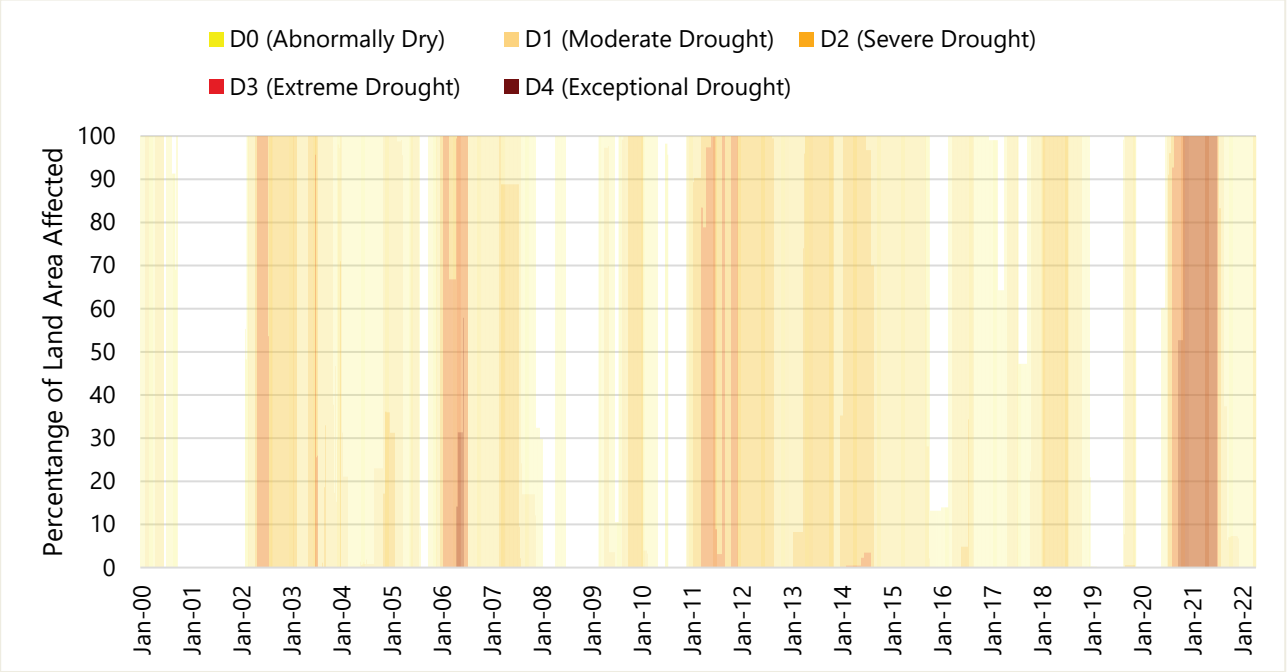
5.4 Drought

Drought is a regional hazard characterized by prolonged dry periods, resulting from abnormally low rainfall and abnormal temperature patterns. The presence of drought is typically measured using variables like precipitation, snowpack, and groundwater levels among others. Drought indices analyze this data over time to determine the severity, location, and duration of a drought.

[29] Buro Happold analysis of Abatzoglou J.T. and Brown T.J. A comparison of statistical downscaling methods suited for wildfire applications, International Journal of Climatology (2012), 32, 772-780.

In the Western United States, drought is a long-term concept; a single dry year does not constitute a drought.[30] Given Arizona's climate, extremely variable precipitation patterns are common. In this circumstance, a drought is characterized by multiple dry years, occasionally interrupted by a wet year. Drought conditions have been prevalent across Arizona since the mid-1990s.[31] Projected rise in temperature due to climate change and related decreases in snowpack increase likelihood of more frequent and more severe droughts in the Southwest in the future.[32]

Figure 4. Historical drought conditions in Tucson[33]



Tucson Water, the City's water provider, obtains water from four sources: the Colorado River (delivered through the Central Arizona Project aqueduct), groundwater, reclaimed water, and rain and stormwater harvesting. This means both local drought conditions (within the Southern Arizona region) and drought conditions throughout the Colorado River basin impact water resources for Tucson. Since the Central Arizona Project's opening in 1993, Colorado River water has largely replaced groundwater as the City's primary water source.[34] The Colorado River is experiencing reduced water inflow, causing the federal

[30] Arizona State Climate Office. (n.d.). "Arizona Drought." <https://azclimate.asu.edu/drought/>.

[31] Arizona Department of Natural Resources (2021). "Arizona Drought Preparedness." <https://new.azwater.gov/sites/default/files/media/ADPAR_2021.pdf>.

[32] USGCRP. (2018). "Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II." <https://nca2018.globalchange.gov>.

[33] United States Drought Monitor (USDM). "Tucson, AZ in US Drought Monitor Categories." <https://droughtmonitor.unl.edu/Data.aspx>.

[34] Tucson Water. (2020). "Drought Preparedness and Response Plan."

government to declare a water shortage and implement water supply cuts in 2022.[35] The Tier 1 shortage equates to 30% reduction of the Central Arizona Project's supply and results in less Colorado River water available for agricultural uses (due to the Project's prioritization system).[36] Current projections signal a potential Tier 2 shortage in 2023, which would reduce supply for municipal/industrial and tribal water users.[37]

There are 30 federally recognized tribes in the Colorado River basin region that depend on the river for agriculture, domestic and commercial uses, cultural and religious practices, economic development, power generation, wildlife, and ecological restoration (among other uses). Tribal communities have long-standing legal rights to the water in the basin, but there is a history of state governments excluding tribal governments from allocation negotiations.[38] Some tribal communities are unable to access their water allocation due to insufficient infrastructure and funding.[39] Drought-related supply constraints further exacerbate these challenges for tribal water users.

Drought can result in stress for communities, industry, natural systems, and infrastructure systems. Drought conditions can increase risk of wildfire and dust storms, negatively impacting air quality.[40] Reductions in water flows can increase the concentration of pollutants and cause stagnation. These environmental conditions can increase risk of contracting West Nile virus and Valley Fever. Drought-related water supply reductions can hit the agricultural industry hard, leading to fallow land, reduced income, and job losses. These consequences can result in higher food prices for Tucson families.

5.5 Wildfire

Tucson is grappling with significant wildfire risks. Fire is a natural and integral ecological process in southeast Arizona's sky islands. However, climate change and human-induced climate suppression have created larger and more intense fires that pose risks to local biodiversity, wildlife habitats, and human communities. Most recently, the 2022 Contreras Fire in the Baboquivari mountains spread over 24,761 acres and destroyed four buildings from the Kitt Peak Observatory, an astronomy research facility

[35] Fountain, H. (2021). "In a First, U.S. Declares Shortage on Colorado River, Forcing Water Cuts." The New York Times. <https://www.nytimes.com/2021/08/16/climate/colorado-river-water-cuts.html>.

[36] Arizona Department of Water Resources. (2021). "Colorado River Shortage Factsheet." <https://knowyourwaternews.com/wp-content/uploads/2021/09/CAP-Colorado-River-Shortage-Factsheet.pdf>.

[37] Central Arizona Project. (2021). "Adapting to Shortage: Colorado River Shortage." <https://www.cap-az.com/water/water-supply/adapting-to-shortage/colorado-river-shortage/>.

[38] M.E. Sakas. (2021). "Historically excluded from Colorado River policy, tribes want a say in how the dwindling resource is used. Access to clean water is a start." Colorado Public Radio. <https://www.cpr.org/2021/12/07/tribes-historically-excluded-colorado-river-policy-use-want-say-clean-water-access/>.

[39] Colorado River Research Group. (2021). "The Status of Tribal Water Rights in the Colorado River Basin." <https://www.getches-wilkinsoncenter.cu.law/wp-content/uploads/2021/04/Policy-Brief-1-The-Status-of-Tribal-Water-Rights.pdf>.

[40] Center for Disease Control and Prevention. (2020). "Drought and Public Health in the US." <https://www.cdc.gov/nceh/multimedia/infographics/drought_public_health.html>.

with one of the largest telescope collections in the northern hemisphere.[41,42] In June 2020, the Bighorn Fire in the Catalina Mountains burned nearly 120,000 acres of wilderness.[43] It took over a month to contain the fire, with the help of rain from monsoons. The fire significantly damaged wildlife habitats and negatively impacted air quality and water runoff that summer.

Wildfire risk is impacted by a variety of indicators, including precipitation, drought, wind, heat, topography, and vegetation. Wildfire risk is increasing due to heat and drought conditions related driven by climate change.[44] Pima County's existing plans identify the higher elevations of the Baboquivari, Rincon, and Santa Catalina mountains as the focus areas for wildfire intervention. Wildfire risk in the region includes forests, shrublands, and grasslands. While the major landcover within the city itself is designated as "impervious," the open lands near the Tucson International Airport, I-10 by Houghton Road, and the Pima County fairgrounds are at moderate to high wildfire risk. Homes that are located within the wildland-urban interface, or the zone of transition between unoccupied wildland and urban or suburban development, are also at elevated risk.

The First Street Foundation National Wildfire Model incorporates USDA Forest Service topographic data, climate projections, and historic patterns of property damage observed in 2,500 historic wildfires to measure wildfire risk. The model projects that 120,279 properties in Tucson, about 68 percent of the properties in the city, will be at some level of wildfire risk in 30 years.[45] The recent development growth in the Tucson area creates impacts from wildfire extend beyond property damage. Wildfire smoke contains particle pollution that can cause eye and respiratory tract irritation and exacerbate pre-existing respiratory and cardiovascular conditions.

[41] Arizona Emergency Information Network. (2022). "Contreras Fire: evacuations issued, increase in activity seen last night." <https://ein.az.gov/emergency-information/emergency-bulletin/contreras-fire-evacuations-issued-increase-activity-seen>.

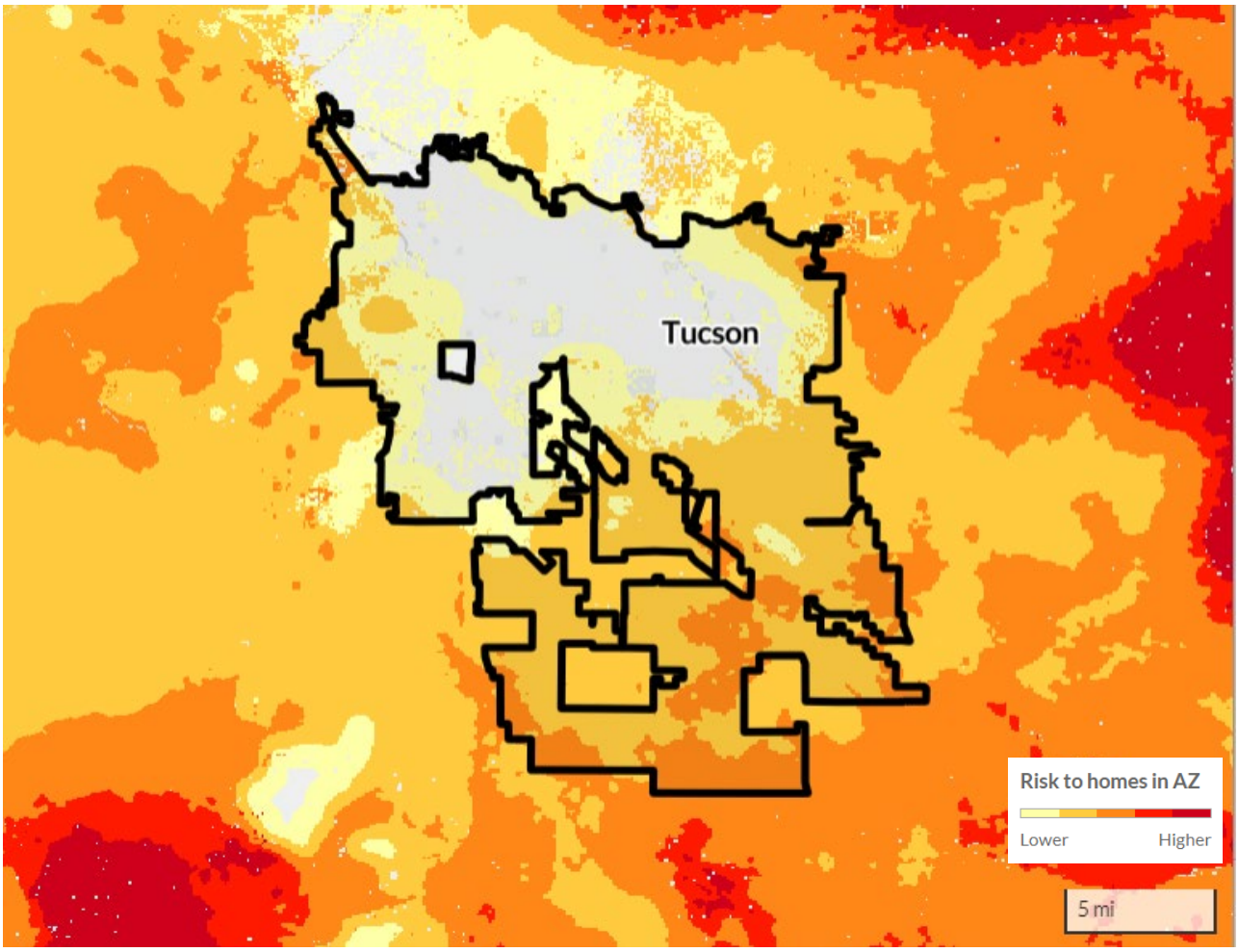
[42] Hill, S. 2022. "Fire reaches Kitt Peak National Observatory, destroys multiple structures." Astronomy. <https://astronomy.com/news/2022/06/fire-reaches-kitt-peak-observatory-destroying-multiple-structures>.

[43] Pima County Public Library. 2022. "Fires – Tucson and Pima County." <https://www.library.pima.gov/content/fires-tucson-and-pima-county/>.

[44] Mueller, S. E., Thode, A.E., Margolis, E.Q., Yocom, L. L., Young, J.D., and Iniguez, J. M. (2020). "Climate relationships with increasing wildfire in the southwestern US from 1984 to 2015." Forest Ecology and Management, 460(15). <https://doi.org/10.1016/j.foreco.2019.117861>.

[45] First Street Foundation. (2022). "Does Tucson have risk?" <https://riskfactor.com/city/tucson/477000_fsid/fire#wildfire_risk_overview>.

Figure 6. Wildfire Risk to Homes in Tucson, AZ[46]



5.6 Flooding

Due to the incidence of heavy rainfall in the summer months, steady expansion of impervious land cover through development, changing ground conditions due to increased wildfire occurrence, as well as the city's surrounding mountain ranges, Tucson faces multiple flooding hazards including flooding within city streets, riverine flooding, and flash flooding. Additionally, Tucson was historically built without underground stormwater infrastructure. When first built, designated streets, usually overlapping with natural washes, were designed as inverted crowned conduits to carry stormwater out to surrounding riverbeds. This historic dependence on streets to act as the conduits for stormwater has exacerbated street flooding issues over time as impervious land cover increased. Between 1983 and 2012, the city experienced 16 flood events with significant economic and environmental

[46] U.S. Department of Agriculture – Forest Service (n.d.) "Wildfire Risk to Communities. <https://www.fs.usda.gov/managing-land/fire/wildfirerisk>.

impacts, including severe damage to bridges spanning the Santa Cruz River.[47] In 2010, two heavy storm events resulted in storm-wide damages of up to $800,000 including water rescues in the Tucson Metro Area.[48]

With the potential increase in the magnitude and intensity of extreme storm events due to climate change, more frequent flash flooding and stream overflows can be expected. As temperatures increase and soils become drier, the capacity for infiltration reduces as drier soils generally store more water. Thus, runoff may be expected to increase, worsening the outlook on flash flooding and the negative impacts of stormwater runoff.[49] Furthermore, new developments are likely to be situated on the outskirts of the city which correspond to areas with old or outdated Special Flood Hazard Area designations, thus limiting flood risk management.[50]

Figure 7 features the Federal Emergency Management Agency (FEMA) Special Flood Hazard High-Risk Areas, showing which parts of the city are in the floodplain and are expected to experience flooding in the event of a 100-year storm. The map also outlines flood hazard areas that have historically experienced flash flooding as reported by Tucson residents. It should be noted that the FEMA Flood Hazard analysis does not consider climate projections and, as a result, does not capture the full extent of flooding potential in the region.

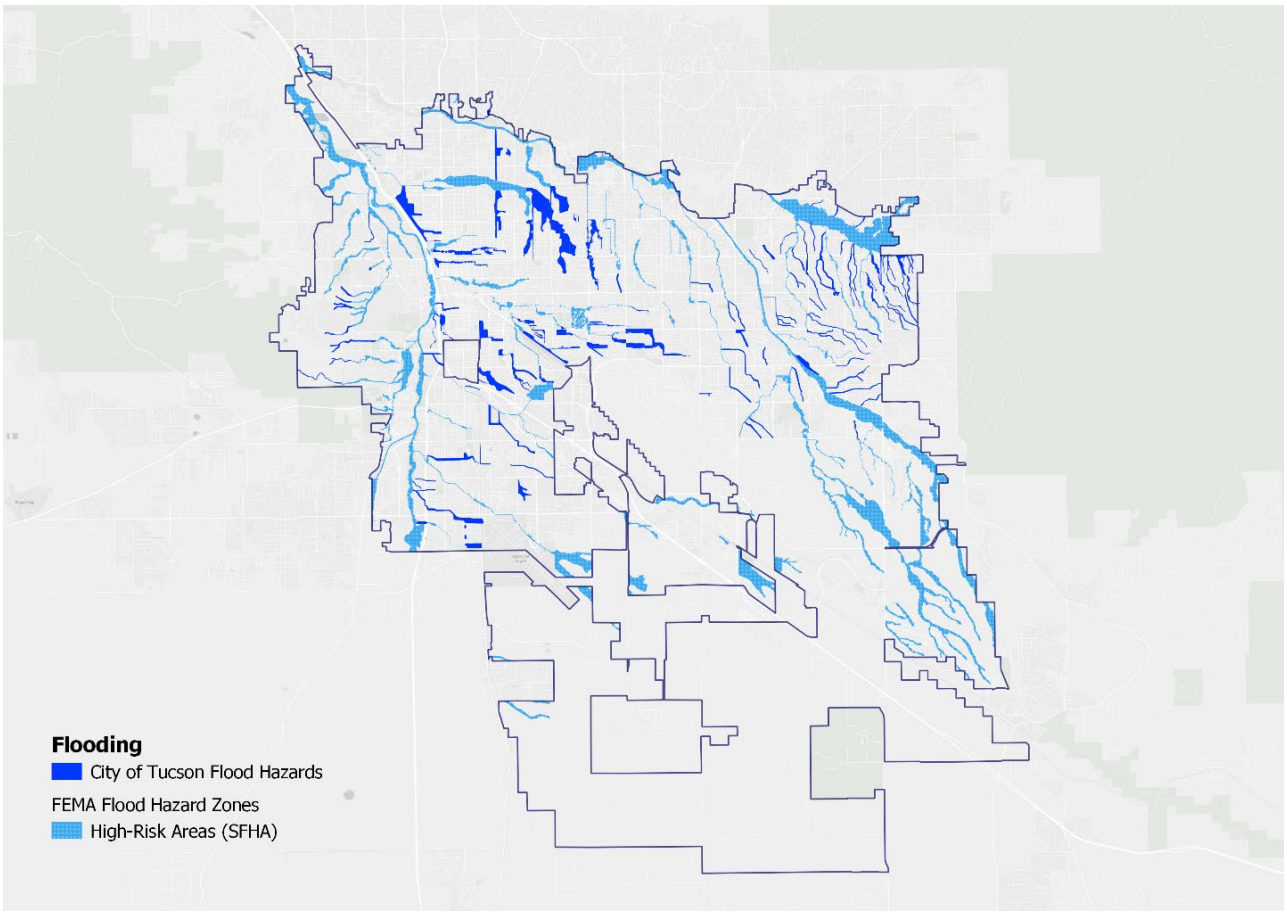
[47] City of Tucson. (2016). "Resolution No. 22619: Relating to Floodplain Management: Updating the 1990 Version of the Tucson Stormwater Management Study (Phase 5) by Adopting the New 2016 Tucson Floodplain Management Plan; and Setting an Effective Date." <https://www.tucsonaz.gov/files/pdsd/Resolution-22619_TucsonFMP.pdf.>

[48] City of Tucson (n.d.). "Floods and Flash Floods." <https://www.tucsonaz.gov/em/floods-and-flash-floods>.

[49] Powell, B. F. (2010). "Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges."

[50] See Footnote #41.

Figure 7. FEMA Special Flood Hazard High-Risk Areas and Flood Hazard Areas in Tucson



Per a hazard assessment conducted as part of the Tucson Floodplain Management Plan, the following are designated as Tucson's flood vulnerability classes, listed from most vulnerable to least vulnerable:

- Public infrastructure conveyance;
- Flood areas with utility/municipal structures;
- Urban high-density flood areas;
- Private drainage infrastructure;
- Natural floodplains;
- Vegetated associated flood hazards; and
- Geomorphological flood hazards.[51]

[51] Tucson Floodplain Management Plan Resolution-22619_TucsonFMP.pdf (tucsonaz.gov)

5.7 Additional Environmental Conditions

5.7.1 Air Quality

Air quality is a serious public health concern in Tucson. In 2021, Tucson was ranked the 10th most challenging city to live in for people with asthma, according to the Asthma and Allergy Foundation of America. Rising temperatures will amplify threats to air quality, including ozone (smog) formation and particulate matter (PM) emissions from wildfire.[52]

In the case of the former, while ozone is not a directly emitted pollutant, it is formed by nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of heat and sunlight. Consequently, sunnier and warmer days tend to result in the production of more ozone than on cooler or overcast days.[53] Ozone levels are significantly associated with respiratory-related hospital admissions.[54] In extreme cases, ozone can trigger heart attacks by causing the lungs to bleed.[55] Excessive atmospheric ozone may exacerbate asthma in children.[56]

In the case of PM emissions from wildfire, the combustion of organic matter and the resulting PM emissions into the atmosphere can significantly impact air quality in airsheds that span miles.[57] These emissions have been linked to health impacts such as asthma, heart disease, and lung disease. Degraded air quality due to wildfire also has the most severe impacts on firefighters, who must spend time at proximity to fires.[58] To address a growing need for firefighters, the State of Arizona has increasingly turned to inmate firefighters, training over 700 inmates in 2021 alone.[59]

5.7.2 Disease Vectors

Rising temperatures are associated with the rise of certain disease vectors. These include changes in mosquito populations, including *Culex spp.* mosquitoes (capable of carrying West Nile Virus) and *Aedes aegypti* mosquitoes, (capable of carrying Zika and Yellow Fever), as well as certain fungi populations, such as the *Coccidioides spp.* fungus (which can cause Valley Fever).

In the case of mosquito populations, these are projected to be highly spatially heterogeneous and dependent on local climate and moisture projections. In Arizona, while mosquito breeding season is likely to extend due to climate change, midsummer populations are likely to significantly decrease.[60] Mosquito-borne diseases, such as West Nile Virus,

[52] Diviant, J. (2021). "Health Impacts of Wildfire Smoke as a Consequence of Climate Change and Recommendations for Public Health Officials and the General Public in the Albuquerque Metropolitan Area." <https://digitalrepository.unm.edu/cgi/viewcontent.cgi?article=1015&context=hsc_climate>.

[53] Requia, W.J., Coull, B.A., and Koutrakis, P. (2020). "Where has air quality been impacted by weather changes in the United States over the last 30 years?" <https://doi.org/10.1016/j.atmosenv.2020.117360>.

[54] Diem, J. and Cormie, A. (2010). "Air Quality, Crime, and Policy: A Case Study of Ozone Pollution in Tucson, Arizona."

[55] Horn-Muller, A. and Davis, T. (2019). "As Temperatures Rise in Tucson, So Do Concerns Over Health Risks Linked to Higher Ozone Risks."

[56] White, M.C., Etzel, R.A., Wilcox, W.D., and Lloyd, C. (1994). "Exacerbations of childhood asthma and ozone pollution in Atlanta."

[57] Neary, D.G. and Leonard, J.M. (2021). "Physical Vulnerabilities from Wildfires: Flames, Floods, and Debris Flows."

[58] Ibid.

[59] Skabelund, A. 17 March 2021. "Arizona to train 700 inmates as wildland firefighters." FireRescue1. <https://www.firerescue1.com/inmate-firefighters/articles/arizona-to-train-700-inmates-as-wildland-firefighters-ikFUy25EIJVr9Q7s/>.

[60] Brown, H.E. et al. (2015). "Projection of Climate Change Influences on U.S. West Nile Virus Vectors."

Dengue Fever, Zika, and Yellow Fever are very uncommon in Tucson.[61] The most recent notable outbreak in Arizona was in 2019, when 174 cases of West Nile Virus were diagnosed (the majority of which were in Maricopa County). However, despite the low risk, caution should be taken as many of these diseases have no vaccine.[62] With these trends in mind, it is important to be cautious when implementing climate adaptation and resource solutions such as green stormwater infrastructure, which may create breeding grounds for mosquitoes if improperly cared for. A 2022 study found evidence that bioretention basins in Tucson, designed to hold water for longer than 12 hours, functioned as breeding grounds for *Aedes aegypti* mosquitoes.[63] Consequently, design decisions must be balanced with vector control.

As with fungi populations, the *Coccidioides spp*. fungus is endemic to the southwestern United States, and thrives most in climatic cycles with a wet season that allow it to proliferate, followed by a dry season allowing soil containing the fungus to turn to dust.[64,65] Contrary to popular narrative, Valley Fever incidence is not linked to frequency of dust storms.[66] However, Valley Fever is a serious disease and risk to the residents of Tucson and Arizona at large. Valley fever killed 39 Arizona residents in 2019, but it is chronically underreported. While records show that Arizona made up about two-thirds of total cases in the United States between 2011 and 2017, the actual number of symptomatic cases could be anywhere from six to 14 times higher than reported. About 60% of cases are asymptomatic. It is important to note that people of color are more likely to experience severe forms of Valley Fever,[67] and that Valley Fever presents a significant economic burden: costs associated with direct and indirect expenditures related to all Arizona Valley Fever cases in 2019 totaled $736 million, including the costs of hospitalizations, home care, complications, and lost wages.[68]

5.7.3 Water Quality and Supply

The City of Tucson currently receives most of its water supply from the Central Arizona Project, which delivers about 1,850,000,000 cubic meters (149,982 acre-feet) of water annually from the Colorado River to Tucson Water.[69] This imported water makes up a significant portion of the City's Greenhouse Gas Emissions. Currently, Tucson does not use its total allocation of water from the Project. Surplus water is banked in the groundwater supply for future use,

[61] Greaber, J. (2021). "Arizona Mosquitoes 101: The different species and how to protect yourself."

