# Securing Water-Energy-Food for the Nation's Future: A Science-Policy Dialogue

## Welcome Breakfast

**8:30 -9:00 AM**

San Antonio, TX | November 4, 2022

TEXAS A&M UNIVERSITY

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WEF NEXUS INITIATIVE

# Welcome Notes

**9:00-9:15 AM**

San Antonio, TX | November 4, 2022

**_Mirley Balasubramanya_**

Chair, Department of Mathematical, Physical, and Engineering Sciences,
College of Arts and Sciences,
TAMU-San Antonio

San Antonio, TX | November 4, 2022

***Henry Fadamiro***

Associate Vice President for Research Strategic Initiatives, Division of Research
TAMU-College Station

San Antonio, TX | November 4, 2022

**Councilwoman Phyllis Viagran**
City of San Antonio Council

San Antonio, TX | November 4, 2022


**Rabi Mohtar**
Professor, Department of Agricultural and Biological & Zachry Department of Civil Engineering
Texas A&M University

**Bassel Daher**
Assistant Research Scientist, Texas A&M Energy Institute
Texas A&M University


# Project Overview & Workshop Introduction

San Antonio, TX | November 4, 2022

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# Overview:
# Texas A&M Water-Energy-Food Nexus Initiative (WEFNI)
# Workshop Objectives

San Antonio, TX | November 4, 2022

# WEFNI Overarching Goal

**INITIATIVE GOAL:** *Expand intellectual capacity and scope of Texas A&M's Water-Energy-Food Nexus Community by:*

i. *developing analytics, policy and governance best practices;*

ii. *establishing a Nexus Community of Science;*

iii. *identifying opportunities and gaps in current WEF nexus related research.*

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# WEFNI Goals

***Support the planning for Water-Energy-Food Resources Nexus in San Antonio and surrounding regions, as climate alters water supplies***

1. Facilitate **science-based policy** by **raising awareness** among academia, society, government, and industry
2. Encourage holistic approaches to address grand challenges and the **Sustainable Development Goals**
3. Identify and respond to **national and global opportunities** in research, education, outreach and policy implementation

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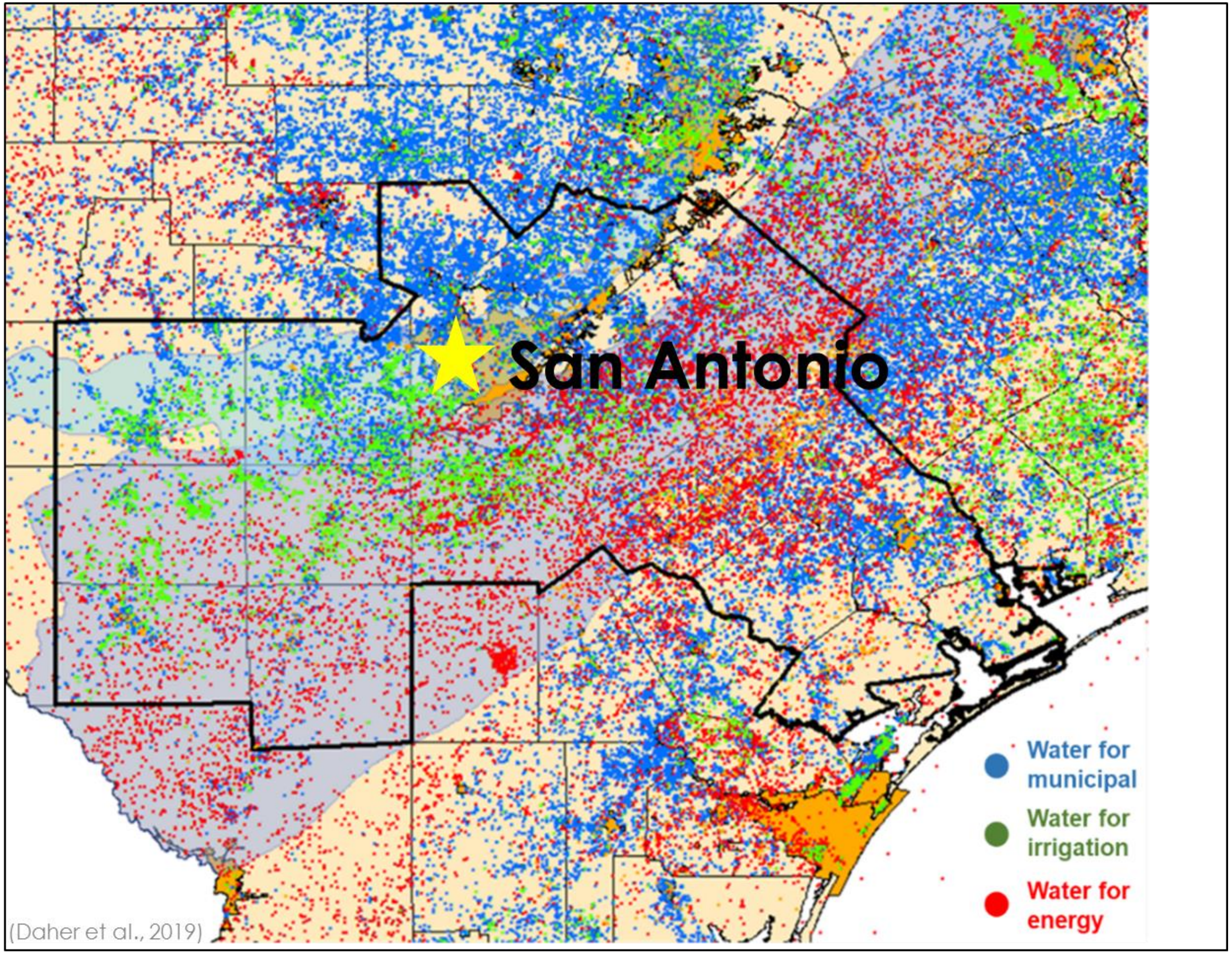
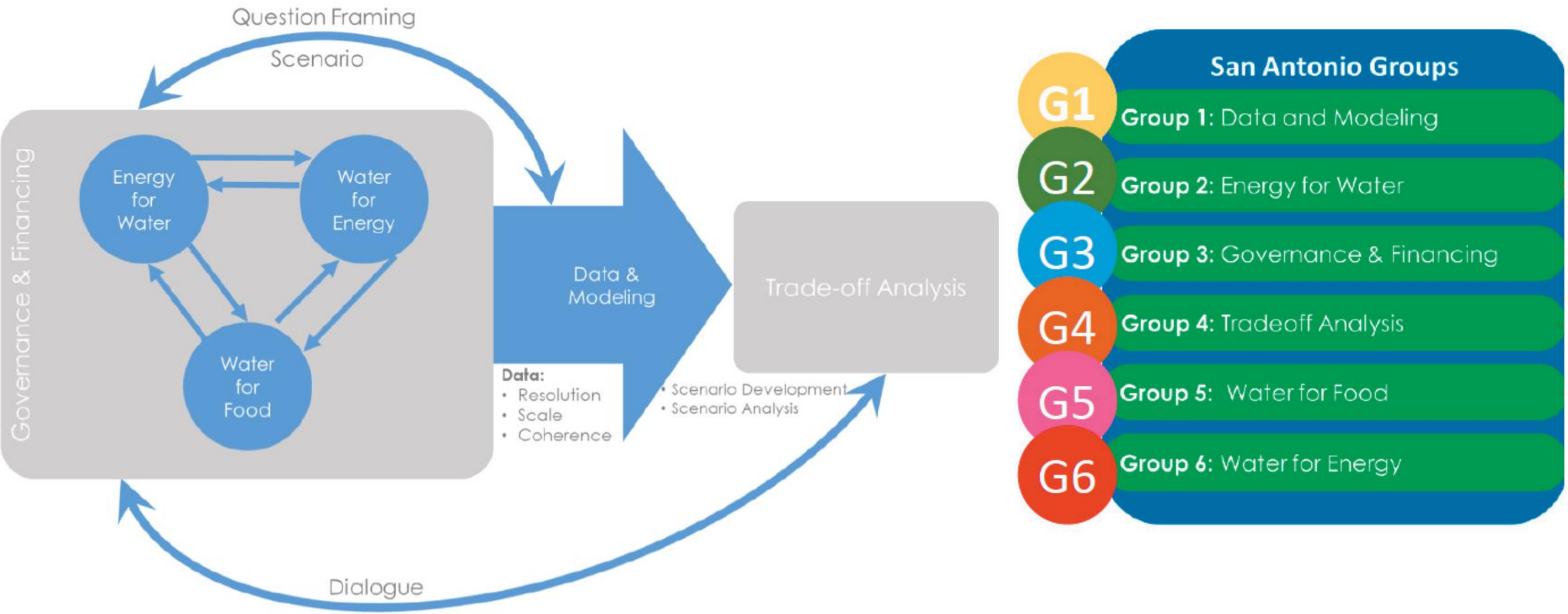
# San Antonio Hotspot



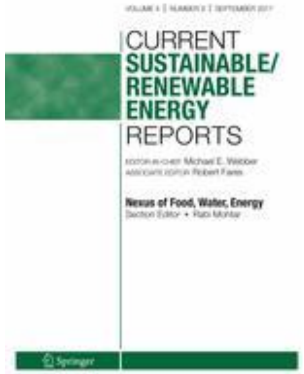
# Creating an Interdisciplinary Team




- **San Antonio Case Studies (SACS)** Coordinators: *Mohtar, McCarl, Pistikopoulos, Portney, Rosen, Daher, Schweitzer (Admin)*
- *WEFNI supported* ***6 PhD*** *and* ***8 MSc*** *students from Geosciences, Geography, WMHS, BAEN, Mechanical, and Chemical Engineering*

# Summary of Outcomes

| | **Water Energy Food Nexus Initiative (WEFNI) in Numbers** |
|---|---|
| **3** | years |
| **200** | research and extension faculty from the Texas A&M System – TAMU Nexus Community |
| **6** | sub-groups formed with expertise in data and modeling, water for energy, energy for water, water for food, governance and financing, and trade-off analysis |
| **6** | PhD students funded |
| **8** | MSc students funded |
| **2** | NSF funded stakeholder and research community meetings |
| **> 18** | INFEWS proposals submitted |
| **1** | WEF Research Coordination Network (RCN) proposal to be submitted to NSF |
| **> 20** | National and Global Partnerships |
| **2** | Special Issues in *"Current Sustainable / Renewable Energy Reports"* and *"Science of the Total Environment"* + numerous articles) |
| **3** | Major campus wide events (WEFNI Launch + 2 Town hall meetings) |
| **$2,431,217** | National Science Foundation proposal INFEWS/T3: Decision Support for Water Stressed FEW Nexus Decisions (DS-WSND), Award Abstract #1739977. |
| **> 15** | Engagement activities included high level participation nationally and globally |

# INFEWS Project

## INFEWS/T3: Decision Support for Water Stressed FEW Nexus Decisions (DS-WSND)

**This project addresses**:
1) integrated and coordinated domain modeling use in FEW Nexus tradeoff analysis, and
2) decision support modeling and optimization regarding improvements in FEW Nexus decision making, both in water scarce areas

**The project objectives**:

1) **integrate** data and analyses from agricultural, hydrologic and energy system domain models within an overall systems framework that is embodied in a multi objective, risk aware model designed to address decision-maker preferences, strategy choices, consequences and trade-offs;
2) **use** the integrated systems framework to assess the added economic, social, and environmental values that can be attained using Nexus-wide, coordinated decision making versus sectoral focused choices
3) **evaluate** how climate change and increasing urban populations stress the case study FEW systems, and Nexus decisions
4) **identify** economic, environmental, and income distributional tradeoffs and possible incentive approaches to compensate potential losers so they cooperate in Nexus strategy implementation
5) **facilitate** coordination and communication between stakeholders and project personnel in an effort to enhance awareness of FEW Nexus decision making and develop relevant decision support tools for the locations of the case study and other settings.

# Timeline

- **Oct 2015** — WEFNI Launch
- **Nov 2016** — Town hall 1
- **Jan 2017** — NSF WEF science community meeting
- **Apr 2017** — Town hall 2
- **Sep 2017** — Special Issue 1
- **Oct 2017** — INFEWS Awarded
- **Jan 2018** — NSF stakeholder engagement meeting
- **Oct 2018** — Special Issue 2
- **Nov 2018** — Multi-stakeholder Dialogue Panel
- **2019-2020** — Practice briefs Surveys
- **2021** — Focus group meetings
- **2022** — Final Stakeholder Engagement Meeting

Momentum continues with New Special issue, Symposium at ACS, WEFRAH, NSF-ACCEL NET on Soil-Water-Food-Carbon Nexus  and global engagement with FAO, World Bank, the World Water Council and the Water community to revise IWRM to include system thinking and impact SDGs among many others

# WEFnexusinitiative.tamu.edu

## Texas A&M University Water-Energy-Food Nexus Initiative

**The Texas A&M University Water-Energy-Food Nexus Initiative** (WEFNI) are Texas A&M University scientists committed to finding solutions to the *nexus grand challenges*. These scientists and educators comprise multidisciplinary teams that share their skills, knowledge and scientific abilities to produce the necessary analytics, grounded in state-of-the-art science, and able to provide a platform to facilitate inclusive stakeholder dialogues at local, regional and global levels.

**The WEF Nexus?** The interconnection of water, energy, and food resources is highly complex and the availability of these resources is increasingly stressed by climatic, social, political, economic, demographic, technological and other pressures. Sustainably addressing these challenges requires a better understanding of the nexus formed by the interconnections between the resources and will lead to a more equitable allocation and improved management of them.

**WEFNI Milestones** (2015-2018)

STOTEN Special Issue STOTEN Webinar

# INFEWS Project Outcomes

- **Data for Integrative Models**
- **Stakeholders Engagement**
- **Energy Modeling**
- **Agricultural Modeling**
- **Hydrological Modeling**
- **Coordinate Integrated and Nexus Sector Modeling**
- **Nexus Strategy Analysis**

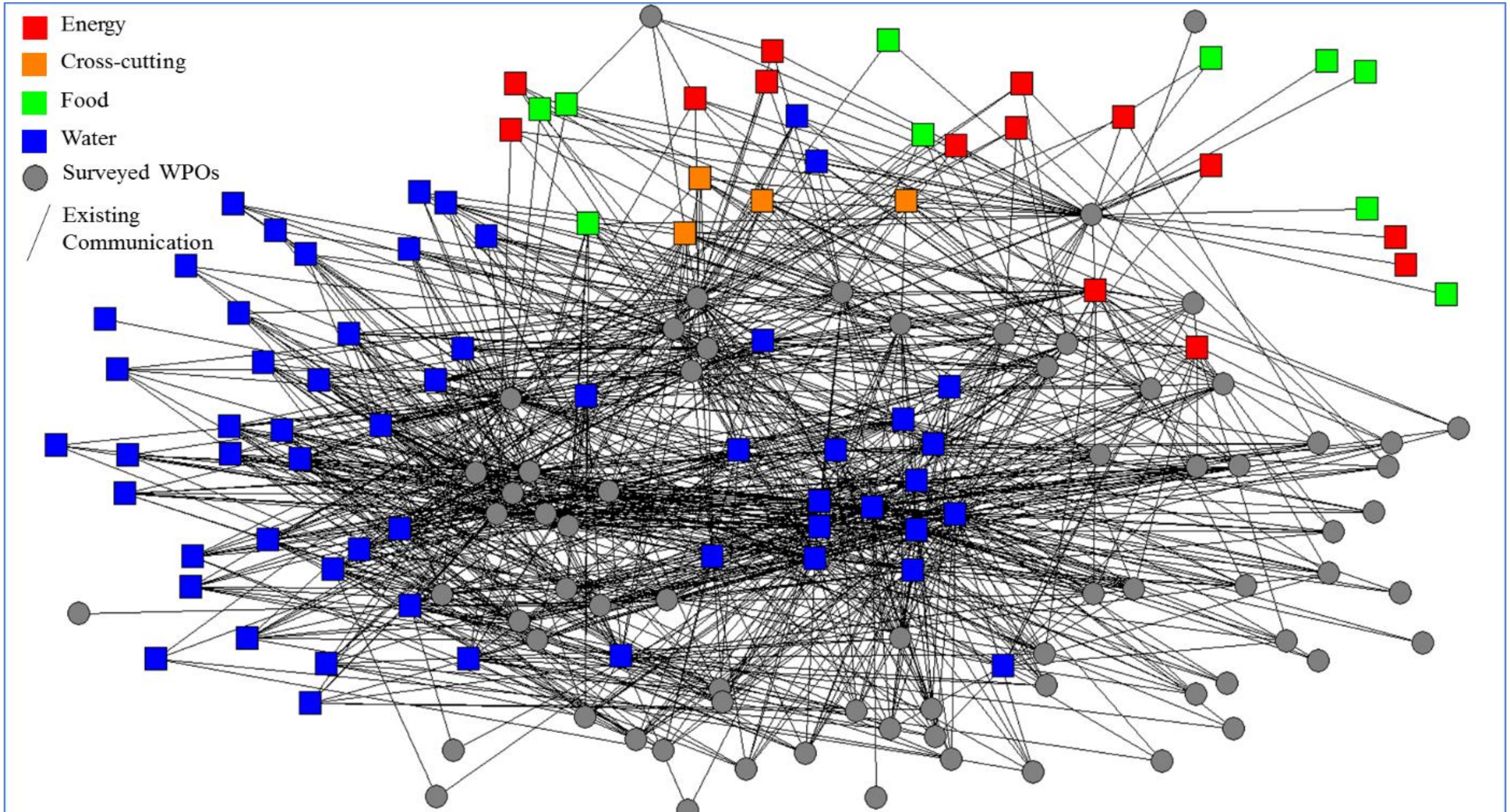
# INFEWS Project Outcomes

- **> 60** journal articles, book chapters and practice briefs
- **> 25** events at state, national and international conferences
- **> 30** invited presentation opportunities

**Theses/Dissertations (can be accessed at the OAKTrust)**

- Aurora M Vargas, ***Three Essays on Freshwater Supply, Fracking Use, and Agricultural Technological Progress***. TAMU 2020.
- ChengCheng Fei, ***Three Essays on Food-Energy-Water Nexus Analysis and Afghanistan Food Security and Poverty***, TAMU, 2019
- Yingqian Yang, ***Economics of Energy Sector in FEW Nexus Water Stressed Region: A Case Study in South Central Texas***, TAMU 2019
- Anastasia Thayer, ***Three Essays on Drivers of Agricultural Change in Texas***, TAMU 2018
- Bassel Daher, ***Bridging physical and social sciences to unlock new potential for addressing interconnected resource challenges***, TAMU 2018

# Network Map: **any level** of communication

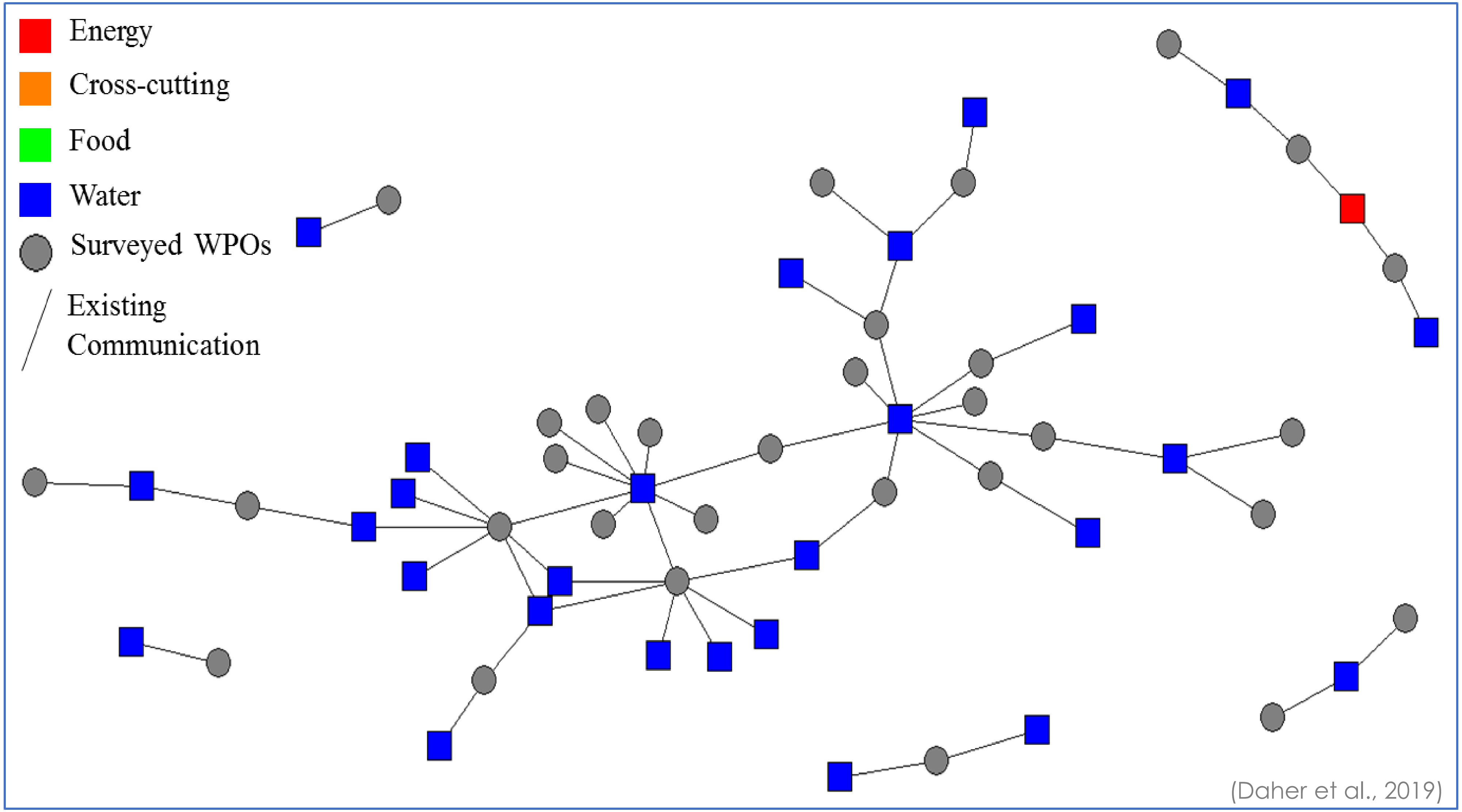



(Daher et al., 2019)

**90%** No communication

**10%** some level of communication

# Network map: **weekly** communication



# Stakeholder Engagement Workshop

## Barriers to Communication


*Stakeholder Engagement Meeting in San Antonio, TX*

**Lessons Learned**

1. It is an **iterative** process which requires multiple methods of engagement and communication
2. Investment of **time** and **effort** are essential to build genuine, honest, one on one relations
3. Importance of early **stakeholder engagement** and understanding of **preferences** and **priorities** of cross-sectoral stakeholder groups

1. **Legal and procedural barriers**: Institutional mandates and lack of coordination mechanisms.
2. **Financial:** who will pay for the time and effort involved in pursuing increased communication?
3. **Uniformity of Language** (units, abbreviations, syntax and context of problems and solutions).
4. **Planning Horizons** differ for water, energy, and food (10 to 50 years) causing ideological differences and creating barriers.
5. **Different values systems** differ across sectors and organizations.
6. **Competition** between local, regional, global organizations and across industries leads to issues of confidentiality, restricted data.
7. **Self-interest versus collective goals** - Silo mentality
8. **Lack of common goals** and collaborative projects

# Workshop Goals

1. **Share** the NSF project findings with key regional stakeholders
2. **Engage** with decision makers and resource managers about the challenges to and opportunities for coordinated management of the food-energy-water systems
3. **Create** a platform for dialogue between science and decision makers with the goal of improving science – policy interactions

# Workshop Expected Outcomes

1. **Learn about challenges and opportunities for operationalizing WEF nexus solutions** *(mandates, coordination mechanisms/platforms)*
2. **Learn about data and tools to support better decision making** *(models, decision support tools, technologies)*
3. **Identify ways for improved evidence-based decision making** *(barriers, governance, financing, technologies, training and capacity)*

# Q&A

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# Resource Management and Practice Panel

San Antonio, TX | November 4, 2022

***Jeremy Mazur***
Senior Policy Advisor
Texas 2036

***Steven Siebert***
Interim Director of San Antonio Water System's Water Resources

***Daniel Leskovar***
Director, TAMU AgriLife Center, Uvalde

**Faruque Hasan**
Assistant Director, Texas A&M Energy Institute

**Professor**
College Of Arts And Sciences
*Moderator*

TEXAS 2036

# Resource Management & Practice Panel

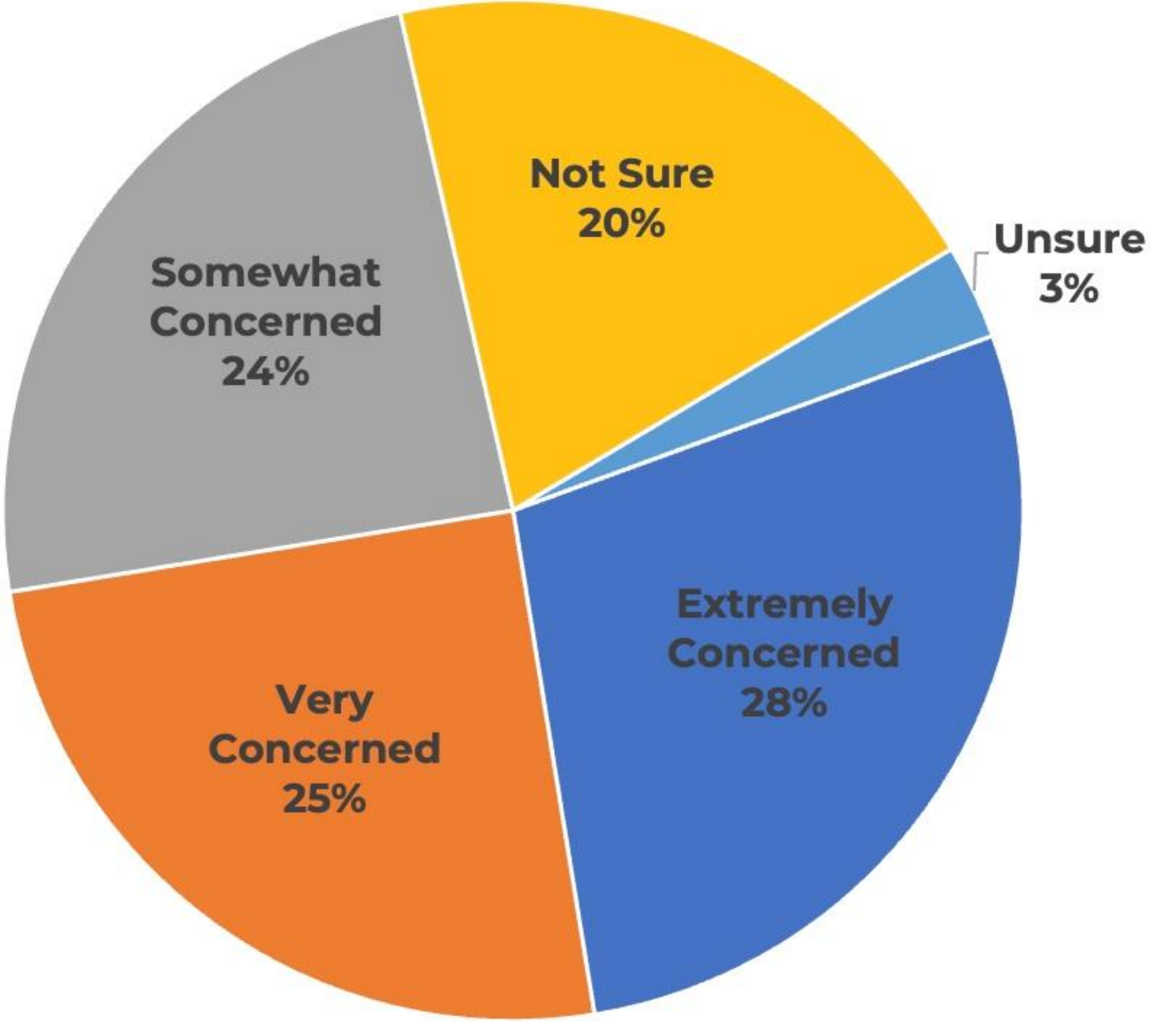
Jeremy B. Mazur, Senior Policy Advisor

November 4, 2022

Water.

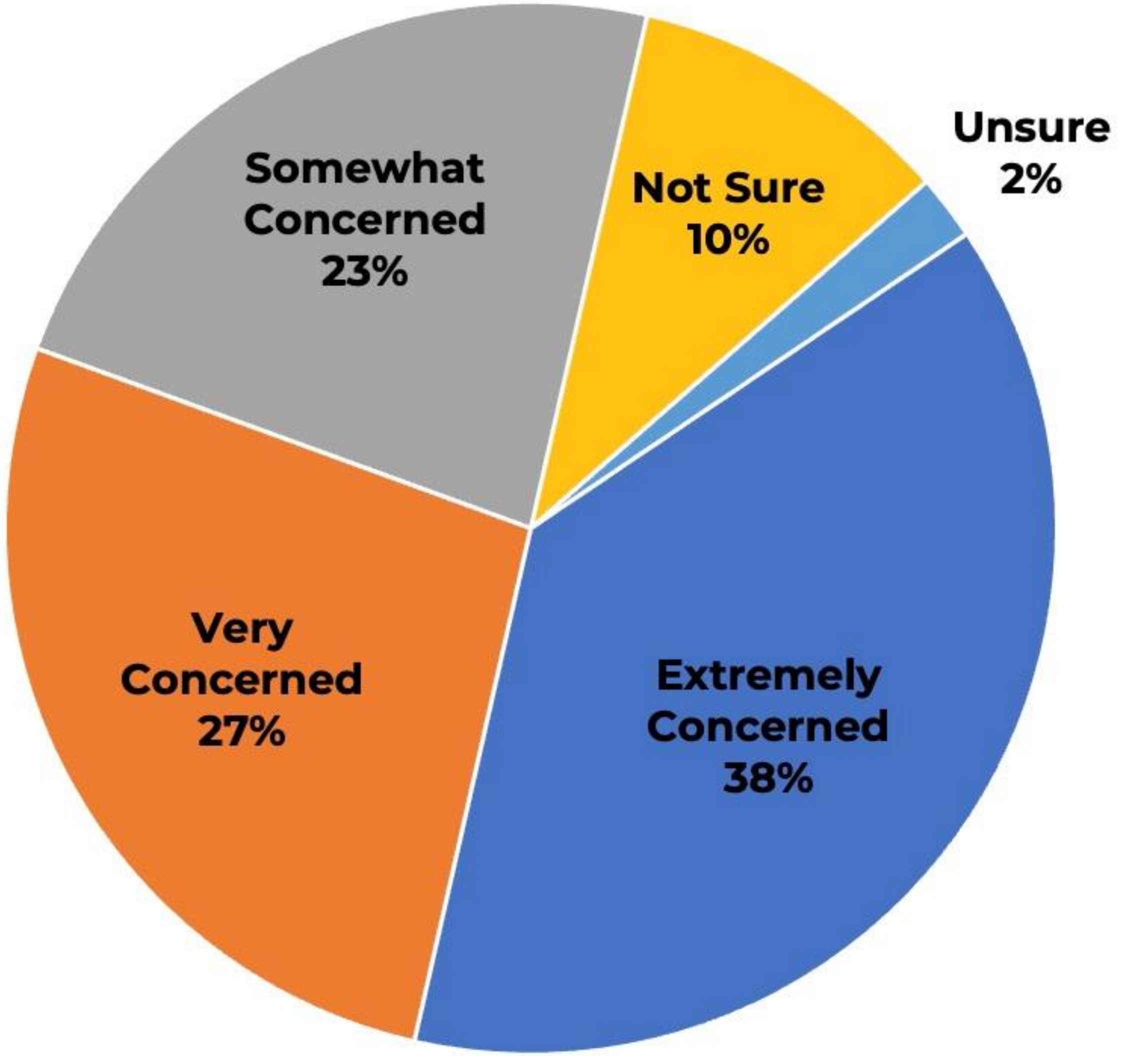
# *Texans are concerned about extreme weather.*

The state's climatologist at Texas A&M estimates that if extreme weather trends continue, Texas will experience more than double the number of 100-degree days, more extreme rainfall, more urban flooding, greater hurricane intensity, and increased drought severity by 2036.



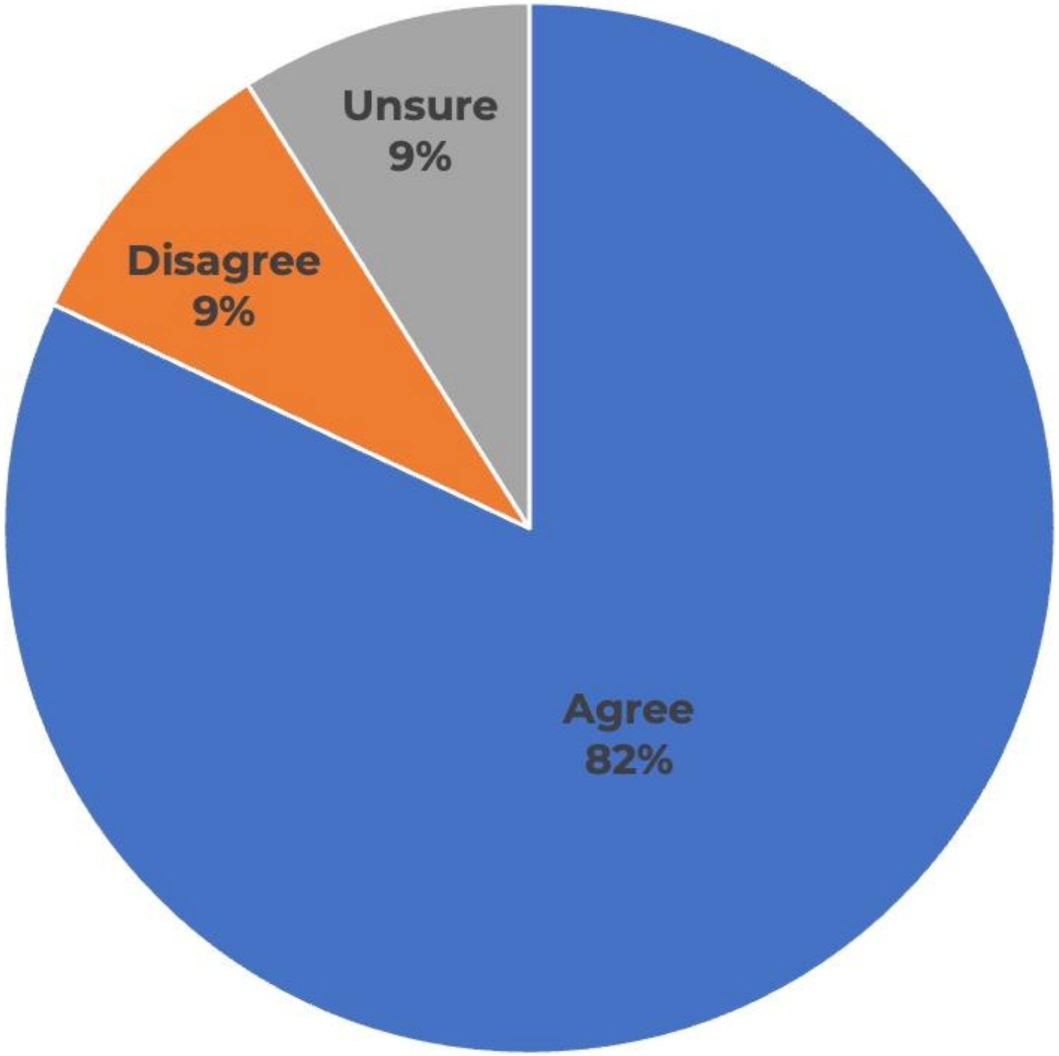
# *Texans worry about their water supplies during drought.*

If a severe drought occurs, then Texas will not be able to meet a significant amount of its water needs, meaning some communities may not have any access to water.



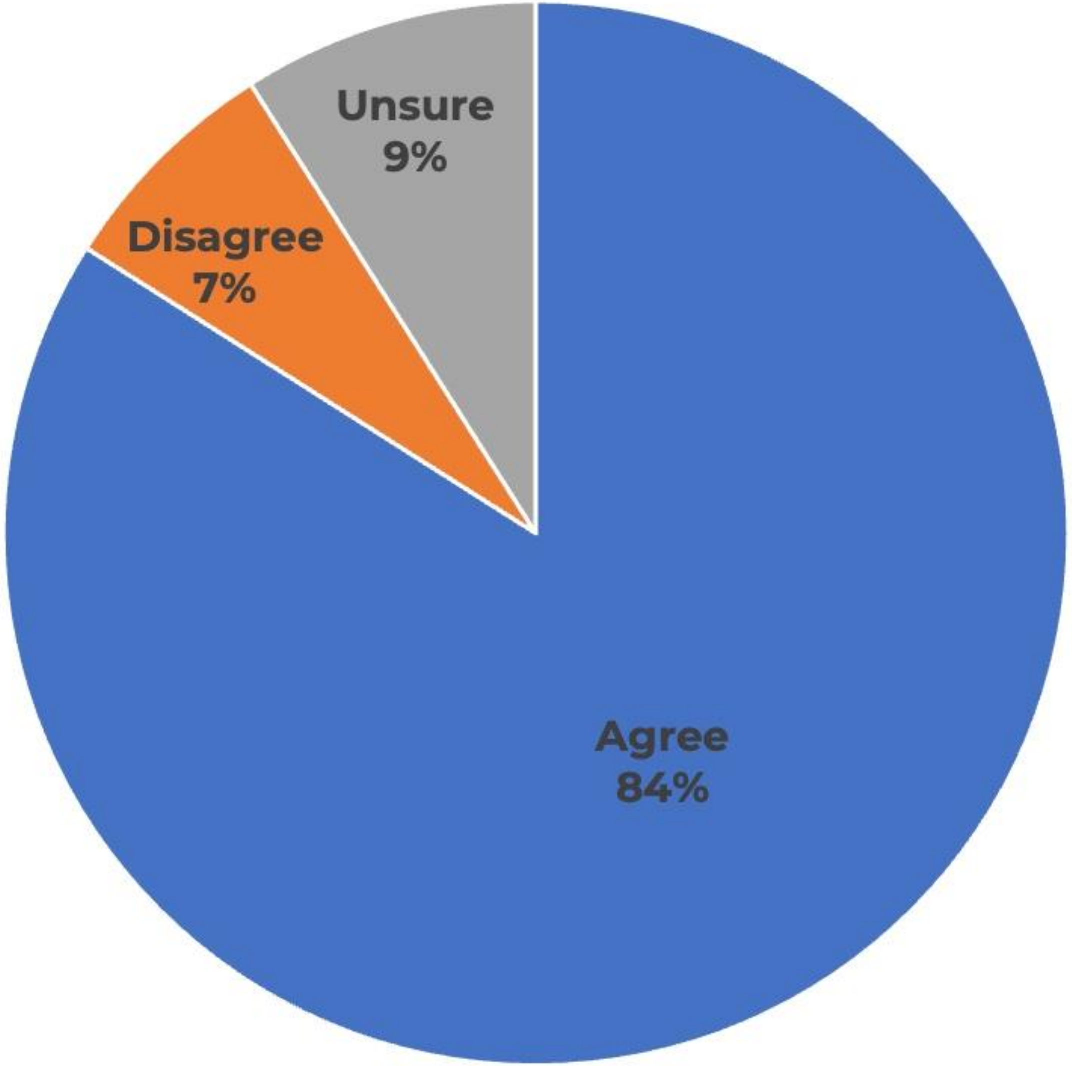
# *Voters support greater state funding for water supplies.*

Much of Texas has endured severe drought in 2022. Do you agree or disagree that the state should increase investments to expand our water supplies?



# *Texans are more worried about their water infrastructure.*

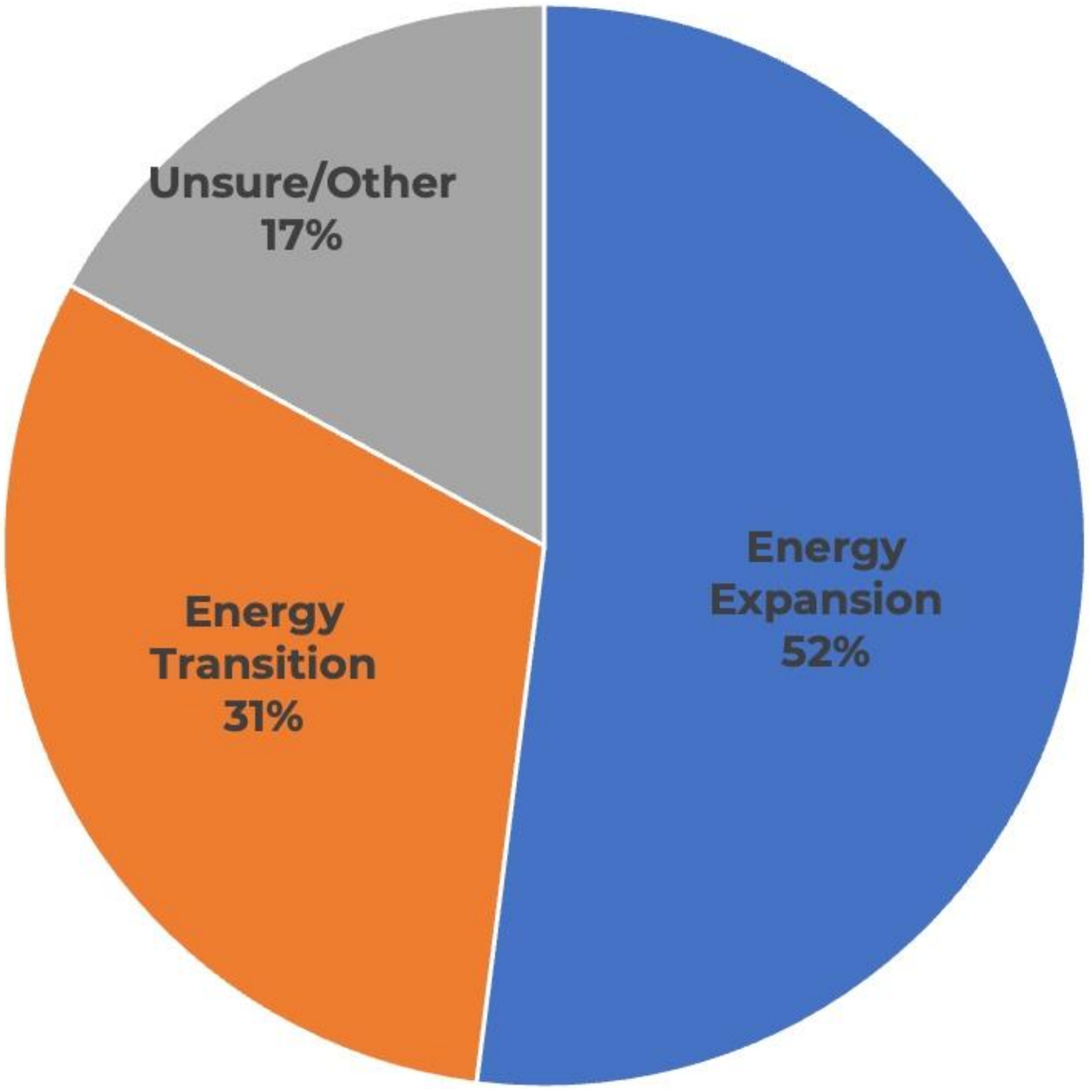
Historically, the state's investment in water has focused on increasing water supplies. Given aging and depreciating water infrastructure needs across the state, do you favor or oppose the Texas legislature creating a fund to help update the aging infrastructure too?



# Energy.

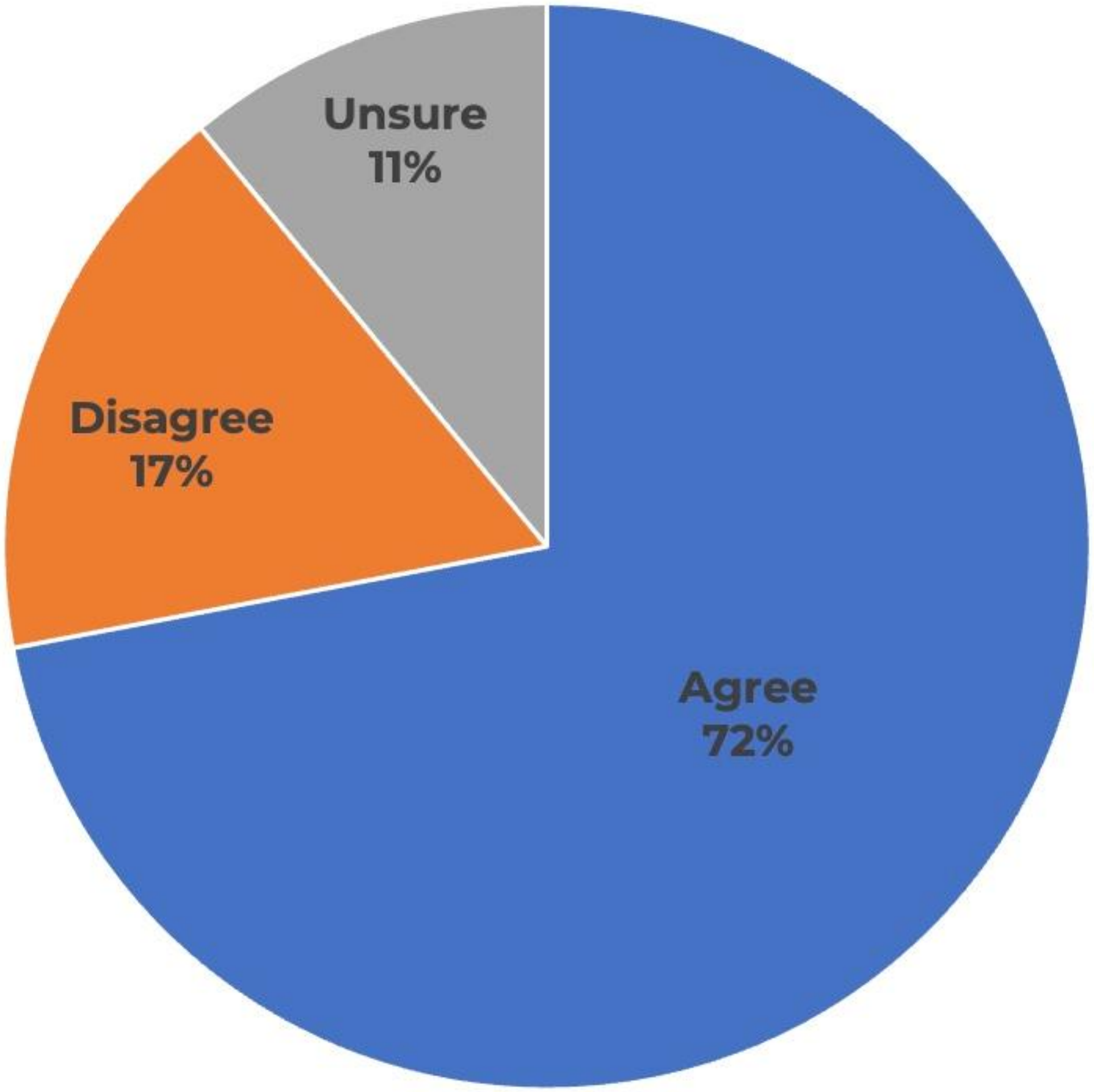
# *Texas voters prefer an Energy Expansion.*

To prepare for the future, in which of these two directions should Texas move? An **energy transition** where Texas moves away from oil and gas towards wind, solar, nuclear, geothermal and new clean energy sources and technologies. Or an **energy expansion** that includes oil, gas, nuclear, wind, solar and geothermal and new clean energy sources and technologies.



# *Texans want energy leadership.*

For a century, Texas has been the nation's energy leader. New technologies allow for cleaner forms of energy that can grow the Texas economy, create jobs, and improve air quality. Do you agree or disagree that Texas should lead the nation in this energy expansion?



# Food.

# Thank you!

Jeremy B. Mazur
Senior Policy Advisor, Texas 2036
Email: jeremy.mazur@texas2036.org

Find me on Twitter: @jeremybmazur

# 2022 Water Management Plan Introduction

**Steven Siebert**
Project Coordinator/ Water Resources

Texas A&M University SanAntonio
November 4, 2022

San Antonio Water System

MAKING SAN ANTONIO WATERFUL

# SAWS by the Numbers

## One of the nation's largest municipally owned utilities

- Over 2.0 million population
- 928 square mile service area
- 13,200 miles of pipe (water & wastewater)
- 4 major treatment plants
- $941 million budget
- $2.6 billion 5-year capital program
- 1,686 employees


# Terminology

- 1 acre-foot (AF) = 325,851 gallons, or approximately enough water to fill a **football field one foot deep**
- Firm Yield: The **volume of water** which can be produced from a defined source during a repeat of the **drought** of record under existing regulatory, legal, contractual, hydrological, or infrastructure constraints.
- Drought of Record: The drought of **1950-1958** in Texas is accepted as the Drought of Record for water resource planning purposes. SAWS utilizes the Drought of Record as the **basis of supply availability** and drought demand management measures.