[62] The University of Arizona – Risk Management (n.d.). "Mosquito & West Nile Virus." <https://risk.arizona.edu/campus-safety/mosquito-and-west-nile-virus>.

[63] Brown, H.E., Keith, L., Madera-Garcia, V., Taylor, A., Ramirez, N., and Ogata, I. (2022). "Greening Up For Mosquitos: A Comparison of Green Stormwater Infrastructure in a Semiarid Region."

[64] Weaver, E.A. and Kolivras, K.N. (2018). "Investigating the Relationship Between Climate and Valley Fever (Coccidioidomycosis)."

[65] Gorris, M.E., Treseder, K.K., Zender, C.S., and Randerson, J.T. (2019). "Expansion of Coccidioidomycosis Endemic Regions in the United States in Response to Climate Change."

[66] Comrie, A.C. (2021). "No Consistent Link Between Dust Storms and Valley Fever (Coccidioidomycosis)."

[67] Montanari, S. (2021). "Arizona leads nation in Valley fever infections – a 'disease of color'."

[68] Grizzle, A.J., Wilson, L., Nix, D.E., and Galgiani, J.N. (2021). "Clinical and Economic Burden of Valley Fever in Arizona: An Incidence-Based Cost-of-Illness Analysis."

[69] Megdal, S.B. and Forrest, A. (2015). "How a Drought-Resilient Water Delivery System Rose out of the Desert: The Case of Tucson Water."

although the Tucson City Council voted unanimously to reduce allocations to replenish water levels at Lake Mead.[70] As of 1992, Tucson has reduced its reliance on groundwater to about 200 wells. Thus, while current rates of subsidence in the Tucson Basin are higher than early- and mid-20th century rates, the current rate of subsidence is declining, and it is not sufficient to affect recharge basin capacity or morphology.[71] Furthermore, climate change is already impacting water levels in the Colorado River, the source of the Central Arizona Project's water. The Colorado River is mostly supplied by melted snowpack from the Colorado Mountains, which is yielding lower amounts of runoff due to increased temperatures and drier soils.[72] Increasing pressures on Tucson's water sources make sourcing safe drinking water a balancing act. If Colorado River water allocations continue at their current rate, Lake Mead is likely to dry up, and the Hoover Dam will not produce electricity.[73]

Some of Tucson's groundwater supply is being impacted by polyfluoroalkyl substances (PFAS) contamination. PFAS chemicals, which are associated with increased risk of cancer, reproductive issues, and hormonal issues, do not break down in water and are considered a health hazard by the U.S. Environmental Protection Agency (EPA).[74] The toxicity of PFAS is still being understood, but the EPA has set its safe lifetime PFAS exposure limit to 70 parts per trillion. The Tucson Airport Remediation Project (TARP) water treatment plant, which served 60,000 Tucson Water customers, was shut down in 2021 due to difficult-to-treat PFAS concentrations that were above the EPA's recommendation for a safe lifetime dose for drinking water. 18 drinking water wells were also shut down in 2018.[75]

To treat its imported surface water, Tucson relies on shallow spreading basins to infiltrate into the groundwater supply. This entails a process by which nitrates, dissolved organic carbon, and total organic halide are naturally filtered from the water.[76] Depending on precipitation patterns, protracted periods of drought exacerbated by climate change can have long-term impacts on groundwater recharge rates. A 2016 analysis of groundwater recharge in California's San Joaquin Valley after the millennium drought of 2012-2015 found a potential aquifer storage loss of up to 3.25% because of the drought.[77] This could impact Tucson's ability to treat its reclaimed water and imported surface water and result in longer turnaround times between spreading and availability. Increased wildfires can also have an impact on water quality. Soil exposed to the extreme heat of wildfires can dry up and erode, artificially increasing the amount of sediment in the water and degrading water quality.[78]

[70] Kelty, B.L. (2022). "Tucson offers to turn off tap on some Colorado River water to try to save Lake Mead."

[71] Carruth, R.L., Kahler, L.M., and Conway, B.D., 2018. "Groundwater-Storage Change and Land-Surface Elevation Change in Tucson Basin and Avra Valley, South-Central Arizona – 2003-2016."

[72] Sakas, M.E., 2022. "Colorado's snowpack is starting to melt. Warmer temperatures and drought likely mean another year of struggling water supplies."

[73] See Footnote #64.

[74] Arizona Department of Environmental Quality. (2022). "ADEQ Announces Actions to Protect the City of Tucson's Drinking Water Supply."

[75] Davis, T. (2021). "Soaring Contamination Causes Shutdown of Tucson Water Treatment Plant."

[76] Wilson, L.G., Amy, G.L., Gerba, C.P., Gordon, H., Johnson, B., and Miller, J., 1995. "Water quality changes during soil aquifer treatment of tertiary effluent."

[77] Ojha, C., Werth, S., and Shirzaei, M., 2019. "Groundwater Loss and Aquifer System Compaction in San Joaquin Valley During 2012-2015 Drought."

[78] Pima County. (2017). "Pima County Multi-Jurisdictional Hazard Mitigation Plan."

5.7.4 Food and Agriculture

As temperatures rise and precipitation potentially decreases, agriculture, a water-dependent industry, will be impacted. While irrigated agricultural land may not immediately reflect the effects of drought due to the artificial presence of moisture, increased demand for and lowered supply of water can significantly affect the agricultural industry.[79]

Pima County only makes up 2% of the total agricultural sales for the State of Arizona. However, its neighbor, Pinal County, is a major producer in the state. Pinal County farmers are currently in the process of reducing their dependence on Central Arizona Project water and switching to groundwater.[80,81] Pima and Pinal Counties share a groundwater basin, the Avra Basin, so competition over water use may encourage some farmers to relocate.[82,83]

Increased temperatures will also require farmers to reconsider what crops they choose to grow. Tucson is a hub for agricultural innovation on climate-adapted crops.[84] Researchers have found promising paths forward by re-examining both agricultural practices and crop cultivation. Drawing on biomimicry and Indigenous or traditional ecological knowledge may help to develop arid-adapted, resilient systems.[85]

6 Social Vulnerability Assessment

While climate hazards pose risk to all Tucson residents, certain populations are and will be more susceptible than others. Social vulnerability describes the conditions determined by physical, social, economic, and environmental factors that affect the susceptibility of individuals, communities, and/or population groups to the impacts of climate hazards. In this context, vulnerability is not an indicator of an individual's weakness or incapacity to cope, but instead an indicator of the factors that put them at greater risk of negative impacts. Historical and ongoing injustices, including housing discrimination, segregation, and land disposition, created many of the environmental conditions that make vulnerable communities susceptible to climate hazards today. Key factors that influence social vulnerability include, but are not limited to:

- inequities in infrastructure and access to the benefits of education, living wages and income, economic opportunity, social capital, healthcare, and/or other services;
- institutionalized bias or exclusion from political and decision-making power;
- inequities in environmental and living conditions and health status;

[79] Anderies, J.M., Smith-Heisters, S., and Eakin, H., 2020. "Modeling interdependent water uses at the regional scale to engage stakeholders and enhance resilience in Central Arizona."

[80] Dungan, R., 2021. "Pinal County Farmers Brace for Central Arizona Project Water Cuts."

[81] Wilcox, M., 2019. "As Water Sources Dry Up, Arizona Farmers Feel the Heat of Climate Change."

[82] Rascona, S.J., 2003. "Hydrologic Map Series Report Number 36." Arizona Department of Water Resources.

[83] Anderies, J.M., Smith-Heisters, S., and Eakin, H., 2020. "Modeling interdependent water uses at the regional scale to engage stakeholders and enhance resilience in Central Arizona."

[84] Brean, H., 2020. "University of Arizona Researchers Unveil New Model for Desert Farming in a Warming World."

[85] Nabhan, G.P. et al., 2020. "An Aridamerican model for agriculture in a hotter, water scarce world."

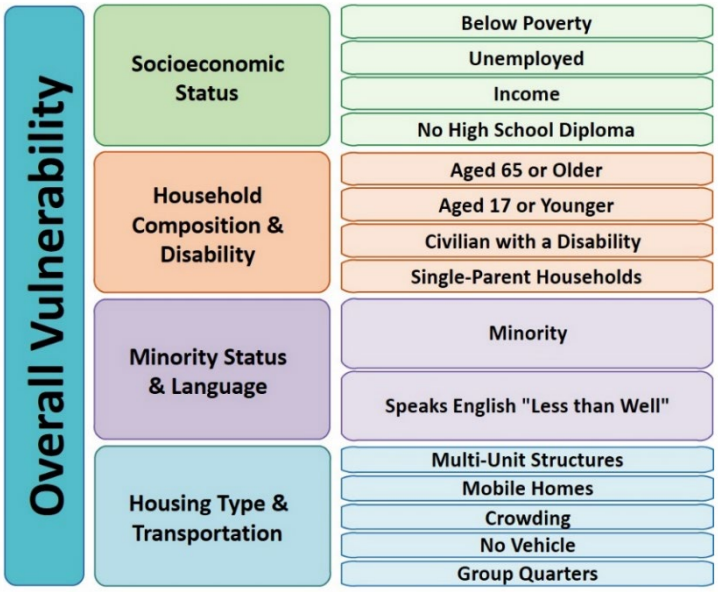
- and differences in individual health, age, and ability.

Future climate adaptation actions and related investments in infrastructure and services will need to incorporate the analysis of present and future social vulnerabilities to best address the needs of the communities most at risk.

6.1 Social Vulnerability Index

Social vulnerability is a nuanced concept that is best measured using both qualitative and quantitative methods. Buro Happold conducted quantitative analysis to understand the geographic distribution of people with specific characteristics that are documented to increase vulnerability to climate hazards. For this initial analysis, Buro Happold used the Center for Disease Control / Agency for Toxic Substance and Disease Registry's 2018 Social Vulnerability Index (CDC/ATSDR SVI).[86] The SVI utilizes 15 American Community Survey variables across four main areas: socioeconomic status, household composition, race/ethnicity/language, and housing/transportation (see Figure 8). The index is a composite score of those indicators and is calculated at the Census tract level. Spatializing this data enables the cross-referencing of vulnerable areas with climate hazard projections and identify priority areas for future adaptation and resilience actions.

Figure 8. American Community Survey indicators used to construct the CDC/ASTDR SVI and its four themes[87]



[86] While the U.S. Census has released American Community Survey data for 2020, the most current SVI results available at the Census tract level are for 2018.

[87] Center for Disease Control – Agency for Toxic Substances and Disease Registry (n.d.). "CDC/ATSDR Social Vulnerability Index. <https://www.atsdr.cdc.gov/placeandhealth/svi/index.html>.

The CDC/ATSDR SVI was developed for disaster mitigation response, and the 15 variables reflect the sociodemographic characteristics of those observed to have limited ability to respond, cope, and recover from a disaster.[88] However, there are characteristics referenced in climate vulnerability literature that are not included in CDC/ATSDR SVI 15 variables, such as gender. Domestic responsibilities disproportionately placed on women, like childcare and family caregiving, add additional obstacles while navigating a climate event. Women also make up the majority of essential workers, who are often at the frontlines of health and environmental crises.[89]

In tandem to this quantitative analysis, Buro Happold and Living Streets Alliance are undertaking an extensive community engagement process. This outreach includes stakeholder interviews with the Mayor, City Council representatives and key City departments; targeted pop-up events; public workshops; small group community dialogues; and leveraging a team of community promotores. Insights from these outreach methods will fill in the gaps to understanding the Tucson's strengths and weaknesses related to climate vulnerability.

[88] Flanagan, B. E. et al., 2011. "A Social Vulnerability Index for Disaster Management." Journal of Homeland Security and Emergency Management. <https://svi.cdc.gov/A%20Social%20Vulnerability%20Index%20for%20Disaster%20Management.pdf>.

[89] Robertson, C. and Gelbeloff, R., 2020. "How Millions of Women Became the Most Essential Workers in America." The New York Times. <https://nyti.ms/3vqUCtM>.

Figure 9. CDC/ASTDR Social Vulnerability Index mapped at the Census tract level in Tucson, AZ

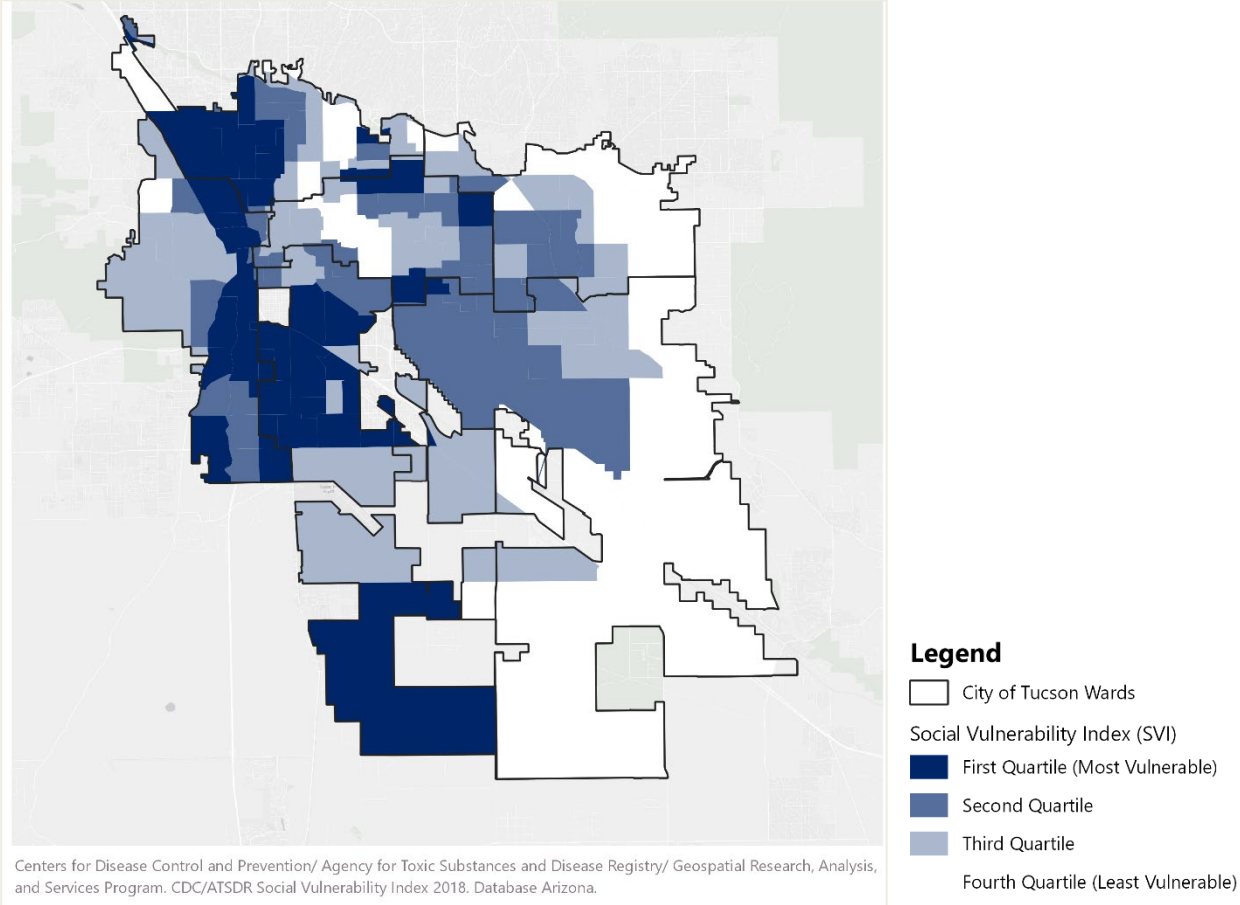


Figure 9 shows the composite results of the index. Tucson's Census tracts are organized from most to least vulnerable and divided into four groups of more-or-less equal number, or quartiles. The first quartile (top 25%), represented in the map by the darkest blue color, represent the most vulnerable Census tracts. These tracts cluster towards the northwest portion of the city, particularly in Wards 5, 1, and 3.

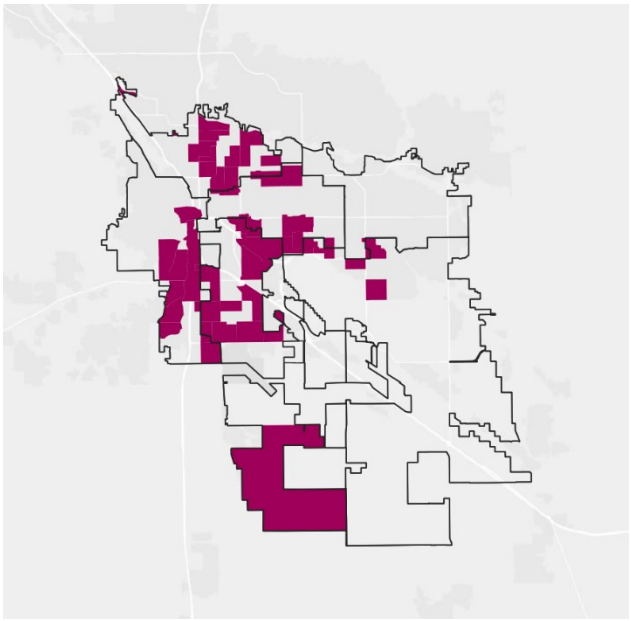
6.2 Vulnerable Populations

The CDC/ASTDR SVI offers one narrative of social vulnerability in Tucson by compiling data into a single metric, but disaggregating the variables reveals additional narratives. Census tracts where concentrations of vulnerable populations in each group fall in the top quartile (25%) of Census tracts are highlighted in a series of maps (Figures 10-17), using eight variables from the original index. Table 2 links each variable to relevant hazards and its corresponding data description from the American Community Survey. Table 3 details the population estimates and percentages for each variable in Tucson.

6.2.1 People living below the poverty line

People experiencing low household income or poverty can have limited access to amenities and resources, such as internet or mobile phone data, necessary for communicating information during an extreme weather event or climate emergency. Limited income can mean greater financial instability and related stress when faced with unexpected pressures. A single fire or flood could lead to a forced move or houselessness. Prolonged air conditioning use increases energy costs, forcing Tucson households to make tough compromises between cooling their homes and paying for basic needs.[90] This can increase risk of mortality during extreme heat events.

Figure 10. Population estimate of individuals whose household income was below the poverty level in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)

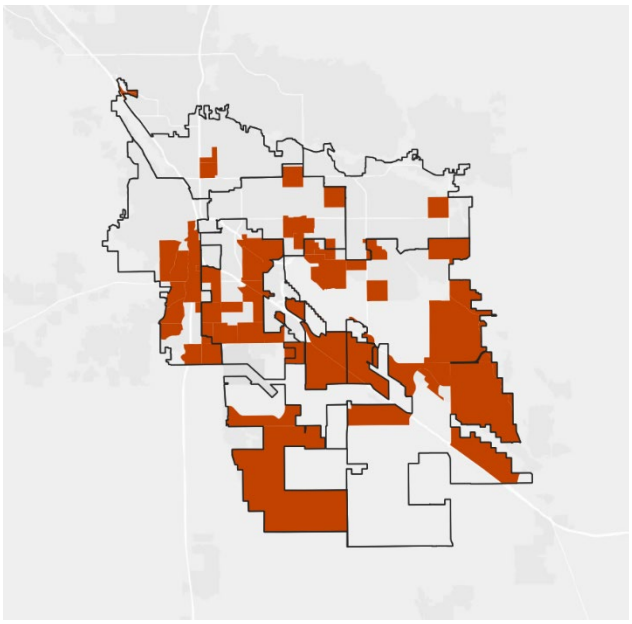


[90] Tucson Mayor's Office, 2022. "Climate Listening Sessions Report."

6.2.2 Children

Children are incredibly sensitive to changes in their physical, social, and cultural environments during their early developmental stages. Their cardiovascular and respiratory systems are especially vulnerable to air pollution and extreme heat.[91] Exposure to air pollutants and heat stress during pregnancy can increase health risks for babies, including low birth weight and pre-term birth. Households without access to reliable childcare may face challenges evacuating during an emergency.

Figure 11. Population estimate of individuals aged 17 years and younger in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)

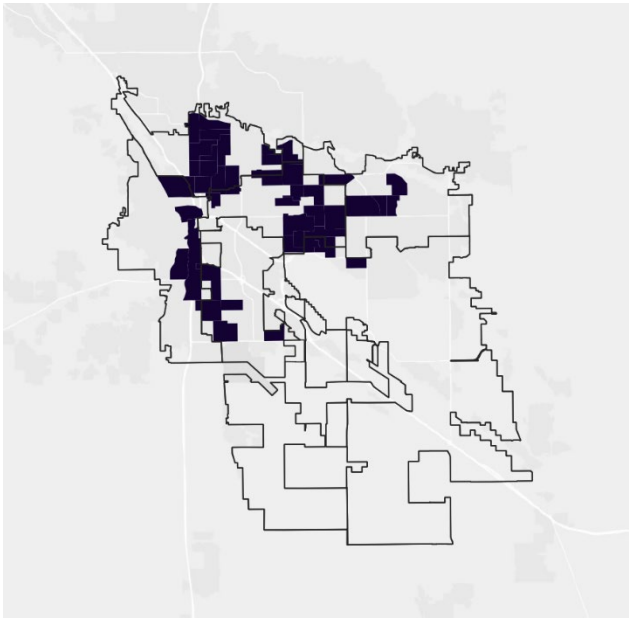


[91] Centers for Disease Control, 2020. "Heat Exposure and Cardiovascular Health: A Summary for Health Departments." <https://www.cdc.gov/climateandhealth/docs/HeatCardiovasculoarHealth-508.pdf>.

6.2.3 Households with no vehicle

Those without access to a vehicle may find themselves unable to evacuate in a timely manner during a climate emergency. Vital resources like healthcare and cooling centers may be inaccessible to those living in areas with limited transit service. Public transit users and people who walk, bike, and/or roll are at increased risk of prolonged heat exposure during extreme heat events, particularly if they rely on routes with insufficient cooling resources.

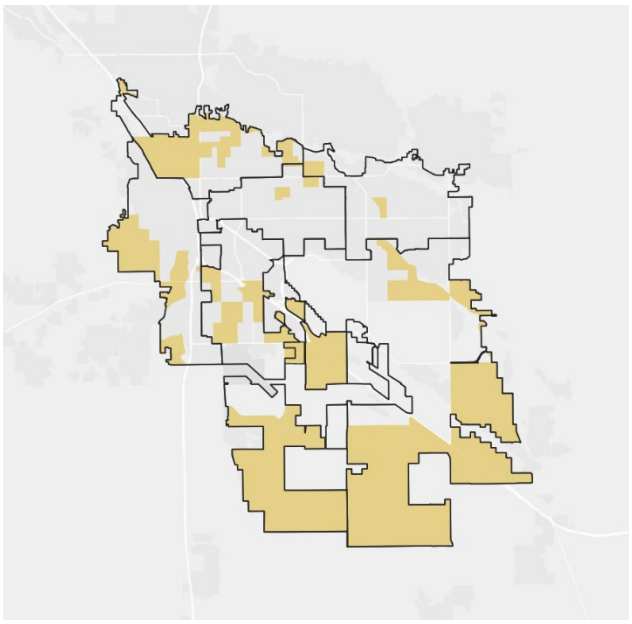
Figure 12. Estimate of households with no vehicle in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)



6.2.4 Mobile homes

Mobile homes are a significant source of affordable, unsubsidized housing in Tucson. However, mobile home residents do not own the land underneath their home, making them vulnerable to lease increases. Fires and floods can destroy entire communities of mobile homes with limited options for residents to recoup their investments. In addition, mobile homes can lack the proper insulation to maintain indoor environments free from air pollution or extreme heat. In Tucson, mobile home communities are often located outside of urbanized areas, isolating residents from core resources.[92]

Figure 13. Estimate of mobile homes in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)

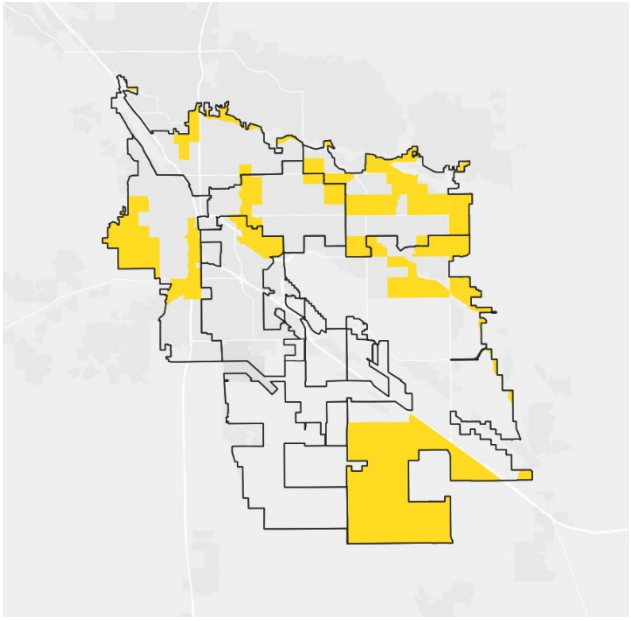


[92] McCann, L., Hibberd, R., and Kear, M., 2021. "A Profile-Based Approach to Indexing Housing Vulnerability in Tucson: A Case Study of Manufactured Housing." Making Action Possible in Southern Arizona. <https://mapazdashboard.arizona.edu/sites/default/files/2021-10/MAP_MH_Final_Oct5_2021%20V2.pdf>.

6.2.5 Older adults

Normal body changes associated with aging, such as muscle and bone loss, can limit mobility over time. Older adults are more likely to have chronic illnesses, which can require medications that increase sensitivity to prolonged heat or pollution exposure. Dependence on electrically powered medical equipment and elevators can pose evacuation concerns during climate-related power outages or events. Without a robust support network, access to necessary amenities such as groceries and medication can be difficult during an emergency.

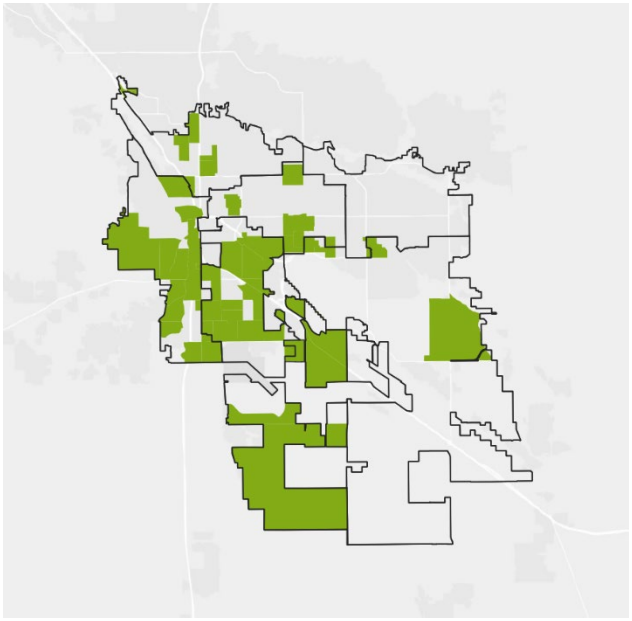
Figure 14. Population estimate of individuals aged 65 and older in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)



6.2.6 People of Color

Historic injustices have created disparities between people of color and their white peers that still exist today. Discriminatory housing practices, such as redlining and restrictive covenants, prohibited households of color from building wealth and perpetuated generations of housing insecurity. Housing-insecure individuals are at increased risk of displacement and houselessness after a climate emergency, and medical biases and distrust can make patients of color hesitant to seek the medical care they need. In addition, native land dispossession and forced migration are directly tied to the present-day location of tribal lands in climate vulnerable areas. Drought threatens agricultural production for Indigenous communities, and wildfire threatens lives, property, and wildlife habitats.

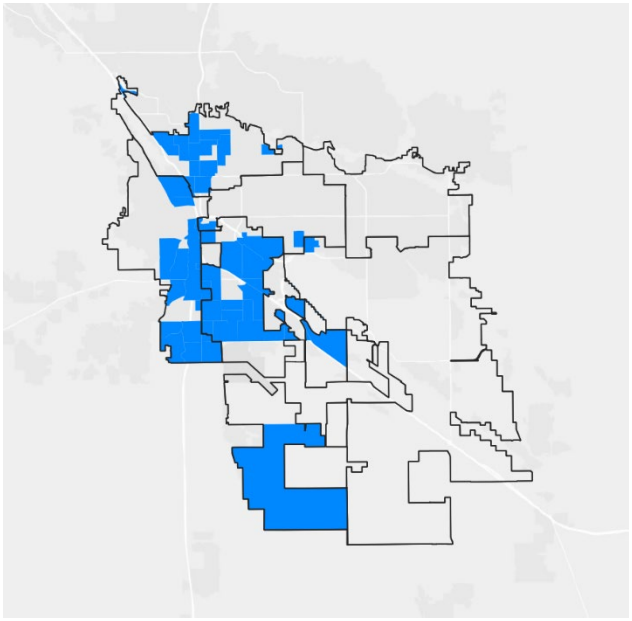
Figure 15. Population estimate of individuals of color (all residents except white, non-Hispanic) in 2020 (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)



6.2.7 People with Limited English Proficiency

Residents with limited English proficiency are at risk of missing important messaging from the City or service providers, especially if they rely on word-of-mouth communication. Working with emergency responders can provide difficult when cultural norms or practices are difficult to translate. Without culturally competent medical care, critical health care concerns can go unaddressed.[93] In Tucson, the majority of people with limited English proficiency speak Spanish as their primary language.

Figure 16. Population estimate of individuals who speak English "less than well" in 2020 (top quartile of Census Tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)

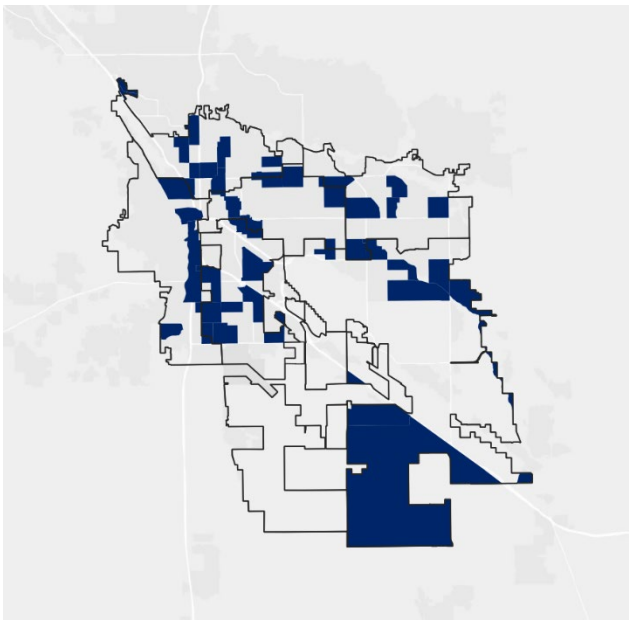


[93] Arizona Prevention Research Center, 2021. "2021 Pima County Community Health Needs Assessment." <https://www.tmcaz.com/assets/documents/community/2021-pima-county-community-health-needs-assessment.pdf>.

6.2.8 People with Disabilities

Disability is multidimensional and nuanced, and the effects of a person's condition on their ability to adapt during a climate event can vary greatly. This means that any effective climate resilience agenda must incorporate a diverse array of resources and services to accommodate a range of abilities. People with disabilities can experience restricted mobility, greater isolation from necessary amenities, and discrimination when seeking proper care. For example, hot pavement can make sidewalks inaccessible during high heat days for those who rely on service animals.[94] Those unable to properly self-regulate internal body temperature are at increased risk of heat stroke. Many people with disabilities are likely to experience the high-risk socioeconomic factors that contribute to instability during a climate crisis, including poverty, unemployment, and housing insecurity.

Figure 17. Population estimate of non-institutionalized civilians with a disability (top quartile of Census tracts) (Source: US Census Bureau, ACS 2020 5-Year Estimates)



[94] Tucson Mayor's Office, 2022. "Climate Listening Sessions Report."

Table 2. Social vulnerability variables linked to relevant hazards (Source: US Census Bureau, ACS 2020 5-Year Estimates)

Variable	Data Description	Relevant Hazard(s)
People Living Below the Poverty Line	Persons whose poverty status is determined	All Hazards
Children	Persons aged 17 and younger	All Hazards
Households with No Vehicle	Occupied housing units with no vehicle available	Heat, Wildfire, Flooding
Mobile Homes	Mobile homes	Heat, Wildfire, Flooding
Older Adults	Person aged 65 and older	All Hazards
People of Color	All persons except white, non-Hispanic	All Hazards
People with Limited English Proficiency	Persons (age 5+) who speak English "less than well"	All Hazards
People with Disabilities	Civilian noninstitutionalized population with a disability	Heat, Wildfire, Flooding

Table 3. Population estimates and percentages of social vulnerability variables in Tucson (Source: US Census Bureau, ACS 2020 5-Year Estimates)

Variable	Population Estimate	Percentage of Population
People Living Below the Poverty Line	108,159	19.9%
Children	112,358	20.7%
Households with No Vehicle	23,375	10.8%[95]
Mobile Homes	15,121	6.6%[96]
Older Adults	80,828	14.9%
People of Color	236,169	56.5%
People with Limited English Proficiency	33,787	6.2%
People with Disabilities	80,204	14.8%

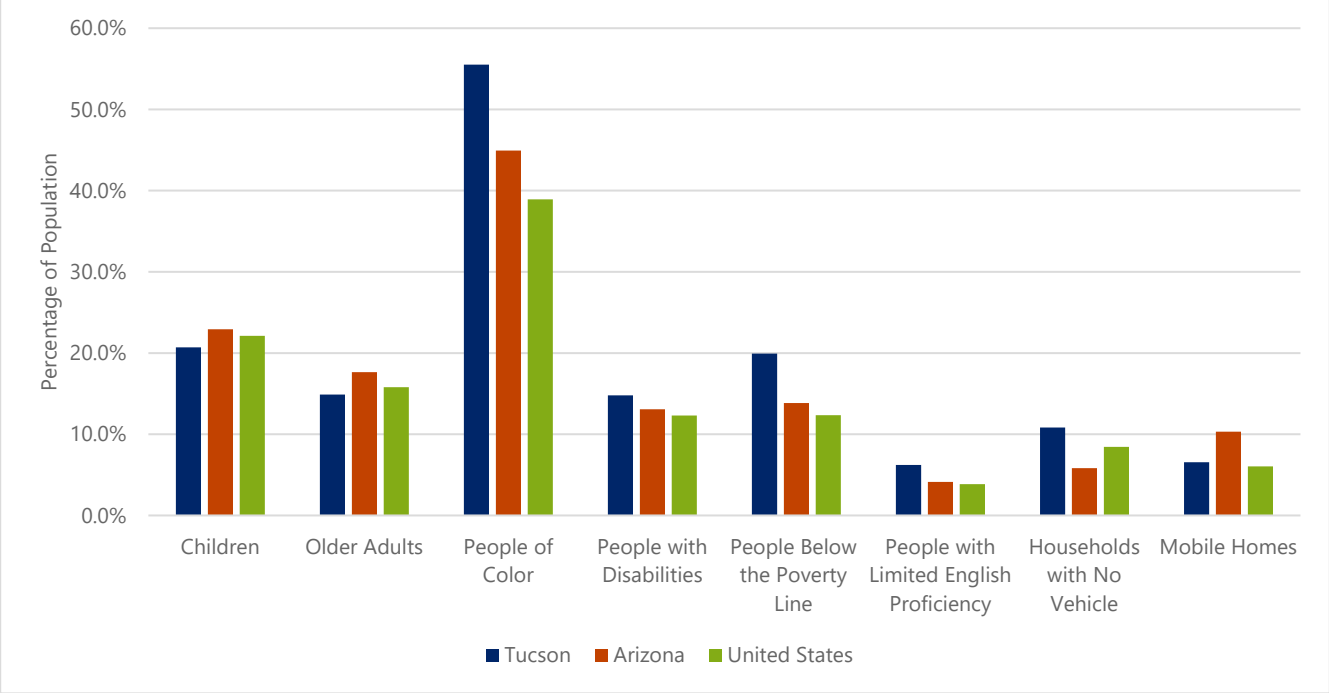
[95] Calculated as a percentage of Occupied Housing Units.

[96] Calculated as a percentage of Total Housing Units.

6.3 State and US Context Comparison

The City of Tucson generally has a proportion of vulnerable communities larger than or comparable to the State of Arizona and the United States. Tucson has a higher prevalence across five indicators: people of color, people with disabilities, people below the poverty line, people with limited English proficiency, and households with no vehicle.

Figure 18. Percentage of key social vulnerability indicators across Tucson, Arizona, and the United States (Source: US Census Bureau, ACS 2020 5-Year Estimates)



7 Physical Vulnerability Assessment

Physical vulnerability is the susceptibility of physical infrastructure such as utility assets, transportation assets, hospitals, public spaces, historic buildings, and schools in the context of climate hazards and extreme events. The hazards which Tucson faces - extreme heat, extreme precipitation & flooding, drought, and wildfire - have the potential to damage physical infrastructure, buildings, and critical facilities thus disrupt services or limit accessibility.

This section highlights the infrastructure systems at greatest risk to climate hazards and examines the potential impacts to such systems. Extreme heat, extreme precipitation, and flooding will be the hazards examined for their impact to physical infrastructure.

7.1 Transportation Infrastructure

The primary mode of transportation in Tucson is vehicular, with most residents traveling by car, utilizing Tucson's public bus system, SunTran, or getting around on bicycle. Thus, the road network is essential to moving around the city and providing access to critical services during hazardous events.

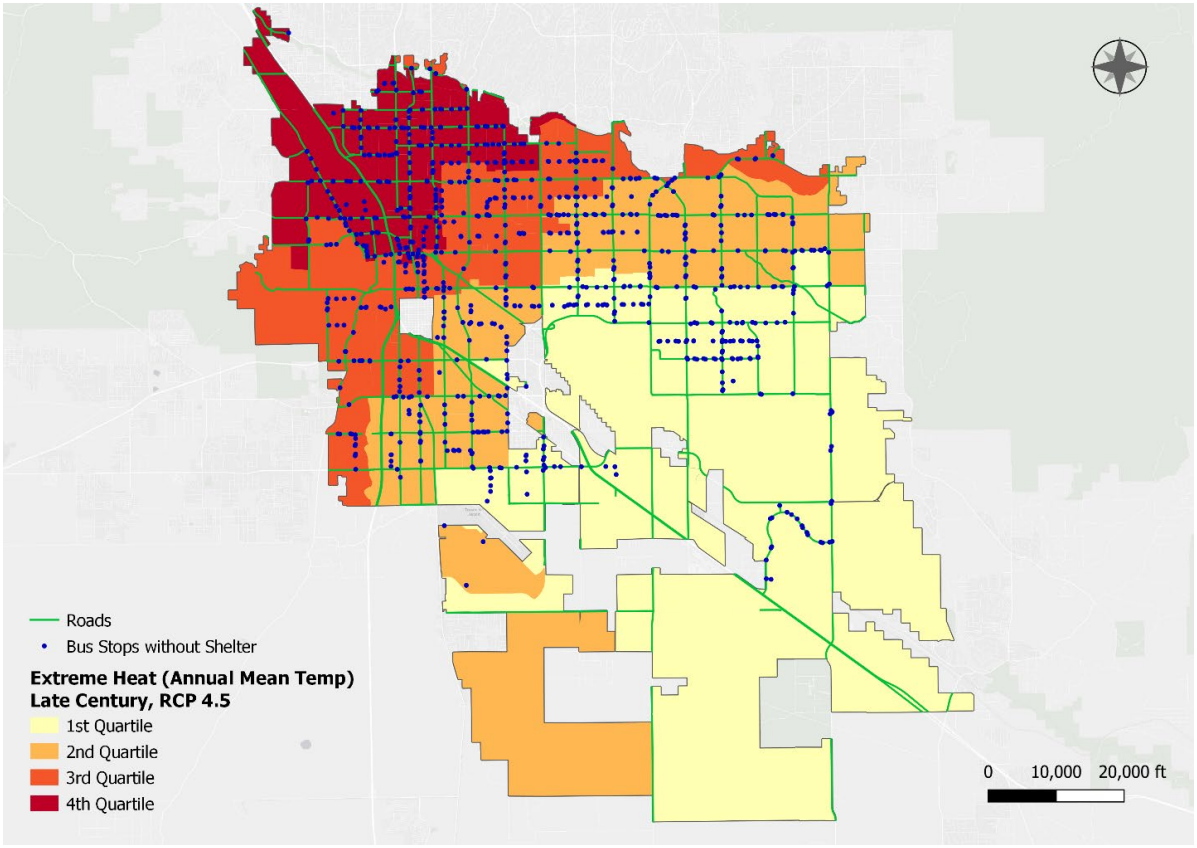
7.1.1 Extreme Heat

Extreme heat negatively impacts the lifespan of roadways and diminishes quality of life related to mobility through increased traffic. Higher temperatures can cause pavements to soften and expand, potentially creating potholes over time in high-traffic areas and placing stress on bridge joints.[97] Temperature fluctuations can also impact fixed railways, leading to track buckling.[98] In addition, commuters may be exposed to higher temperatures while waiting at bus or streetcar stops. Figure 19 shows the transportation assets at risk from extreme heat. For example, nearly 50% of SunTran bus stops do not have shelter from the elements, and most of these unsheltered stops lie within the hottest 50% of Census tracts as measured by annual mean temperature by late century.

[97] U.S. Environmental Protection Agency, 2017. "Climate Impacts on Transportation." <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-transportation_.html>.

[98] Bobby Magill, 2014. "Sun Kinks" in Railways Join the List of Climate Change's Toll." Scientific American. <https://www.scientificamerican.com/article/sun-kinks-in-railways-join-the-list-of-climate-change-s-toll/>.

Figure 19. Transportation and Extreme Heat in Tucson

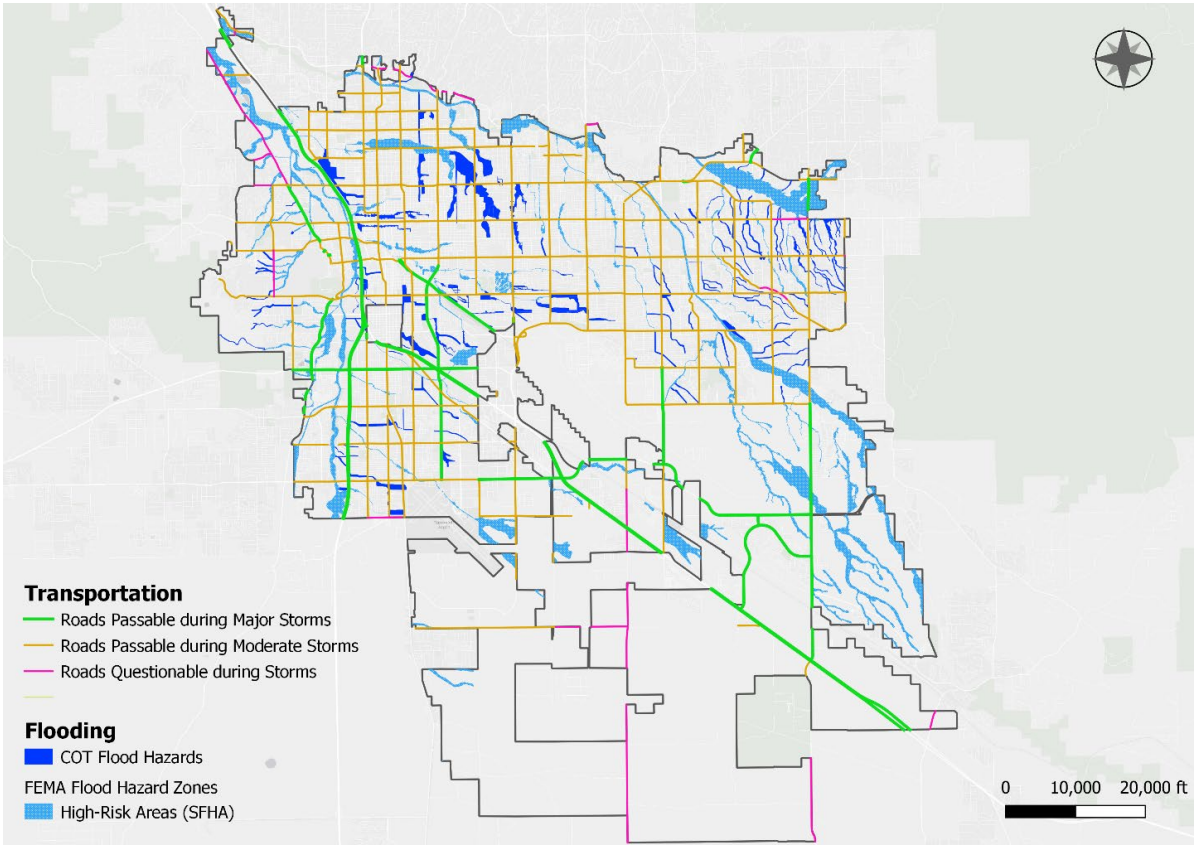


7.1.2 Flooding and Extreme Precipitation

Inland flooding from severe storm events in Tucson has historically led to road closures, limiting residents' access to emergency services or evacuation. In 2006, the summer monsoon brought storms that washed away roadways and flooded an estimated 100 vehicles.[99] Figure 20 shows how passable roads in Tucson are vulnerable to extreme flooding or precipitation events.

[99] City of Tucson (n.d.). "Floods and Flash Floods." <https://www.tucsonaz.gov/em/floods-and-flash-floods>.

Figure 20. Roadways and flood hazards in Tucson



7.2 Water Infrastructure

Increased variability in precipitation, earlier snow melt, and higher temperatures will all place stress on Tucson water resources and infrastructure. The impacts of these climate hazards will be exacerbated by population growth: the population of the Tucson Water service area is expected to double in size by 2050 from 2000.[100] Expanded economic development, including tourism and manufacturing, can also place significant pressures on water resources. At the same time, the Colorado River, where Tucson gets approximately 70% of its potable water supply, is rapidly shrinking: the gap between projected demand and supply is estimated at three million acre-feet for the entire rivershed.[101]

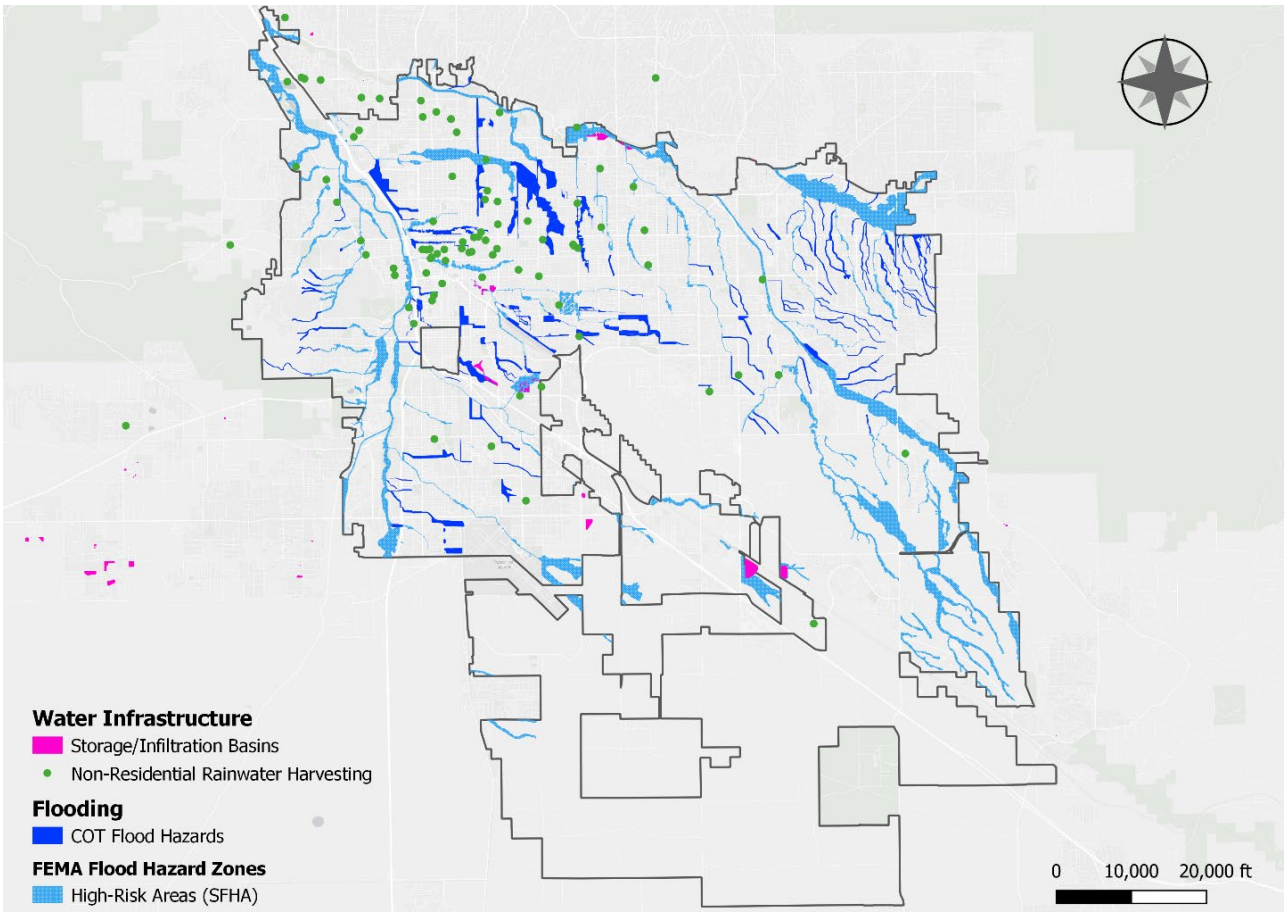
As extreme precipitation events become more intense and pervious land cover is increased through development, Tucson's stormwater infrastructure will come under pressure and existing storage and infiltration basins will be inadequate to address inland flooding (see Figure 21 below). The City has taken efforts to manage stormwater runoff through rainwater harvesting,

[100] City of Tucson, 2004. "Water Plan 2000 – 2050." <http://www.tucsonaz.gov/water/waterplan>.

[101] Stolte, D., 2014. "Arizona's Future Climate: Temps Rising, Water Disappearing."<https://news.arizona.edu/story/arizonas-future-climate-temps-rising-water-disappearing>.

with most systems located in the northwest portion of Tucson. However, several flood hazard zones remain without significant stormwater management practices.