# WMP Development

## What is the Water Management Plan (WMP)?

- Guiding document to meet long-term water needs of SAWS' customers
  - Population projections
  - Water demands
  - Conservation programs and goals
  - Current and future supplies
  - Updated approximately every five years

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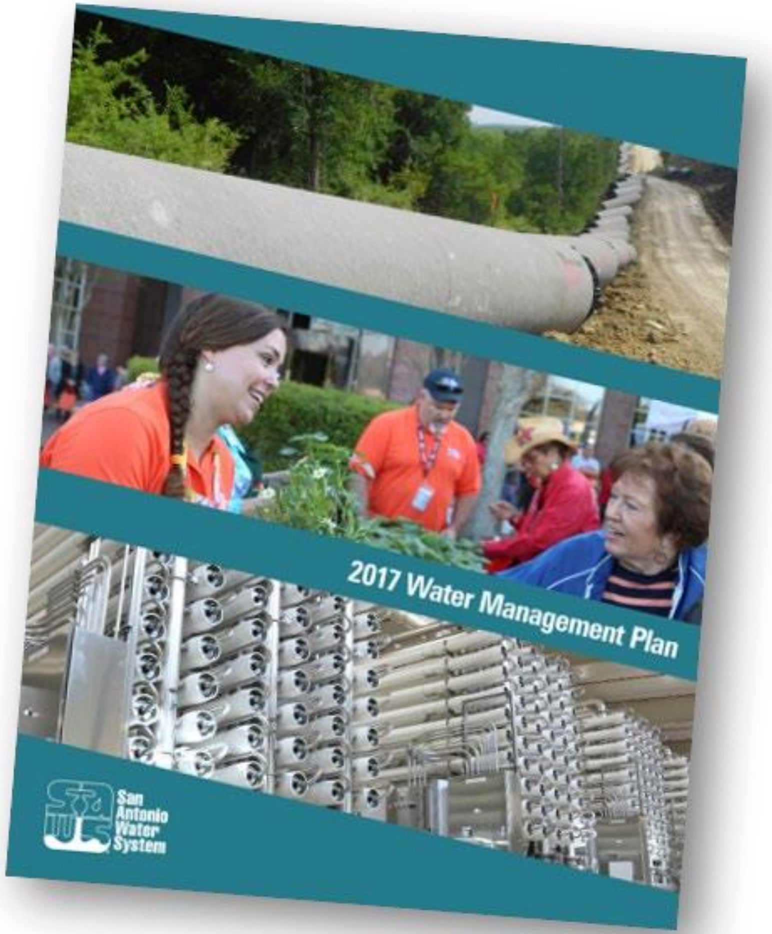
# 2017 Water Management Plan Results

## Highlights

- Goal of 88 GPCD
- Planning population of 3.3 million
- Introduction of hybrid drought scenario
- New supplies
  - Vista Ridge
  - Expansion of Local Carrizo
  - Additional phases of Brackish Desal



# Core Topics

## Changes & Considerations Moving Forward

- Population
- Growth & Development
- Conservation
- Nonrevenue Water (NRW)
- Drought triggers
- Water supplies

# 50-Year Water Management Plan

Population Demands

Diversified Water Sources

Conservation

Supply Management

Climate Change

Regional Partnerships

# Community Engagement

- SAWS Public Committees
- Stakeholder Organizations
- Traditional & Social Media
- WaterCitySA Website
- Virtual & In-Person


WATER CITY SA

# 2017 Water Management Plan Results

## Highlights

- Goal of 88 GPCD
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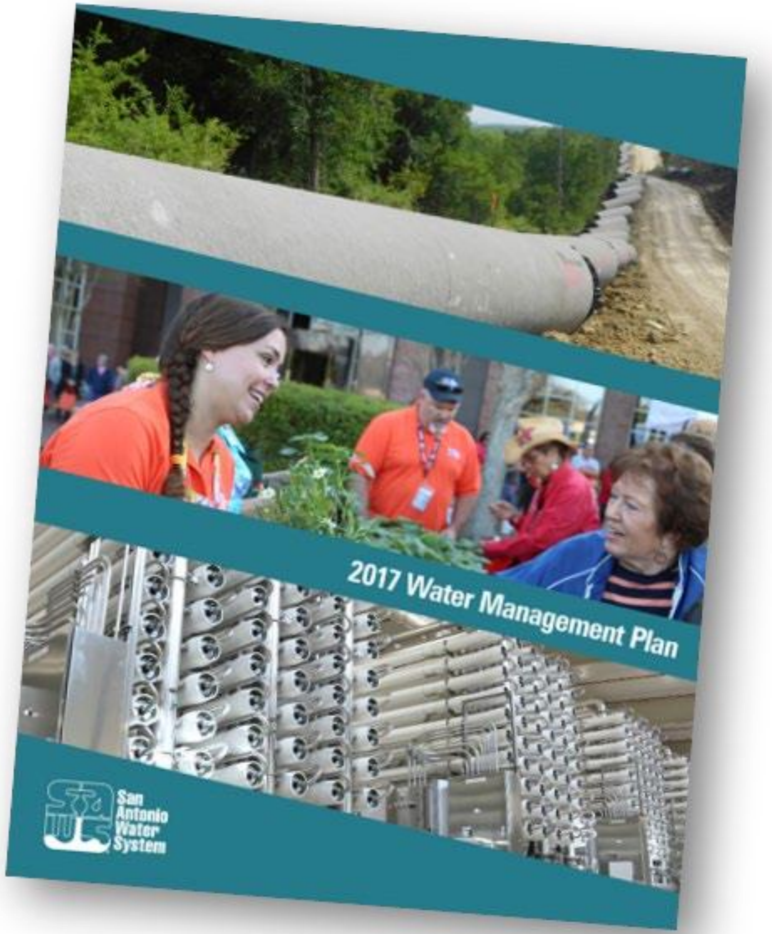




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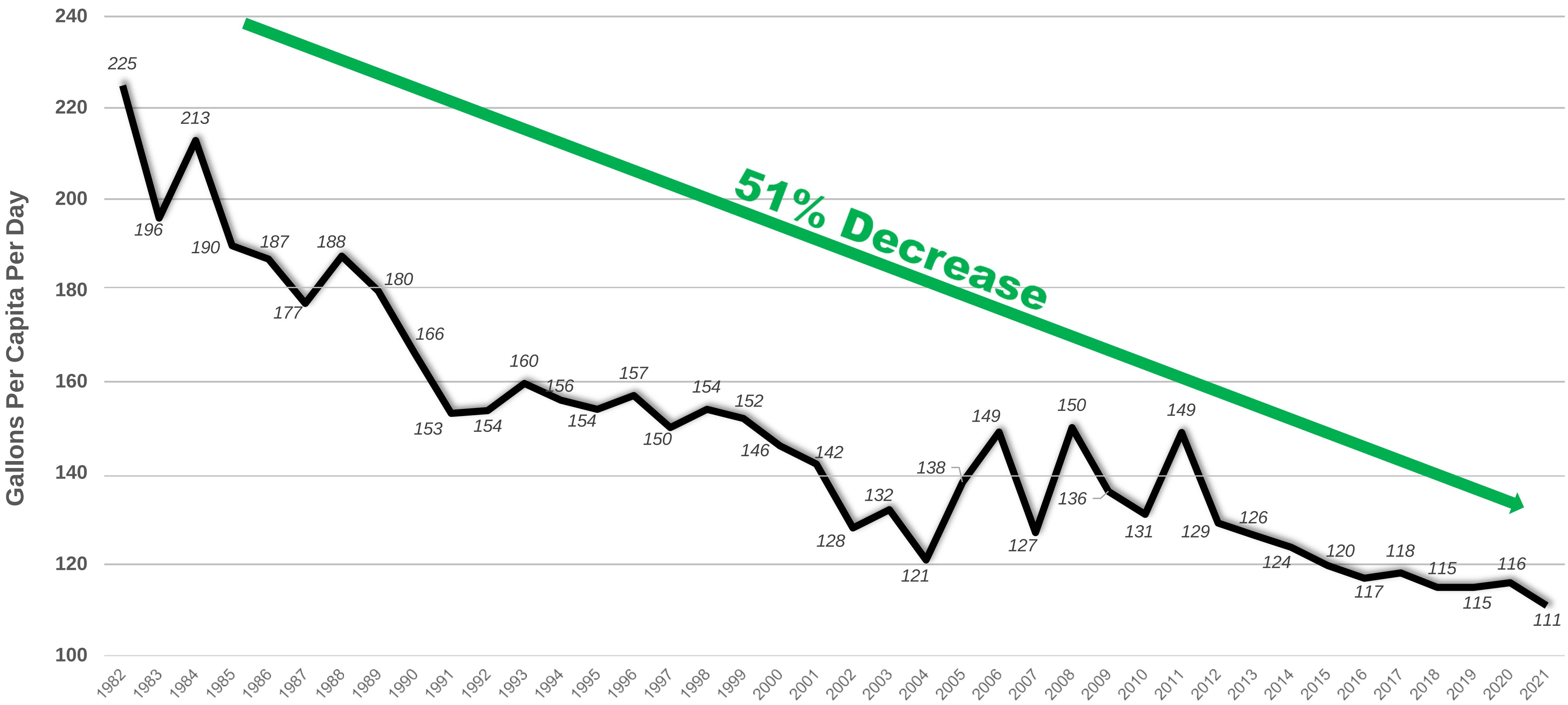
# Conservation – First New Source



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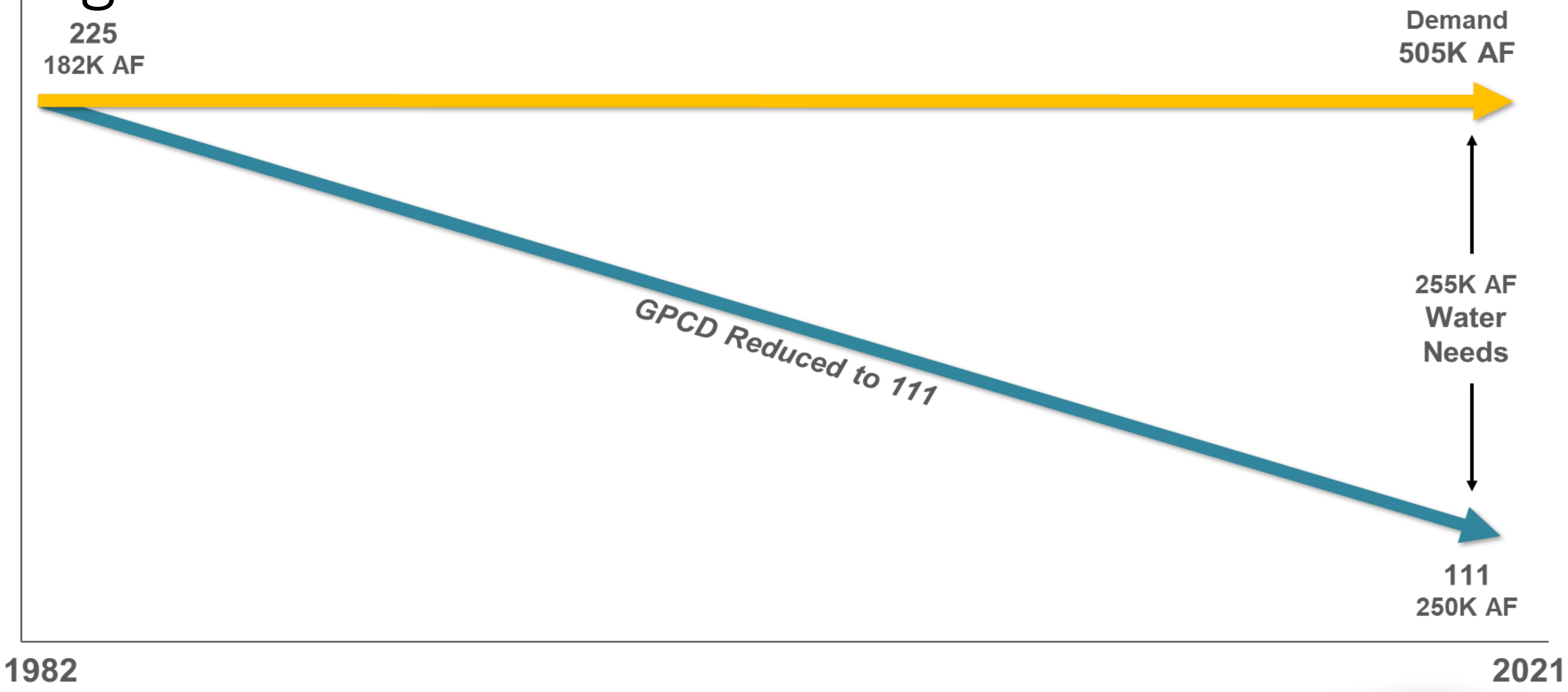
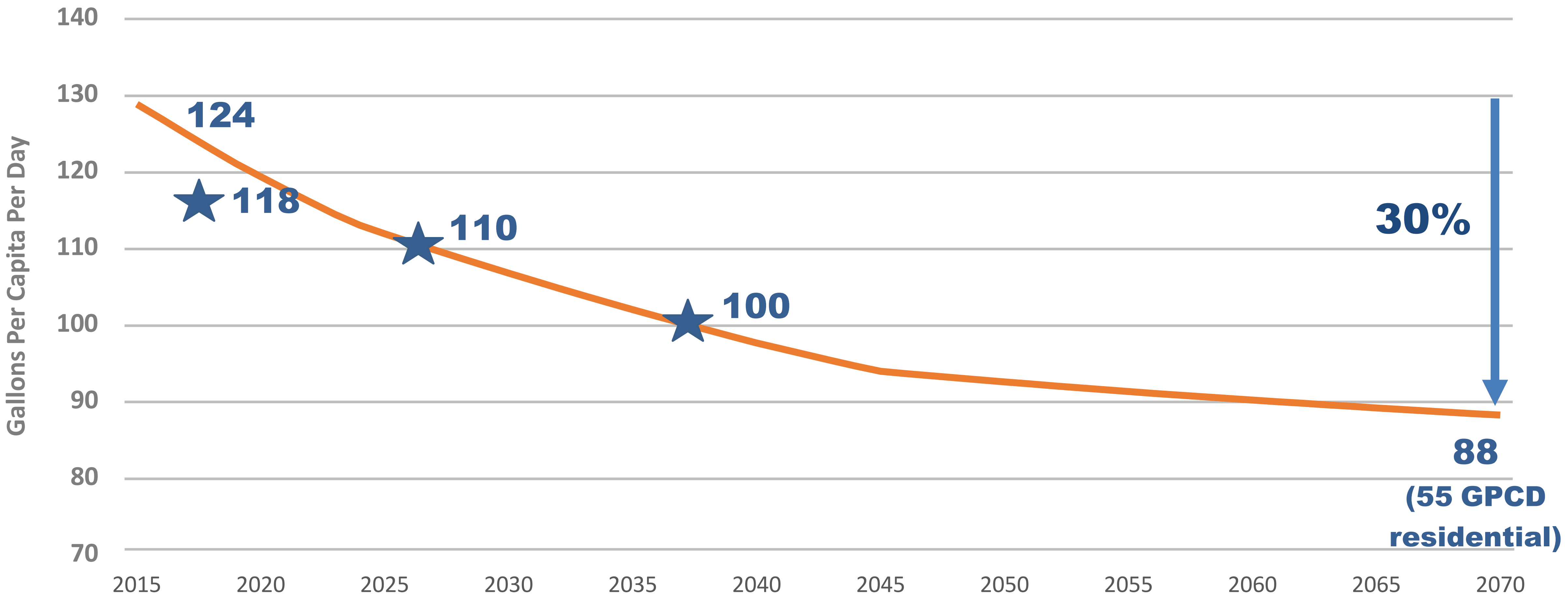
# SAWS Demand Savings

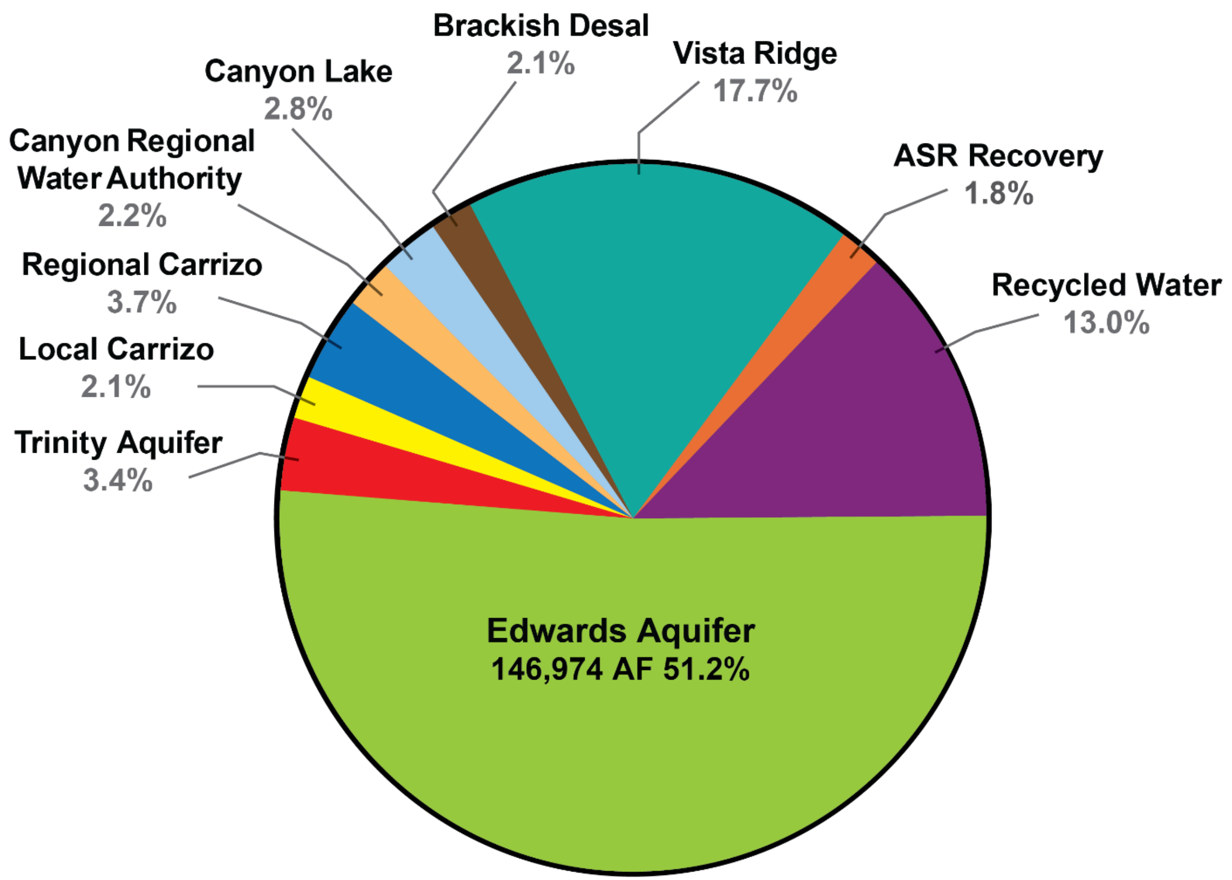


# Progressive Conservation Goals to Continue



# Diversified Water Supply Portfolio

## 2021 Water Supply Distribution



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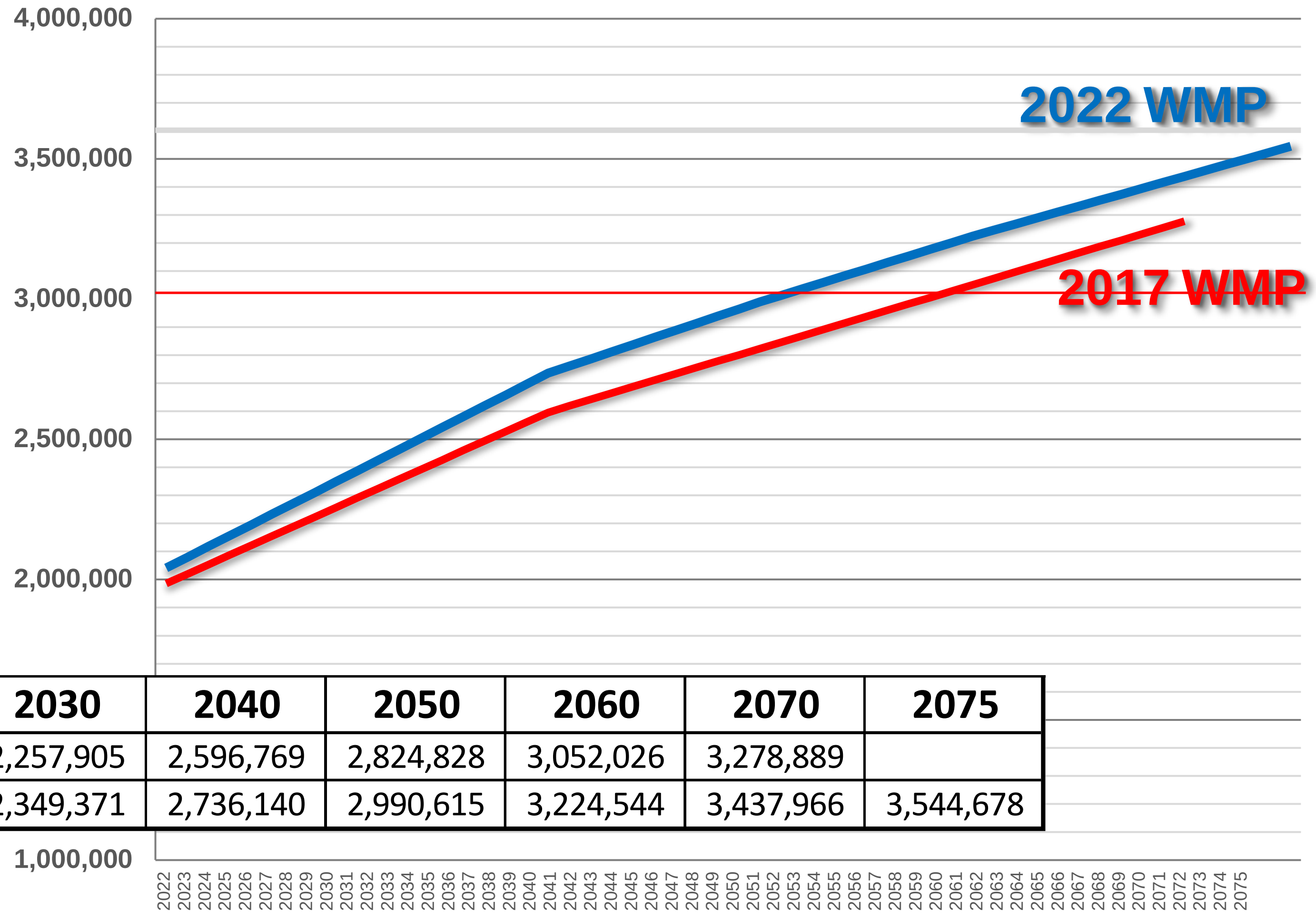
# Population Projections

## SAWS Revised Growth

- SA Fastest growing city in the nation 2020-2021
- 694,000 more by 2040
- 1.5 million more by 2075 (74% increase)




| Plan Population Projections | 2022 | 2030 | 2040 | 2050 | 2060 | 2070 | 2075 |
|---|---|---|---|---|---|---|---|
| 2017 WMP Population Projections | 1,986,998 | 2,257,905 | 2,596,769 | 2,824,828 | 3,052,026 | 3,278,889 | |
| 2022 WMP PopulationvProjections | 2,042,120 | 2,349,371 | 2,736,140 | 2,990,615 | 3,224,544 | 3,437,966 | 3,544,678 |



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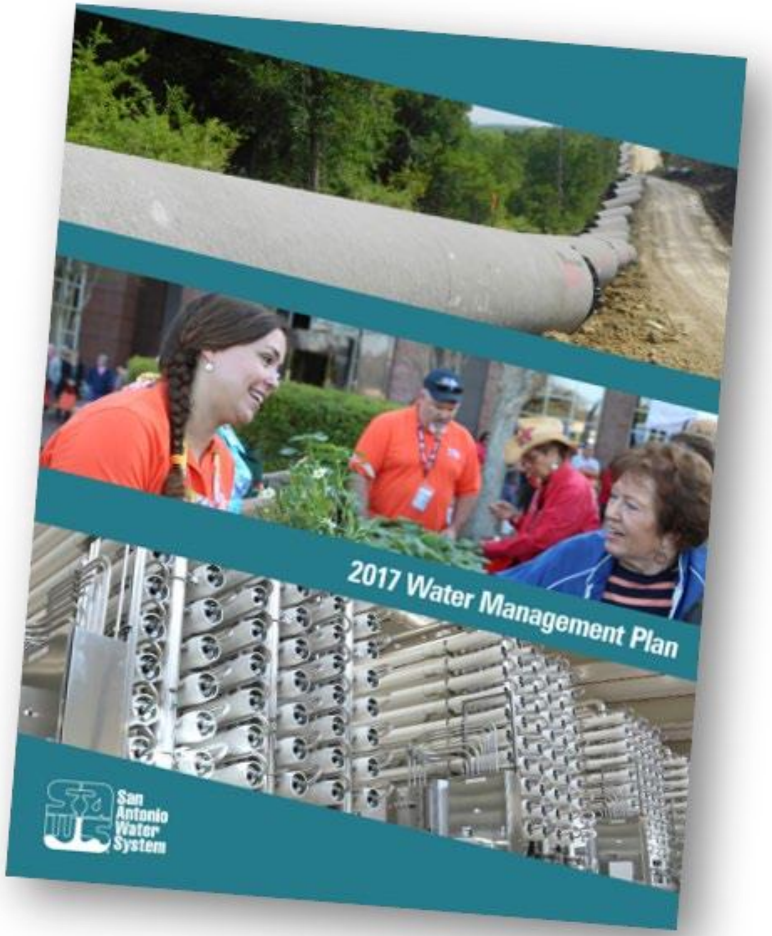
# Climate Change in Water Management Plans

## Highlights

- First time addressed 2009 WMP
- Introduction of hybrid drought scenario
  - Intensity of 2011-2014 + duration 1950s
  - 108-month drought (9 years)
  - 77-month drought State Water Plan (~6.5 years)
- Ensured resiliency



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Highlights

# Climate Change

- We think of this...

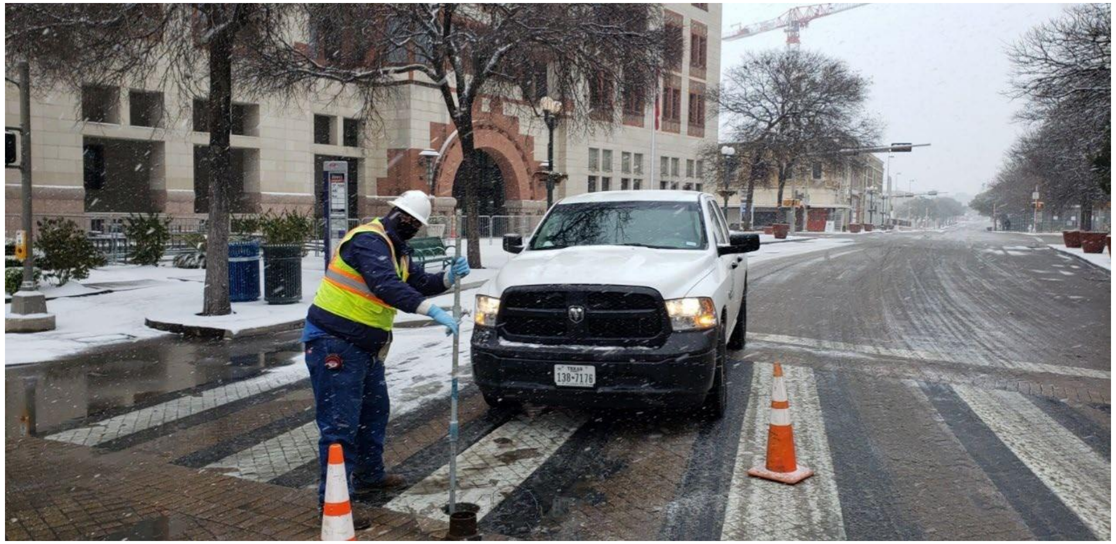



San Antonio Water System

Highlights

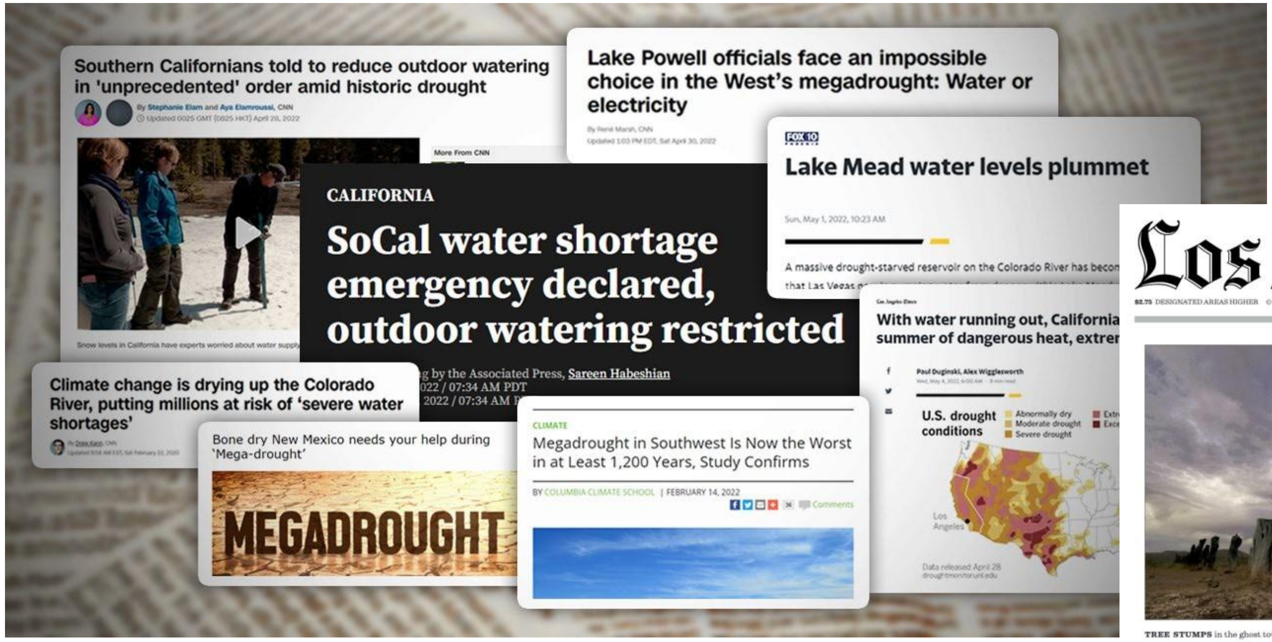
# Climate Change

- But it is also this…



# SW Climate Enhanced Drought

## Southwest Megadrought




Los Angeles Times

TUESDAY, FEBRUARY 15, 2022

TREE STUMPS in the ghost town of St. Thomas, Nev., which resurfaced as Lake Mead's water receded.

This Western megadrought is the worst in a millennium

Study says it's being driven by climate change

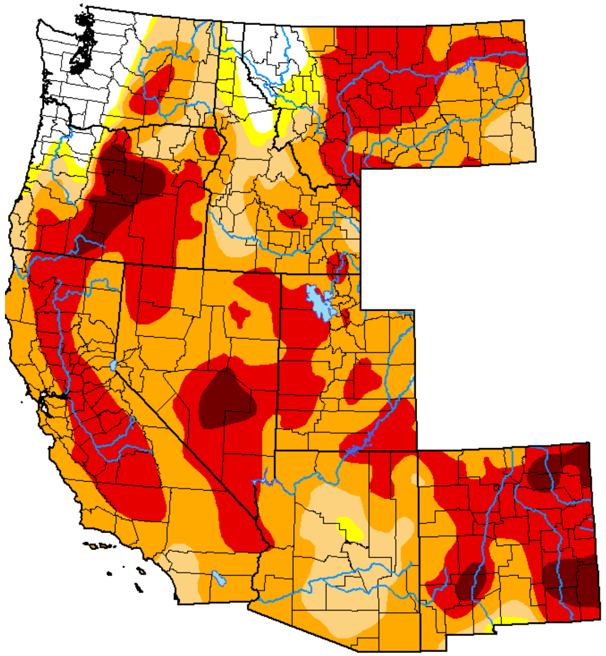
Homelessness, crime damage Newsom in poll

The governor's approval rating falls as a majority of voters say state is heading in the wrong direction.

Public support for tougher sentences

Pair get 12 years for watch robbery

Will new chief take LAUSD to greater





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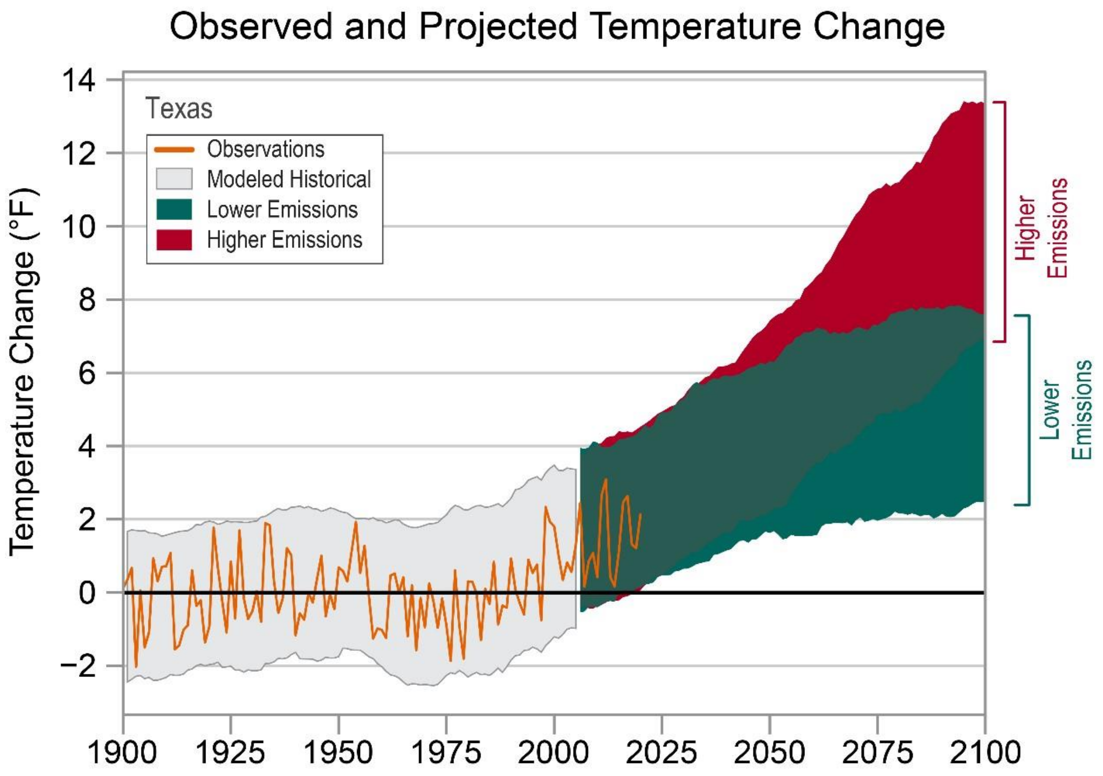
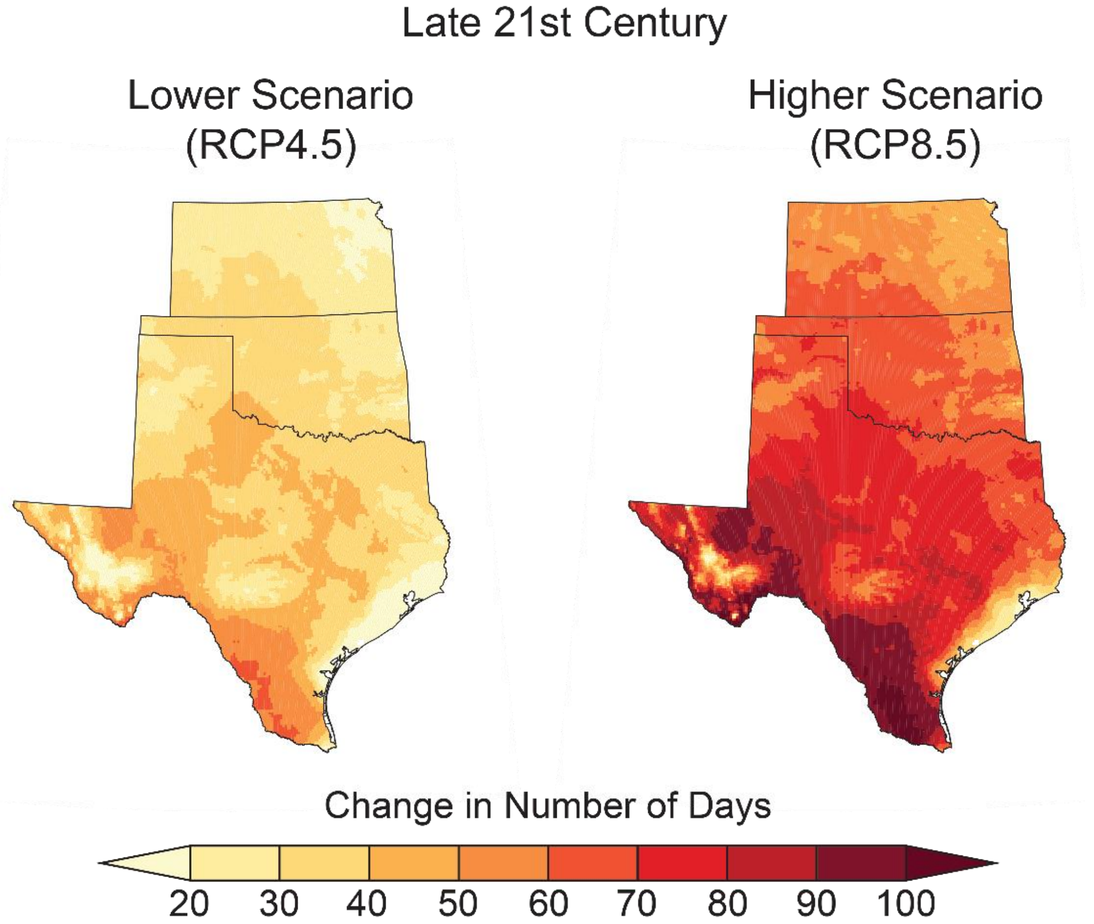
# Climate Change

## Projected Future Climate Conditions in Texas



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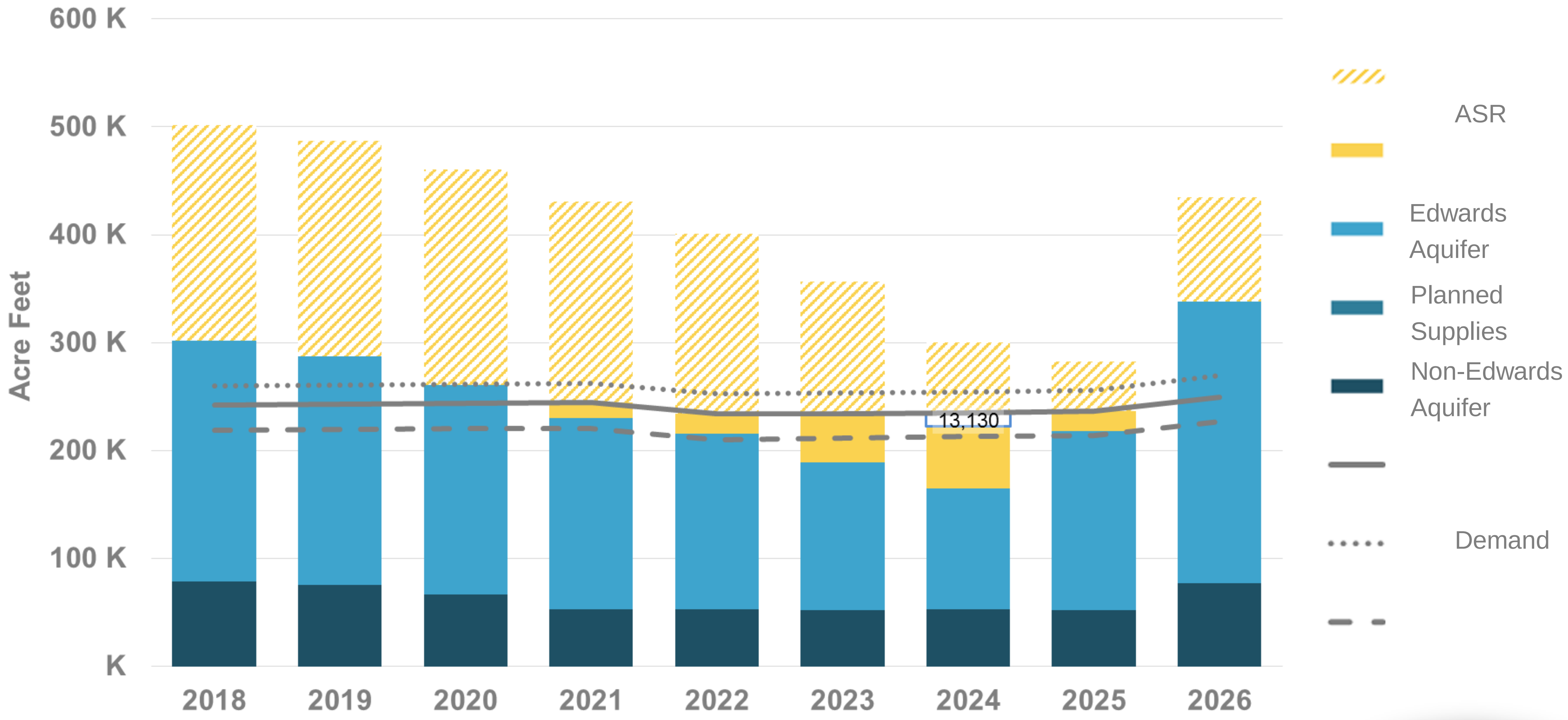
# Securing San Antonio's Water Future






San Antonio Water System

# Next Steps

- Continuous Community Engagement and Feedback
- SAWS Board & City Council Briefings
- Draft Plan
- SAWS Board Approval

# Contacts

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San Antonio Water System

# 2022 Water Management Plan Introduction

Steven Siebert

Project Coordinator/ Water Resources

Texas A&M University San Antonio

November 4, 2022

San Antonio Water System

MAKING SAN ANTONIO WATERFUL

# WORKSHOP

# Securing Water-Energy-Food for the Nation's Future

**Daniel I. Leskovar**

*Professor in Vegetable Physiology – Center Director*

*Texas A&M AgriLife Research Center at Uvalde*

Texas A&M University – November 4, 2022

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# Winter Garden and Southwest Texas Economics

- ✓ Contribution: $ 1.4 billion to the Texas Economy
  - $ 622 million from irrigated agriculture
  - $ 685 million form livestock production
- ✓ Exotic game
  - $ 1.3 billion economic impact
  - Provides hunting, fishing and ecotourism contribution to $ 6.2 billion in the state economy
- ✓ Production of:
  - Commodity crops
  - Forages
  - High-value fruits & vegetables
  - Cattle, sheep, goats, and poultry

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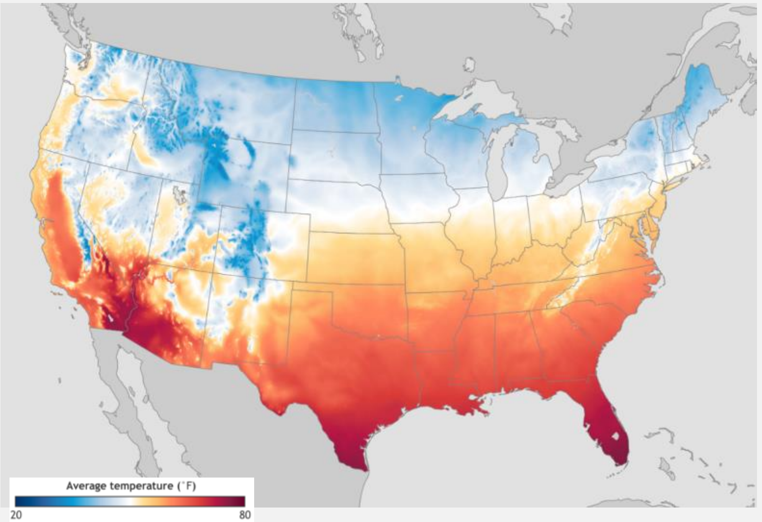
# Winter Garden Strengths for Agriculture

- Rechargeable water resources
- Excellent soil and water quality
- Mild winter climate – Long seasons
- Efficient irrigation technologies
- Balanced crop rotation systems
- Solid Ag-based regional economy
- Dynamic corridors (SAT-Austin-Laredo)

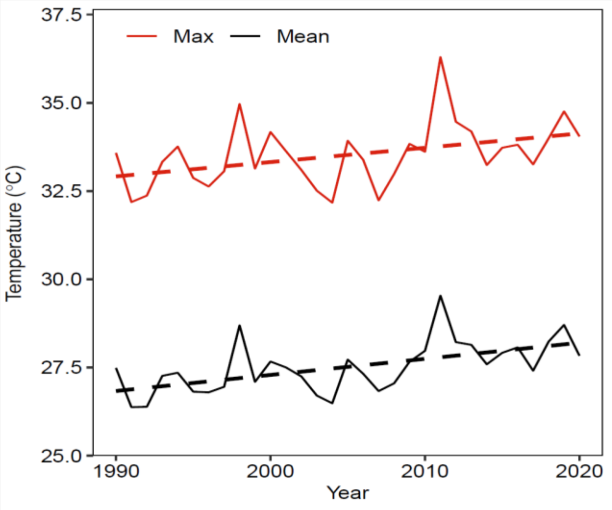
# Climate Change Challenges

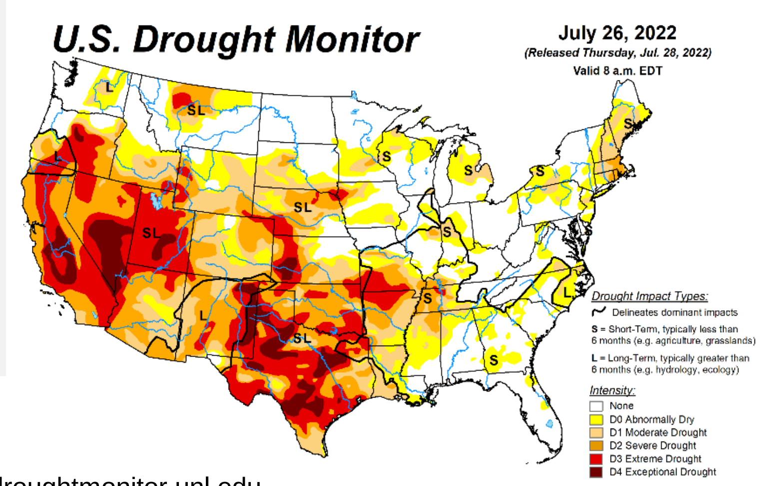

## US average annual temperature




NOAA Climate.gov, 2022

Average summer temperature
- Maximum: 1.2°C increase
- Mean: 1.4°C increase
  (since 1990)




droughtmonitor.unl.edu

NOAA, 2021; NWS, 2021

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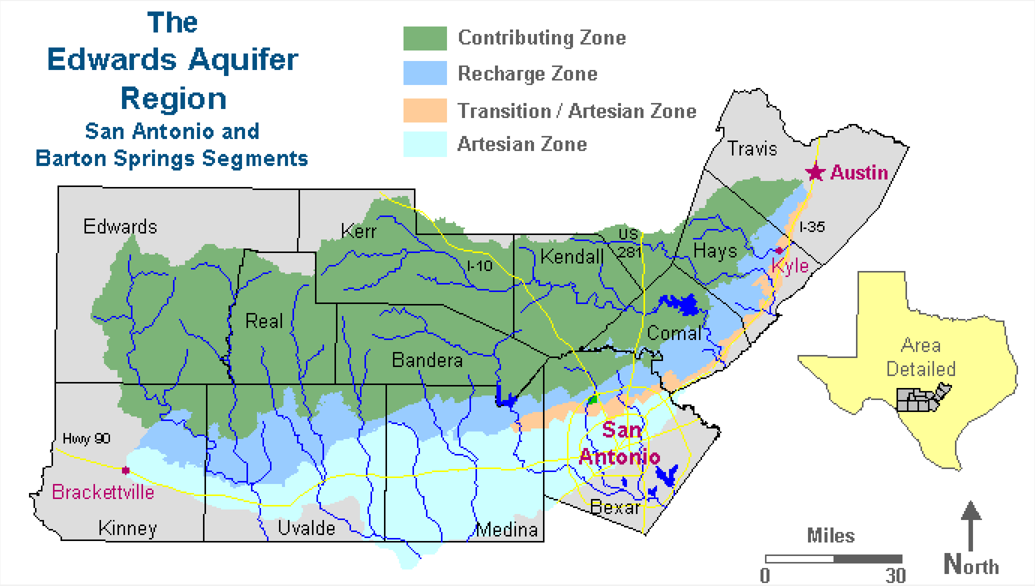
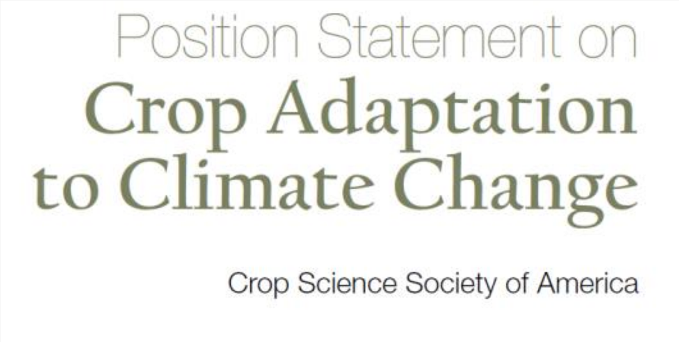
# Other Challenges in Food Systems

- ✓ Extreme weather
- ✓ Rapid population growth
- ✓ Labor shortage
- ✓ Limited water availability
- ✓ Depletion of natural resources
- ✓ Disruption in the supply chain
- ✓ Obesity ($30 MM in 2030 in Texas)




TEXAS A&M AGRILIFE

*“New crop varieties, cropping systems, and agricultural management strategies are needed to provide options to farmers to counterweigh these changes.”*


Position Statement on
Crop Adaptation to Climate Change
Crop Science Society of America

Boote et al. (2011)

# Improved Technologies – Growers Adaptation

*Examples in the Wintergarden Region and South-Central TX*

# Selection of Crops:

*Balance between water use, costs and profits*

# Integrated Water & Crop Management Practices: Uvalde Studies

*J. Plant Nutr. Soil Sci.* 2018, *181*, 655–663 **DOI:** 10.1002/jpln.201800078 655

**Lignite-derived humic substances modulate pepper and soil-biota growth under water deficit stress**

**Kuan Qin**[1] and **Daniel I. Leskovar**[1]*

Applied Soil Ecology 138 (2019) 80–87

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

ELSEVIER

Short communication

Rhizosphere microbial biomass is affected by soil type, organic and water inputs in a bell pepper system

Kuan Qin[a], Xuejun Dong[a], John Jifon[b], Daniel I. Leskovar[a,*]

HortScience 55(5):716–721. 2020. https://doi.org/10.21273/HORTSCI14872-20

**Assessments of Humic Substances Application and Deficit Irrigation in Triploid Watermelon**

**Kuan Qin and Daniel I. Leskovar**

*agriculture* MDPI

*Article*

**Humic Substances Improve Vegetable Seedling Quality and Post-Transplant Yield Performance under Stress Conditions**

**Kuan Qin and Daniel I. Leskovar ***

Texas A&M AgriLife

# Vegetable Crop Responses to Deficit Irrigation

*Yield penalty*

| Crop | Deficit Irrigation | | | Irrigation Rate | Reference |
|---|---|---|---|---|---|
| | Phytonutrients | | Yield | | |
| Artichoke | ↑ | Phenolics | ↓ | 100, 75, or 50% ETc | Shinohara et al. 2014 |
| Carrot | ↔ | Vitamin C | ↔ | - 0.03, -0.06, or -0.12 MPa (water to FC) | Sorensen et al. 1997 |
| Celery | ↑<br>↑<br>↔ | α-Carotene<br>β-Carotene<br>Thiamine | ↓ | Irrigation (404 mm) or no irrigation (248 mm) | Evers et al., 1997 |
| Leek | ↑ | Vitamin C | ↓ | -0.03 or -0.09 MPa (water to FC) | Sorensen et al., 1997 |
| Pepper | ↑<br>↑ | Vitamin C<br>β-Carotene | ↓ | 100 or 50% ETc | Leskovar et al. (unpublished) |
| Spinach | ↑<br>↑<br>↑ | Vitamin C<br>β-Carotene<br>Lutein | ↓ | 100, 75, or 50% ETc | Leskovar et al. (unpublished) |
| Tomato | ↑<br>↑<br>↔ | Vitamin C<br>Lycopene<br>β-Carotene | ↓ | 100 or 20-30% FC | Zushi and Matsuzoe 1998 |
| Watermelon | ↑<br>↔ | Lycopene<br>Lycopene | ↓<br>↓ | 100, 75, or 50% ETc<br>100, 75, or 50% ETc (3 locations) | Leskovar et al., 2004<br>Bang et al., 2004 |

# **Irrigation Technologies for Food Systems:**
## A Lettuce Case Study at Uvalde

| Variable | Hydroponics | LEPA | SDI |
|---|---|---|---|
| **Cost ($)** | Very High | High | High |
| **Salinity (ds/m)** | Medium to High | Medium | High |
| **Precocity (days to harvest)** | Early | Late | Late |
| **Yield** | Very High | Medium | Medium |
| **Water Use Efficiency** | Very High | Medium | Medium |
| **Water use (L/plant)** | Very Low (1-2 L) | Very High (27-31) | Medium (14-22) |
| **Freshness** | Excellent | Good | Good |
| **Chlorophyll content** | Medium | High | High |
| **Overall appearance** | Excellent | Medium-Good | Medium-Good |
| **Post-harvest quality** | Excellent | Good | Good |
| **Pest control – Pesticides** | Very low to none | Normal schedules | Normal schedules |