Figure 21. Water infrastructure and flood hazards in Tucson



7.3 Energy Infrastructure

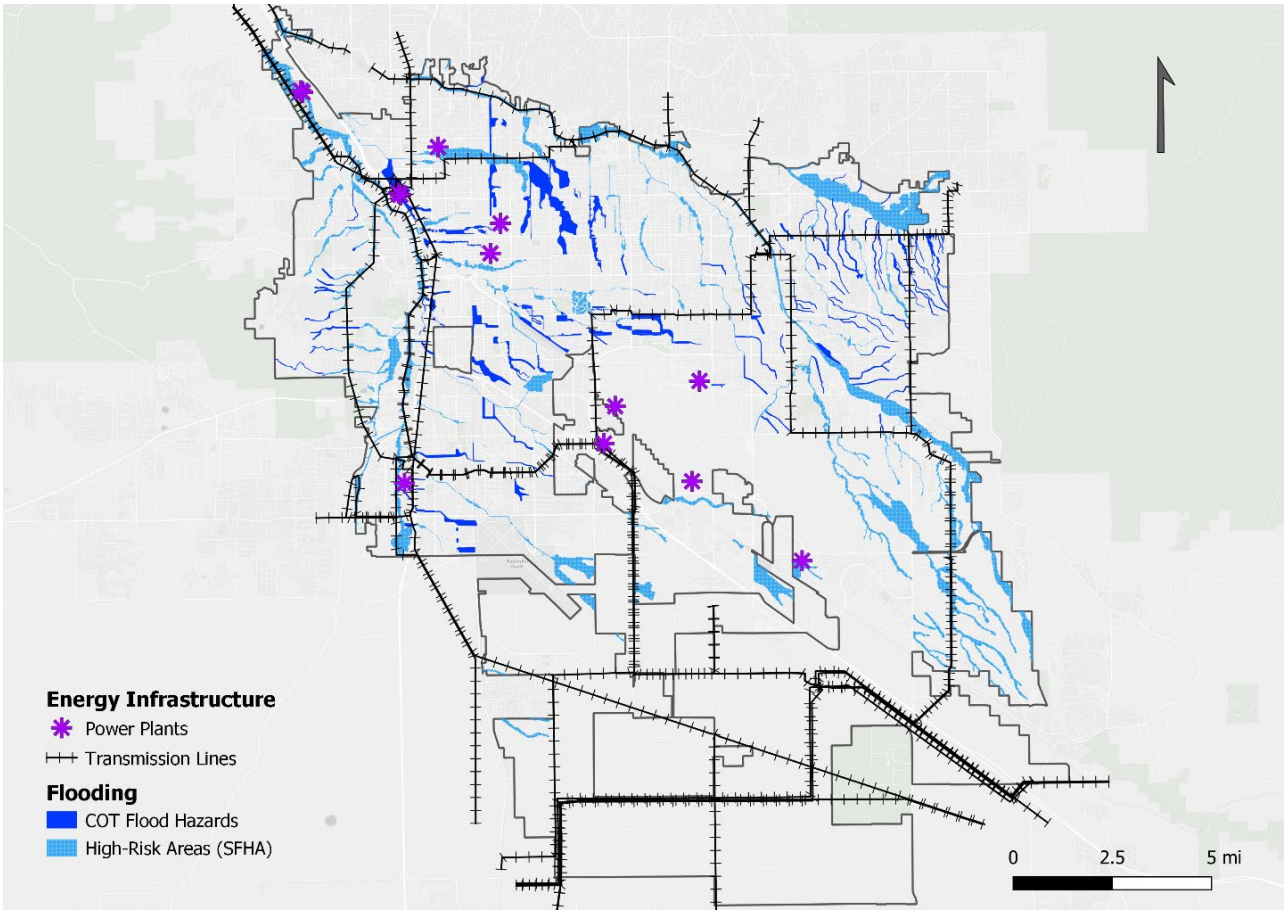
Transmission lines and power plants will be among the most vulnerable infrastructure to extreme heat in Tucson. Heat can cause transmission lines to sag and lose carrying capacity, and higher temperatures can lead to increased demand and overburdened substations and power plants. Rising air temperatures can also reduce the efficiency and output of natural gas power plants as dry-cooled and combined cycle processes rely on keeping the gas at low temperatures.[102]

Extreme precipitation and flooding may also cause damage to transmission lines and fell poles, leading to power outages across the city. Power outages can create dangerous conditions with regards to heat exposure, which especially impacts people who

[102] Burillo, D. et al., 2018. "Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat." California Energy Commission. <https://www.energy.ca.gov/ sites/default/files/2019-11/Energy_CCCA4-CEC-2018-013_ADA.pdf>.

are less mobile and/or have pre-existing health conditions. Several power plants are located within the 100-year flood zone as shown in Figure 22. Flood-resilient measures are required to minimize vulnerability of the facilities to severe storms and flooding. Tucson Electric Power, the primary electricity supplier in Tucson, has made significant investments in recent years towards building resiliency.[103]

Figure 22. Electricity infrastructure and flood hazards in Tucson



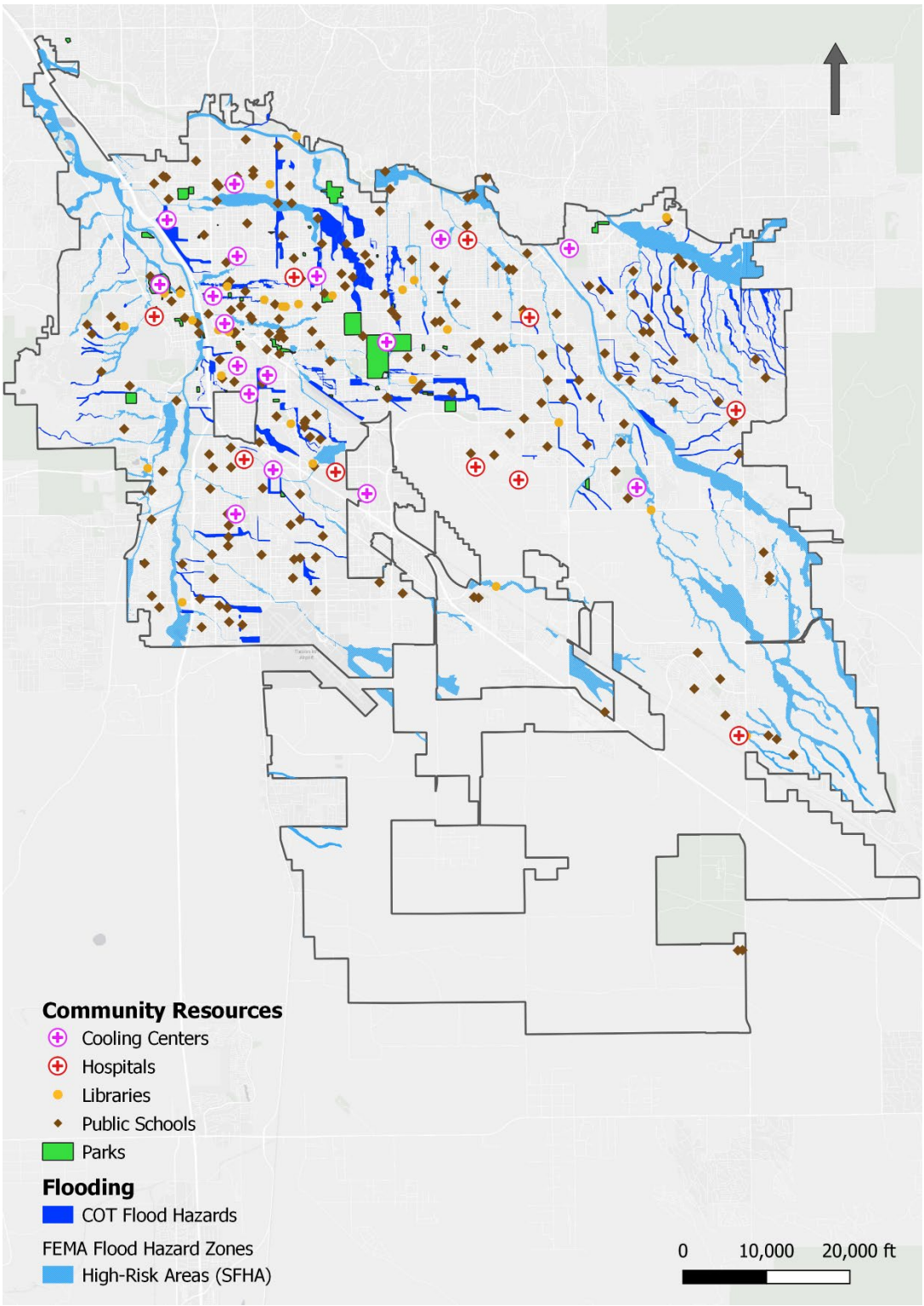
7.4 Community-Serving Assets

Community assets are facilities that provide essential public services, especially during emergencies, such as hospitals, fire stations and parks. Other facilities, such as schools and libraries, are also considered community assets as they are predominantly occupied by vulnerable populations and may be used as centers for emergency response. These facilities, while supporting community resilience, can themselves be vulnerable to physical damage from climate hazards.

[103] Tucson Electric Power (n.d.). "Reliable, Resilient, Ready." <https://www.tep.com/reliable/>.

As shown in Figure 23, most hospitals lie outside of the floodplain and are thus less exposed to floods during severe storm events. Similarly, most schools and libraries lie outside the floodplain, although it should be noted that they have experienced flooding historically (as displayed by the intersection with the COT Flood Hazard layer).

Figure 23. Community Assets and Flood Hazard in Tucson



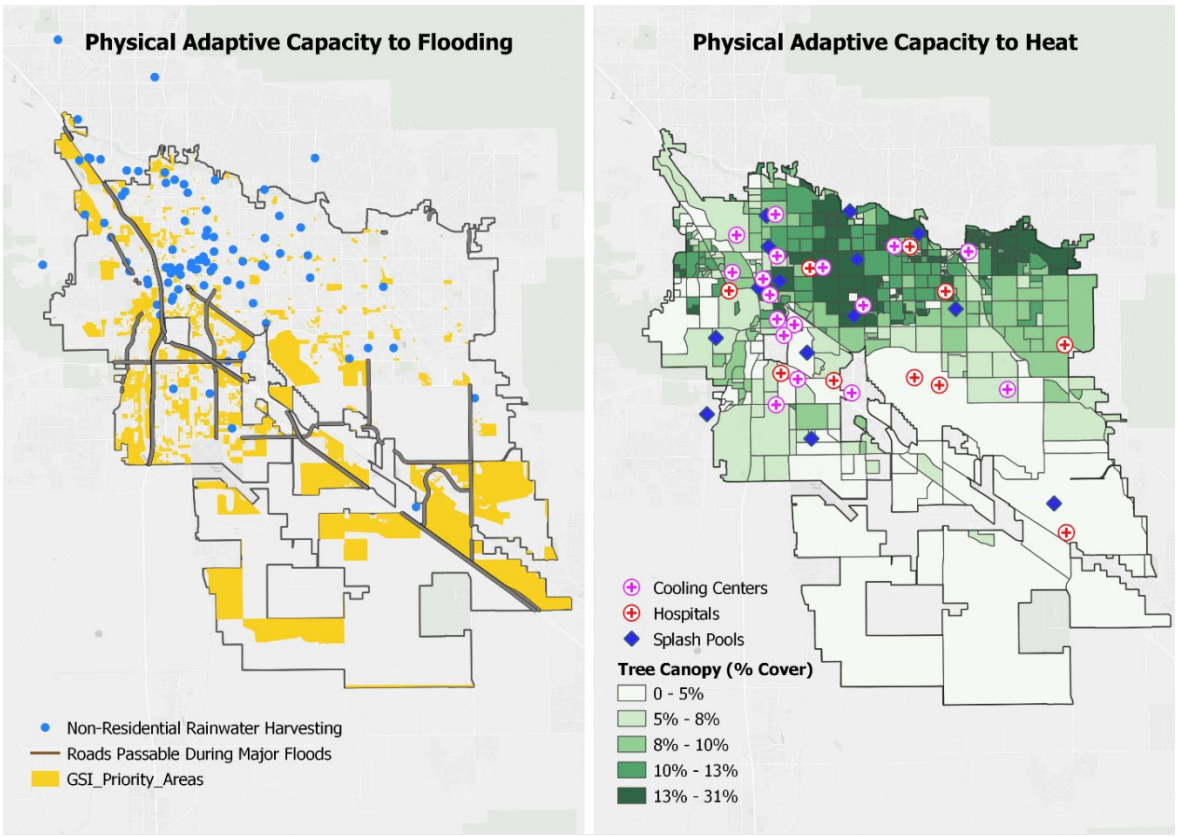
8 Adaptive Capacity

Tucson is already experiencing the impacts of climate change, from reduced water availability to higher temperatures, and has taken steps to manage these impacts. The city's existing ability to mitigate or cope with damage caused by climate hazards can be referred to as its adaptive capacity. Adaptation can be structural, natural, and/or political. For example, tree canopy, green spaces, cooling centers, and grid resilience help illustrate adaptive capacity to heat. Similarly, rainwater harvesting increases adaptive capacity to flood. Positively, several of these adaptations are cross-cutting across structural, natural, and/or political systems and provide multiple benefits. Green stormwater infrastructure, a form of passive water harvesting, provides cool corridors, reduces localized flooding, and reduces irrigation demand for an expanded tree canopy. Identifying opportunities for adaptations that address multiple hazards and support natural and social systems is a key to successfully addressing the impacts of climate change. Adaptive capacity spans multiple scales of government (city, county, state, national) as well as multiple City departments; therefore, it requires a holistic approach. Climate hazards are not restricted to municipal boundaries, making regional cooperation with other government entities essential. This section examines Tucson's existing adaptive capacity to inform subsequent climate adaption planning.

In Figure 24, adaptive capacity to flooding (left) is illustrated through the rainwater harvesting systems installed across the city and the areas of high priority green stormwater infrastructure (GSI) implementation. These features represent the city's established commitment to managing stormwater runoff and flooding. In addition, evacuation routes are included, and the map shows the available roads to reach emergency services if needed. It is worth differentiating between adaptation strategies for localized chronic flooding and peak shock flooding events. Green stormwater infrastructure expands urban resilience to localized, routine flooding. Larger pieces of infrastructure are necessary to provide resilience to peak events.

In the map to the right, adaptive capacity to heat, tree canopy is mapped by Census tracts and sorted by quintiles. This acts as a proxy for current tree canopy shade, which mitigates the effects of extreme heat and reduces urban heat island effect. As such, Census tracts with higher tree canopy coverage enjoy cooler temperatures than other areas. It should be noted that the concentration of Census tracts in the top quintile correspond to those with highest income levels per the CDC/ATSDR Social Vulnerability Index, suggesting that structural inequalities do impact the adaptive capacity of different communities within the city. The city also has dedicated cooling centers and splash pools available to the public during high temperature days.

Figure 24. Adaptive capacity to flooding (left) and adaptive capacity to heat (right)



Other forms of physical or structural adaptive capacity include grid and water resilience. According to an annual survey conducted by the Edison Electric Institute, Tucson Electric Power (TEP) consistently ranks in the top quartile for reliability among the nation's electric utilities.[104] A review of TEP's performance over time revealed that after posting a three-year average System Average Interruption Duration Index (SAIDI) of 60.5 minutes from 2016-2018, TEP improved its score from 2019-2021 to 58.8 minutes, despite record high temperatures.[105] The utility has also made extensive investments in transmission and distribution infrastructure, including $432 million from 2019-2022 for distribution system reinforcement and expansion, public improvement projects, substation construction and maintenance, and the replacement of aging infrastructure such as power lines and electric poles. [106]

Tucson Water, the city's water provider, has also made strides towards addressing climate change through its water conservation programs. The utility company has comprehensive water efficiency rebate programs with a total budget of $3.5 million, including $1.4 million for conservation rebates and incentives, $750,000 for education programs, and $350,000 for a neighborhood-scale stormwater harvesting program. The conservation program is funded by a dedicated fee on water bills.[107] The GHG emissions from City operations points to the interrelationship between energy and water. A significant portion of the

[104] Tucson Electric Power, 2017. "Infrastructure & Reliability." <https://www.tep.com/news/tep-infrastructure-reliability/>.

[105] Tucson Electric Power, 2022. "Reliable, Resilient, Ready." <https://www.tep.com/reliable/>.

[106] See Footnote #96.

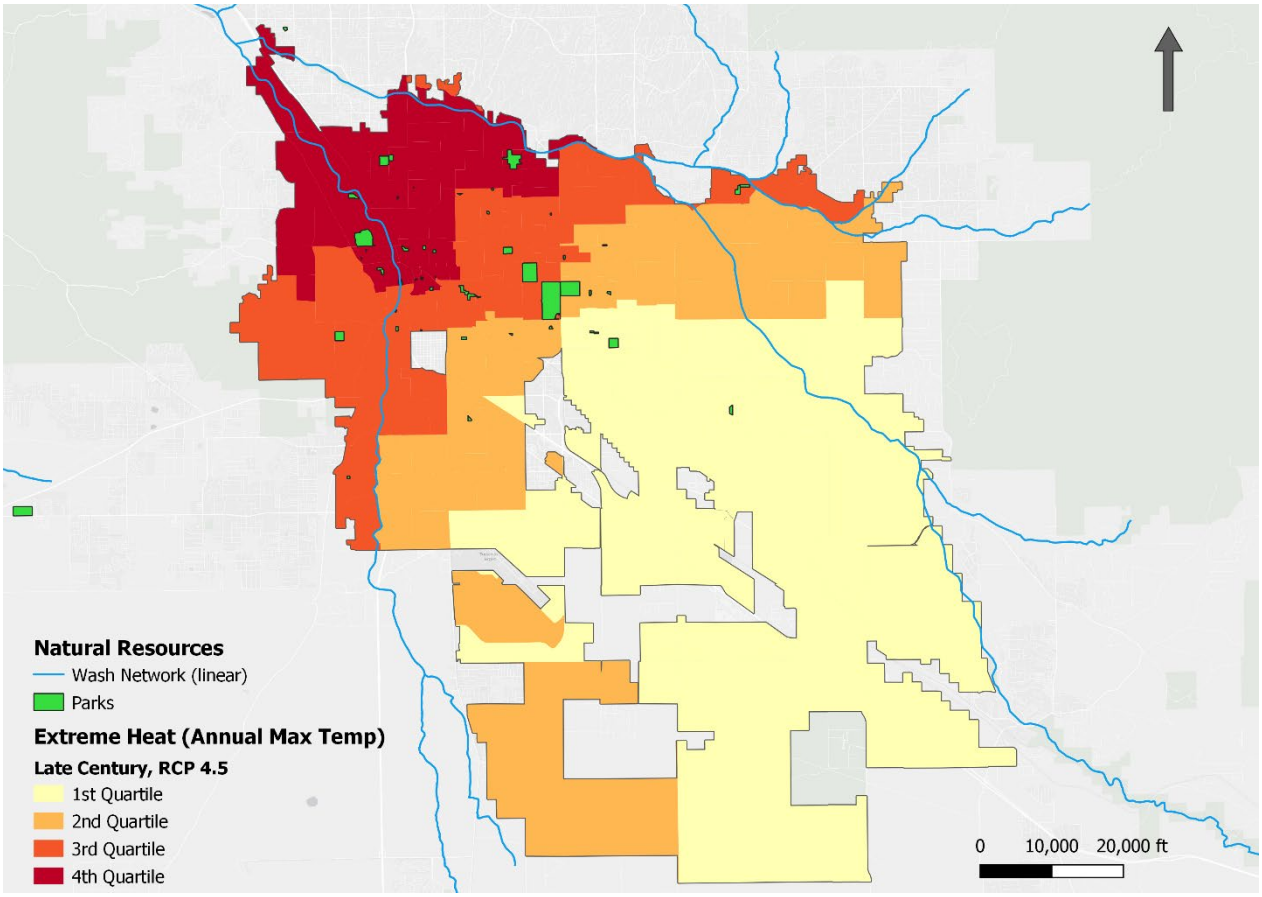
[107] Tucson Water (n.d.). "Case Study, Tap into Resilience." <https://tapin.waternow.org/resources/tucson-water/>.

City's GHG emissions are from transporting imported water. When there is greater localized water resilience, energy is also reduced and vice versa.

9 Landscape and Ecosystem Vulnerability

Natural resources such as conserved natural lands, urban parks and open spaces, washes (river tributaries), as well as ecosystems, biodiversity, and species distribution are all susceptible to the adverse impacts of climate hazards. Figure 25 shows the distribution of parkland and washes in Tucson. Parkland in Tucson is mostly limited to regions in the 3rd and 4th quartile of projected annual maximum temperature by the late century. As such, it is expected that increasing temperatures will diminish vegetative cover and dry out soil in those areas, erasing the necessary ecosystem services they provide such as temperature regulation and infiltration.[108]

Figure 25. Natural resources and extreme heat in Tucson



[108] U.S. National Park Services (n.d.). "Santa Cruz River." <https://www.nps.gov/places/santa-cruz-river.htm>.

In addition to the impacts on parks and washes, biodiversity and species distribution in the region are also susceptible:

- **Vegetation community types**: There is an observed trend of semi-desert grasslands being encroached upon by woody shrubland, which is driven by both climate- and non-climate-related factors.[109] More research is needed to understand what future changes might happen.
- **Biodiversity and species distribution**: Rising minimum temperatures may endanger species that are adapted to a narrow range of conditions. Species such as Alligator juniper may migrate upward in elevation to find suitable habitat, leaving mountaintop communities with nowhere to migrate to.[110,111] Rising temperatures and changes in rainfall patterns may alter flowering/fruiting timing of plants and pollinator migration patterns, which can disturb sensitive host/pollinator interactions.[112]
- **Invasive species**: Invasive Buffelgrass crowds out native plants. It resprouts after fire faster than native plants and encourages hotter, larger, and more frequent fires.[113] Invasive bark beetles in the genera *Dendroctonus* and *Ips* can significantly influence carbon cycles and ecosystem dynamics by damaging or killing pine trees. When trees are killed, they release atmospheric carbon as part of the decomposing process.[114] According to a 2014 analysis of trees in the western United States, the amount of carbon in trees killed by bark beetles exceeds that in trees killed by wildfires. As the climate changes, many trees are exposed to climate conditions that promote sub-optimal growth. This makes them more susceptible to infestation.[115] Earlier hot weather also promotes faster growth in bark beetles, causing them to reach reproductive maturity more quickly.[116]
- **Drought and precipitation**: Decreased water availability may cause moisture stress in plants, especially in biodiverse riparian areas.[117] Changing precipitation patterns, along with increased atmospheric carbon, may further encourage high-biomass woody shrubs to encroach on grasslands.[118]

[109] Brown, J.H., Valone, T.J., and Curtin, C.G., 1997. "Reorganization of an arid ecosystem in response to recent climate change."

[110] Roman-Palacios, C., and Wiens, J.J., 2020. "Recent responses to climate change reveal the drivers of species extinction and survival."

[111] Stolte, D., 2020. "One-Third of Plant and Animal Species Could be Gone in 50 Years."

[112] Pima County Office of Conservation Science and Environmental Policy. (2010). Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges.

[113] National Park Service. (n.d.) Buffelgrass: What is the threat?

[114] United States Department of Agriculture, (n.d.). "Forest Carbon FAQs."

[115] Bentz, B., and Klepzig, K., 2014. "Bark Beetles and Climate Change in the United States." U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. <https://www.fs.usda.gov/ccrc/topics/insect-disturbance/bark-beetles>.

[116] Strain, D., 2012. "Climate Change sends Beetles into Overdrive". <https://www.science.org/content/article/climate-change-sends-beetles-overdrive>.

[117] Pima County Office of Conservation Science and Environmental Policy, 2010. "Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges."

[118] Brown, J.H., Valone, T.J., and Curtin, C.G., 1997. "Reorganization of an arid ecosystem in response to recent climate change."

- **Soil:** Increased wildfires can lead to decreased soil carbon, decreased soil moisture, decreased soil fertility, and increased soil erosion.[119] Newly exposed soil due to conversion to woody shrubland may have increased respiration rates and become a carbon source during increased summer storms.[120]
- **Watershed function:** More intense summer storms combined with urbanization can lead to changing stream bed structure, which can increase depth to groundwater.[121] Additionally, as temperatures increase and soils become drier, the capacity for infiltration reduces as drier soils generally store more water. As such, runoff may be expected to increase, worsening the outlook on flash flooding and negative impacts of stormwater runoff.[122]

10 Conclusion

This Climate Risk and Vulnerability Assessment highlights the many ways in which Tucson, its communities, its infrastructure, and natural environments are vulnerable and at risk to various climate hazards. But in exploring these vulnerabilities, a few key takeaways emerge.

First, climate vulnerability is not discrete, but rather it is dynamic and nuanced. As the climate changes, how various components of our physical and social environments are impacted will evolve and shift over time. While sophisticated climate models and mapping tools enable planners and officials to envision future scenarios and make informed policy decisions, the future itself is still unknown. The City and its community stakeholders must be prepared to revisit and adapt strategies that not only prepare them for different futures, but that also enable them to respond effectively in the moment.

Second, the climate futures shown here are not certain or set. Efforts taken now to mitigate GHG emissions can secure futures that are safer and less uncertain for Tucson and its residents. However, as Tucson develops mitigation strategies, it should also consider where there are co-benefits that also build climate resilience.

Third and finally, with every vulnerability comes opportunity. Listed below are the key findings with respect to each hazard covered, followed by potential actions to explore or expand upon to build resilience to those hazards:

- **Extreme Heat**: Tucson's high heat days will increase in severity, frequency, and length across the entire city. The City can explore actions such as building weatherization, expanded cooling resources and communications, cool corridors, tree equity, outdoor worker outreach, and building community capacity.
- **Wildfire**: Wildfire risk in the mountains will increase, raising property damage and air quality concerns for the broader community of Tucson. In response, the City can coordinate cooling response with wildfire response resources, expanded communications for the most at-risk, build energy-resilient infrastructure, and create resilience hubs.
- **Drought**: Tucson's drought conditions will continue and increase in severity, with direct impacts to agricultural and municipal water users. The City should build on existing efforts centered on drought-resilient landscaping, water conservation, local water supply, passive and active rainwater harvesting, expanding alternative water sources,

[119] See Footnote #108.

[120] Cable, Jessica M., Ogle, Kiona, Williams, David G., Weltzin, Jake F., and Huxman, Travis E. (2008). Soil Texture Drives Responses of Soil Respiration to Precipitation Pulses in the Sonoran Desert: Implications for Climate Change.

[121] See Footnote #108.

[122] Ibid.

expanding fit-for purpose reclaimed and recycled water use within buildings, and access to and eligibility for incentives.

- **Precipitation/Flooding**: Extreme storm events are likely to increase, leading to channel overflow and flash flooding – especially in denser, urban areas. The City can continue investing in and building out rainwater harvesting and green stormwater infrastructure to mitigate the impacts. The City can also expand low-impact development practices for new development and incentivize the conversion of existing impervious surfaces to permeable or semi-permeable where possible.
- **Multi-Benefit Potential Actions:** It is important to note that there are opportunities that address multiple vulnerabilities. Expanded green stormwater infrastructure addresses extreme heat through cool corridors, flooding through slowing and absorption of stormwater at its source, and, to a less degree, drought through irrigation demand reductions. Increasing the use of alternative water sources adds to local water supplies and reduces the energy load required to important water across the state, which provides resilience to drought and resilience to the peak energy load for cooling in times of dryness and extreme heat. A multi-benefit approach is key to expanding urban adaptation potential.

Addendum

A.1 CDC/ATSDR Social Vulnerability Index[123]

ATSDR's Geospatial Research, Analysis & Services Program (GRASP) created Centers for Disease Control and Prevention Social Vulnerability Index (CDC/ATSDR SVI) to help public health officials and emergency response planners identify and map the communities that will most likely need support before, during, and after a hazardous event.

SVI indicates the relative vulnerability of every U.S. Census tract. Census tracts are subdivisions of counties for which the Census collects statistical data. SVI ranks the tracts on 15 sociodemographic factors, including unemployment, minority status, and disability, and further groups them into four related themes. Thus, each tract receives a ranking for each Census variable and for each of the four themes, as well as an overall ranking.

The SVI data set includes a category "RPL_THEMES", which indicates the overall percentile ranking of vulnerability inclusive of all 15 sociodemographic factors. The list of all 15 variables and their respective source tables from the American Community Survey are listed in Table 3. This is the data was then grouped into quartiles and mapped from most to least vulnerable.

SVI uses demographic data from the US Census American Community Survey 2018 5-year estimates. An updated version of the index using 2020 data has yet to be developed. Considering the timelines of the project, our team decided to use the 2018 version for this report. However, the series of eight individual variable maps in section 3.3 Vulnerable Populations utilize 2020 US Census data.

Table 3. Social vulnerability variables linked to relevant hazards (Source: US Census Bureau, ACS 2020 5-Year Estimates).

Category	Variable	Description	ACS Source Table
Socioeconomic Status	Below Poverty	Persons below poverty level	B17001
	Unemployed	Civilian (age 16+) unemployed	DP03
	Income	Per capita income	B19301
	No High School Diploma	Persons (age 25+) with no high school diploma	B06009
	Aged 65 or Older	Person aged 65 and older	S0101
	Aged 17 or Younger	Persons aged 17 and younger	B09001

[123] A detailed description of the variable selection rationale and methods can be found in A Social Vulnerability Index for Disaster Management. (2011). <https://www.atsdr.cdc.gov/placeandhealth/svi/img/pdf/Flanagan_2011_SVIforDisasterManagement-508.pdf>.

Household Composition & Disability	Civilian with a Disability	Civilian noninstitutionalized population with a disability	DP02
	Single-Parent Households	Single parent household with children under 18	DP02
Minority Status & Language	Minority	Minority (all persons except white, non-Hispanic)	B01001H
	Speaks English “Less than Well”	Persons (age 5+) who speak English "less than well"	B16005
Housing Type & Transportation	Multi-Unit Structures	Housing in structures with 10 or more units	DP04
	Mobile Homes	Mobile homes	DP04
	Crowding	At household level (occupied housing units), more people than rooms estimate	DP04
	No Vehicle	Households with no vehicle	DP04
	Group Quarters	Persons in group quarters	B26001

BURO HAPPOLD

Tucson Climate Adaptation and Action Plan

Existing Conditions Assessment

July 2022

BURO HAPPOLD

Table of Contents

BURO HAPPOLD

1 Context

In 2020, Tucson Mayor Regina Romero and the Tucson City Council (Mayor and Council, or M&C) committed to take decisive and equitable action on climate change and environmental sustainability, resulting in the declaration of a Climate Emergency and the establishment of a 2030 carbon neutrality goal (i.e., net zero greenhouse gas emissions) for City operations. In 2021, the M&C initiated multiple engagements with the Tucson community at large, including a community survey and multiple community listening and planning sessions, to identify community priorities for climate action.

In January 2022, the City contracted with a consultant team led by Buro Happold to develop and finalize a Climate Action and Adaptation Plan (CAAP) for the City of Tucson, to be completed by the end of calendar year 2022.

2 Purpose

As part of its scope of work, Buro Happold has been asked to complete a comprehensive **Existing Conditions Assessment** as an interim deliverable for the Tucson CAAP. This Assessment serves as a comprehensive evaluation of existing measures, plans, and programs on behalf of the City of Tucson to advance climate action and environmental sustainability at large. More specifically, it is an examination of how existing City and community initiatives align with the desired outcomes for the forthcoming CAAP, how those initiatives are impacting the City's greenhouse gas (GHG) emissions now and in the future, and how those initiatives align with the Climate Emergency Declaration, the M&C's priorities, and the values, frameworks, and regulations identified as significant or relevant to the development of the CAAP. This Assessment also functions as a gap analysis, identifying gaps and areas of greatest need across the City's existing actions and initiatives that stand in the way of achieving carbon neutrality. It will also serve as an evaluation of the City's alignment with state and federal programs around climate action and adaptation.

The document is structured as follows:

- **Section 3: Review of Existing Conditions** – Summarizes materials collected and reviewed per the Existing Conditions Assessment, with summaries of each piece provided in an addendum.
- **Section 4: Existing Conditions Assessment** – Provides a summary of Tucson climate action and adaptation actions to date, accompanied by gap analyses across major scope areas. This section also highlights international best practices and provides recommendations regarding each major scope area, constituting an overarching framework and structure for the Plan.
- **Section 5: Funding and Resource Opportunities** – Provides an overview of private, external, and public funding opportunities and resources for climate action.

3 Review of Existing Conditions

This section is a summative review of existing conditions in the City of Tucson as it pertains to the City's climate action and adaptation efforts. It begins with a review of existing and forthcoming City plans, followed by existing emissions and adaptation reports, frameworks, and analyses. Also included are overviews of pertinent City Council resolutions, City codes and ordinances, and departmental initiatives. It concludes with an overview of pertinent Advisory Bodies and their actions to date, as well as past and ongoing engagement efforts on the subject of climate action and adaptation.

3.1 Existing City and Regional Plans

This Assessment entailed a comprehensive review of nine citywide and regional plans, which are shown in Table 1 below. These documents, while only a sample of the City's planning efforts, constitute some of the most prominent or relevant planning efforts from the last 20 years.

Table 1. Existing City and Regional Plans

ITEM	YEAR
Regional Transportation Authority Plan	2006
Drought Preparedness and Response Plan (2021 Update)	2007[1]
Action Plan for a Sustainable Water Future	2009
Climate Mitigation Report	2011
Community Economic Security and Climate Action Analysis	2011
Plan Tucson General and Sustainability Plan	2013
Pima County Multi-Jurisdictional Hazard Mitigation Plan (2022 Update)	2017[2]
Pima County Sustainable Action Plan for County Operations 2018-2025	2018
People, Communities, and Homes Investment Plan (P-CHIP)	2021
Move Tucson Transportation Master Plan	2021
Electric Vehicle (EV) Readiness Roadmap	2022

[1] The *Drought Preparedness and Responsiveness Plan* was updated in 2021.

[2] The *Pima County Multi-Jurisdictional Hazard Mitigation Plan* was updated in 2022.

The consultant team reviewed each of these documents in the context of their contributions or reference to climate action and adaptation in the City of Tucson. Due to the volume of documents, the team has included its summaries of each in the Addendum to this Assessment.

The above documents demonstrate a history of planning efforts in Tucson that touch on various aspects of climate action and adaptation, though none necessarily constitute a plan focused on climate mitigation or adaptation, save for the 2011 *Climate Mitigation Report*. However, their collective constitution indicates that the City, and the region at large, have accounted for climate change on an ongoing basis through planning efforts, but that efforts to act on that front are largely delegated to the departments, stakeholders, and/or entities responsible for each individual plan.

In Section 4, the Assessment provides additional summary and gap analysis with respect to the City's planning efforts to date.

3.2 Forthcoming City Plans

Two forthcoming city plans are in process concurrently with the development of the City's climate action and adaptation plan.

3.2.1 City of Tucson General & Sustainability Plan | 2023

The City anticipates completing an update to its General and Sustainability Plan in 2023. The Plan will examine Tucson's progress and development since 2013, and consequently update and introduce goals and policies for multiple focus areas, including the social, economic, natural, and built environments. It is expected that the City's forthcoming climate action and adaptation plan will serve as a chapter within *Plan Tucson 2023*.

3.2.2 *One Water 2100* Master Plan | 2023

The *One Water 2100* Master Plan is being prepared by Tucson Water, the agency which supplies water to Tucson and the surrounding metropolitan area. The Plan will serve as the first comprehensive long-range plan for water resource management since the 2004 *Water Plan 2000-2050*, and it will utilize a nationally recognized integrated water resource management system known as "One Water" that applies a holistic approach to water supply, stormwater, and wastewater. The goal of *One Water 2100* is to ensure sustainable and high-quality water for Tucson by addressing climate change impacts, particularly drought, through conservation practices and a commitment to equity, resilience, and quality of life. The plan is intended to inform capital and financial planning as well as policy decisions. Relevant elements from the Plan include, but are not limited to, identifying efficiencies and conservation options, as well as scenario planning and preparing for potential risks.

3.3 Climate Change Frameworks, Reports, and Analyses

The consultant team reviewed 10 additional documents, which are shown in Table 2 below, which comprise frameworks, reports, and analyses pertaining to climate change mitigation and adaptation.

Table 2. Climate Change Frameworks, Reports, and Analyses

ITEM	YEAR
Framework for Advancing Sustainability	2008
Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges	2010
Community Economic Security and Climate Action Analysis	2011
Arizona: Extreme Weather, Climate and Health Profile Report	2015
Drought and Climate Change in Pima County and Western States	2017
Pima County Climate Brief	2018
Southwest, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*	2018
Climate Profile for the Highlands at Dove Mountain	2019
Pima Association of Governments Regional Greenhouse Gas Emissions Inventory	2019
Asset Management, Extreme Weather, and Proxy Indicators Pilot Program	2020
Vulnerability and Risk Assessment: Recommendations from Climate Action Advisory Council	2022

Due to the volume of documents, the team has included its summaries of each in the Addendum to this Assessment.

The above documents include a wide range of analyses, assessments, and projections with respect to the impacts of climate change across Tucson and the region at large. The notable exception on this list is the *Framework for Advancing Sustainability*, which serves as more of a roadmap and gives direction to the City with respect to acting on climate change and integrating mitigation into its planning and activities. The *Community Economic Security and Climate Action Analysis* from 2011 is one of the most in-depth climate action documents in the City's history, inclusive of specific strategies accompanied by cost-benefit analyses. However, most of these documents largely examine the region at multiple scales, with only the *Framework*, the *Climate Action Analysis*, and the *Vulnerability and Risk Assessment* recommendations document turning focus to the City and its operations.

Section 4 provides additional summary and gap analysis, contextualizing these efforts in terms of emissions accounting, mitigation, and climate change adaptation.

3.4 Mayor and Council Actions and Resolutions

The consultant team reviewed various Mayor and Council actions and resolutions, five of which are specifically highlighted in Table 3 below. Additional resolutions were reviewed but are covered in other sections due to their relationship with existing City plans, or are otherwise referenced but not detailed due to their age.

Table 3. Mayor and Council Actions and Resolutions

ITEM	YEAR
City Council Resolution No. 20443: Endorsing the Mayors' Climate Protection Agreement	2006
City Council Resolution No. 20322: Sustainable Energy Standard – Adopting an Updated Green Building Policy for City Building Construction Projects	2006
City of Tucson Mayor & Council Retreat Priorities	2020
City Council Resolution No. 23166: Requesting the Arizona Corporation Commission Adopt a Clean Energy Standard of 100% by 2050	2020
City Council Resolution No. 23222: City of Tucson's Climate Emergency Declaration	2020

The most notable actions taken by the Mayor and Council include the 2006 resolution to endorse the Mayors' Climate Protection Agreement, as well as the more recent resolution to declare a Climate Emergency – the primary impetus for the development of the City's climate action and adaptation plan.

The 2020 Retreat Priorities detail a number of action areas related to climate action and adaptation, including but not limited to housing and homelessness, transportation and mobility infrastructure, parks and trees, children and youth, economic development, poverty, crime and safety, and information technology and cybersecurity. These priorities will not only serve to guide the development of the climate action and adaptation plan, but they also set some context for current and forthcoming City actions. Additional analysis is provided in Section 4.

3.5 City Ordinances and Codes

The consultant team reviewed the City zoning code and various City ordinances, five of which are specifically highlighted in Table 4 below. Additional ordinances were reviewed but are covered in other sections due to their relationship with existing City plans, or are otherwise referenced but not detailed due to their age.

Table 4. City Ordinances and Codes

ITEM	YEAR
Ordinance No. 10579: Gray Water Harvesting Ordinance	2008
Ordinance No. 10591: Amending Chapter 10A Creating the Climate Change Committee and Dissolving the Environmental Accords/Green Cities Declaration and Sustainability Committee	2008
Ordinance No. 10597: Commercial Rainwater Harvesting Ordinance	2008
Ordinance No. 11496: Amending Chapter 10A establishing the Commission on Climate, Energy and Sustainability, Dissolving the Climate Change Committee and Terminating the City's Participation in the Tucson-Pima County Metropolitan Energy Commission	2017
Ordinance No. 11621: Tucson Complete Streets Policy	2019

Given the wide range of ordinances, it is likely that there are other pertinent ordinances with secondary or tertiary connections to climate action and adaptation. However, the above ordinances highlight action on gray water and rainwater which are a significant focus area for the City, and they also detail some history with respect to the City's committees and commissions tasked with addressing climate issues. Additional analysis is provided in Section 4.

3.6 Citywide or Departmental Programs and Initiatives

The consultant team also completed a desktop review of seven citywide or departmental programs and initiatives pertaining to climate action, listed below in Table 5.

Table 5. Citywide or Departmental Programs and Initiatives

ITEM
Low-Income Rainwater Harvesting Program
Neighborhood Scale Green Infrastructure
Tucson Million Trees Initiative
Green Stormwater Infrastructure Fund
Environmental and General Services Initiatives
Transportation and Mobility Initiatives

Planning and Development Services Initiatives

Many of these listed initiatives have some relation to climate action and adaptation, with many having to do with water use and recycling. Many programs are also geared towards low-income families to support the installation of resource mitigation or conservation systems, or increase access to city resources and services. As with existing City and regional plans, initiatives are largely housed within City departments and stakeholders, and are not guided or contextualized within a broader climate action- or adaptation-focused plan. Additional analysis is provided in Section 4.

3.7 Advisory Bodies

3.7.1 Commission on Climate, Energy, and Sustainability | 2017-Present

In 2017, the City passed Ordinance No. 11496, dissolving the previously existing Climate Change Advisory Committee, and creating the Commission on Climate, Energy, and Sustainability (CCES). The Commission meets on the 4th Wednesday of every month, and advises the Mayor and Council on meeting the climate, energy, and sustainability goals laid out in the General Plan, as well as methods for improving the City's impact and achieving incremental and transformative systemic outcomes necessary to respond to pertinent challenges in the region.

The Climate Change and Advisory Committee that preceded the Commission was created as part of the *Framework for Advancing Sustainability* in 2008, with the intent to develop a Climate Change Mitigation and Adaptation Plan. The Committee was initially established through Ordinance No. 10591, and at the time dissolved a previously existing Environmental Accords/Green Cities Declaration and Sustainability Committee.

3.7.2 Climate Action Advisory Council | 2020-Present

The Climate Action Advisory Council was formed following the Climate Emergency Declaration via Resolution No. 23222. The Council is composed of various stakeholders across Tucson and the State of Arizona, including representatives from Commission on Climate, Energy, and Sustainability, the Coalition for Sonoran Desert Protection, Active 48, the Sierra Club, the University of Arizona and its University Climate Change Coalition, the International Indian Treaty Council, Tucson Clean & Beautiful, Arizona State University, and local businesses. The Council is tasked with advising the Mayor and City Council, particularly as it pertains to the development and implementation of the City's climate action and adaptation plan.

3.7.3 Mayoral Advisory Council on Racial Equity & Justice | 2020-Present

The Mayoral Advisory Council on Racial Equity & Justice was established in June 2020, and is comprised of stakeholders and organizers representing the full diversity of Tucson's communities. The Council is responsible for identifying opportunities to integrate equity and justice into policy and government services and operations. More specifically,

the Council is tasked with reviewing policy recommendations, ensuring that an equity lens is applied to policy and budget decisions, advising on community and police relations, and developing an Equity Needs Assessment.

3.8 Legislative and Regulatory Drivers and Considerations

Tucson's climate planning efforts must align with and account for legislative and regulatory drivers and considerations that exist outside of the City's political and geographic boundaries, including at the county, regional, and state level. In addition, policies imposed by local utilities and energy providers bear on the ability of Tucson to execute its climate action and adaptation plan. This section speaks to those drivers and considerations at a high level.

3.8.1 State Actions

The State of Arizona has historically been inactive, and at times hostile, with respect to action on climate change. For example, Arizona was the first state in the nation to prohibit local governments from banning natural gas. In February 2020, Governor Doug Ducey signed into law House Bill (HB) 2686, prohibiting municipalities from creating any code, ordinance, regulation, or fine/penalty imposition on utilities for providing natural gas for new construction projects. HB 2686 was supported by Southwest Gas and the parent company of Tucson Electric Power, which service the greater Tucson metropolitan area. Older legislation also continues to hinder climate action statewide, including HB 2442 (2010), which prevents State agencies from monitoring GHG emissions for the purpose of addressing climate change.

Opponents of climate action also seek to limit grid electricity regulation. In 2021, opponents introduced HB 2448 which sought to prohibit the Arizona Corporation Commission's ability to regulate energy resources and maintain the Renewable Energy Standards and Tariff (REST). REST required electric utilities to generate 15% of their energy from renewable resources by 2025. HB 2448 ultimately did not pass.

The State has taken observable action on water issues. The Arizona Department of Water Resources and the Central Arizona Project reconvened its Lower Basin Drought Contingency Plan Steering Committee delegates as the Arizona Reconsultation Committee in 2020, tasked with developing new guidelines for the long-term management of the Colorado River system. In response to Arizona's Groundwater Management Act of 1980, the Department of Water Resources has also set a goal of establishing safe-yields for groundwater by 2025 in Tucson's Active Management Areas. Safe-yield conditions reflect sustainable groundwater extraction as opposed to long-term declines in local water tables.

Through the Arizona Corporation Commission (AZCC), some actions have been executed to reduce environmental impacts. The AZCC is an elected public utilities commission responsible for regulating public utility companies. In 2020 the Commission approved its Energy Modernization Plan that requires utilities to source half of their energy from carbon-free sources by 2035, with a goal of 100% carbon-free by 2050. The plan includes a renewables mandate, the Clean Peak Standards, that regulates peak hour energy delivery from renewable sources. Most energy providers statewide are subject to these standards and requirements.

With respect to transportation, the AZCC developed an Electric Vehicle Policy Implementation Plan via Decision 77289 in 2019, providing guidelines on how to best electrify the transportation sector. The AZCC also issued a requirement

for utilities to develop implementation plans for electric vehicles and infrastructure via Decision 77044. In response, Tucson Electric Power and Arizona Public Services developed a Statewide Transportation Electrification Plan in 2020, providing a roadmap for transportation electrification statewide and committing to the addition of over one million electric vehicles to the state by 2030.

3.8.2 Utility Actions

With respect to the City of Tucson, Tucson Electric Power (TEP) supplies power to the city and the metropolitan area at large, generating energy mostly from fossil fuel power plants, with nearly a fifth of its energy coming from renewable sources. TEP has a plan to fully transition off coal power by 2032 and to increase its renewable energy share to 70% by 2035. It has also committed to reduce its carbon emissions by 80% from 2005 levels by 2035, as outlined in its Integrated Resource Plan.

However, Arizona legislation still only imposes a requirement dating back to 2006, mandating that utilities only provide 15% of their energy from renewable sources by 2025. Consequently, the Tucson Mayor and Council adopted Resolution No. 23166 in 2020, recommending that the AZCC adopt a clean energy standard of 100% by the year 2050.

In recent years, groups have initiated efforts to establish community choice energy in Arizona, which would allow customers to either opt into or opt out of renewable energy that would be provide through the existing grid. In 2019, Arizonans for Community Choice was created to advise Arizona Corporation Commissioners, energy industry stakeholders, climate action and environmental advocates, municipalities, and counties in Arizona on the benefits of community choice aggregation (CCA) as an avenue to increase the use of clean, renewable energy across the state. To date, the organization has organized multiple events, webinars, and official briefings, and has called upon the AZCC to set rules allowing cities and counties to establish CCA programs.

3.9 Engagement Efforts

3.9.1 People, Communities, and Homes Investment Plan (P-CHIP) | 2021

To determine community priorities for the People, Communities, and Homes Investment Plan (P-CHIP), the Tucson Department of Housing and Community Development (HCD) utilized a community survey to identify top challenges, impacts, funding priorities, and target populations for its investment efforts. A website and accompanying story map were also used to communicate history and progress. Finally, HCD held multiple virtual public and stakeholder meetings, including a meeting conducted in Spanish for monolingual speakers.

3.9.2 *Move Tucson* Transportation Master Plan | 2021

As part of the *Move Tucson* planning effort, the Department of Transportation and Mobility (DTM) utilized multiple engagement approaches to collect extensive community input. Between 2019 and 2021, DTM provided both in-person and online avenues for community engagement, reaching over 4,000 people across Tucson. Avenues included a launch event, multiple stakeholder interviews, sidewalk surveys, virtual open houses, online surveys, interactive web maps,

public meetings, and advisory committee presentations. DTM also partnered with 11 community members who served as street ambassadors, using a peer-to-peer model of community engagement to connect with underserved communities, particularly those in geographic areas with higher mobility vulnerabilities, risks, and inequities. Through this engagement effort, DTM identified various mobility and transportation needs to be addressed via the plan's implementation, including but not limited to safety and comfort for all modes of travel, infrastructure improvement, increased transportation options, heat resilience, and transit system reliability.

3.9.3 Community Climate Survey | 2021

In early 2021, the City of Tucson released an online community survey, the first step in engaging the Tucson Community in the development of the Climate Action and Adaptation Plan. The survey measured community concerns about global warming, climate hazards and action that could be taken to reduce greenhouse gas emissions focusing on sectors like energy, planning, transportation, and waste. To understand who was participated, the survey compiled sociodemographic information on items such as age, race and ethnic, gender, and employment status. Most respondents were white or Caucasian, high income, owned their own home, and had college degrees. Frontline communities that are most impacted from climate change, such as low-wealth households and people of color, did not participate in the survey in significant numbers, likely due to various barriers to engagement.

3.9.4 Climate Listening Sessions | 2021

The City of Tucson organized a series of community listening sessions and workshops in 2021, in collaboration with University of Arizona's Climate Change Coalition program (UC3), to identify concerns and priorities for the climate action plan. To carry out these sessions, the City of Tucson received funding from the Arizona Institute for Resilience. The goal of this engagement strategy was to deepen engagement with those communities most affected by climate change. The City held 14 community listening sessions, reaching over 150 Tucsonans, and gathering over 1,300 points of climate concerns and recommendations. For these community listening sessions, 29 individuals – reflecting Tucson's demographic diversity - were trained as facilitators. As part of an effort to engage younger community members, 8 high school and college students were trained to collect, sort, and analyse data. The community listening sessions revealed that the top concerns among participants include extreme heat, drought, and equitable access to resources.

3.9.5 Additional Ongoing Engagement Efforts

As of the time this memo is being written, the City is undertaking multiple planning efforts with coordinated community engagement efforts to inform those plans. Those include the forthcoming General and Sustainability Plan update and *One Water 2100*, as well as *Tucson Delivers Parks + Connections*. It is expected that community engagement surrounding the forthcoming climate action and adaptation plan can synchronize with and inform engagements as performed under these other planning endeavors.

4 Existing Conditions Assessment

Within this Existing Conditions Assessment section, categorical evaluations are provided across select areas as they pertain to climate action and adaptation efforts across the city, including: (1) stakeholder and community engagement; (2) greenhouse gas emissions accounting and monitoring; (3) climate change adaptation and resilience analyses and assessments; and (4) climate mitigation and adaptation strategies. Underneath each of these categories, a summary of observations will be provided, followed by a brief provision of best practices. Categories will conclude with a gap analysis and specific recommended actions.

4.1 Stakeholder and Community Engagement

4.1.1 Summary of Observations

To date, the City of Tucson has demonstrated a history of community and stakeholder engagement within and across its major planning endeavors. Some more recent community outreach efforts, including but not limited to P-CHIP, deployed various approaches to engage a diverse range of community groups and residents. These included the use of a website and accompanying story map to communicate history and progress, virtual meetings that included a Spanish-only meeting for monolingual speakers, and an online survey to identify challenges and priorities. In the case of P-CHIP, the outcomes of those engagements were not only summarized in the Plan, but more detailed findings were provided in appendices for reference.

In the context of climate action, while other plans' stakeholder engagement processes have touched on pertinent issues – notably the 2013 *Plan Tucson* General and Sustainability Plan, P-CHIP, and the *EV Readiness Roadmap* - the City has undertaken more concerted efforts over the last couple of years to solicit diverse input on climate action. The Community Climate Survey, conducted in 2021, garnered a substantial response from the community at large and helped the City begin to identify some of the most prominent issues facing the City relating to climate mitigation and adaptation. However, survey administrators observed a lack of diversity in the respondent base, noting that input from frontline and historically marginalized communities was largely absent.

Noting the largely homogeneous response to the survey, the City followed with a series of Climate Listening Sessions used to capture targeted feedback from frontline communities. The listening sessions deployed a *promotoras* (community ambassadors) program approach whereby community members were trained as facilitators to manage, collect data from, and communicate findings from the listening sessions. 14 community groups were identified, 12 of which were successfully engaged during the process.

It is anticipated that through ongoing citywide planning efforts, including *Plan Tucson* and *One Water 2100*, diverse and intentional community engagement activities will be conducted to inform the City's long-range planning – some of which stand to touch on climate action and adaptation issues.

The City also has structures in place to continue soliciting input from representative stakeholder groups. The Climate Action Advisory Council, for example, includes stakeholders from academia, environmental advocacy groups, local businesses, and City government. The Commission on Climate, Energy, and Sustainability includes representation from different City Council wards, community advocates, utility representatives, and members of community-based

organizations. These advisory bodies offer indirect avenues of community input that will continue to be of value going forward.

4.1.2 Gap Analysis

Historically, community engagement on topics pertaining to climate change has been limited to planning efforts with more overt overlaps. P-CHIP, for example, touches on the impact of tree canopy and community shading on neighborhoods and residents. Up until 2020, the City has not directly engaged community members on the issues of climate change mitigation, adaptation, and resilience, although this has changed with the recent Community Climate Survey and Climate Listening Sessions.