Lettuce (Hydroponics )

Spinach & Lettuce (SDI)

Spinach & Lettuce (LEPA)

**CEA - Vertical farming can provide solutions to the current and future problems such as:**

- Decreasing arable lands and freshwater resources
- Increasing population and urbanization
- Climate change

**By providing:**

- ➢ Land-use optimization
- ➢ All-year-round crop production
- ➢ Local fresh food production
- ➢ Water recycling
- ➢ Reduction in Fossil fuels

# Opportunities in LAC : Development of Resilient Urban Systems … Applicable to Texas?

**Challenges and opportunities to *better production***
*"Ensure sustainable consumption and production patterns, through efficient and inclusive food and agriculture supply chains at local, regional, and global level, ensuring resilient and sustainable agri-food systems in a changing climate and environment".*

**Challenges and opportunities related to *better nutrition***
*"End hunger, achieve food security and improved nutrition in all its forms, including promoting nutritious food and increasing access to healthy diets" (13.5 million U.S. households are food insecure)*

**Challenges and opportunities related to a *better environment***
*"Protect, restore and promote sustainable use of terrestrial and marine ecosystems and combat climate change (reduce, reuse, recycle, residual management) through MORE efficient, inclusive, resilient and sustainable agri-food systems"*

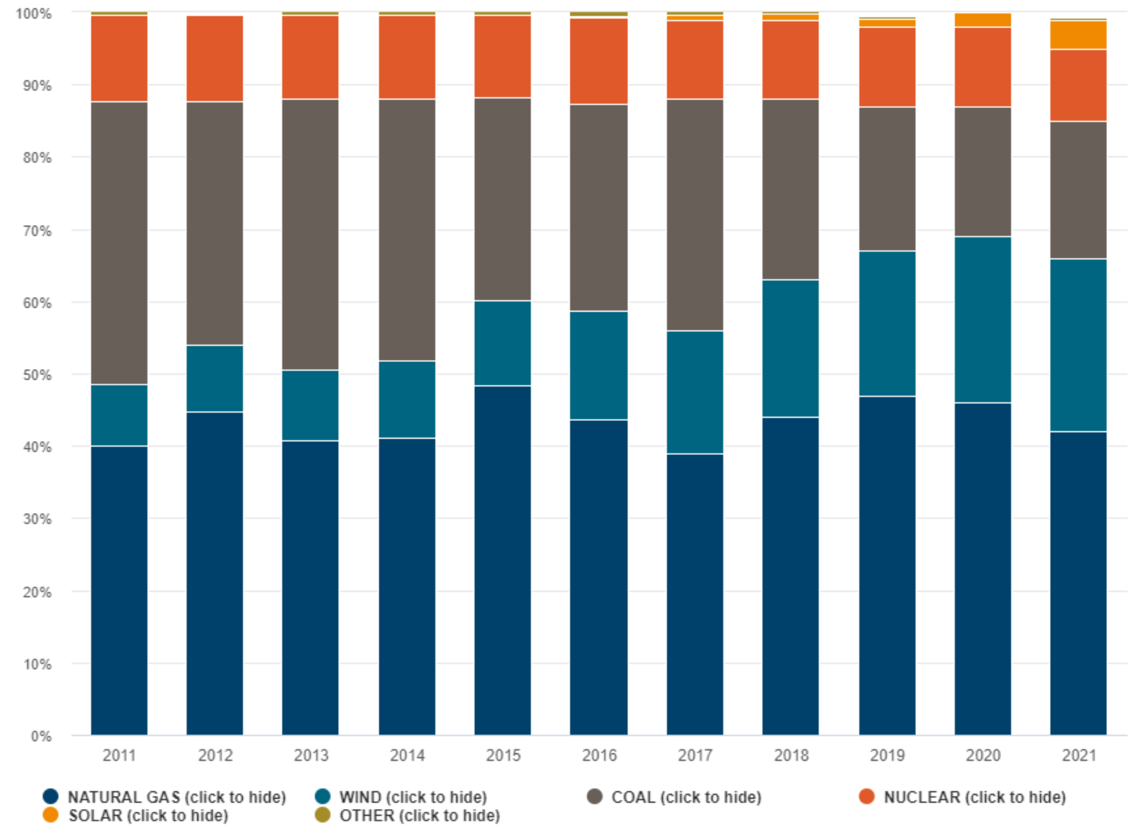
**Challenges and opportunities related to a *better life***
*"Promote inclusive economic growth by reducing inequalities (urban/rural areas, rich/poor countries, men/women)"*

FAO Regional Conference, February 2022 – Quito, Ecuador

# Texas Energy Portfolio

Faroque Hasan, Professor,
Chemical Engineering, Energy Institute. TAMU

Over the last decade, Texas has made substantial progress in diversifying its energy portfolio.




Note: Figures may not sum due to rounding.
Source: ERCOT

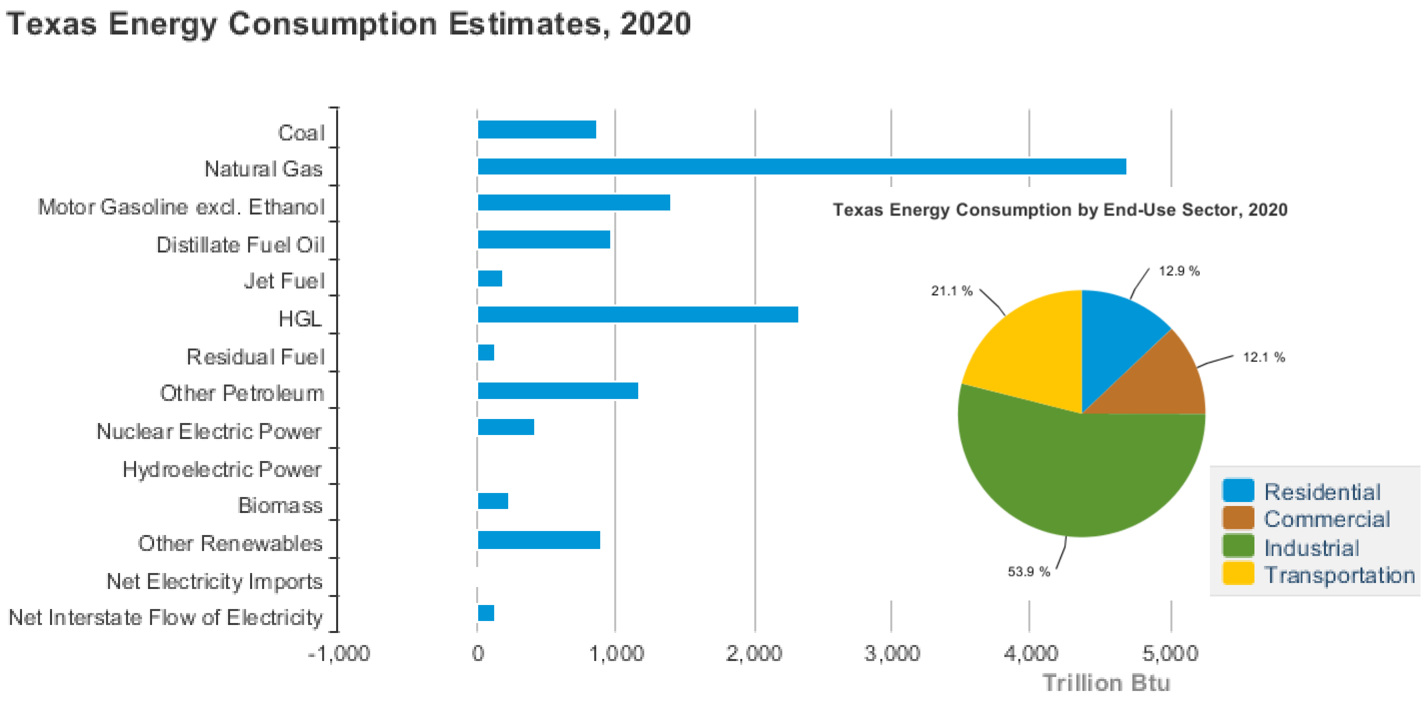
ERCOT generation fuel mix, 2011-2021

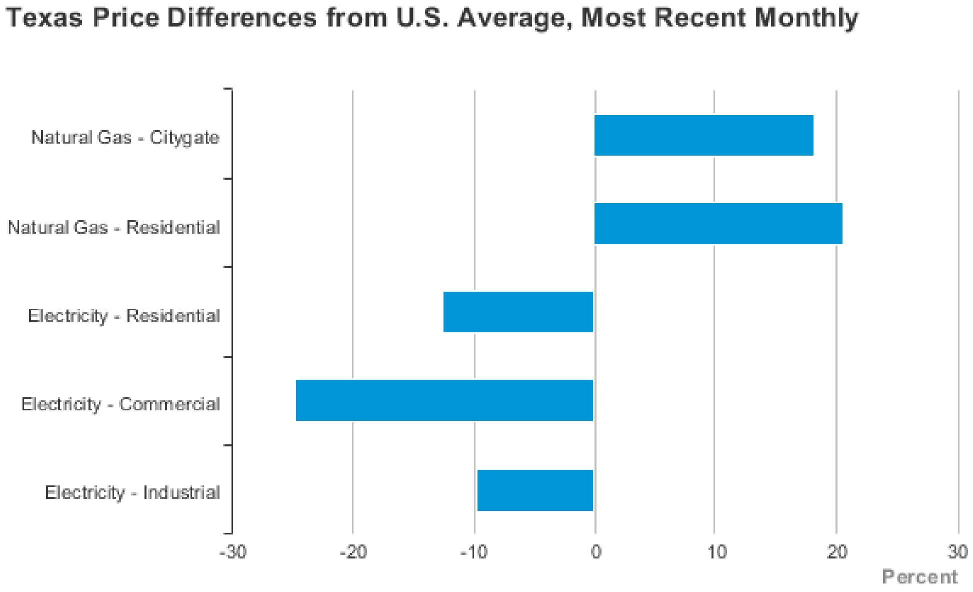
## QUICK FACTS – Texas energy profile (2021)

- 43% of the nation's crude oil production
- 25% of its marketed natural gas production
- 26% of all U.S. wind-powered electricity generation
  ( leading the nation for the 16th year in a row)
- Wind power surpassed the state's nuclear generation for the first time in 2014 and exceeded coal-fired generation for the first time in 2019
- Texas produces more electricity than any other state (generating nearly twice as much as second-place Florida)

# Texas Energy Portfolio

The industrial sector, including the state's refineries and petrochemical plants, accounts for more than half of the state's energy consumption and for 23% of the nation's total industrial sector energy use.




Source: Energy Information Administration, State Energy Data System

# Lessons from Texas Freeze: Strengthen US Energy Resilience Future Challenges

Cold weather in Texas froze infrastructure at natural gas, coal and nuclear facilities, as well as wind turbines

1. Protect Power Generation and Fuel Supplies
2. Expand the Grid and its Interconnection
3. Rethink Market Design and Resource Adequacy
4. Create Multi-day Energy Storage Systems
5. Modernize Buildings, Infrastructure and Technology


*https://www.wri.org/insights/lessons-texas-freeze-5-ways-strengthen-us-energy-resilience#*


CATASTROPHE | UNITED STATES OF AMERICA

Biden declares a 'major disaster' in Texas

02/20/2021

While power has been restored across Texas, residents are still facing water shortages. President Joe Biden's declaration will allow his administration to free up federal funding for the snow-hit state.


*https://www.dw.com/en/texas-freeze-joe-biden-declares-major-disaster/a-56636256*

# Energy Transition in Texas

Texas embraces everything about energy — especially what's new

Coupled with ongoing leadership in renewable energy and energy storage, innovations like carbon capture, hydrogen-fueled energy and geothermal power generation offer more economic growth.

The recently passed **federal bipartisan Infrastructure Investment and Jobs Act** are critical opportunities to catalyze Texas' energy expansion

- $10 billion for **carbon-capture technology** grants, large-scale carbon sequestration and transportation and geologic storage permitting.
- The legislation also establishes a grant program for regional **direct air carbon capture hubs** — perfect opportunities for Houston and Corpus Christi.
- The bill allocates $8 billion to create four regional **clean hydrogen hubs**
- And the bill offers $11 billion in grants to enhance electric **grid reliability and resiliency** against extreme weather events and cyberattacks

*https://texas2036.org/posts/energy-transition-texans-should-plan-expansion/*

# Future Challenges

Decarbonizing the Energy Supply Chain

Reduce Methane Emissions and Flaring

Balancing the water-energy-food-environment nexus

Advancing Alternative Energy Technologies

Advancing the Hydrogen Economy

Next-Generation Biofuels

Process Emissions: Low-Carbon Feedstock Solutions

Electricity Market Design and Technologies

Renewable Generation and Energy Storage

Circular Economy: Life-Cycle Obligations, Plastics, and Chemicals

# Thank You!!

TEXAS A&M UNIVERSITY

TEXAS A&M UNIVERSITY SAN ANTONIO

TEXAS A&M UNIVERSITY
WEF NEXUS INITIATIVE

# Q&A

# Science Panel

San Antonio, TX | November 4, 2022

***Bruce McCarl,***
Project PI, Professor, Department of Agricultural Economics, Texas A&M University

***Stratos Pistikopoulos,***
Director, Texas A&M Energy Institute

***Styliani Avraamidou,***
Assistant Prof., Chemical and Biological Engineering, University of Wisconsin Madison

***Hoori Ajami***
Department of Environmental Sciences, University of California Riverside

***Ronald Green***
Consultant, Southwest Research Institute

***Samuel Zapata***
Assistant Professor, Department of Agricultural Economics, Texas A&M University

*Moderator*

Pivot irrigation


Pasture and livestock

Environmental Sensitive area

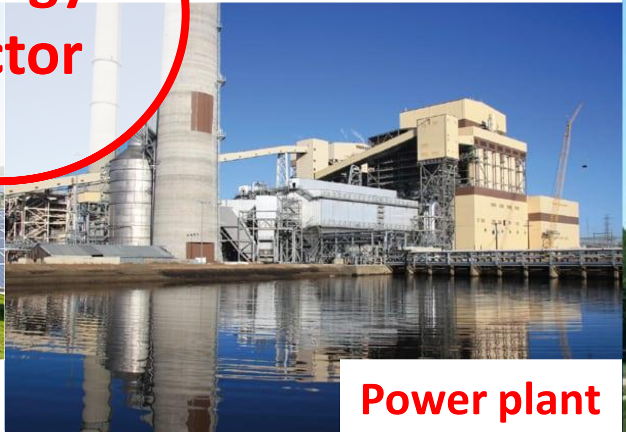
# Food Energy Water Nexus in Regional Modeling Study

Water Tower

Comal Spring

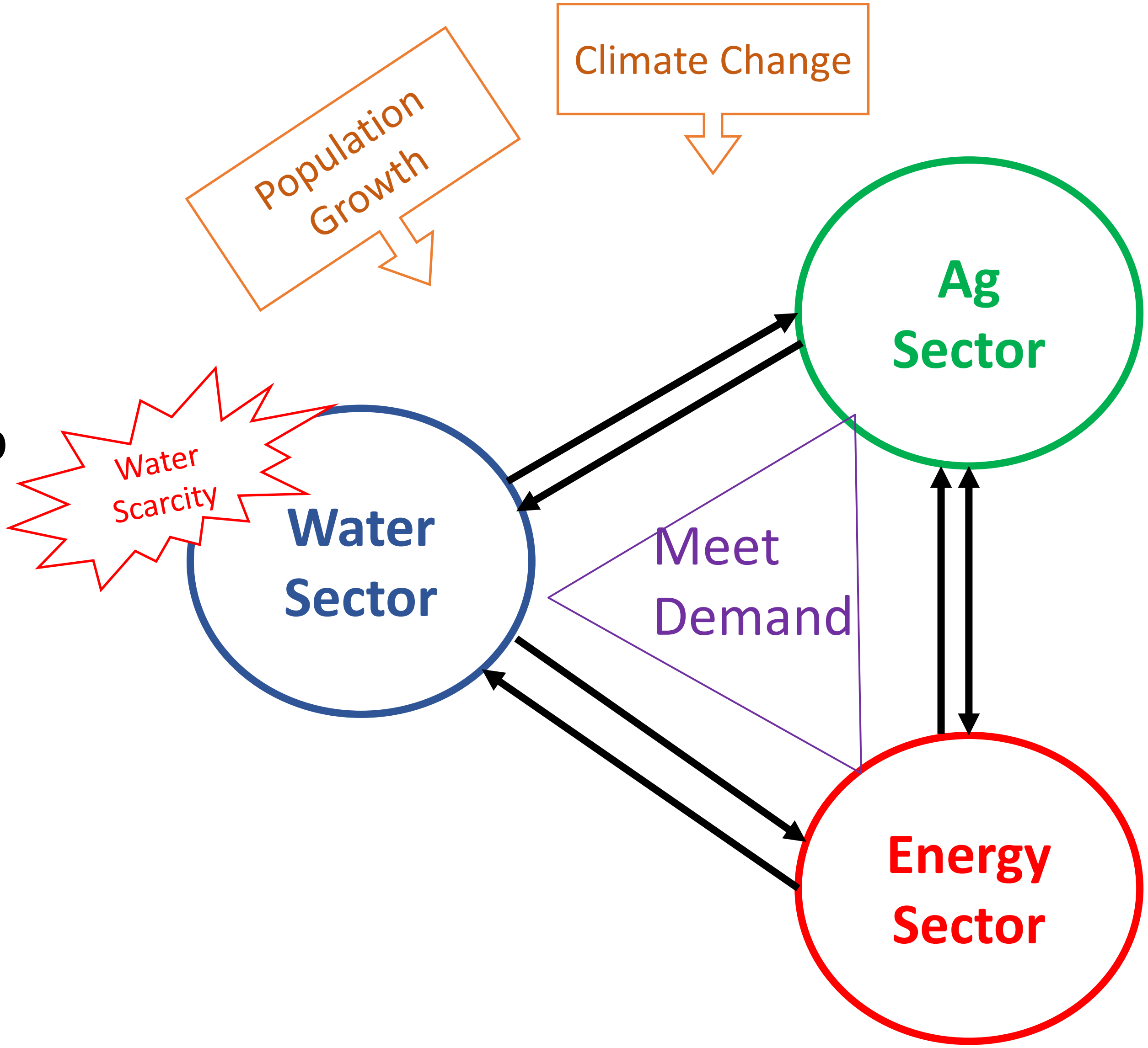

Texas blind salamander

Solar Farm


Power plant

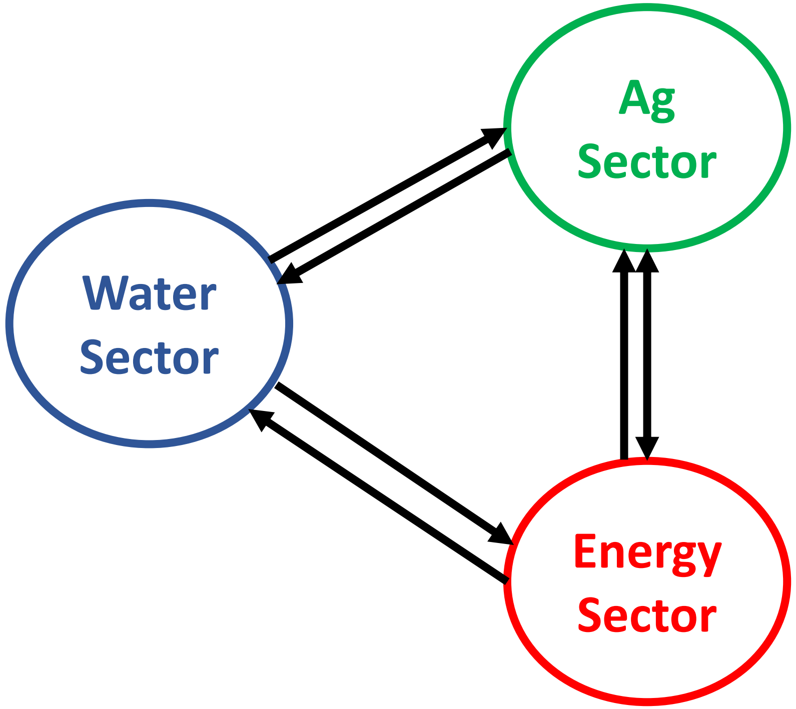
# Analysis Objective

- Study interrelationships between sectors and water / energy supply along with agricultural activity
- Determine the optimal mix of ag, water and energy project options to meet growing water and energy demand
- Investigate the influence of climate change and population growth on sectoral actions and water/ energy supply decisions.
- Develop analytical tool



# Food-Energy-Water Integrated Regional Simulating Model Overview of Components

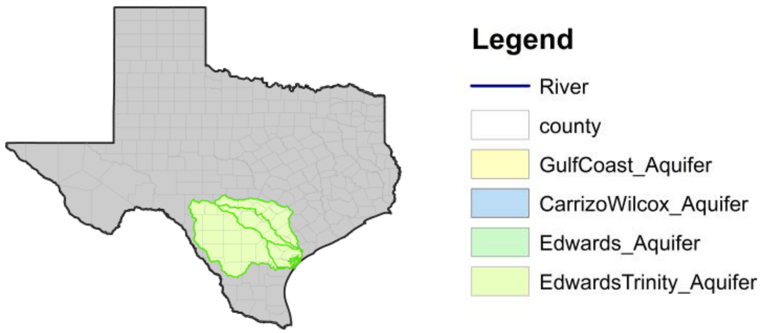
- Aquifer elevation
- River flows
- M&I Water Demand now and over time
- Recreational and Environmental
- **Water Projects construction and operation including electricity demand**
- Return flows
- Water treatment
- Water transfers
- Water demand under climate change




- **Land use for irrigation, dryland cropping and pasture**
- Water use and yields as influenced by climate
- Crop mix
- Livestock herd
- **Deficit Irrigation and yields**
- Product sale at fixed prices
- Water sale and lease
- Land conversion for dryland and pasture

- **Power Plants and fracking**
- **Electricity Demand**
- Cooling facility retrofits
- Renewable Energy (Wind & Solar & Biomass)
- Fracking water usage
- Altered demands - population

# Study Region - Geographic & Hydrologic Scope


Hydrology

- 4 River Basins
- 5 Aquifers
- 2 Springs
- 5 Lakes/Reservoirs

★ City of San Antonio


Edwards Aquifer

- 2 large springs (Hard to retain water)
- Major water source for ag and City of San Antonio
- Endangered species finding in the Edwards Aquifer (EAA, 2019)

# Analysis Design

- **Base 2020**
  - Replicate Reality; Model validation
- **Population Growth (2030, 2050, 2070, 2090)**
  - Base 2020 Info
  - M&I water demand increase
  - Electricity demand increase
  - Projected water conservation
- **Climate Change (16 scenarios)**
  - Additional M&I water demand
  - Additional electricity demand
  - Altered river flow
  - Crop / grass yields and irrigation water needs, stocking rate

# Climate Change Scenarios

- Climate scenarios: IPSL-CM5A-LR (Driest) and MIROC5 (Wettest)
- 2 Representative Concentration Pathway (RCP) : RCP 4.5, RCP 8.5

Average changes for the 10 years period compared with 1981-2016

**Panel A: Temperature Change Based on Average Temperature during 1981-2016**

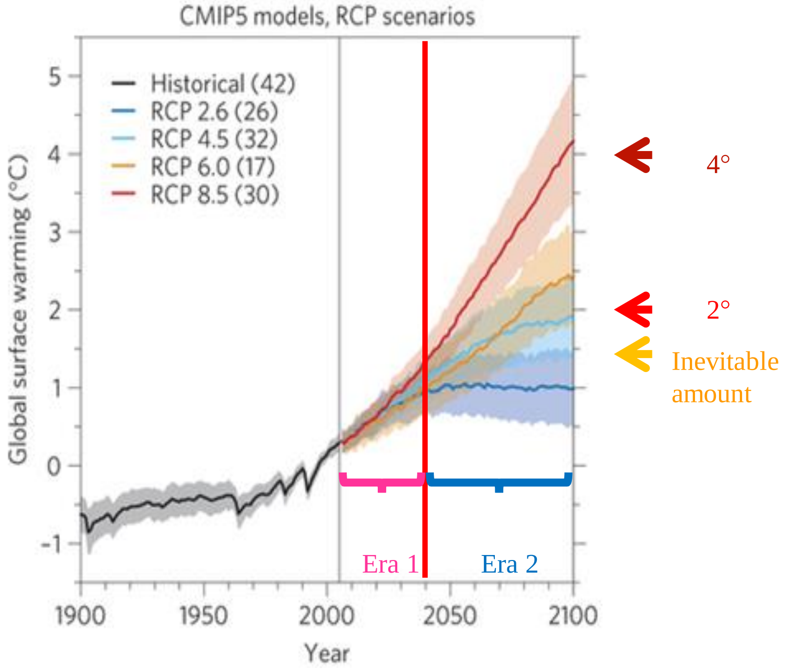
| Climate Model | RCP | 2030 | 2090 |
|---|---|---|---|
| IPSL-CM5A-LR (Driest) | RCP4.5 | 10.01% | 13.49% |
| | RCP8.5 | 7.18% | 31.02% |
| MIROC5 (Wettest) | RCP4.5 | 8.08% | 12.72% |
| | RCP8.5 | 8.00% | 23.89% |