The City has itself recognized the limitations with respect to the survey and listening sessions held in the last two years. The listening sessions were in and of themselves a deliberate follow-up to a survey that garnered a response from a largely homogenous set of privileged community groups and residents. The listening sessions demonstrated great progress to administer more collaborative engagement and thought partnership with historically marginalized members of the community, but the City was still unable to reach members of Indigenous and monolingual Spanish-speaking communities.

The City's engagement efforts to date have entailed the use of some best practices, including the use of peer-to-peer methods such as community ambassadors to engage certain groups. The City has used other methods such as communitywide surveys and tabling at community events to conduct focused outreach. However, even through these formats, there are still segments of the community that may be unable to participate through those means. In other words, there is space for more targeted engagement to reach these groups.

4.1.3 Best Practices

Engagement efforts surrounding the delivery and implementation of a climate action and adaptation plan have to be intentional, and guided by core values around participation, inclusion, and justice. There are various resources available that provide more concrete explications of values and codes of ethics that can be adopted to govern a community engagement process. Resources include, but are not limited to, the International Association for Public Participation (IAP2), the U.C. Berkeley Othering & Belonging Institute, the Urban Sustainability Directors Network, and C40 Inclusive Climate Action. Across each of these resources, however, it is clear that specificity and explicit communication surrounding values, desired outcomes, approaches, and methods are critical, as they both align the administrators of the planning effort and provide transparency to community members. Earnest communication regarding how engagement efforts will not be extractive,[3] and how they will instead lend themselves to reciprocity,[4] ongoing

[3] In this context, engagement efforts that are "extractive" will simply consult individuals or groups within a community for input as a means of completing a prerequisite task and without the intent to further involve or partner with those entities. In these situations, truths, knowledges, and perspectives are "extracted" without follow-up, which can contribute to community alienation and result in planning and implementation efforts with limited to no benefits to the community at large.

[4] In this context, "reciprocity" or reciprocal engagement – as defined by the University of North Carolina, Greensboro – refers to "the recognition, respect, and valuing of the knowledge, perspective, and resources that each partner contributes to the collaboration."

collaboration, and thought partnership stands the best chance to not only elicit meaningful feedback that will better inform the strategies and actions identified within the Plan, but also to improve and solidify relationships with communities in the long term.

With that said, the following practices are identified as they have not only been widely deemed as best practices, but also appear to be applicable to the City of Tucson's needs for this planning effort:

1. **Communicate the desired outcomes.** These outcomes are likely to include more than the delivery of a plan, and extend into the plan's long-term viability, community involvement in its execution, and the equitable distribution of benefits and burdens emerging from the actions and impacts of the Plan.

2. **Use equity-forward approaches or frameworks to guide engagement.** Achieving equitable outcomes requires an equitable process. Frameworks or concepts that guide an engagement process, such as targeted universalism,[5] are useful as a reference point throughout the engagement process to ensure that the planning process is completed with equity at its center. Establishing or adopting definitions around the types of equity being prioritized is also recommended.

3. **Recognizing and overcoming barriers to engagement.** Conventional methods of engagement, such as physical or online surveys and large public meetings, have utility but may not be accessible to certain communities. Furthermore, time and budget allotted for a planning effort can also pose limitations to reaching intended audiences. It is important to recognize and communicate these barriers outright, while addressing what efforts are being made to overcome them.

4. **Partnering with trusted messengers.** Within and across communities exist various knowledges and truths that are critical to informing long-term planning efforts, but these are not easily discovered or shared when outside parties enter into community spaces for engagement. Working with and supporting community members who live within and know the community one seeks to engage, using peer-to-peer approaches, can help build trust and create safe and accessible spaces for historically excluded communities and residents to engage.

5. **Exercise diversity in methods and tools of engagement.** Going beyond the conventional survey or public workshop can go a long way toward more diverse and inclusive engagement. Expanding the toolkit to include community-led dialogues, pop-up events, and ambassador programs, for instance, can help facilitate more targeted and meaningful engagement and partnership with members of the community.

[5] Targeted universalism is a term coined by the Othering & Belonging Institute at the University of California, Berkeley. Per their definition, "targeted universalism means setting universal goals pursued by targeted processes to achieve those goals." A framework based on targeted universalism establishes universal goals for all parties concerned, for which the strategies developed are "targeted, based upon how different groups are situated within structures, culture, and across geographies to obtain the universal goal[s]."

4.1.4 Recommended Action(s)

Buro Happold, in partnership with local engagement organization Living Streets Alliance, have drafted a Community Engagement Strategy for the Tucson climate action and adaptation planning effort that will not only outline values, approaches, and methods, but also explicitly lay out a timeline for the execution of the engagement effort at large and the specific deliverables to be provided to the City.

However, it is recommended that the City continue to reflect on its past engagement experiences, and consider how it engages on the implementation of planning efforts or initiatives after their development is complete. Throughout all its planning efforts, including the development of this climate action and adaptation plan, the City should continue incorporating strategies that touch on how it will continually engagement with individuals and groups across Tucson – especially those who may often be excluded or left at the margins.

The City may also consider adopting its own values and code of ethics with respect to engagement efforts to which all departments and City entities must adhere. It can also create resources that guide residents to community groups and advocates to which the City has pre-existing relationships to better connect those residents to the City's work.

4.2 Greenhouse Gas Emissions Accounting and Monitoring

4.2.1 Summary of Observations

The City has a history of policies and initiatives centered on mitigating greenhouse gas emissions, largely informed and driven by the 2011 *Climate Mitigation Report* and the 2013 *Plan Tucson* General and Sustainability Plan. The City has largely reported its operational emissions through the Pima Association of Governments (PAG) Regional Greenhouse Gas Emissions Inventory, which usually reports six-year trends of emissions across the County, and is updated every two years. For Tucson, the inventories are summative and broken down by sector or sub-sector. Trends are described with respect to changes in emissions, but detailed explanations of emissions trends as it pertains to City actions are not provided, with only surface-level evaluations included.

Conversations with City staff have indicated that the City of Tucson does not calculate or directly report on its own greenhouse gas emissions. Instead, the City provides PAG staff with data from City operations (e.g., utility data for government-owned buildings). Data for City operational emissions comes from a variety of sources, including but not limited to Tucson Electric Power Company (TEP), Southwest Gas Corporation (SWG), and Arizona Department of Transportation registrations and vehicle travel patterns data. A summary of emission sub-sectors, sources, and data sources is provided below in Table 6.

Table 6. Tucson Operational GHG Emissions Sub-Sectors, Emissions Sources, and Data Sources

Sub-Sector	Emission Source	Data Source
Residential, commercial, and industrial (RCI)	Electricity use	Tucson Electric Power Company (TEP) staff

Residential, commercial, and industrial (RCI)	Natural gas (and diesel)	Southwest Gas Corporation (SWG) staff
On-Road	Private and commercial vehicle travel	Arizona Department of Transportation's Pima County vehicle registrations, fuel, speed, and vehicle travel patterns data
On-Road	Public transit	VMT by fuel type from Cat Tran, the Loop, Sun Shuttle ADA Dial-a-Ride, Sun Shuttle, Sun Tran, Sun Link and Sun Van
Non-Road	Agriculture, commercial, industrial and construction, residential lawn/garden equipment, airport/railroad support vehicles, recreational vehicles	Not listed
Aircraft	Airplanes	Volume of aviation gas and Jet A data from airport staff
Solid Waste	Landfill waste	Emissions from regional landfills obtained from EPA's GHG Reporting Program, USEPA 2020a.
Wastewater	Wastewater reclamation	Wastewater treatment based on sum of nitrification/denitrification, lagoon treatments, and handling of digester gas
Industrial Processes	Cement production (CalPortland Company Rillito Cement Plant is not in Tucson limits)	Cement production reporting, USEPA 2020a
Other	Central Arizona Project (CAP)	Energy-related Tucson Water CAP water delivery emissions

Community-wide emissions are also included in the PAG inventory. However, these emissions are not sourced from the City. Instead, the data and methodology are collected, determined, and applied directly by PAG. At the time of drafting, Buro Happold has not yet received data and documentation detailing the methodology for community-wide emissions. Nevertheless, this process is owned by PAG, as are the calculations and methodological applications for City operational emissions.

Collectively, per PAG's regional inventory, City government emissions for Tucson have declined by 5% since 2014 (as of 2019), with stationary energy being the single largest contributor to City government emissions. In addition, during the same period, communitywide emissions have dropped by 15%. Stationary energy also constitutes the majority of communitywide emissions (as of 2019).

The inventory does not necessarily attribute reductions to specific City- or community-deployed strategies or initiatives, and it does not appear that the City has tracked the impacts of its climate mitigation initiatives. There also does not appear to be staff or protocols in place to implement and maintain a reporting system that tracks City operational and community-wide emissions.

Finally, as there are no strategy-specific attributions and no long-term emissions goals in place at the moment beyond the recently set goal for carbon neutrality by 2030 for City operations and the communitywide emissions targets in 2030 and 2050 (i.e., the central target of the forthcoming climate action and adaptation plan), no comprehensive emissions pathway or scenario analyses have been performed or have been included in any document reviewed as part of this Existing Conditions Assessment at the City and community level.

Tucson Water conducts and completes its own GHG emissions inventory with respect to its own operations and facilities. While the source data is the same, there may be methodological differences that could result in different emissions accounting between PAG and Tucson Water (this has yet to be reviewed or verified). Furthermore, Tucson Water's GHG emissions inventory follows a more widely accepted reporting methodology, separating emissions into Scopes 1-3 which reflect different levels of control and influence, as opposed to using sub-sectors or other categorizations. At the time of drafting, a more thorough review of Tucson Water's emissions inventories is in progress.

In sum, the emissions inventory accounting process is not wholly owned by the City of Tucson, nor is it wholly reported through the City itself. Progress on emissions is tracked through PAG, but is otherwise not monitored or reported via City staff.

4.2.2 Gap Analysis

As of the time this memo is issued, a more thorough review of the emissions source data and methodology across PAG and Tucson Water is underway. An assessment of gaps with respect to emissions accounting, data, and methodology will be provided as a baseline emissions scenario is developed.

However, the primary gap is lacking ownership of the emissions accounting and reporting process. This poses a number of risks for the City as it endeavors to reduce its emissions. First, another party is responsible for the actual development of the City's inventory. While the City does provide the data to PAG for much of City government operations, the City does not own or oversee the methodological applications that translate that data into GHG emissions. Furthermore, it provides no data or methodological input to inform the calculation of communitywide emissions – a process owned entirely by PAG. While the emissions inventory differentiates between Pima County at large and the City of Tucson in terms of geographic boundary, how finely that geographic boundary or differentiation is applied in the calculation of communitywide emissions is unclear or at least not overtly addressed in the inventory. This memo does not assess the validity of PAG's methodology and approach with respect to either category of GHG emissions, but given that the focus of this analysis is the City of Tucson, the methodologies applied require further examination.

Additionally, the inventories for Tucson at the City government operations and communitywide levels are differentiated by sub-sector, but not assigned between Scope 1, Scope 2, and Scope 3 emissions. This gap is highlighted for a few reasons: first, internationally recognized standards regarding the preparation of emissions inventories call for this categorization, in part because these categorizations help institutions define which emissions can be directly and indirectly attributed to their operations and activities, as well as which emissions have more to do with an institution's sphere of influence.[6] Second, internationally recognized standards regarding the verification of emissions also hinge on this categorization. And third, it creates uncertainty and potentially discrepancy regarding emissions accounting for Tucson Water internally versus how it is reported in the PAG inventory.

Another critical gap is that there is no verification process in place for GHG emissions at either the city level or at the PAG level. At the very least, no data validation process is explicitly defined, whether it be at an internal or external level, and there is no mention of verification in the PAG inventory or in any related material from the City of Tucson. Third-party verification can identify material discrepancies between internally calculated emissions and externally calculated emissions based on internationally recognized and affirmed methodology.[7] Without a verification process in place, material errors can be missed, and these can result in a miscalculation and misreporting of emissions that disables departments and City leadership from meaningfully defining, executing, and evaluating strategies to mitigate emissions.

Finally, because emissions are reported on a biennial basis, calculations for two years of emissions have to be performed simultaneously. While this is a generally minor gap, there can be differentiations between emission factors year-to-year (e.g., grid electricity shifts year-to-year based on the carbon intensities of its energy sources) that could potentially contribute to material differences between reported emissions and actual emissions in a given year if emissions factors are incorrectly applied. Furthermore, the handling of more data generally contributes to an increased risk, and lacking evaluation of data on an annual or biennial level may inhibit the City's ability to track its progress on emissions mitigation.

4.2.3 Best Practices

Given the City's ambitious target of communitywide carbon neutrality by 2050, a comprehensive emissions accounting and reporting protocol that is internally owned and managed – and externally verified on a routine basis – will be critical to the city's success in climate change mitigation. There are robust and internationally recognized standards that pertain to emissions reporting and verification that the City can use as guidance to institute a more robust and manageable emissions accounting process. However, whichever approach a city takes to accounting for and reporting

[6] Per the Greenhouse Gas Protocol, Scope 2 emissions (i.e., purchased energy such as grid electricity) should be calculated and reported twice in each reporting period to reflect two separate emission factors: market-based emission factors and location-based. Market-based emission factors reflect the actual carbon intensities of the electricity purchased based on the provider's energy sources. Location-based emission factors reflect the average intensity of grid electricity across a larger region. While market-based emission factors can generally be considered the more accurate reflection, location-based emission factors are useful as they provide added context, and they can also serve as a back-up if market-based emission factors are unavailable.

[7] For the purposes of this document, "material" is defined as a difference of 5% or greater between reported emissions or calculations and what is deemed actual or correct.

its emissions, ownership and documentation of that process are critical if meaningful progress on emissions reduction is to occur.

With that said, the following practices are identified as they have not only been widely deemed as best practices, but also appear to be applicable to the City of Tucson's needs for this planning effort:

1. **Dedicating resources to GHG emissions reporting on an annual or biennial basis.** For any organization interested in reducing its greenhouse gas emissions, dedicating resources to the development of GHG emissions inventories on an annual or biennial basis is imperative. These resources can include internal staff who are tasked with compiling and cleaning data and calculating GHG emissions, or external parties or organizations that can be brought on as contractors to complete the work routinely. As GHG emissions inventory becomes more customary and routine, the costs of this work can decline over time.

2. **Identifying the scope and boundary of the GHG emissions inventory.** Determining the scope and boundary of an emissions inventory is a useful exercise, in that an organization can identify which emissions fall within its realms of control and influence, whether or not they fall within a certain geographic boundary, and focus its resources on calculating those emissions. For instance, some cities may elect to not include or report on certain Scope 3 emissions (e.g., commuting), as the estimated impacts of those emissions are minimal, or the cities' reach and resources regarding those activities are limited or constrained. Generally speaking, including Scope 3 emissions is considered a best practice, given that every organization has some capacity to reduce indirect emissions from operations, but in some circumstances, selectivity may be necessary so that limited resources are devoted to the areas of greatest potential impact.

3. **Adopting an internationally recognized accounting protocol in alignment with the ISO 14060 family of standards.** The International Organization for Standardization (ISO) sets quality management standards for companies and organizations of any size and geography. The ISO 14060 family of standards, in particular, clarifies and provides consistency with respect to the quantification, monitoring, reporting, validation, and verification of GHG emissions. Organizations such as the World Resources Institute and the GHG Protocol provide further guidance on how to calculate and report on emissions in alignment with these standards, and provide the most up-to-date information with respect to calculation methodologies, emission factors and pertinent constants for calculating emissions, and reporting formats and methods. Other protocols that are pertinent to the City and its reporting include, but are not limited to, the Global Protocol for Community-Scale Greenhouse Gas Emissions and the Local Government Operations Protocol.

4. **Creating a data management strategy and infrastructure that is consistent and accessible across business units.** Behind every GHG emissions inventory is a time-consuming process to compile and collect data, to clean data and organize it in a consistent format, and complete organized and occasionally complicated calculations. Depending on the scope and boundary of the inventory, it can involve a high volume of data –and managing that data through its collection, cleaning, and calculation is critical to the integrity of emissions inventories. This process includes consistent file storage, naming, cleaning, and sharing practices that can be applied and shared across business units, which can be done through guidelines or templates.

5. **Implementing an accessible and routine monitoring, reporting, and evaluation process.** Mitigation efforts cannot be tracked successfully without a monitoring, reporting, and evaluation process in place. Monitoring can be successfully performed using tools such as Microsoft Excel workbooks or internal Microsoft Power BI dashboards, the latter of which can communicate with data as it is inserted and show progress, whether it be in in designated time intervals or in real-time (depending on the sophistication and regularity of the data management process in place). Reporting can be performed in multiple ways, whether it be through simple, consolidated or graphically designed reports whereby graphs, tables, and other measurement visuals are created manually to communicate progress to various audiences, or through an online dashboard with some level of interactivity to enable users to better understand the City's mitigation progress. Evaluation can be integrated into any of the above tools, using formulas, visuals, or tools provided via dashboard software to show whether an institution is behind, on-schedule, or ahead-of-schedule with respect to mitigation. Reporting tools such as ICLEI ClearPath can provide all of the above to some extent, but may need to be supplemented with additional internally or externally facing tools, depending on need.

4.2.4 Recommended Actions

In this case of emissions accounting and mitigation for the City of Tucson, all of the above best practices are recommended actions – but these steps will need to occur over a reasonable period of time to accommodate the potential additional resources required to execute them.

A review of the City's 2019 inventory is currently in progress, which will uncover some additional gaps and/or risks. Next, the City needs to determine if and how those gaps can be remedied, and confer on a framework for accounting and reporting that can be owned internally while still enabling the City to contribute to the regional PAG inventory. This framework should align with internationally recognized standards, and the Buro Happold team can provide immediately implementable recommendations that can be incorporated into the strategies and actions of the climate action and adaptation plan, as well as through the emissions inventory included in the plan.

Next, the City should identify implementable actions in the mid- to long-term that can increase the integrity, comprehensiveness, and usefulness of its GHG emissions inventory – such as data management protocols and third-party verification. Buro Happold can work with the City to provide these recommendations as potential strategies and actions for inclusion within the Plan.

Finally, the City should explore dashboard tools such as ICLEI ClearPath that it can independently use and contribute to as a means of monitoring, reporting, and evaluating the City's progress on GHG emissions mitigation. Buro Happold is working on providing additional recommendations in this regard.

4.3 Climate Change Adaptation and Resilience Analyses and Assessments

4.3.1 Summary of Observations

Through a number of plans and initiatives, the City of Tucson has already committed to several adaptation and resilience efforts. These have mainly focused on green infrastructure, stormwater and flooding, mobility, and

neighborhood health and equity. Efforts such as the Tucson Million Trees Initiative and the Green Stormwater Infrastructure Fund are already in effect, working to increase and provide shade to Tucson residents, reduce the urban heat island effect, and mitigate the risk of flooding. Funding mechanisms such as Proposition 407 have spurred projects that will improve both parks and connectivity across the city. These improvements can include, but are not limited to, the addition of community serving assets such as recreation centers or other amenities, as well as the provision of heat adaptation resources such as pools and splash pads. Connection projects include greenways, bike paths, and other mobility improvements.

The City also has a wealth of research, tools, and resources at its disposal to better understand and act on climate risks, as well as adaptation and resilience opportunities, at the local, regional, and state level. Examples of these resources include *Arizona's Extreme Weather, Climate and Health Profile Report* (2015), ADOT's Asset Management, Extreme Weather, and Proxy Indicators Pilot Program (2020), the *Pima County Multi-Jurisdictional Hazard Mitigation Plan* (2017), and Tucson's own *People, Communities, and Homes Investment Plan* (2021), which together provide a foundational understanding of the climate hazards and risks, systems, infrastructure, people, and communities on which the City can aim its focus.

Finally, the City has also undertaken efforts to better understand its priorities and opportunities with respect to climate change adaptation and resilience. Most recently, the Climate Action Advisory Council is nearing the finalization of a Vulnerability and Risk Assessment Recommendations document. The document serves as the City's most comprehensive effort to date to consolidate the findings of past efforts and the current recommendations of local and regional experts regarding climate vulnerability and risk across the City of Tucson.

4.3.2 Gap Analysis

Despite the City's aforementioned progress and available resources, the City has yet to complete a consolidated Climate Vulnerability and Risk Assessment, although that will be one of the primary tasks of the climate action and adaptation planning effort. Nevertheless, this remains the City's biggest existing gap with respect to climate adaptation and resilience.

While social vulnerability to climate change hazards has been discussed, those conversations have remained fairly broad and have occurred largely through reports and tools developed at the county, state, or regional level. None of those discussions, beyond partial efforts through plans such as P-CHIP, have focused exclusively within the Tucson city boundary.

Additionally, discussions of infrastructure vulnerability have been spread out among various department- and sector-specific studies, but have not otherwise been consolidated into a comprehensive citywide assessment. Most of these discussions have also focused on the county, state, or regional level, and have not delved into Tucson-specific issues.

Finally, there has been little discussion – at least within City plans, reports, and policy – regarding the projected impacts of climate hazards on the various communities of Tucson, let alone the likelihood and nature of their disproportionality within and between population groups or geographic areas. Again, this is partially discussed through some existing plans and research, but a consolidated, comprehensive evaluation of climate hazards that looks at their varying impacts through mid- and late-century has yet to be completed.

4.3.3 Best Practices

Climate adaptation and resilience efforts must by and large be guided by an understanding of the climate hazards within a specific geographic boundary, the nature and variety of those impacts over time on communities, as well as social networks, physical infrastructure, and local ecosystems. In completing a climate vulnerability assessment, a municipality or regional entity can identify the people, infrastructure, and ecosystems that are most vulnerable to the impacts of climate change. This information can then be used to develop focused adaptation and resilience strategies to mitigate or completely remedy those vulnerabilities over time.

With that said, the following best practices are the most applicable to the City of Tucson's needs at this time:

1. **Identifying past and current climate events and hazards.** The climate vulnerability assessment should identify past and current climate events within the city and its surroundings. Where possible, it should provide projections of climate hazards or anticipated future trends. These can include, but are not limited to, extreme heat events, flooding, drought, and wildfires – which are typically more common in the Southwest.

2. **Including multi-method analyses of vulnerable populations, infrastructure, and ecosystems.** The assessment should provide findings from both quantitative and qualitative analyses of vulnerability, cutting across populations, infrastructure, and ecosystems. The assessment should cover historic and existing social equity concerns as they relate to climate hazards. Experiences, stories, and other findings should be used to address gaps and biases in more quantitative approaches.

3. **Discussing adaptive capacity.** The assessment should discuss and identify adaptive capacity resources, challenges, and opportunities. Adaptive capacity refers to the ability of a system, institution, community, or ecosystem to respond, adjust, or thrive in the face of potential damage or harm.

4. **Informing co-benefits.** While the primary intention of a climate action and adaptation plan is to reduce GHG emissions and improve community resilience, proposed mitigation and adaptation measures can often result in wider, shared benefits for the community. Capturing these co-benefits requires an estimation of the financial costs (e.g., capital expenditures) and benefits (e.g., utility cost savings) of climate action and adaptation measures, but moreover, it requires the demonstration of the social benefits (e.g., reduced heat-induced illness or mortality) and environmental benefits (e.g., improved air quality). To inform strategies and actions within the context of a plan, co-benefits can broadly be organized into three categories: social benefits, environmental benefits, and economic benefits, which can then be assigned to actions where warranted.

4.3.4 Recommended Actions

In the case of climate adaptation and resilience, the City's next step should be to determine the scope and focus areas of the climate vulnerability assessment that will be completed as part of the climate action and adaptation planning effort. Given that this would be the first comprehensive assessment performed on behalf of the City, a framework outline of the assessment should be developed, reviewed, and approved by the City and the Climate Action Advisory

Council. At the time of drafting, Buro Happold is working on the development of a Framework Memorandum that will be shared with these stakeholders for feedback.

In addition, through forthcoming community engagement efforts, both the proposed framework and eventual results of the assessment should be shared with the community for feedback and input, as a precursor to thought partnership on strategies and actions. This will also be included as a step in the Community Engagement Strategy being co-developed by Buro Happold and Living Streets Alliance.

4.4 Climate Change Mitigation and Adaptation Actions

4.4.1 Summary of Observations

To this point, the bulk of actions taken with respect to climate change mitigation and adaptation by the City of Tucson have largely been housed within separate departments and accompanying stakeholders. However, even as these efforts have remained largely siloed, it is clear that there are mitigation and adaptation efforts underway across the City.

Mitigation

With respect to emissions mitigation, the City has agreed to broader goals to reduce emissions through the 2011 *Climate Mitigation Report* and the 2013 *Plan Tucson* General and Sustainability Plan. It is clear that, through City activity, it is apparent that overall achievement of emissions mitigation has taken place within the past decade – and this has been made clear through the PAG 2014-2019 Emissions Inventory, which indicates a drop in City government emissions by 5% in 2019 from 2014 levels, with a majority of the contributions to that reduction coming from fleet emissions (~35% decrease) and employee commuting emissions (~19% emissions).[8] With respect to these areas, it is clear that fleet emissions and citywide commuting emissions are expected or intended to decline further, per the commitments made in the City's *EV Readiness Roadmap*. It is also likely that some reductions on the commuting side have occurred and sustained following the COVID-19 pandemic.

However, stationary energy emissions only declined by ~4%. While there is notable progress with respect to grid-supplied electricity used for facilities and parks, Tucson Water, and street and traffic lighting, further investigation is needed as to how much of that can be attributed to deliberate City action and how much can be applied to an improvement in the carbon intensity of grid electricity. Across the board, actual fossil fuel combustion made modest declines, and in the case of Tucson Water and the Central Arizona Project, fossil fuel combustion emissions increased. With respect to pertinent mitigation strategies, aside from TEP's commitment for 70% renewables-sourced electricity by 2035, there do not appear to be cohesive, active electricity or even energy demand reduction strategies beyond building and energy standards built into the City's Code. While there is community conversation and City involvement in preliminary conversations regarding community choice energy, there is otherwise no known effort to increase the procurement of off-site renewable energy to mitigate stationary energy emissions.