Hotter

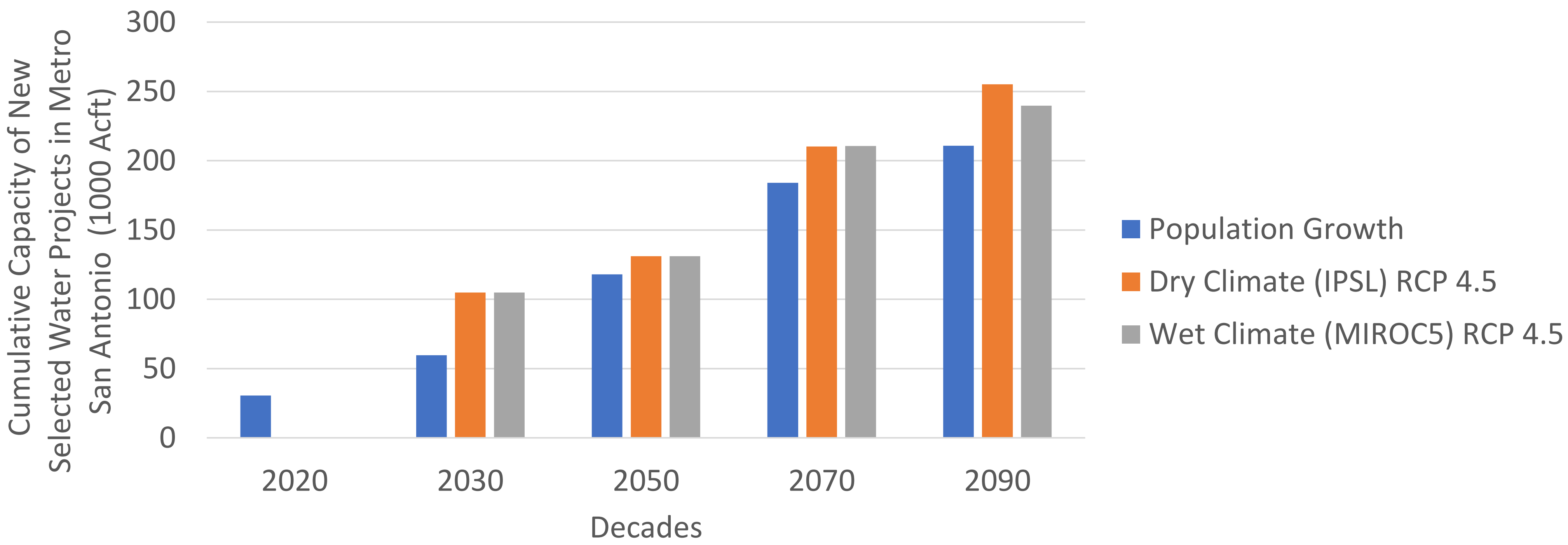
**Panel B: Precipitation Change Based on Average Precipitation during 1981-2016**

| Climate Model | RCP | 2030 | 2090 |
|---|---|---|---|
| IPSL-CM5A-LR (Driest) | RCP4.5 | -13.27% | -11.77% |
| | RCP8.5 | 12.86% | -24.02% |
| MIROC5 (Wettest) | RCP4.5 | 1.11% | 13.86% |
| | RCP8.5 | 13.32% | 2.86% |

Maybe drier

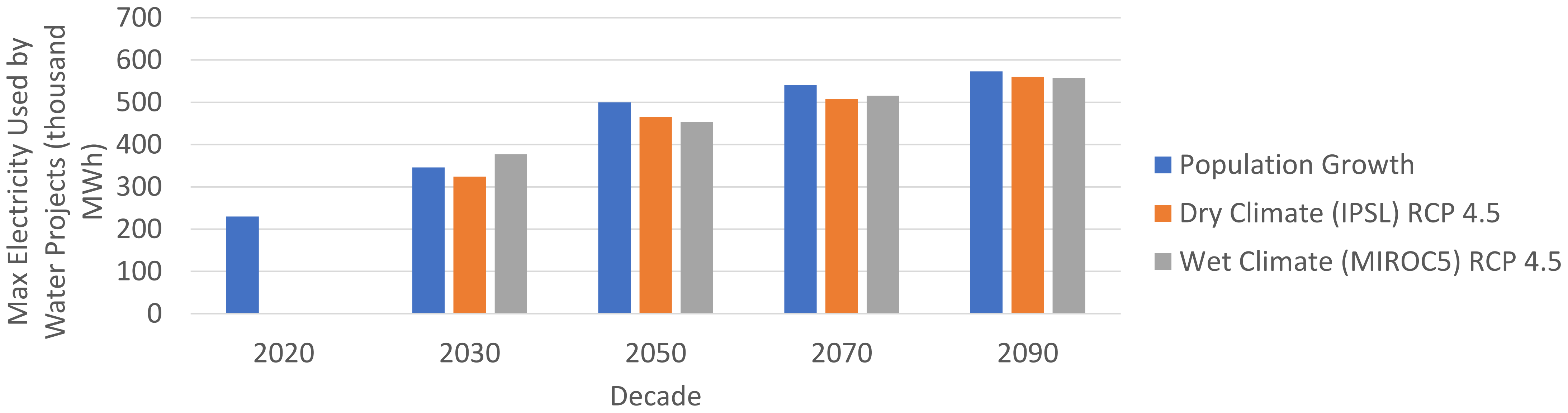


# Cumulative Capacity of Model Selected New Water Projects in Thousand Acft



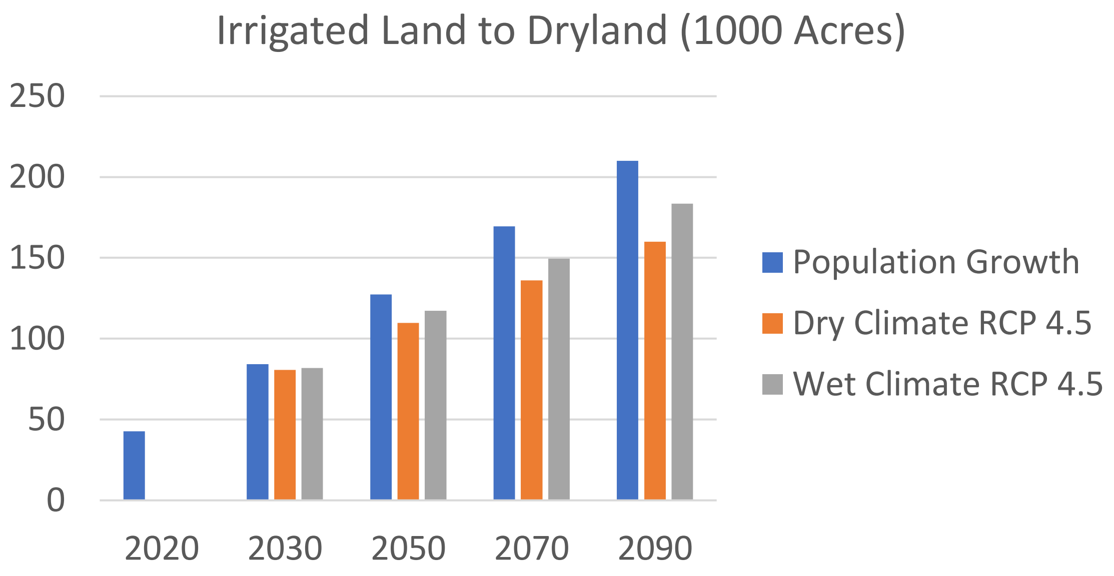

- Water demand increases (population growth) stimulate projects
- Climate change increases water demand and accelerates project development whether wet or dry

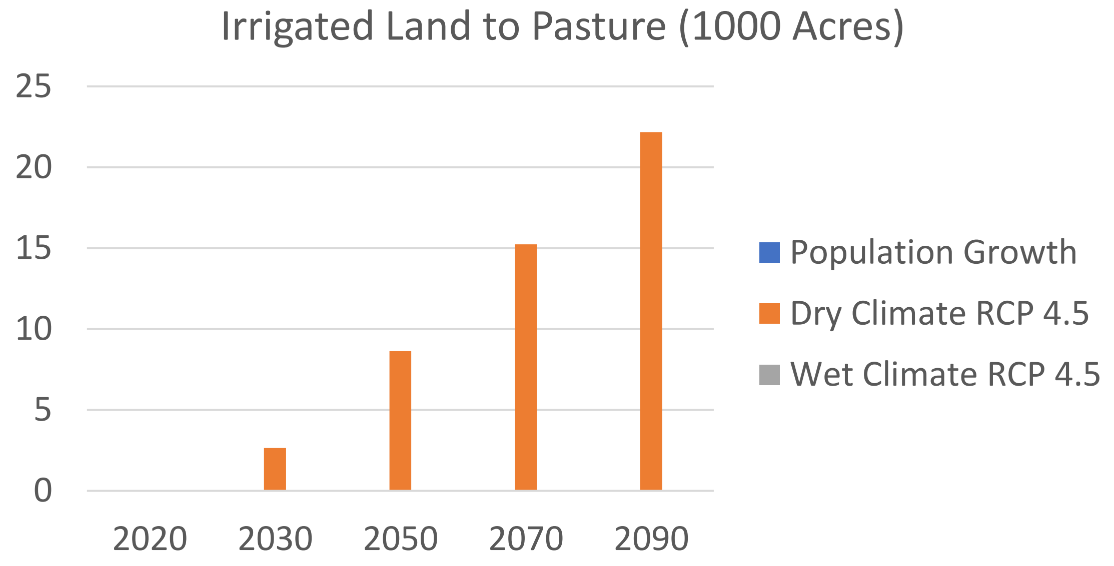
# Maximum Electricity Consumption by Water Projects across SON (thousand MWh)




- Adding water projects increases electricity demands
- By 2090, the water projects add 573 thousand MWh electricity use per year, which is equivalent to
  - Residential electricity consumption in Texas averages **1,168 kWh/month (rank 5)**
  - Equivalent to 41,000 households consumption (size of College Station)

# Result 4: Land Transfer to Dryland and Pasture




- Irrigated land transferred to dryland and pasture under climate change and over time
- More irrigated land  transferred to pasture rather than dryland in the drier and hotter cases
- Mainly due to scarce water

# Conclusions

- Coordinated Nexus action will help meet demands in South Central Texas
  - Population growth → More water projects
  - Climate change → Accelerate the needs of water projects
  - Water Project will be operated more in the drier state of nature
  - The electricity usage by water projects cannot be omitted
  - Land transfer + deficit irrigation → ag cooperation
    - More irrigated land will be transferred to dryland and pasture
    - More land will be deficit irrigated in drier states of nature

# Model Availability

- We have a version on GITHUB
- We encourage its usage by those in the region
- We would be willing to dialogue with those who would want to consider use
- We would also be willing to advise groups throu some scenario runs of regional issues
- We have done analyses not reported today
  - Power plant cooling
  - Value of Ag cooperations

# Thank you!

Bruce A. McCarl

mccarl@tamu.edu

# Energy System Planning Under Energy-Water Nexus Considerations

R. Cory Allen[1,2] , Marcello Di Martino[1,2], **Styliani Avraamidou**[3], **Efstratios N. Pistikopoulos**[1,2]

1. Artie McFerrin Department of Chemical Engineering, Texas A&M University
2. Texas A&M Energy Institute, Texas A&M University
3. Department of Chemical & Biological Engineering, University of Wisconsin Madison

# Energy-Water Nexus

## Problem Statement

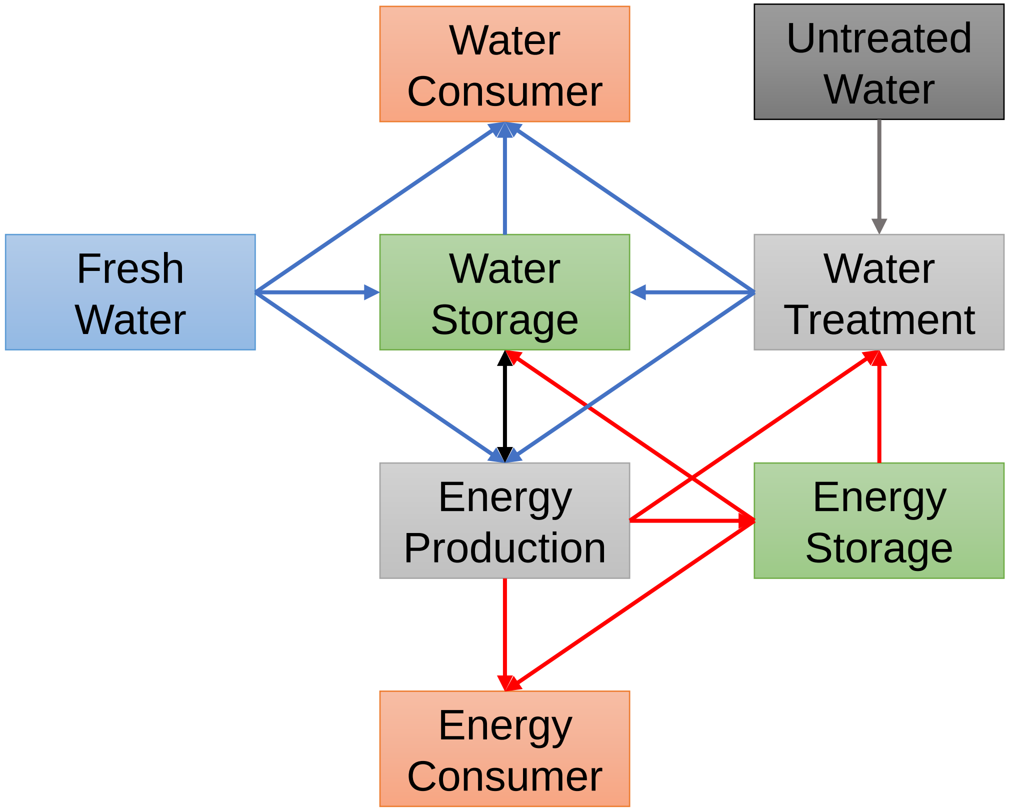
**Goal of the research:** develop a systematic methodology based on nexus connections for improving and expanding power generating systems and water treatment facilities in Region L

**Nexus connections in the system:**

- Renewable energy and gas turbine generators
- Generators with combined and steam cycles
- Water treatment plants
- Aquifers
- Energy storage units

**Stochastic fluctuations of the parameters - allow for a realistic representation:**

- Energy demands
- Water demands
- Solar availability
- Wind availability



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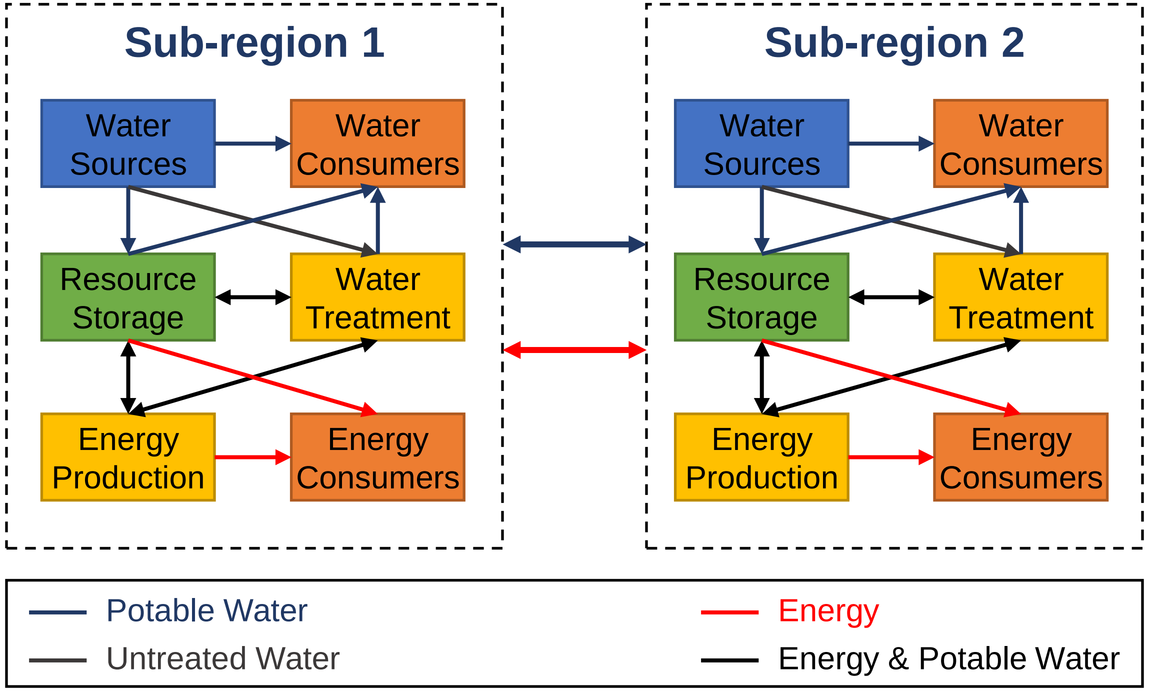
**Interconnected Sub-Regions in Region L**



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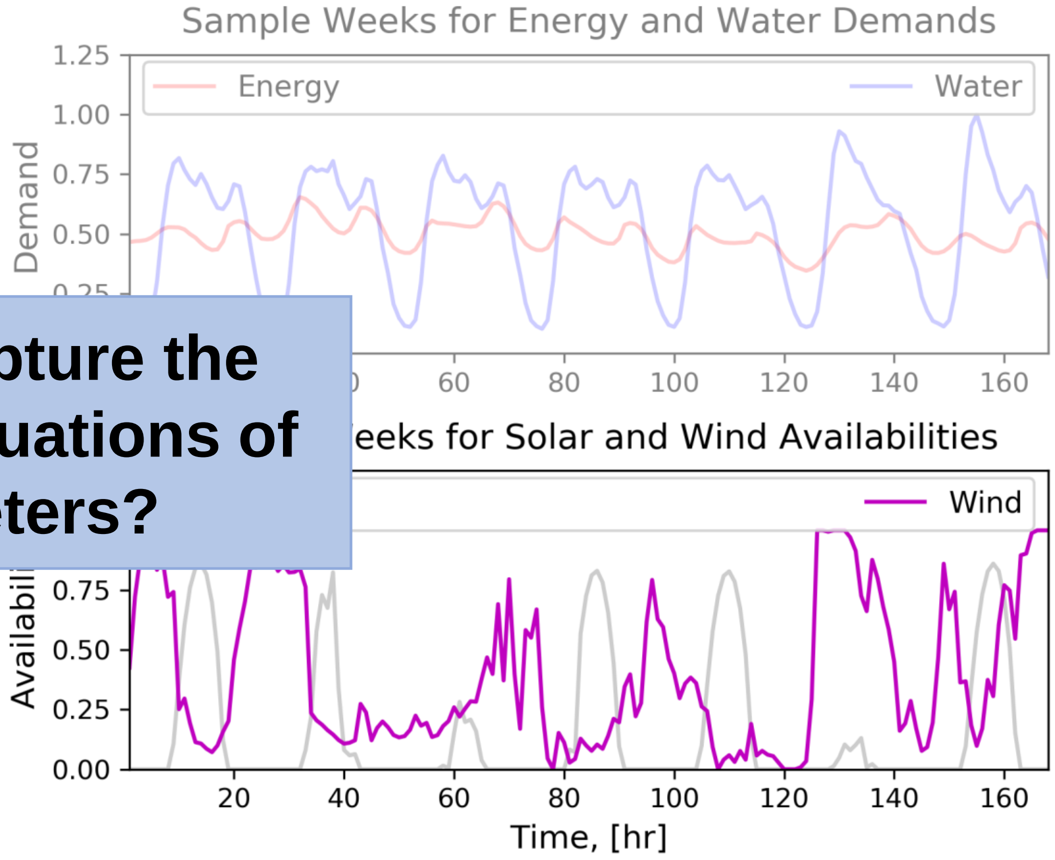
**How do we capture the stochastic fluctuations of the parameters?**



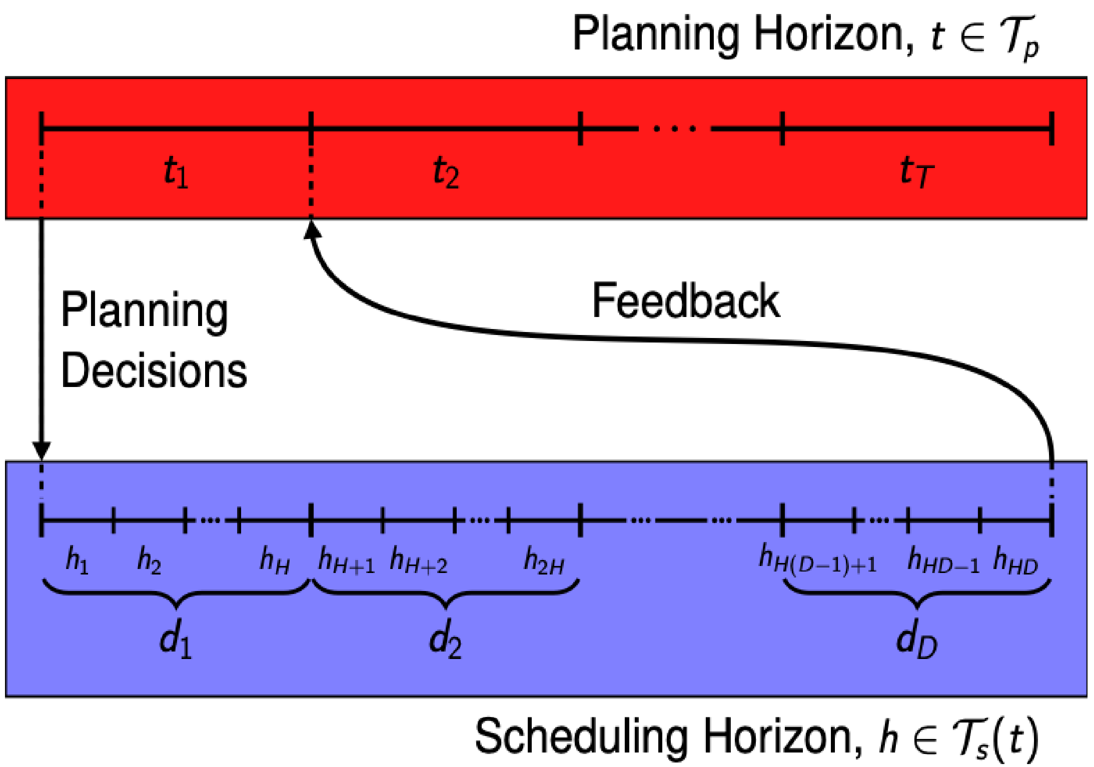
# Energy-Water Nexus
## Problem Statement

Integrate planning and scheduling decisions:

- Scheduling decisions are based upon the planning decisions
- Scheduling decisions capture the stochastic fluctuations of the parameters

Computational difficulties:

- There are ~20,000 variables (binary and continuous) generated to schedule a component for a year



# Energy-Water Nexus

## Problem Formulation – EW-N Algebraic Model

**Economic Objectives:**

- Minimize capital and operational cost

**Parameters:**

- Cost data for components
- Hourly water availabilities and demands
- Hourly energy demands and prices
- Hourly wind and solar availabilities

**Planning Decisions for Expansion:**

- If, when, and what sub-region to construct new:
  - Power generators
  - Water treatment facilities
  - Storage facilities (water & energy)

**Scheduling Decisions for Operations:**

- Unit commitments for each generator, storage unit, and treatment facilities
- How to allocate water and energy between regions

**Demand Constraints:**

- Ensure water and energy demands are met

**Optimization Problem (Large Scale MILP)**

min construction cost for generators
+ construction cost for storage units
+ construction cost for water treatment facilities
+ operational fixed cost
+ operational variable cost
+ start-up and shut-down cost
+ material sources purchased

s.t. planning constraints for expansion
scheduling constraints for operations
demand constraints

# Energy-Water Nexus

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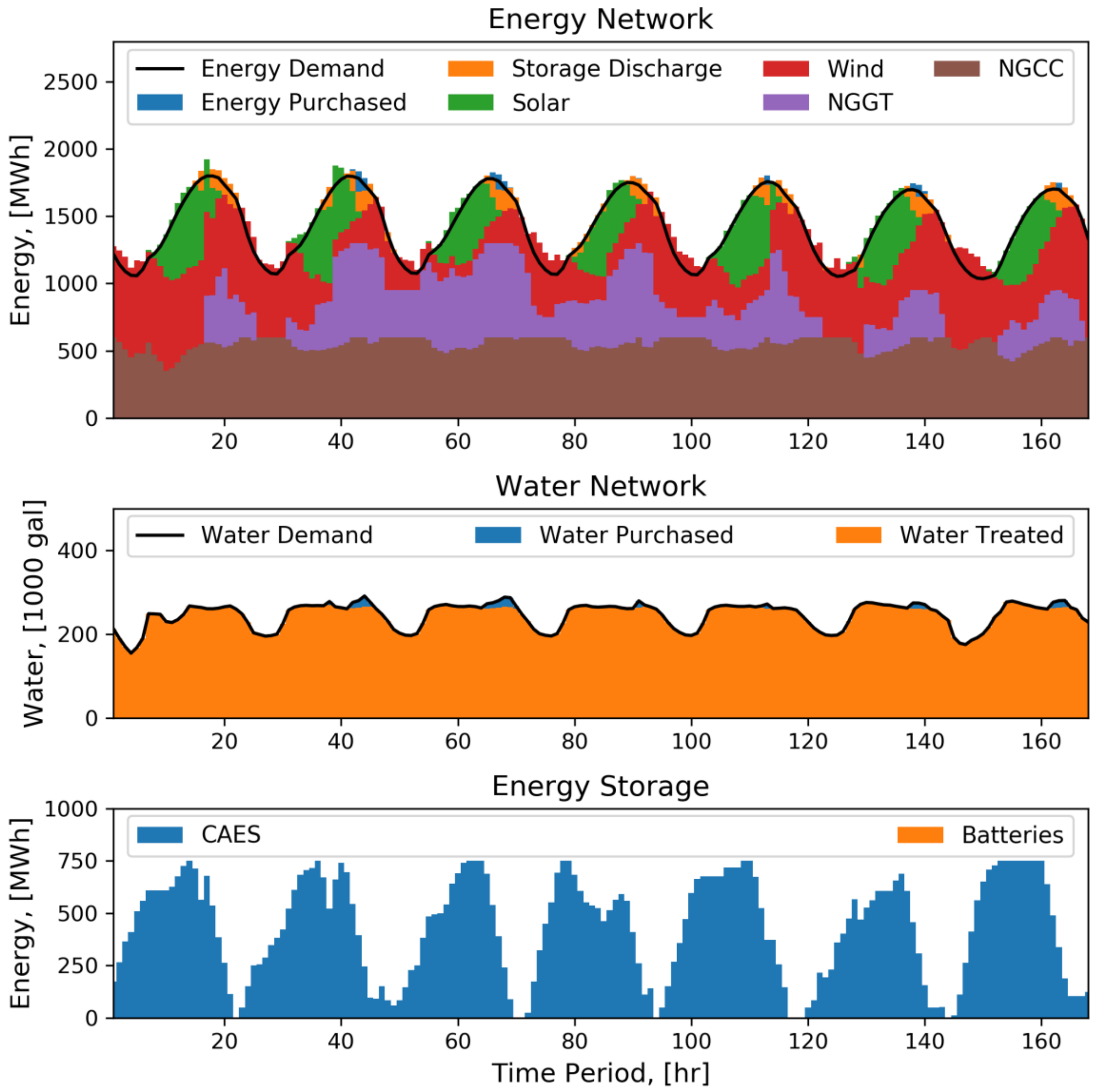

# Energy-Water Nexus

## Scenario Testing

### Optional User Inputs:

**Objectives:**

- Minimize capital and operational cost
- Minimize GHG emissions
- Minimize Energy-Water Nexus stresses
- Etc.

**Constraints:**

- Budgets
- GHG Emissions
- Water use
- Etc.

**Uncertainties:**

- Climate related uncertainties:
  - Water availability
  - Wind and solar availability
- Population related uncertainties:
  - Water demands
  - Energy demands and prices

**EW-N Model**

### Model Outputs:

**Planning Decisions for Expansion:**

- **If**, **when**, **how big**, and **at what sub-region** to construct new or decommission:
  - Power generators
  - Water treatment facilities
  - Storage facilities (water & energy)

**Scheduling Decisions for Operations:**

- Unit commitments for each generator, storage unit, and treatment facilities
- How to allocate water and energy between regions

**Optional outputs:**

- Budget required per planning period
- Water utilization per day
- Energy utilization per day
- GHG emissions per day

# Energy System Planning Under Energy-Water Nexus Considerations

R. Cory Allen[1,2] , Marcello Di Martino[1,2], **Styliani Avraamidou**[3], **Efstratios N. Pistikopoulos**[1,2]

1. Artie McFerrin Department of Chemical Engineering, Texas A&M University
2. Texas A&M Energy Institute, Texas A&M University
3. Department of Chemical & Biological Engineering, University of Wisconsin Madison

# Improving Water Resources Management Under Change by Integrating Hydro-Economic Modeling Frameworks

**Hoori Ajami, Juan S. Acero Triana, Kurt Schwabe**
*University of California Riverside*

**ChengCheng Fei, Dhanesh Yeganantham, Bruce McCarl, Raghavan Srinivasan**
*Texas A&M University*

**Science-Policy Dialogue at the Food-Energy-Water Nexus Workshop November 4th, 2022**

TEXAS A&M UNIVERSITY
WEF NEXUS INITIATIVE

THE TEXAS A&M UNIVERSITY SYSTEM

UC RIVERSIDE

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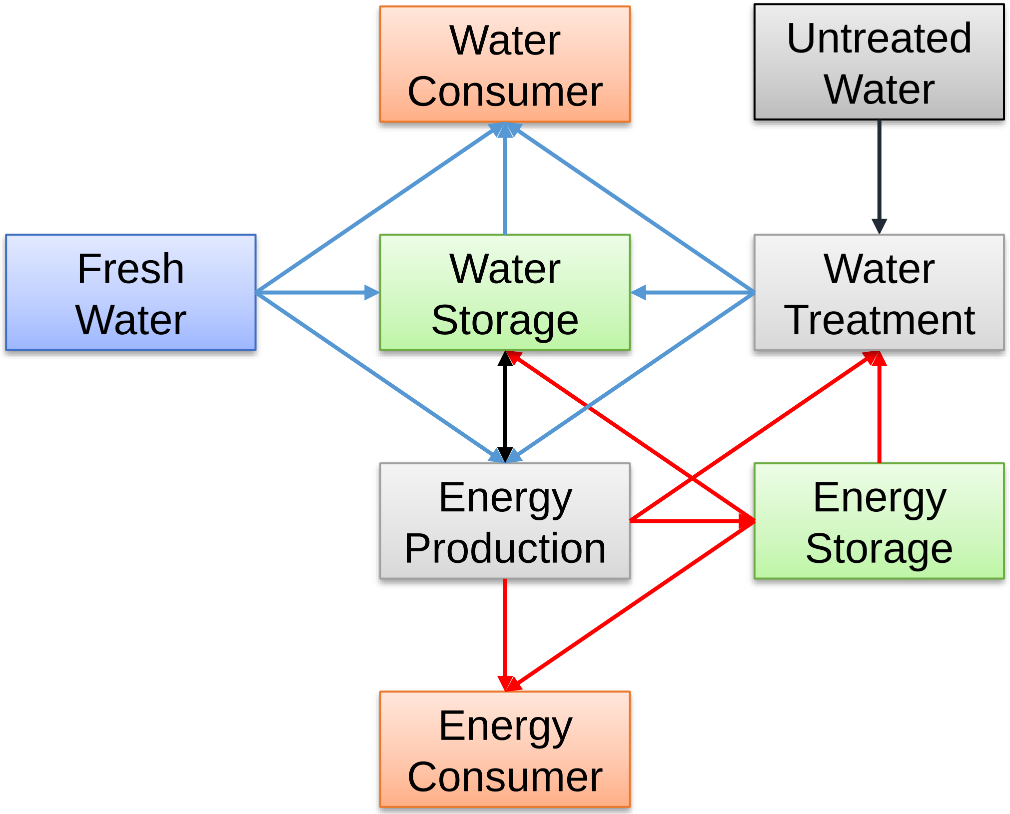

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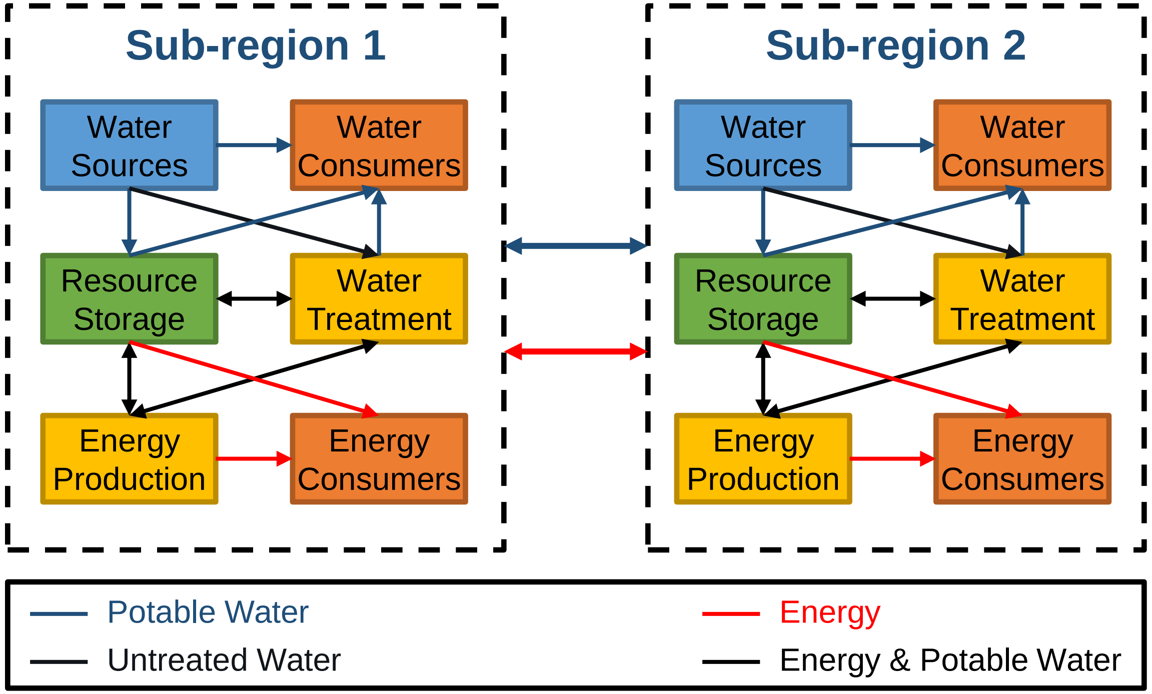
- Wind availability

**Interconnected Sub-Regions in Region L**



# Energy-Water Nexus
## Problem Statement

TEXAS A&M ENERGY INSTITUTE

MSEL Energy Environment Health

Multi-parametric Optimization & Control

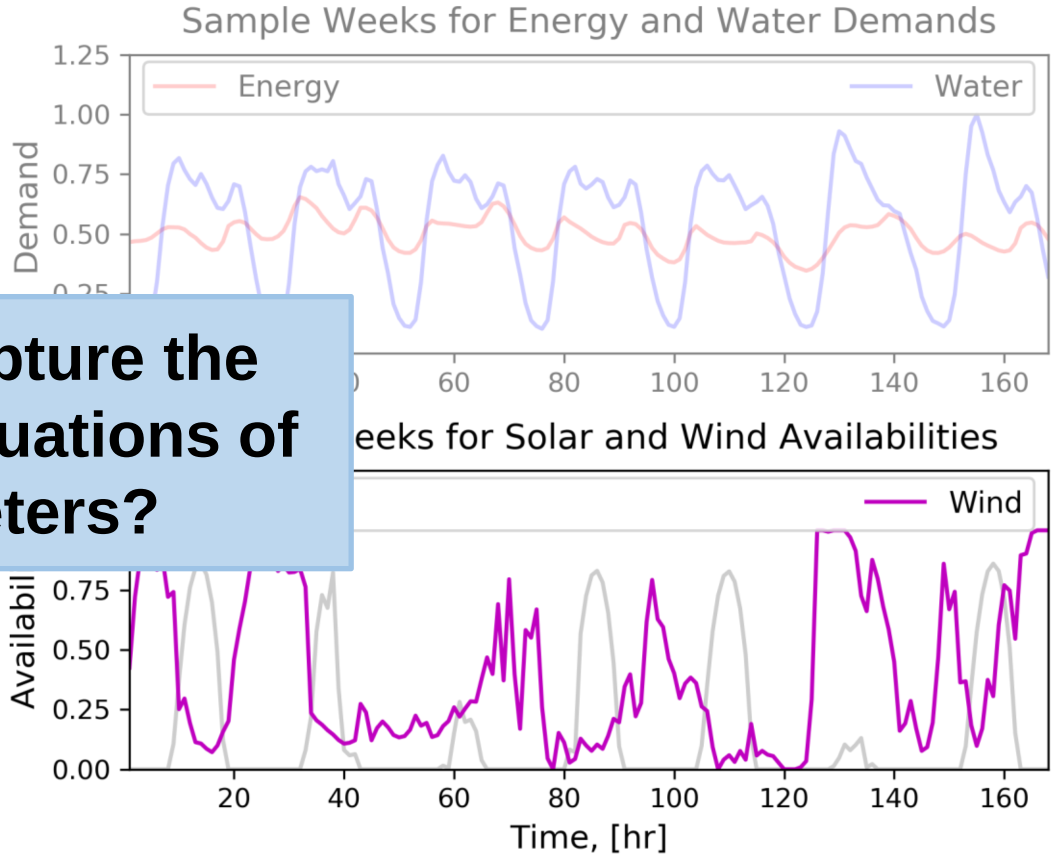
**Goal of the research:** develop a systematic methodology based on nexus connections for improving and expanding power generating systems and water treatment facilities in region L

**Nexus connections in the system:**

- Renewable and gas turbine ge
- Generators with combined and
- Water treatment plants
- Aquifers
- Energy storage units

**Stochastic fluctuations of the parameters - allow for a realistic representation:**

- Energy demands
- Water demands
- Solar availability
- Wind availability




**How do we capture the stochastic fluctuations of the parameters?**

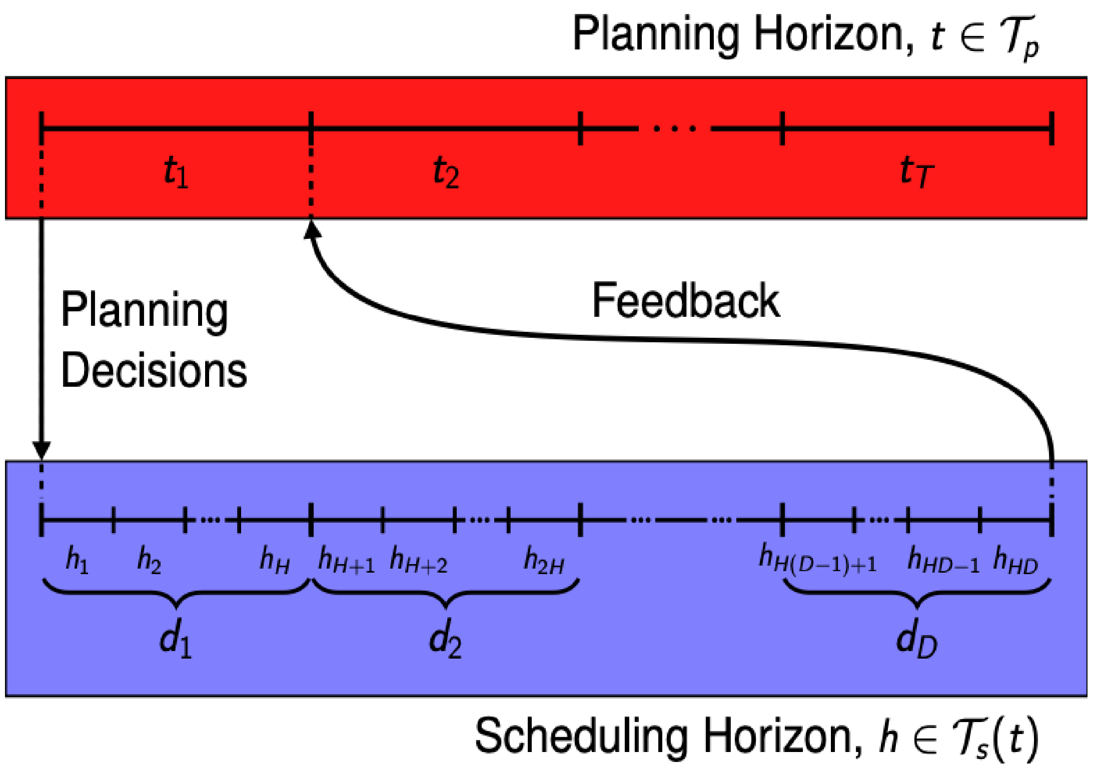
# Energy-Water Nexus
## Problem Statement

**Integrate planning and scheduling decisions:**

- Scheduling decisions are based upon the planning decisions
- Scheduling decisions capture the stochastic fluctuations of the parameters

**Computational difficulties:**

- There are ~20,000 variables (binary and continuous) generated to schedule a component for a year



**Economic Objectives:**
- Minimize capital and operational cost

**Parameters:**
- Cost data for components
- Hourly water availabilities and demands
- Hourly energy demands and prices
- Hourly wind and solar availabilities

**Planning Decisions for Expansion:**
- If, when, and what sub-region to construct new:
    - Power generators
    - Water treatment facilities
    - Storage facilities (water & energy)

**Scheduling Decisions for Operations:**
- Unit commitments for each generator, storage unit, and treatment facilities
- How to allocate water and energy between regions

**Demand Constraints:**
- Ensure water and energy demands are met

**Optimization Problem (Large Scale MILP)**

min construction cost for generators
+ construction cost for storage units
+ construction cost for water treatment facilities
+ operational fixed cost
+ operational variable cost
+ start-up and shut-down cost
+ material sources purchased

s.t. planning constraints for expansion
scheduling constraints for operations
demand constraints

# Energy-Water Nexus
## Problem Formulation – EW-N Algebraic Model

Multi-parametric Optimization & Control

**Economic Objectives:**
- Minimize capital and operational cost

**Parameters:**
- Cost data for components
- Hourly water availabilities and demands
- Hourly energy demands and prices
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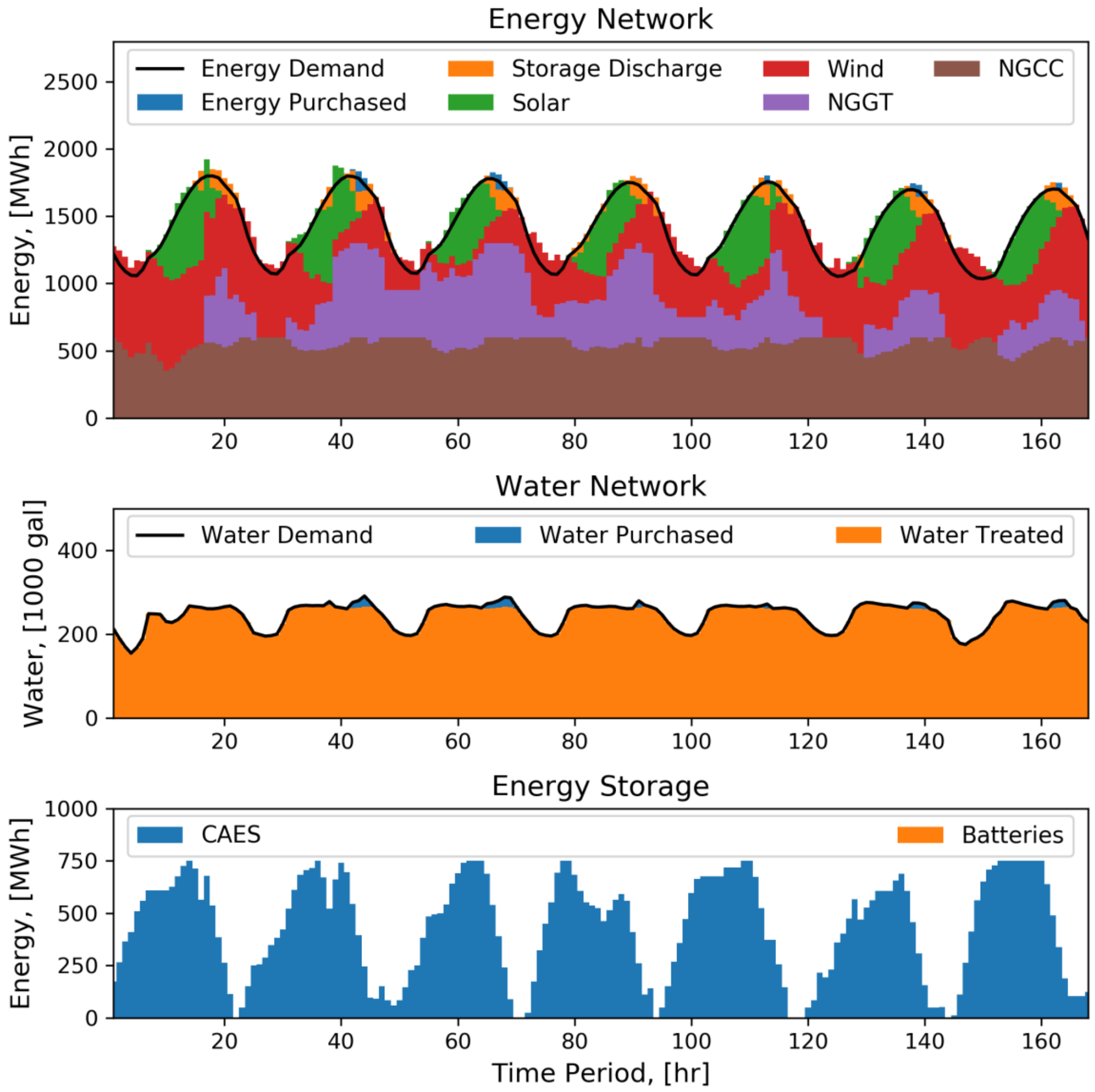

# Energy-Water Nexus
## Scenario Testing

Multi-parametric Optimization & Control

## Optional User Inputs:

**Objectives:**
- Minimize capital and operational cost
- Minimize GHG emissions
- Minimize Energy-Water Nexus stresses
- Etc.

**Constraints:**
- Budgets
- GHG Emissions
- Water use
- Etc.

**Uncertainties:**
- Climate related uncertainties:
  - Water availability
  - Wind and solar availability
- Population related uncertainties:
  - Water demands
  - Energy demands and prices

## EW-N Model

## Model Outputs:

**Planning Decisions for Expansion:**
- **If**, **when**, **how big**, and **at what sub-region** to construct new or decommission:
  - Power generators
  - Water treatment facilities
  - Storage facilities (water & energy)

**Scheduling Decisions for Operations:**
- Unit commitments for each generator, storage unit, and treatment facilities
- How to allocate water and energy between regions

**Optional outputs:**
- Budget required per planning period
- Water utilization per day
- Energy utilization per day
- GHG emissions per day

# Irrigated agriculture is a major water user

- Irrigated agriculture is the world's largest consumer of freshwater.

- Irrigated agriculture produces 40% of the food globally.

- In the US, 65% of the total groundwater withdrawals are used for irrigation (Maupin et al., 2014).

https://www.watereducation.org/aquapedia/groundwater

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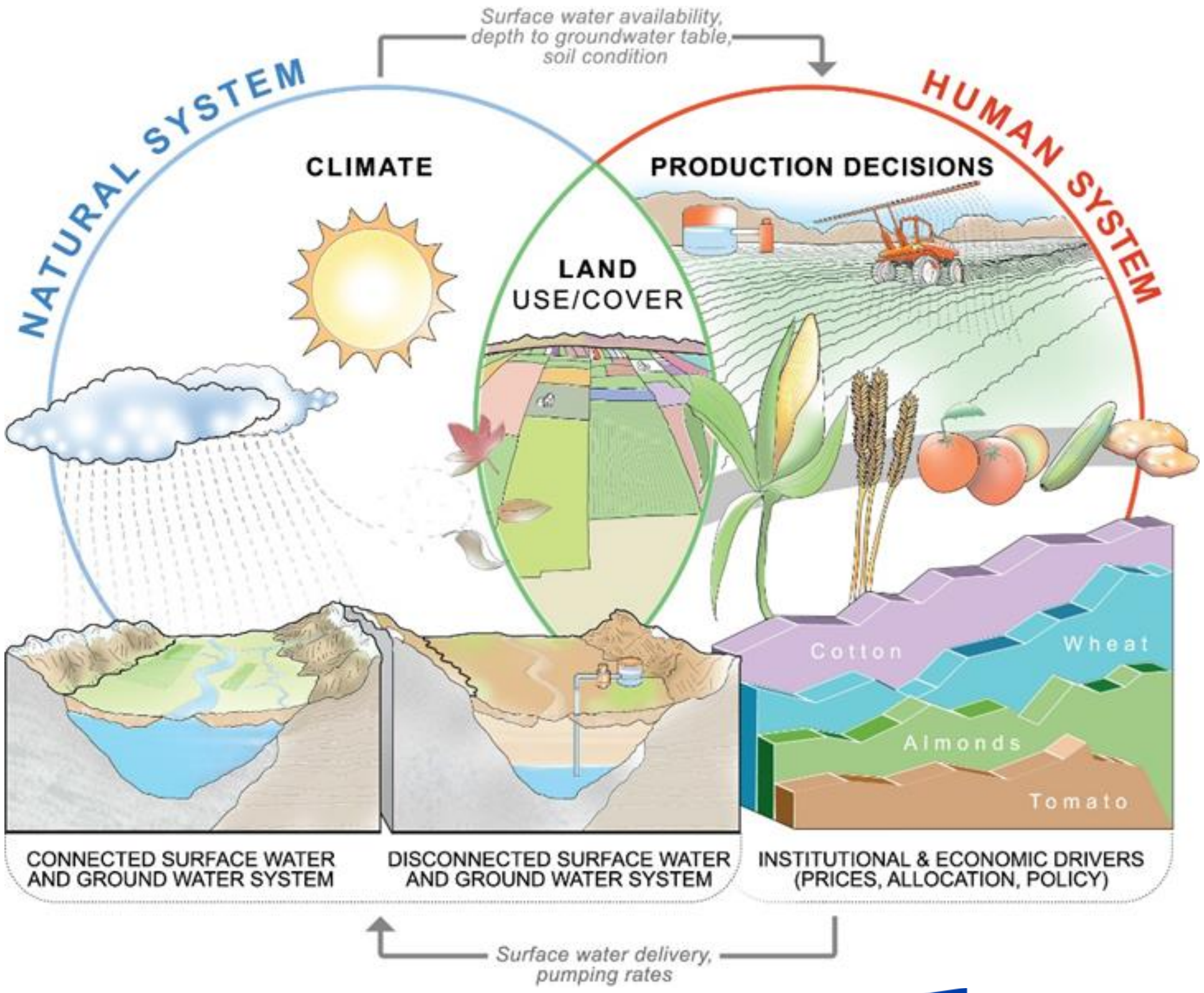
# Water resource management in agroecosystems is challenging

Agroecosystems are complex and their dynamics are controlled by natural & human factors.