[8] At the time of this Assessment's drafting, the methodology for these calculations is being reviewed, but the calculations are assumed as authentic and accurate for the purpose of this document.

The above items are focused on City operational emissions. At the time of this Assessment's drafting, communitywide emissions calculations and methodology are still being evaluated. However, as is the case in other communities, it is expected that stationary energy use is also a significant source of emissions, and thus a significant opportunity for emissions mitigation.

That being said, there is no other stated commitment prior to the Mayor and Council's Climate Emergency Declaration that focuses on specific emissions mitigation efforts, let alone goals with quantifiable targets by which to measure and evaluate that progress.

Adaptation

The City has made greater strides with respect to climate change adaptation, with some more notable and concerted efforts to address the ongoing and future impacts of climate change. Efforts such as the Million Trees Initiative speak to the City's recognition of extreme heat as a pertinent issue for many residents across Tucson, with opportunity to address acute vulnerabilities within certain communities. Various green infrastructure, stormwater, and gray water initiatives, in addition to supply protection and demand reduction efforts from Tucson Water, also show a clear commitment on the City's behalf to address current and future water issues across the region. The *One Water 2100* Master Plan will address these issues in full, and serve as a meaningful complement to the climate action and adaptation plan, as well as the City's forthcoming general plan update in 2023. A variety of other natural and environmental hazards are addressed through Pima County's *Multi-Jurisdictional Hazard Mitigation Plan*, including drought and wildfire, though the plan in and of itself cuts across jurisdictions and isn't in and of itself a City-specific plan (though components of the plan are devoted to the City). *P-CHIP* also speaks to extreme heat as a hazard to the well-being and mobility of residents and neighborhoods, and offers higher level strategies to address the issue.

Other issues related to climate hazards (and with some overlap with decarbonization), such as urban heat island effect, remain partially addressed by the Million Trees Initiative and *P-CHIP*, but it is likely that urban heat island effect remains an issue. It is touched on in *Plan Tucson*, but only in broad strokes without specific actions to look at City-owned buildings as a venue for urban heat island effect reductions. Resilience is conceptually mentioned once under The Natural Environment element of *Plan Tucson*, but otherwise seems indirectly addressed through other City efforts.

4.4.2 Gap Analysis

Across both areas of mitigation and adaptation, the City has clear opportunities to act, but it has lacked a cohesive and recent set of strategies – defined further by actions with attributed resources – to advance in those areas. Departmental initiatives aside, some of the City's greatest gaps lie in the areas where it has the greatest opportunity.

With respect to mitigation, stationary energy is an area with tremendous potential for impact – given that it constituted 96% of the City's operational emissions in 2019. While committed shifts to electrifying grid electricity on TEP's behalf will yield significant reductions to stationary energy's emissions share, it will not be sufficient to meet the City's operational carbon neutrality goal. A share of those emissions come from fossil fuel combustion, which will require the City to explore electrification opportunities while simultaneously seeking ways to increase its share of electricity from renewables. While that share of solar energy generation has gone up nearly threefold since 2014, that share will

need to increase substantively within the next seven or eight years to provide a more substantive and sufficient offset of emissions.

As a note, the above speaks only to City operations, but does not address communitywide emissions. While the methodology for communitywide emissions calculations is being evaluated at the time of this Assessment's drafting, it is likely that City outreach, programs and initiatives, and other efforts are needed that will be directed more toward grid decarbonization and sustainable mobility.

As for adaptation, the City itself has identified many of those gaps through the *Vulnerability and Risk Assessment Recommendations Document*. However, the Climate Vulnerability Assessment that the consultant team will complete as part of the scope of this effort will provide more specific insights into the gaps with respect to adaptation. It is anticipated that some of the gaps in action will fall within the broader categories of extreme heat, drought, and ecosystem health, though there is more to be uncovered and explore by way of air quality, food security, mobility, and energy resilience.

However, one significant gap is that the City has not fully assessed the potential impacts of climate hazards to its critical facilities. While Tucson Water has completed its own Risk and Resiliency Assessment for its critical facilities, those have largely pertained to more conventional natural and anthropogenic hazards as opposed to specifically climate impacts. The City has also not explored these hazards in the context of other facilities it might deem critical outside of water infrastructure, and thus has also not explored opportunities to protect those facilities or to utilize them as community centers or resilience hubs to support communitywide resilience.

4.4.3 Best Practices

With respect to best practices, while the below does not constitute an exhaustive list, the following are considered best practices with respect to mitigation and adaptation:

1. **Electrifying buildings and transportation.** Over time, the difference between the carbon intensity of fossil fuels and grid electricity continues to widen as sourcing for electricity improves. Given a nearly default improvement in carbon intensity, the most significant opportunity to reduce carbon emissions remains in the electrification of buildings (e.g., replacing fossil fuel heating systems with electric heat pumps) and vehicles (i.e., replacing internal combustion engine vehicles with battery electric vehicles). State legislation, especially in Arizona, may create challenges with respect to requiring electrification, so incentives may need to be considered to encourage development with electric appliances as opposed to mandates.

2. **Pursuing community choice energy or aggregation.** Community choice energy offers a significant opportunity for municipalities or regions to reduce emissions, bringing down or eliminating the carbon intensity of their electricity without having to take on the responsibility of building out utility-scale renewables. Customers can also be opted into differing levels of renewable energy based on their financial abilities.

3. **Building out solar and battery storage.** Solar photovoltaics (PV) have become an increasingly viable and affordable option to help decarbonize facilities and infrastructure, but solar is subject to intermittency and does not produce electricity during evening hours. Battery storage offers a solution to that issue by storing excess

electricity during daytime production that can be used during evening hours. Combined solar and battery storage systems, especially systems that are standalone or "islandable," can serve as an energy resilience strategy, providing electricity to facilities or groups of buildings when there is grid disruption.

4. **Move towards transit-oriented, complete streets, and infill development.** Transit-oriented development focuses on creating walkable, pedestrian-oriented communities, hand-in-hand with developing high-quality and highly accessible transit systems as a way of moving away from vehicle-dependence. Complete streets are designed to encourage safe use and mobility for everyone. Infill development refers to the use or rededication of unused or underutilized space within the urban margins of a city to avoid new developments in outlying areas. Each of these create environmental and climate safeguards, with the former two contributing to mode shift away from vehicles to less carbon-intensive (or zero-carbon) forms of transit, and the latter protecting lands with important ecological or natural services from development.

5. **Using building design standards and incentives to increase internal and external comfort, reduce climate impact, and create climate-resilient buildings and spaces.** Building standards, voluntary codes, and incentives can be implemented to drive upgrades within buildings to reduce energy demand and emissions (e.g., lighting upgrades, windowpane film, etc.). In new construction, passive design can be used to designate the orientation, materials, and design of buildings such that they mitigate the impact of external conditions on interior temperature, avoiding increases in energy use and thermal discomfort for building occupants. Canopy cover can provide a similar benefit in the case of extreme heat for people in outside spaces. Together, given their ability to reduce urban heat island effect, these strategies can help with decarbonization by reducing energy demand to cool spaces, while increasing resilience by protecting people from the impacts of extreme heat.

6. **Identifying and establish resilience hubs.** Resilience hubs can serve as locations for residents to protect themselves, get access to necessary resources, or find support during major disruptions or exposure to hazards – regardless of their relation to climate change. These sites can include, but are not limited to, grocery stores, food banks, fire and police stations, libraries, community centers, and other municipal buildings. Consequently, these buildings can be targeted or prioritized for decarbonization or resilience improvements given their ongoing use and importance to the community.

4.4.4 Recommended Actions

The recommended actions stated here reflect the process that will be undertaken to complete the climate action and adaptation plan. First, from a mitigation perspective, an evaluation of greenhouse gas emissions and determining where there seems to be the greatest decarbonization potential from the City's inventory is necessary to begin selecting broader strategies. The subsequent selection of strategies, informed by both data and community input, will also then require input from City officials to begin to identify the specific actions that need to be taken, how they should be prioritized, and the resources available to execute them.

Second, with respect to adaptation, the climate vulnerability assessment will inform the direction of strategies and actions to build adaptation and resilience across Tucson. However, it will be most important for the City to examine particular social and physical vulnerabilities, targeting the geographies and communities that will be most susceptible

to the climate hazards and risks identified in the assessment. Again, mirroring the process above, input is required to make sure that executable actions underlie the strategies selected.

Where the City can act further is by taking on more assertive roles in conversations around grid decarbonization, where the City stands to make the most significant impact with respect to emissions. Advancing existing conversations with respect to bolstering commitments to decarbonize the existing grid, as well as those taking place regarding community choice energy, may help bring transformative decarbonization strategies to fruition. However, the City will also have to consider how any efforts it makes to electrify will be sustained by the grid over the course of time, and how it can then deploy resilience strategies to protect grid reliability, which supports so many of the City's critical systems and infrastructure.

Finally, the City should continue to engage in conversations with the communities of Tucson, peer cities across Arizona and the nation, and scientific and academic experts around how to utilize cutting edge decarbonization and resilience strategies going forward. It should also build adaptability and review into the climate action and adaptation plan, whereby it can review progress every 2-5 years and reorient strategies and focus as needed to better meet the City's goals.

5 Funding and Resource Opportunities

Over the next eight years and beyond, implementation of selected climate mitigation and adaptation strategies will require funding and resource support that the City of Tucson may not immediately have at its disposal. It is very likely that the City will need to turn to external funding and resources to support its efforts. Funding can include grants available to public agencies, whereas resources can include a broader set of programs such as sponsored internships whereby the City can utilize paid, temporary staff to execute actions.

This list will inevitably not be exhaustive, as new opportunities are bound to emerge in the coming months and years, but it will identify some of the major opportunities available to the City.

5.1 Funding Opportunities

5.1.1 Building Resilient Infrastructure and Communities (Hazard Mitigation Assistance Grant) – Federal Emergency Management Administration

The Building Resilient Infrastructure and Communities program, or BRIC, is administered by the Federal Emergency Management Administration (FEMA). BRIC supports states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. The BRIC program's guiding principles are to support communities through capability- and capacity-building, encouraging and enabling innovation, promoting partnerships, enabling large projects, maintaining flexibility, and providing consistency. Grants are issued for a period of performance of 36 months.

5.1.2 Loan Guarantee Program – U.S. Department of Energy

The US Department of Energy (USDOE) Loan Guarantee Program through its Loan Programs Office, which has over $40 billion in loans and loan guarantees to help deploy large-scale energy infrastructure projects. Loans can be issued for technologies across various sectors, including local government, commercial, industrial, non-profit, schools, agricultural, and institutional sectors. Many technologies are eligible, including geothermal electric, solar thermal electric, solar thermal process heat, solar photovoltaics, wind, biomass, hydroelectric, fuel cells, landfill gas, and daylighting. Full repayment is required over a period not to exceed the lesser of 30 years, or 90% of the projected useful life of the physical asset to be financed.

5.1.3 Engaging Communities to Design Nature-based Solutions to Mitigate Climate-related Hazards – National Academies of Science, Engineering, and Medicine

The National Academies of Sciences, Engineering, and Medicine is seeking proposals from U.S. academic institutions and non-profit research organizations, in partnership with local or tribal governments, to adapt an existing or design a new project incorporating nature-based solutions to mitigate climate-related hazards. At the time of drafting, this opportunity is being administered through the Gulf Research Program and thus is only available in the Gulf of Mexico region or Southcentral Alaska. However, it is recommended that the City of Tucson monitor the National Academies webpage for opportunities that may be available for projects in the Southwest in the near future.

5.1.4 Partnerships for Climate-Smart Commodities – U.S. Department of Agriculture

The U.S. Department of Agriculture (USDA) is sponsoring the Partnerships for Climate-Smart Commodities opportunity, which provides up to $1 billion for pilot projects that create market opportunities for commodities using climate-smart practices. This program may be valuable for projects in rural communities across Tucson.

5.1.5 Climate Adaptation Fund – Wildlife Conservation Society

The Wildlife Conservation Society's Climate Adaptation Fund focuses on supporting adaptation for wildlife and ecosystems. In 2022, it will provide up to $2.5 million in competitive grants, though awards will be made to non-profit conservation organization. In this case, the City can explore partnering with local organizations for grant opportunities through this fund.

5.1.6 Competitive Funding Opportunities – National Integrated Drought Information System

The National Integrated Drought Information System (NIDIS, or "Drought.gov") offers a variety of competitive funding opportunities related to drought research. Pertinent opportunities that are available, or may come available again in future cycles, include the Coping with Drought Research Competition (supporting research that assesses impacts of

drought and develops decision support tools for regional, state, and local use) and the Tribal Climate Resilience Program (an annual awards program designed to support resilience through tribally-designed training, adaptation planning, vulnerability assessments, and engagement), among others.

5.1.7 Environment Program Funding Opportunities – The Kresge Foundation

The Kresge Foundation's Environment Program provides funding specifically for cities looking to combat and adapt to climate change while advancing racial and economic equity. Investments are focused on initiatives addressing climate change, health and equity, climate resilience and urban opportunity and climate resilient and equitable water systems. While the program does not accept unsolicited proposals, grant opportunities are available through the Foundation's Current Funding and Opportunities page.

5.1.8 Indian General Assistance Program in Region 9 – U.S. Environmental Protection Agency[9]

The U.S. Environmental Protection Agency (EPA) provides General Assistance Program (GAP) grants to Indigenous tribal governments and intertribal consortia to build capacity, administer regulatory programs, and develop programs addressing environmental issues on Indigenous lands.

5.1.9 Funding via the Office of Indian Energy Policy and Programs – U.S. Department of Energy[10]

The U.S. DOE's Office of Indian Energy Policy and Programs provides information with respect to current and ongoing funding opportunities for Indigenous communities to support tribal energy projects. There are a variety of opportunities available at any time, but the Office provides a valuable consolidation of available opportunities.

5.2 Resources and Support

5.2.1 University of Arizona University Climate Change Coalition (UC3)

The University of Arizona (UA) joined the University Climate Change Coalition (UC3) in 2018. UC3 has supported ongoing climate action and adaptation efforts with the City of Tucson, primarily through its representation on the CAAC. At the time of this Assessment's drafting, the group has continued to offer its support and time, having supported the development of the Vulnerability and Risk Assessment Recommendations Document and the execution of the Community Survey and Climate Listening Sessions. Furthermore, a Research Fellow with UC3 will be supporting the project team with various components of the plan development process. Going forward, UC3 will continue to be

[9] This is a funding opportunity for tribal governments, not the City of Tucson, but the City may consider how it can help enable the use of these resources.

[10] See Footnote #8.

a resource in terms of time and expertise as Tucson moves forward with climate action and adaptation planning and implementation.

5.2.2 USGBC LEED for Cities Local Government Leadership Program[11]

The U.S. Green Building Council's (USGBC) LEED for Cities and Communities certification, through which cities can be certified for their performance across various sustainability metrics, offers a Local Government Leadership Program through which U.S. governments (i.e., cities, towns, and counties) commit to certifying in LEED for Cities and participate in a cohort of peers as they proceed with certification. Through this program, local governments receive a dedicated USGBC staff liaison, access to orientation programs, educational resources, and networking opportunities, support with public relations and marketing assistance, and access to policy and advocacy support.

5.2.3 CivicWell Assistance Programs and Services

CivicWell, formally known as the Local Government Coalition, provide services across a variety of areas to support elected officials and communities. In particular, the organization provides policy assistance around climate change, energy, community design, and water issues. These services include policy development assistance, direct assistance, participatory planning and design, and workshops and presentations.

5.2.4 Climate Corps Fellowship Program – Strategic Energy Innovations

The Climate Corps Fellowship Program, administered by Bay Area non-profit Strategic Energy Innovations, provides staffing to support sustainability projects across the United States. The program assists with the recruitment, employment, and training of Fellows to support municipalities, local agencies, and other organizations. Cities and other potential partners can express interest in hosting a Fellow, which would be employed full-time over the duration of 10 months.

5.2.5 Equity Diversity Inclusion Fellowship – Urban Sustainability Directors Network

The Urban Sustainability Directors Network (USDN) offers an Equity Diversity Inclusion (EDI) Fellowship, a summer program with local governments, intended to address lacking representation of people of color in sustainability fields. Fellowships are full-time for 12 weeks or more, providing a living wage, full-time employment, and health benefits for Fellows through the duration of the program. At the time of drafting, the City of Tucson is participating in this program and is actively soliciting for an EDI Fellow for summer 2022.

[11] At the time of drafting, the City is participating in the 2022 Leadership cohort. Program launch took place in late April 2022.

5.2.6 C40 Cities

C40 is a network of mayors from nearly 100 cities working on addressing the climate crisis, with a mission in place to halve the emissions of member cities within 10 years. C40 has multiple programs and resources in place, many of which Buro Happold has directly supported and co-developed, including resources around Green & Just Transitions. Membership in C40 provides direct access to these resources, as well as to a growing network of leading Cities and Mayors in the climate action space.

5.2.7 Global Covenant of Mayors for Climate & Energy

The Global Covenant of Mayors for Climate & Energy, or GCoM, is a global alliance of city climate leaders, providing local governments with resources, support, and networks for advancing climate change mitigation. At the time of drafting, Tucson a member city of GCoM.

6 Conclusion

This Existing Conditions Assessment is intended to serve as a summary and guide for the City of Tucson with respect to pertinent climate action and adaptation efforts to date. The City of Tucson has a long history of action and intent around addressing climate change, also is actively working towards addressing issues of climate adaptation, resilience, and social equity. Through a range of plans, policies, and actions, Tucson has set itself firmly on a path of climate leadership through its actions to date – with its plan to issue a climate action and adaptation plan being the latest of those actions.

However, the City also has an arduous path ahead. Despite setting an ambitious target to achieve complete carbon neutrality by 2050, some critical steps need to be taken to begin charting the path to that goal – including but not limited to ownership, standardization, and routine reporting of the City's greenhouse gas emissions inventory. Furthermore, despite a wealth of plans and studies that have covered regional vulnerabilities to the impacts of climate change, no efforts to date have consolidated that knowledge into an assessment of social, infrastructural, and ecosystem vulnerability for the City of Tucson specifically.

This Assessment does identify a number of higher-level strategies with respect to GHG emissions mitigation and climate adaptation, pointing to where the most significant opportunities lay after observation of the City's emissions inventory and existing plans and initiatives. However, as efforts are in progress focused on the City's inventory and the development of a Climate Vulnerability Assessment, more concrete and tangible opportunities – and ultimately executable strategies and actions – will be uncovered over the next several months that the City and the community will be able to consider and ultimately include in its climate action and adaptation plan.

The City not only faces an ambitious timeline, but it will also likely meet challenges with respect to resourcing and funding to implement the eventual strategies and actions underpinning a city climate action and adaptation plan. This is why funding opportunities and resources are provided later in this document, to assure the City and its stakeholders that the City may not need to lean on taxpayer dollars alone to achieve its goals.

Finally, this Assessment speaks to community engagement efforts – an area in which the City has demonstrated leadership and utilized progressive approaches that focus engagement towards historically marginalized and excluded communities and geographic areas. The Assessment recognizes this leadership, but acknowledges as well that this engagement has not centered on the issue of climate change, save for a survey and a handful of listening sessions within the last two years. That being said, as with other areas of action, there is room for the City to grow and act intentionally in this space.

In providing this Assessment, Buro Happold also recognizes and reaffirms the work for which the firm is scoped to provide assistance over the next year to help Tucson develop, publish, and track progress on a comprehensive climate action and adaptation plan. Buro Happold looks forward to working with the City, the communities of Tucson, and our consultant partners in Living Streets Alliance, Autocase, and the University of Arizona to help Tucson deliver a leading climate action and adaptation plan by the end of 2022.

Addendum

A.1 Review of Existing Conditions: Existing City and Regional Plans

A.1.1 Regional Transportation Authority Plan | 2006

The Regional Transportation Authority (RTA) Plan is a 20-year $2.1 billion multimodal plan managed and written by the RTA, an independent taxing district within Pima County. The plan and half-cent excise tax used to fund the implementation of the plan was approved by voters in 2006. The plan focuses on four elements, including roadway, environmental and economic vitality, safety, and transit. A majority of the projects within the RTA Plan are managed and delivered by the Pima Association of Governments (PAG) member jurisdictions. As of the date this Assessment is issued, the RTA plan is entering its fourth and final 5-year implementation period and is considered behind schedule due to the impacts of the Great Recession, which significantly reduced RTA revenue collection and other sources of transportation funding, as well as due to increasing community opposition and project costs over time.[12]

A.1.2 Drought Preparedness and Response Plan | 2007[13]

The *Drought Preparedness and Response Plan* was adopted by Mayor and Council in 2006, approved as an ordinance in 2007 and updated in July 2021. The plan aims to minimize the impact of drought on public health and safety, and it covers supply sources including groundwater, reclaimed water, rain and stormwater harvesting, Colorado River Lake Mead water, and potable well fields. It also reviews distribution infrastructure including central distribution boosters, pipelines, reservoirs, and smaller distribution systems. Threats to water supply and infrastructure include increasing surface temperatures, precipitation intensity, evaporation, and reduced water flows. Measures to mitigate impact include increasing awareness of drought conditions, implementing water audits, issuing targeted conservation recommendations to customers, and suspending new requests for water service.

A.1.3 Action Plan for a Sustainable Water Future | 2009

The *Action Plan for a Sustainable Water Future* was the result of a multi-year water and water infrastructure supply and planning study between the City of Tucson M&C and the Pima County Board of Supervisors. The goal of the study was to identify sustainable community water sources given the anticipated strain on water supply due to population growth. The final report lays out principles for water management, and delivers shared goals and recommendations, including comprehensive integrated planning around land use planning and water use, environmental restoration, water supply, and demand management. Post action reports have been delivered by Pima County through 2021.

[12] This assessment of the RTA Plan's implementation progress was provided by County Administrator C.H. Huckelberry in a written update provided to the Pima County Board of Supervisors, dated March 16th, 2021.

[13] The *Drought Preparedness and Response Plan* was updated in 2021.

A.1.4 Climate Mitigation Report | 2011

The *Climate Mitigation Report* was written and released in 2011 by Mayor Bob Walkup and the City Council's Climate Change Advisory Committee. The Committee was charged with developing a climate change mitigation and adaptation plan to implement the Mayors' Climate Protection Agreement,[14] providing strategies to prepare for the effects of climate change on city infrastructure and operations, as well as recommendations to reduce energy and water use, lower utility costs, improve air quality, and reduce greenhouse gas (GHG) emissions. Recommendations were to be implemented beginning in 2012, with benefits to be measured through 2020. The Report, developed in collaboration with the University of Arizona, offers various voluntary strategies and actions, including but not limited to investments into commercial and residential photovoltaics (PV), carshare and bikeshare programs, low-emission vehicles, and resource efficiency across government facilities and operations.

A.1.4 Community Economic Security and Climate Action Analysis | 2011

The *Community Economic Security and Climate Action Analysis* was a report developed by Office of Conservation and Sustainable Development and Westmoreland Associates in 2011. The report includes a comprehensive approach to analyzing various climate action measures, inclusive of co-benefits and a cost-benefit analysis, and provides specific recommendations cutting across energy efficiency, local government policy, and transportation policy.

A.1.5 *Plan Tucson*, City of Tucson General and Sustainability Plan | 2013

Plan Tucson is the City's existing General and Sustainability Plan, developed in 2013 to replace the 2001 Tucson General Plan.[15] The plan guides City action pertaining to various elements, including but not limited to housing, education, business, energy and climate, historic preservation, and public infrastructure, and provides a set of goals and policies under four focus areas: social environment, economic environment, natural environment, and built environment. Under the Natural Environment focus area, the City of Tucson establishes two goals pertinent to climate change mitigation and adaptation, among others:

- "A reduction in the community's carbon footprint, and greater energy independence;" and
- "A community that is resilient and adaptive to climate change."

In addition, Energy & Climate Readiness is a major component of the Natural Environment focus area. Under this section, the Plan highlights the City's efforts to date with regards to pursuing sustainable energy efficiency standards, promoting solar energy technologies, and understanding the impacts of climate change on the region. It highlights the City's efforts to date installing solar PV on City facilities, installing solar water heating at community facilities, and educating the public on solar energy. The City's 2010 emissions inventory and the anticipated impacts of climate change in Tucson are also explicated in detail.

[14] The Climate Change Committee was assembled in 2008 in response to the Mayors' Climate Protection Agreement and its goal to reduce City and community-wide greenhouse gas emissions to 7% below 1990 levels.

[15] Per Arizona statewide requirements, citywide general plans must be updated every ten years.

Several policies are outlined under this section to advance energy and climate readiness, notably focused on energy efficiency, reducing urban heat island effect, using low-carbon and renewable energy sources and fuels, developing programs on energy conservation and efficiency, increasing the use of solar and other renewables, assessing the effects of climate change, and assessing the community's vulnerability to climate change. Related policies across the other focus areas of the plan are included therein.

A.1.6 Pima County Multi-Jurisdictional Hazard Mitigation Plan | 2017[16]

The *Pima County Multi-jurisdictional Hazard Mitigation Plan* was created by the Pima County Office of Emergency Management in 2017, pursuant to the requirements of the Disaster Mitigation Action of 2000 and regulations set forth in the Federal Register. The County identified natural hazards threatening communities, determined their likely impacts, and provided accompanying goals and strategies to mitigate or lessen their impacts. The City of Tucson is included within the planning area, as is unincorporated Pima County, the Towns of Marana, Oro Valley, and Sahuarita, and the Pascua Yaqui Tribe. Probability, magnitude, and vulnerability are assessed with respect to specific hazards, including drought, earthquake, extreme cold, extreme heat, flood, landslide, severe wind, and wildfire.

With respect to the City of Tucson, mitigation measures identified as highest priority are largely designated to target flooding. However, multiple strategies are recommended tackling drought that require ongoing actions as opposed to new actions. Awareness programs are recommended for severe wind and extreme cold, and an assessment is recommended to identify at-risk populations vulnerable to long-term power outages to spur the establishment and promotion of heating and cooling centers.

A.1.7 Pima County Sustainable Action Plan for County Operations 2018-2025 | 2018

The 2018 *Sustainable Action Plan for County Operations* (SAPCO) is a framework created by the Pima County Board of Supervisors and County administration to reduce GHG emissions in Pima County through 2025. The plan looks at five different focus areas, including carbon, water, landscape, materials, and workforce, each with underlying core areas. Under each core area, the Plan provides specific targets, recommended implementation strategies, and performance measures. In addition to the 2018 SAPCO, Pima County has also developed supplementary reports and updates. These include the SAPCO Implementation Plan 2018 – 2025, Baseline Sustainability Report, and several SAPCO Annual Reports through the 2020-21 fiscal year.

A.1.8 People, Communities, and Homes Investment Plan (P-CHIP) | 2021

The *People, Communities, and Homes Investment Plan* (P-CHIP) was adopted by the City of Tucson Mayor and Council in January 2021 via Resolution No. 23292. Developed and administered by the City's Housing and Community Development (HCD) department, P-CHIP replaced the 2017 *Human Services Plan* and was developed to lay out HCD programs and funding allocations for the next five years. P-CHIP identifies six major conditions and challenges facing

[16] The Pima County Multi-Jurisdictional Hazard Mitigation Plan is currently being updated.

the City, including economic disparities, education and economic mobility, health and healthcare disparity, homelessness, housing instability, and neighborhood inequity.

In laying out its three major priorities, People, Communities, and Homes, the Plan sets out a number of pertinent goals with potential climate action planning overlap. These include, though are not limited to:

- Transition from Managing Homelessness to Ending Homelessness
- Advance Social Equity and Inclusion
- Support safe, resilient, active, equitable, and sustainable neighborhoods
- Actively Support Inclusive Economic Development
- Ensure stable, healthy, and safe housing

Speaking specifically to neighborhood inequities, P-CHIP points out various neighborhood vulnerabilities that are also relevant, including transportation disadvantaged areas, areas with insufficient shade and resilience to climate change, and areas with limited access to parks and open space. The Plan lays out areas of further exploration for HCD near its conclusion, posing the question of whether or not HCD is truly reducing disparity and "eliminating environmental justice issues associated with pollution, extreme heat and climate change."

A.1.9 *Move Tucson* Transportation Master Plan | 2021

Move Tucson is the City's transportation master plan, created by the Department of Transportation and Mobility and released in fall 2021. The plan is a direct follow up to Tucson's *Complete Streets Policy*, adopted in 2019. The plan lays out a vision to make the City's transportation investments economically and environmentally resilient and to create a transportation system that improves safety and increases equity in transportation. In doing so, the plan aims to increase travel options, increase safety for pedestrians and cyclists, provide multimodality, and increase equity in transportation investments across neighborhoods. The master plan identifies over 200 programs and projects for the next 20 years with an estimated cost of $5.7 billion, including roadway modernization, bus rapid transit integration, new greenways, bus service improvement, road repair, and programs and policies such as Vision Zero and Safe Routes to School.

The theme of heat resilience is mentioned early in the plan, with an emphasis on increasing shade and vegetation to improve comfort and safety along roads and paths.

A.1.10 Electric Vehicle (EV) Readiness Roadmap | 2022

The *Electric Vehicle Readiness Roadmap* was released in 2022 and prepared by the Office of Tucson Mayor Regina Romero. Acknowledging climate change as a serious threat and referring to the City's Climate Emergency Declaration (Resolution No. 23222), the Roadmap recognizes electric vehicles (EVs) as a key climate strategy to reduce GHG emissions and sets a course of action to support EV across the community of Tucson. Consequently, it sets several city government and community-wide goals and lays out several strategies that address barriers to EV adoption, which are accompanied by responsible City departments, key partners, suggested timelines, budget levels, level of effort, and potential impacts.

Notable goals include, but are not limited to:

- Transition 100% of the City light-duty vehicle fleet to electric by 2030
- Increase the stock of zero emissions battery powered transit to 90% by 2030
- Support school districts in increasing the stock of zero emissions battery powered buses
- Make EVs and charging infrastructure accessible and equitable to a broad range of users, including historically underserved communities, by making it easier to purchase, charge, operate, and ride an EV

Per the Roadmap, all strategies and actions identified are intended to be implemented within 10 years or less, unless specified as an ongoing activity.

A.2 Review of Existing Conditions: Climate Change Frameworks, Reports, and Analyses

A.2.1 Framework for Advancing Sustainability | 2008

The *Framework for Advancing Sustainability* was formally adopted by the Mayor and City Council in 2008, effectively establishing a sustainability program for the City of Tucson. The purpose of the Framework was to provide a structure for how City departments would identify priorities and key actions to integrate sustainability into their operations and administrative culture. One desired outcome of the document was to create a decision-making framework for the City that "explicitly considers sustainability and facilitates sustainable development within the community."

A.2.2 Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges | 2010

Climate Change and Natural Resources in Pima County: Anticipated Effects and Management Challenges is a document prepared by the Pima County Office of Conservation Science and Environmental Policy in 2010, which offers valuable information regarding the region's ecology and the intersection of climate change with soils, watershed function, vegetation, invasive species, range changes, and phenology. The document details the impacts to specific species of plants and animals covered in the county's Multiple-Species Conservation Plan (MSCP). Finally, the report provides both management response and recommendations as well as adaptation strategies, providing an overarching argument for climate assessments to be included in any natural resource planning efforts on the County's behalf.

A.2.3 Community Economic Security and Climate Action Analysis | 2011

The *Community Economic Security and Climate Action Analysis* was a report developed by Office of Conservation and Sustainable Development and Westmoreland Associates in 2011. The report includes a comprehensive approach to analyzing various climate action measures, inclusive of co-benefits and a cost-benefit analysis, and provides specific recommendations cutting across energy efficiency, local government policy, and transportation policy.

A.2.4 Arizona: Extreme Weather, Climate and Health Profile Report | 2015

This state profile report was prepared by Arizona State University (ASU) and the Arizona Department of Health Services (ADHS) in 2015. It offers historical context of climate and health related efforts in the State of Arizona and lessons learned from their outcomes. The primary focus of the report is on health and extreme heat and air pollution.

The authors used a downscaled version of the HadGEM2-ES model as their general circulation model (GCM), which is a type of climate model that uses mathematical modeling to simulate the general circulation of the planet's oceans and atmosphere.[17] The model had a resolution of about 12 kilometers and was obtained from the US Bureau of Reclamation. For heat, they suggested using maximum temperature (in July) as a metric since it was found to be more important than other factors for assessing heat-related ambulance dispatches in Phoenix. They examined projections for 2010, 2030, and 2060 under multiple Representative Concentration Pathways (RCPs), including RCP-2.6, RCP-4.5, RCP-6.0, and RCP-8.5.[18] The authors found that the largest temperature increases were in the northern portions of the state, but they suggested that a fuller assessment is necessary. The report also provides an overview of historical air quality in the state, including nonattainment areas and air pollutants of concern.

In the final section of the report, the authors discuss conceptual pathways for linking climate, air quality, extreme heat, and health. This final section also addresses vulnerability indictors and indexes, citing the CDC's Social Vulnerability Index (SoVI) alongside a 2010 county-level SoVI map for Arizona in which Pima County is categorized as "Medium."[19] A noteworthy excerpt about extreme heat and vulnerable groups cites a 2012 ADHS report which indicates "that the majority of heat-related deaths occurred in Maricopa, Pima, and Yuma counties (ADHS 2012). Approximately seven out of every ten of those deaths were males and 58.5% were Hispanic or Latino individuals."

A.2.5 Drought and Climate Change in Pima County and Western States | 2017

Drought and Climate Change in Pima County and Western States is a document that was put together by the Pima County Office of Sustainability, Conservation and Historic Preservation in December 2017. The document covers recent drought impacts, conditions, and future trends. It begins by providing a regional context on drought and describing historical droughts that have occurred in Pima County. It discusses specific drought impacts, such as the exacerbation of wildfire, heatwaves and heat related illness, air quality, and agricultural losses. Next, climate change and implications

[17] HadGEM2 stands for the Hadley Centre Global Environment Model, version 2. HadGEM2 is a family of models developed by the Met Office Hadley Centre for Climate Science and Services in the United Kingdom. Some HadGEM2 models were used in the Intergovernmental Panel (IPCC) on Climate Change's Fifth Assessment Report (AR5). HadGEM2-ES is an earth system model with specific geographic resolutions that enable simulations of greenhouse gas forcing through to the year 2300.

[18] Representative Concentration Pathways, or RCPs, are GHG concentration trajectories, adopted by the IPCC and used to describe different climate future based on different volumes of GHG emissions. In the case of this report, the RCPs used were RCP-2.6, or the "very stringent" pathway that reflects a decline in carbon dioxide emissions by 2020 toward zero emissions in 2100; RCP-4.5, an intermediate scenario whereby emissions peak in 2040 and then decline (widely considered the most probable baseline) without policy intervention; RCP-6.0, whereby emissions peak around 2080 and then decline; and RCP-8.5, whereby emissions continue to rise throughout the remainder of the 21st century. Since AR5's release, these original RCPs are now being considered together with Shared Socioeconomic Pathways, and new RCPs have been developed.

[19] The CDC/Agency for Toxic Substances and Disease Registry's Social Vulnerability Index, or SoVI, examines social vulnerability – defining it as "the potential negative effects on communities caused by external stresses on human health… [including] natural or human-caused disasters, or disease outbreaks. It uses 15 U.S. census variables to identify communities that may need assistance before, during, or after disasters.

for these impacts is discussed. The report concludes with an outline of Pima County's existing drought response measures and strategies as well as involved partners and groups

A.2.6 Pima County Climate Brief | 2018

The *Pima County Climate Brief* was compiled by a group of experts at the University of Arizona. It was compiled as a response to two climate change resolutions (2017-39 and 2017-51) adopted by the Board of Supervisors, with the goal of helping the County prioritize and address upcoming climate change efforts. The brief covers several stressors and both their direct and indirect impacts to the county. For each stressor, the brief also provides a list of adaptation opportunities. Stressors covered in this brief include heat, drought, and flooding.

A.2.7 Southwest, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* | 2018

The Fourth National Climate Assessment (NCA4) contains a Southwest chapter, covering climate impacts across the region.[20] It outlines important trends, including declining snowpack, reduced crop yields, increased warming and drought, extreme heat, more insects, and more wildfires. It also highlights key messages around water resources, ecosystems, Indigenous communities, energy, food, and human health.

This report is a valuable resource with respect to regional impacts, such as drought and water supply. It also provides useful adaptation case studies and strategies. The report's authors single out the City of Tucson in the following excerpt about food security in the face of drought: "In urban areas across the Southwest, such as Tucson, Arizona, and Sacramento, California, community food banks that grow food in community gardens can help maintain food security in a drier and more variable climate. Urban gardens and local food organizations provide fresh produce, foster community education, and support networks of local growers."

A.2.8 Climate Profile for the Highlands at Dove Mountain | 2019

The *Climate Profile for the Highlands at Dove Mountain* is a report released by the University of Arizona's Climate Assessment for the Southwest (CLIMAS) in May 2019. The Highlands at Dove Mountain is an active adult community in the foothills of the Tortolita Mountains, just north of Tucson city limits. The profile provides information on existing conditions as well as anticipated changes to both average and extreme temperature and precipitation. It covers impacts such as human health, water, energy, housing, and wildfires. It also covers adaptation strategies for the community's golf course, emergency preparedness, flood insurance, landscaping, energy, and social resilience.

[20] The National Climate Assessment, developed by the U.S. Global Change Research Program, assesses the science and impacts of climate change across the United States. NCA4 was released in 2018. The Fifth National Climate Assessment, or NCA5, is currently under development and is expected to be completed and published in 2023.

A.2.9 Pima Association of Governments Regional Greenhouse Gas Emissions Inventory | 2019

The *Pima Association of Governments (PAG) Regional Greenhouse Gas Emissions Inventory* provides GHG emissions inventory subsets for city operations and community-wide emissions for jurisdictions within Pima County, including the City of Tucson. The most recent inventory covers five years of data, from 2014 through 2019, across three eastern Pima County regions. For these inventories, PAG used the International Council for Local Environmental Initiatives (ICLEI) *US Community Protocol for Accounting and Reporting of GHG Emissions* as its emissions accounting framework. In 2019, 64% of the City of Tucson's emissions came from stationary energy, 32% from transportation, 1% from waste, and 3% from other sources. For City government operations, 96% of all emissions came from the stationary energy sector.

Per conversations with the City of Tucson and PAG, the City of Tucson does not calculate or report on its own GHG emissions inventory. The City provides data to PAG directly for city operations only.

A.2.10 Asset Management, Extreme Weather, and Proxy Indicators Pilot Program | 2020

This report was developed by the Arizona Department of Transportation with the purpose of better understanding how natural hazards and weather-related risks will impact the State's transportation system. The report provides findings from a pilot program that was created to define methods for Lifecycle Planning, establish procedures for risk assessment of assets and locations, develop a GIS resilience database, and identify actions that improve resilience for the most vulnerable assets. The report covers the following stressors and climate risks: intense precipitation, system flooding, wildfires, wildfire-induced floods, drought-related dust storms, rockfall incidents, slope failures, and increased surface temperature. However, the pilot program focuses on flooding, as that was the most frequently reported issue statewide.

A.2.11 Vulnerability and Risk Assessment: Recommendations from Climate Action Advisory Council | 2022

A set of recommendations was developed by the Climate Action Advisory Council, providing a summary of data requirements, best practices, and suggested report structure for a Vulnerability and Risk Assessment for the City of Tucson that would be incorporated into, or completed as part of, its climate action and adaptation plan. The document, currently in draft form at the time of this writing, also identifies key sectors that should be covered in the assessment, including water, energy, health, food, transportation, ecosystems, Indigenous cultures, business, economy, real estate, and housing and shelter. Key data sources are also provided to inform the assessment.

A.3 Review of Existing Conditions: Mayor and Council Actions and Resolutions

A.3.1 City Council Resolution No. 20443: Endorsing the Mayors' Climate Protection Agreement | 2006

In September 2006, the Mayor and Council adopted Resolution No. 20443, endorsing the US Conference of Mayors' Climate Protection Agreement, and declaring a climate emergency. The Agreement served as a vow on behalf of cities to reduce their carbon emissions below 1990 levels, in line with the Kyoto Protocol.[21]

A.3.2 City Council Resolution No. 20322: Sustainable Energy Standard – Adopting an Updated Green Building Policy for City Building Construction Projects | 2006

In April 2006, the Mayor and Council adopted Resolution No. 20322 relating to prescriptive sustainable energy standards, authorizing and approving application of the sustainable energy standards to certain city buildings, additions, modifications, and renovations and requiring compliance with the requirements of the Leadership in Energy and Environmental Design (LEED) program at the Silver Certification level or higher.

A.3.3 City of Tucson Mayor & Council Retreat Priorities | 2020

The Mayor and Council Retreat was held on January 28, 2020, bringing together the Mayor's Office, Councilmembers representing the City's seven wards, and City department representatives. During the retreat, City representatives of different wards and departments, identified priorities for their departments and wards, such as climate action and environment, housing and homelessness, transportation and mobility infrastructure, parks and trees, children and youth, economic development, poverty, crime and safety, and information technology and cybersecurity. Councilmembers summarized challenges for each of these priorities, such as the need to expand funding for program, create new roles to manage coordination between departments, update reports, and use an equity lens in decisions and operations.

A.3.4 City Council Resolution No. 23166: Requesting the Arizona Corporation Commission Adopt a Clean Energy Standard of 100% by 2050 | 2020

Council Resolution 23166, adopted by Mayor and Council in April 2020, constitutes a recommendation to the Arizona Corporation Commission to adopt a clean energy standard of 100% by the year 2050, and issuing an accompanying emergency declaration. The resolution authorizes City officers and employees to "perform all acts necessary or desirable" to execute the Resolution.

[21] The Kyoto Protocol was adopted in 1997 and entered into force in 2005. The Protocol operationalized the United Nations Framework Convention on Climate Change, or UNFCCC, committing industrialized countries to reduce GHG emissions per agreed individual targets. The Protocol set binding emission reduction targets for signatories, adding up to an average five-percent emission reduction compared to 1990 levels between 2008-2012 (first commitment period).

A.3.5 City Council Resolution No. 23222: City of Tucson's Climate Emergency Declaration | 2020

Resolution No. 23222, adopted in September 2020, declares a Climate Emergency for the City of Tucson, and calls for carbon neutrality from citywide operations by 2030. In addition, the City commits to a communitywide emissions reduction target of 50% by 2030, and 100% by 2050. To substantiate the emergency, the resolution references reports and studies that highlight the effect of climate change to the environment, ecologies, vulnerable populations, safety and justice, and the particular threats that climate change poses to the Southwest's water, habitat, and economy. To reach carbon neutrality, the resolution calls for action within the City of Tucson, demanding collaboration between city departments and regional leaders to develop an equitable and just transition to climate neutrality by 2030, and the development of a 10-year climate action and adaptation plan to guide the climate emergency response. that is committed to engaging residents, particularly frontline and marginalized communities, in the creation and implementation of the plan.

A.3.6 Additional Resolutions and Council Actions of Relevance

Additional council resolutions and actions of relevance were uncovered during the development of this Existing Conditions Assessment, including:

- Resolutions No. 10178 and 10417: Adopting the Sustainable Energy Standards (Ordinance No. 11590);
- Resolution No. 20322: Adopting LEED Silver Standards (U.S. Green Building Council) for new City buildings and renovations over 5,000 square feet;
- Resolution No. 21369: Adopting the voluntary Green Building Program; and
- Mayor and Council Study Session – 2/12/2013: Adopting cost-recovery solar permit flat fee.

These resolutions were passed up through 2013, prior to the adoption of *Plan Tucson* in 2013.

A.4 Review of Existing Conditions: City Ordinances and Codes

A.4.1 Ordinance No. 10579: Gray Water Harvesting Ordinance | 2008

The residential gray water ordinance requires the installation of gray water plumbing systems in all new single family and duplex residential construction to reduce water demand and increase water efficiency and recycling gray water for outdoor irrigation. The ordinance requires the installation gray water harvesting stub-outs, which are plumbing connections for bathroom sinks, showers, bathtubs, and washing machines that redirect gray water to outdoor basins for landscape irrigation. The resolution recognizes the double use value of greywater both for daily home necessities (besides toilets, kitchen sinks and dishwashers) and for the use in outdoor irrigation.

A.4.2 Ordinance No. 10591: Amending Chapter 10A Creating the Climate Change Committee and Dissolving the Environmental Accords/Green Cities Declaration and Sustainability Committee | 2008

Ordinance No. 10591 was adopted in October 2008, which effectively created the Climate Change Committee and dissolving a previously existing Environmental Accords/Green Cities Declaration and Sustainability Committee.

A.4.3 Ordinance No. 10597: Commercial Rainwater Harvesting Ordinance | 2008

The Commercial Rainwater Harvesting Ordinance (10597), adopted by the Mayor and Council in 2008, amended the City's code to require a rainwater harvesting plan for all new commercial development plans submitted to the City after 2010 to reduce water use for outdoor irrigation. The ordinance required that 50% of irrigation water, measured on an annual basis, come from rainwater capture systems. New commercial developments were also required to submit an annual report to Tucson Water detailing the monthly water use and rainwater totals collected on site, to be measured through separate water meters and irrigation sub-meters.

A.4.4 Ordinance No. 11496: Amending Chapter 10A establishing the Commission on Climate, Energy and Sustainability, Dissolving the Climate Change Committee and Terminating the City's Participation in the Tucson-Pima County Metropolitan Energy Commission | 2017

Ordinance No. 11496 was adopted in October 2017, creating the Commission on Climate, Energy, and Sustainability (CCES). The Commission advised the Mayor and Council on meeting the climate, energy, and sustainability goals laid out in the General Plan, as well as methods for improving the City's impact and achieving incremental and transformative outcomes necessary to respond to pertinent challenges in the region. This ordinance also effectively dissolved the original Climate Change Committee, and dissolved the City's authorization for and participation in the Tucson-Pima County Metropolitan Energy Commission.

A.4.5 Ordinance No. 11621: Tucson Complete Streets Policy | 2019

In 2019, the Tucson Mayor and Council adopted the *Tucson Complete Streets Policy* via Ordinance No. 11621. "Complete Streets" refers to an approach to transportation planning and design that focuses on safe, connected, and equitable transportation for everyone. In adopting a Complete Streets Policy, Tucson formalized its intent to fund, plan, design, construct, and operate an interconnected street network for all users and transportation nodes. The Complete Streets Policy was drafted by the Tucson Department of Transportation, in collaboration with Living Streets Alliance, the Complete Streets Task Force, and community stakeholders. The Policy was supplemented by a *Complete Streets Design Guide*, passed by Tucson Mayor and Council via Ordinance No. 11885 in 2021.

A.4.6 Additional Ordinances of Relevance

Additional ordinances of relevance were uncovered during the development of this Existing Conditions Assessment, including:

- Ordinance No. 11042: Adopting 2012 International Energy Conservation Code;
- Ordinance No. 10178: Adopting 5% solar requirements for City buildings; and
- Ordinance No. 10549: Establishing requirements that all new single-family homes and duplexes be "solar ready" for installation of electric (photovoltaic) and hot water systems.

These ordinances came into effect up through 2013, prior to the adoption of *Plan Tucson* in 2013.

A.5 Review of Existing Conditions: Citywide or Departmental Programs and Initiatives

A.5.1 Rainwater Harvesting Grant / Loan Program

In partnership with Sonora Environmental Research, Inc. (SERI), Tucson Water offers grant and loan programs for families to receive assistance with installing passive or active rainwater harvesting systems. Grant eligibility depends on income, with those at or under Federal Poverty Level (FPL) eligible to receive grants up to $750 and those at or twice the FPL receive grants up to $500. Loans are issued to help pay for the cost of the system, which go up to $2,000 for 18 months, or up to 12 months if the loan amount is under $500.

A.5.2 Neighborhood Scale Green Infrastructure

In partnership with Tucson Clean & Beautiful, Tucson Water offers neighborhood groups funding to support the planning and construction of stormwater harvesting projects. The program has supported neighborhood-wide passive stormwater harvesting systems in public areas such as parks, open space, and rights-of-way. The intent of the program is to couple passive stormwater harvesting with vegetation planting to increase urban tree canopy, reduce the urban heat island effect, decrease stormwater runoff, increase shade for pedestrians, and increase safety by reducing traffic speeds through vegetation cover. Proposals can be submitted through wards and are evaluated based on anticipated human and environmental health benefits, as well as community safety and capacity for maintenance.

A.5.3 Tucson Million Trees Initiative

The Tucson Million Trees Initiative is a mayoral initiative to plant one million new trees across the City of Tucson by 2030. The goal of the initiative is to increase the city's tree canopy and reduce the heat island effect, cool homes, decrease energy bills, provide shade for pedestrians and cyclists, and capture carbon and stormwater runoff. At the center of the initiative is a commitment to equity and justice, prioritizing creating green spaces in in communities of color and low-income communities, which are most impacted by climate change and extreme heat. 800,000 trees will be planted in developed areas, nearly 200,000 trees will be planted for natural regeneration, and 10,000 will be planted for afforestation. Trees will be selected using a science-based approach, selecting specifically for native and drought-

resistant trees with best practices for desert forestry in mind. It is estimated that nearly 700,000 metric tons of carbon will be sequestered through the newly planted trees over the next 50 years.

A.5.4 Green Stormwater Infrastructure Fund

The Green Stormwater Infrastructure Fund dedicates City funds for planning, executing, and maintaining infrastructure that captures stormwater runoff and redirects it to vegetated areas across the city. The program relieves stress on underground stormwater infrastructure, reduces stormwater pollution, decreases flooding risks and urban heat island effect, and increases tree canopy, particularly in vulnerable communities that lack the resources or organization to maintain green infrastructure. Tucson Water collects fees for the program based on customers' water use. It is estimated that the fund will raise around $3 million per year to fund the maintenance of both existing and new green stormwater infrastructure.

A.5.5 Tucson Water Initiatives

Tucson Water provides over 30 billion gallons of water to Tucson and the surrounding metropolitan area each year. To decrease water demand, increase equity, and improve the reliability of water sources, Tucson Water has implemented several programs and initiatives. Most notably, these include long-range water plans such as *Water Plan: 2000-2050* and the forthcoming *One Water 2100 Master Plan*. Tucson Water also helped prepare the *Drought Preparedness and Response Plan*, as well as water management programs such as the Neighborhood Scale Green Infrastructure program. To increase equity in access to quality water, Tucson Water also has a low-income assistance program, which provides monthly discounts to qualified customers. Since 1996, Tucson Water has run its Zanjero Program, which provides residential customers free water use management assistance.

A.5.6 Environmental and General Services Initiatives

The Department of Environmental and General Services (EGSD) is responsible delivering effective waste management and environmental protection services, providing weekly trash collection and biweekly recycling services, managing compost collection, improving air quality, and managing waste discharge and landfills, and managing groundwater remediation. EGSD has installed solar panels across City facilities and departments and was active in the development of the *EV Readiness Roadmap*, leading outreach and education, incorporating EVs into the City's fleet, and installing charging stations across the City for fleet, employee, and public use.

A.5.7 Transportation and Mobility Initiatives

The Department of Transportation and Mobility is responsible for maintaining a safe and reliable multi-modal system for people and goods. It oversees capital improvement projects including bicycle boulevards, major arterial roads, streetscaping, and pedestrian and bus access improvements. The department creates plans and administers initiatives that help create a comprehensive, safe, and reliable multimodal transportation system for the city, such as *Move*

Tucson, *Tucson Norte-Sur*, and the *Complete Streets Policy*. The department also oversees the City's bicycle and pedestrian program, which aims to create a comprehensive network for safe and comfortable walking and biking. As part of this program, the department helps support initiatives that encourage walking and biking, including the Safe Routes to School initiative and Cyclovia Tucson. Collectively, these programs help reduce traffic congestion and improve air quality by promoting multi-modal travel.

A.5.8 Planning and Development Services Initiatives

The Department of Planning and Development Services (DPDS) is tasked with advancing a safe built environment, primarily through the development and regulation of building codes, zoning, and land use, with a focus on equity and economic growth. The department oversees the unified development code and supporting documents, and it leads the development of city, area, and neighborhood development and redevelopment plans, such *as Plan Tucson* and the *Streetcar Land Use Plan*. Like other city departments, DPDS has also been tasked with helping to execute the *EV Readiness Roadmap* and oversees policies and procedures to facilitate access to EV charging citywide.