- Climatic variability
- Water supply
- Water management practices
- Legal and economic consideration




Ajami et al. *In Preparation*

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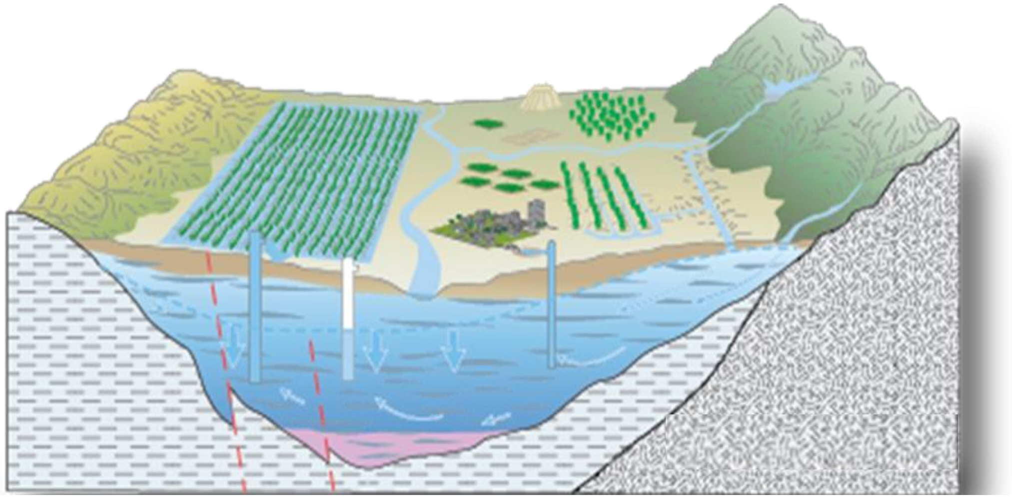
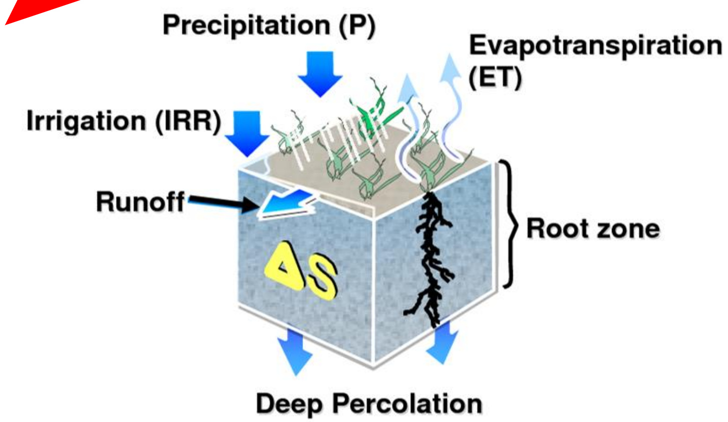
# Accurate estimates of the basin water balance is needed for successful water management





# Utilized a semi-distributed hydrologic modeling approach with water management options

## Soil & Water Assessment Tool – SWAT

### Why?

**Useful**
- Simulates water movement and sediment/nutrient transport in highly managed basins.

**Versatile**
- Enables the simulation of field operations, reservoirs/lakes, water transfers, and point sources.

**Suitable**
- Simulates plant growth and hence estimates plant biomass and crop yields.

### How?

**HRU**
- Soil + Slope + Land cover/land use

**Subbasin**
- Clusters based on given drainage area

**Outlet**
- Routing to the basin outlet

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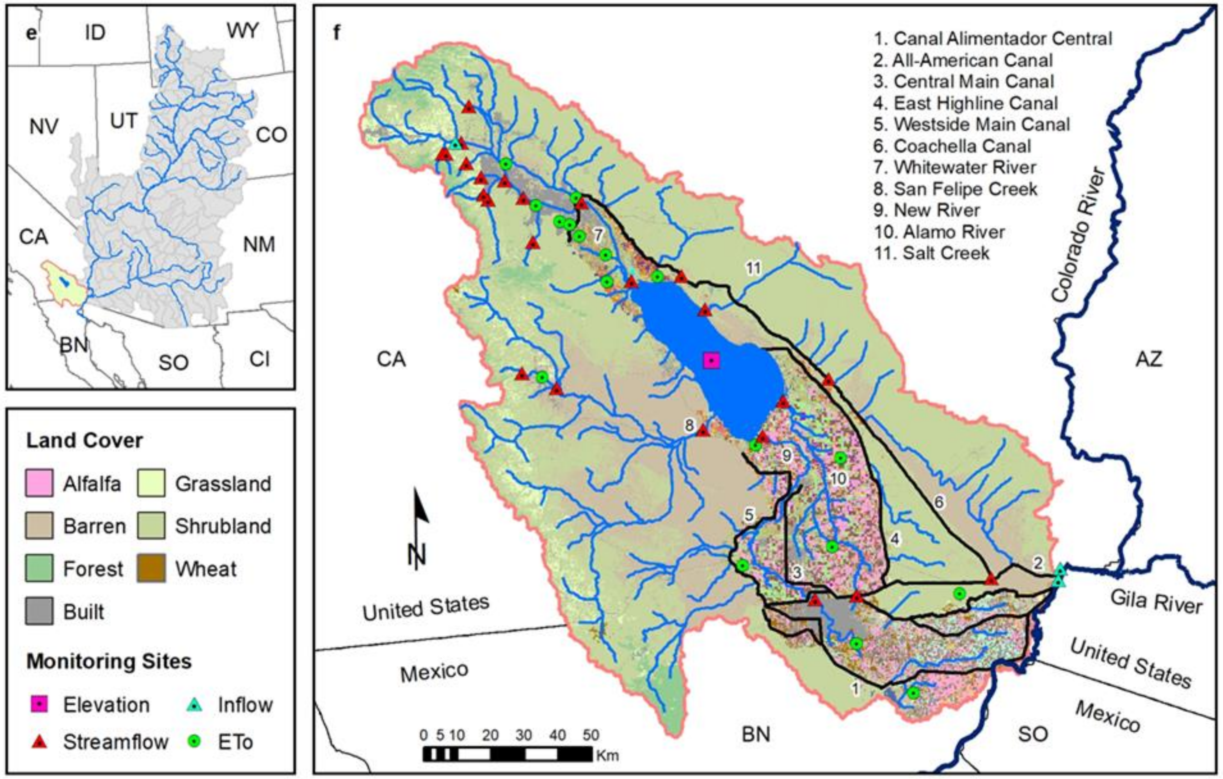
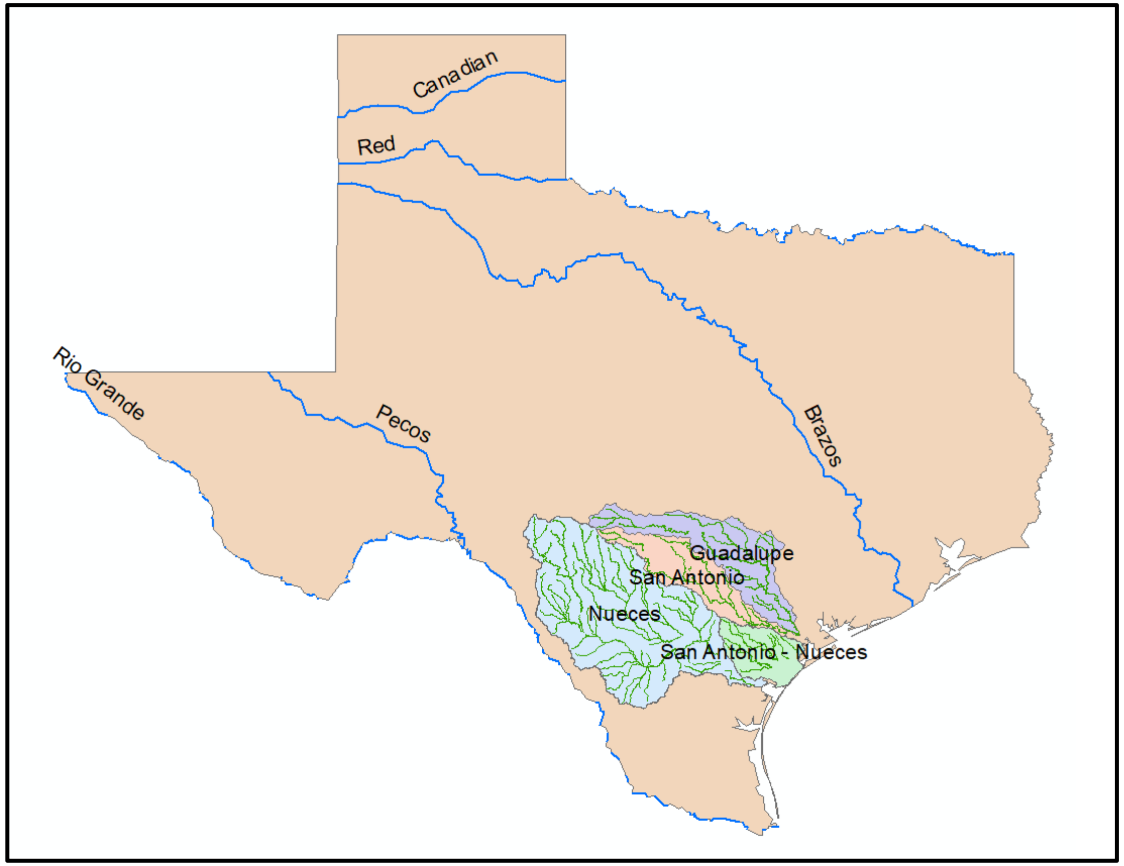
# Study basins

## Salton Sea basin - California




## Guadalupe, San Antonio, San Antonio-Nueces and Nueces watersheds - Texas



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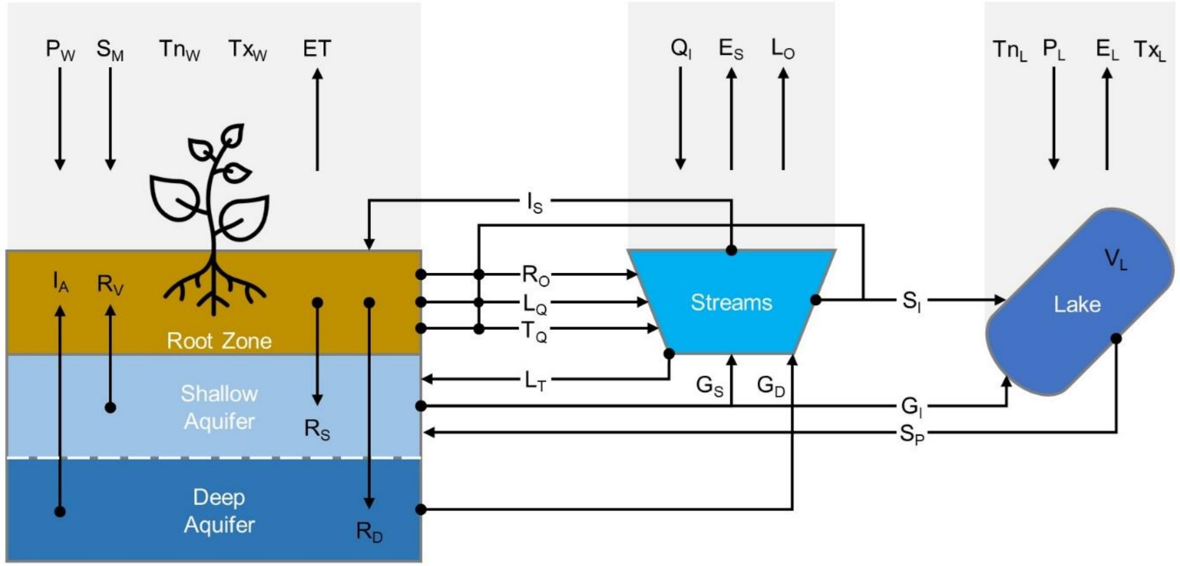
# Objectives

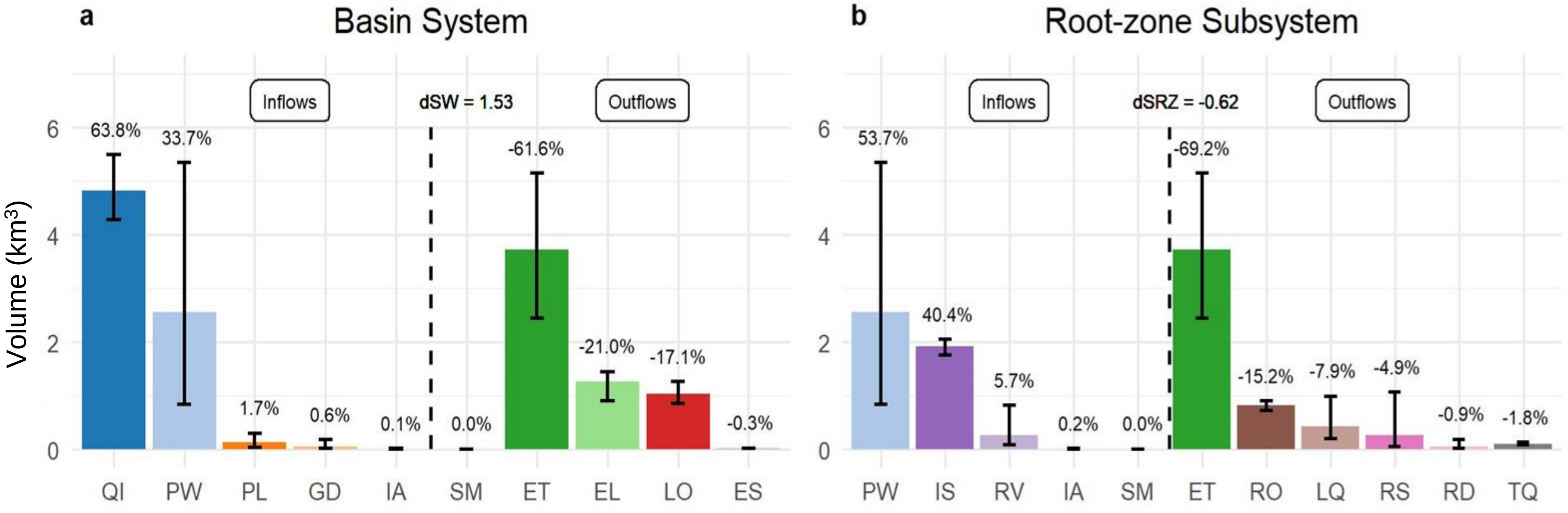
✓ **Model hydrological processes and agricultural production**
(River flow and crop yield)

✓ **Analyze potential impacts of water savings strategies**
(Improve irrigation scheduling, crop selection and deficit irrigation)

✓ **Run climate change scenarios**
(Anticipate future environmental & socioeconomic issues)

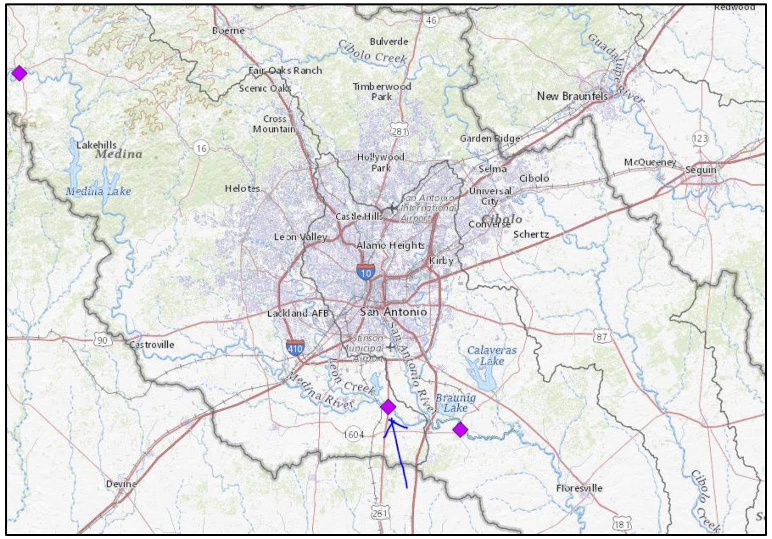
# Detailed water budget analysis

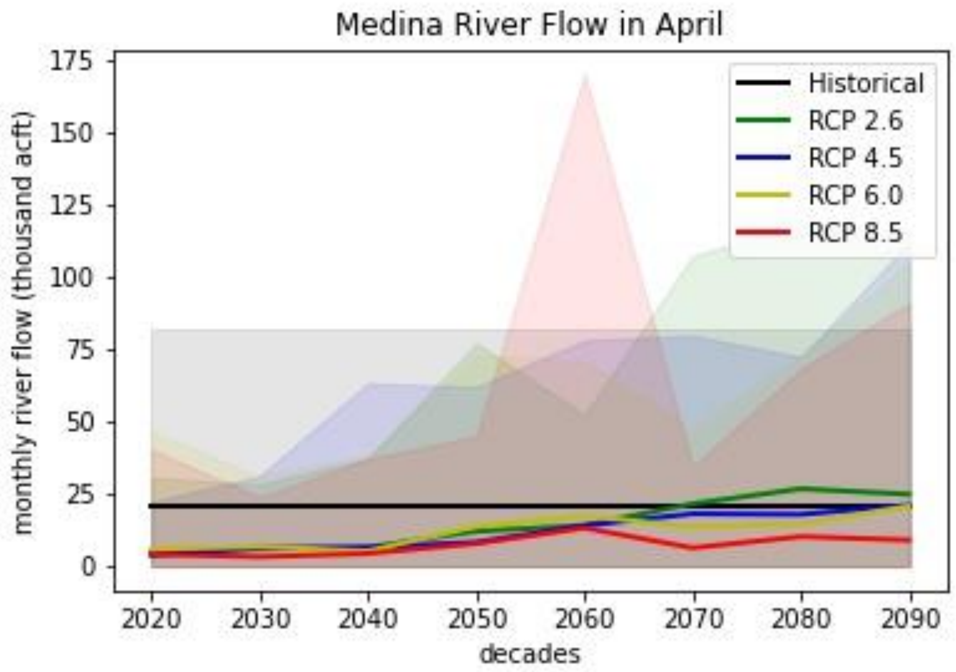


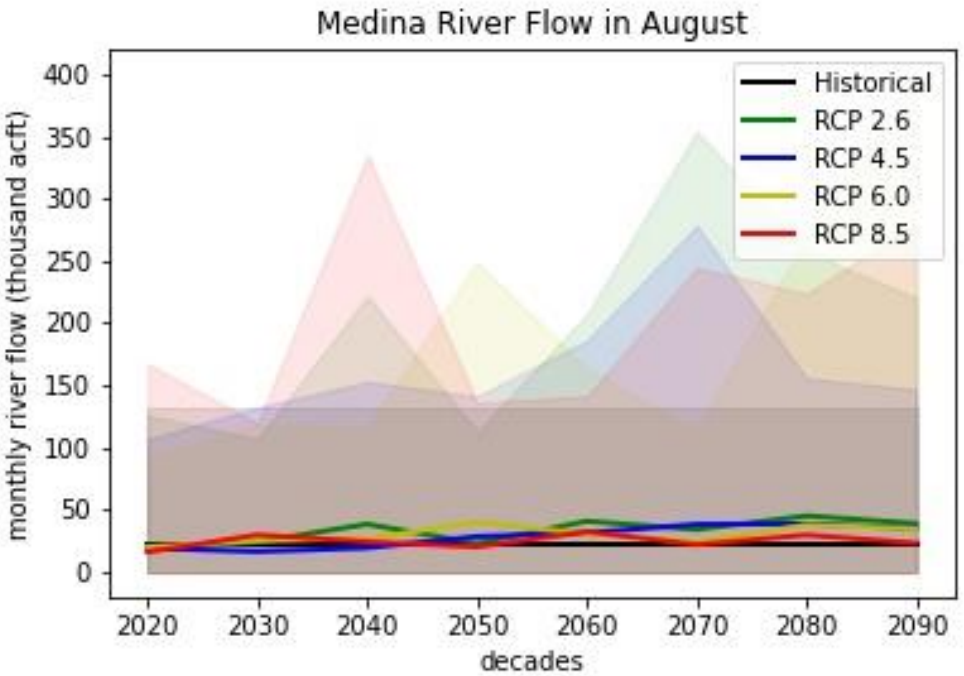




*Acero and Ajami. 2022. Water Resources Research*

# Impact assessment due to climate change




Under climate change

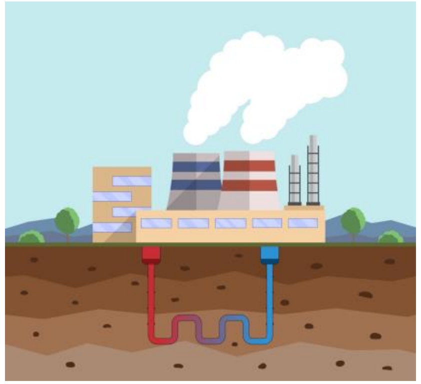
- Springs may be more drier
- But more floods in the summer

# Water resource management is a multifaceted issue.

Land Subsidence

Food Production

Environmental Flows



Energy Production


Legal considerations

Economic considerations


120

# Integration with economic models

- River flow changes under Climate Change

→ Water availability in the economic model

- Deficit Irrigation / Irrigation Efficiency

→ Crop yield and water usage

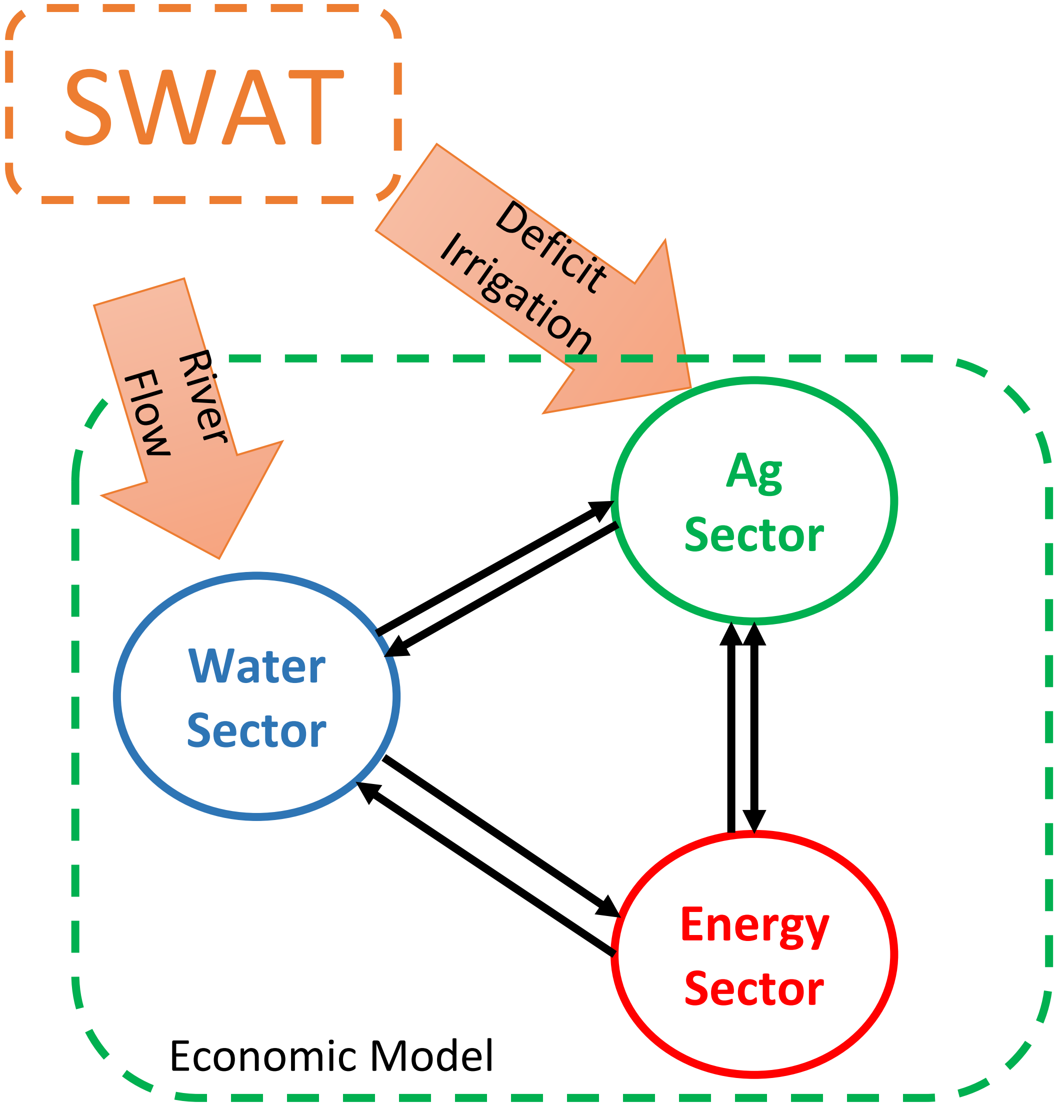
→ Energy usage

→ Varies under climate change

- Energy Supply / Energy Costs change

→ with water use and food production

→ with climate change



# Main Conclusions

- Hydrologic processes of agricultural ecosystems are complex and multiple drivers control crop yield.
- Hydrologic models are powerful tools to assess the impacts of various management practices on water resources.
- Integrated hydro-economic models are valuable tools for decision making.

# Improving Water Resources Management Under Change by Integrating Hydro-Economic Modeling Frameworks

# THANK YOU

**Contact us: NSF INFEWS Project Website**

https://wefnexusinitiative.tamu.edu/nsf-infews/project-roster-2020/

TEXAS A&M UNIVERSITY
WEF NEXUS INITIATIVE

THE TEXAS A&M UNIVERSITY SYSTEM

UC RIVERSIDE

# Networking Lunch

12:05-1:30 PM

TEXAS A&M UNIVERSITY

NSF

TEXAS A&M UNIVERSITY
WEF NEXUS INITIATIVE

TEXAS A&M UNIVERSITY
SAN ANTONIO











*Moderators*

# Science-Policy Dialogue

# Science-Policy Dialogue Questions

1. How might we best address the remaining barriers to implementing science-based decisions?
   a. Institutional
   b. Knowledge dissemination
   c. Personal awareness / capacity
2. What mechanisms can be used to facilitate such dialogue?
   a. Digital Platforms
   b. Community of Practice
   c. Communication
3. What is the future of system-based approaches to decision making?

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TEXAS A&M UNIVERSITY SAN ANTONIO

TEXAS A&M UNIVERSITY
WEF NEXUS INITIATIVE

# Summary

**Rabi Mohtar**

San Antonio, TX | November 4, 2022

# Way Forward

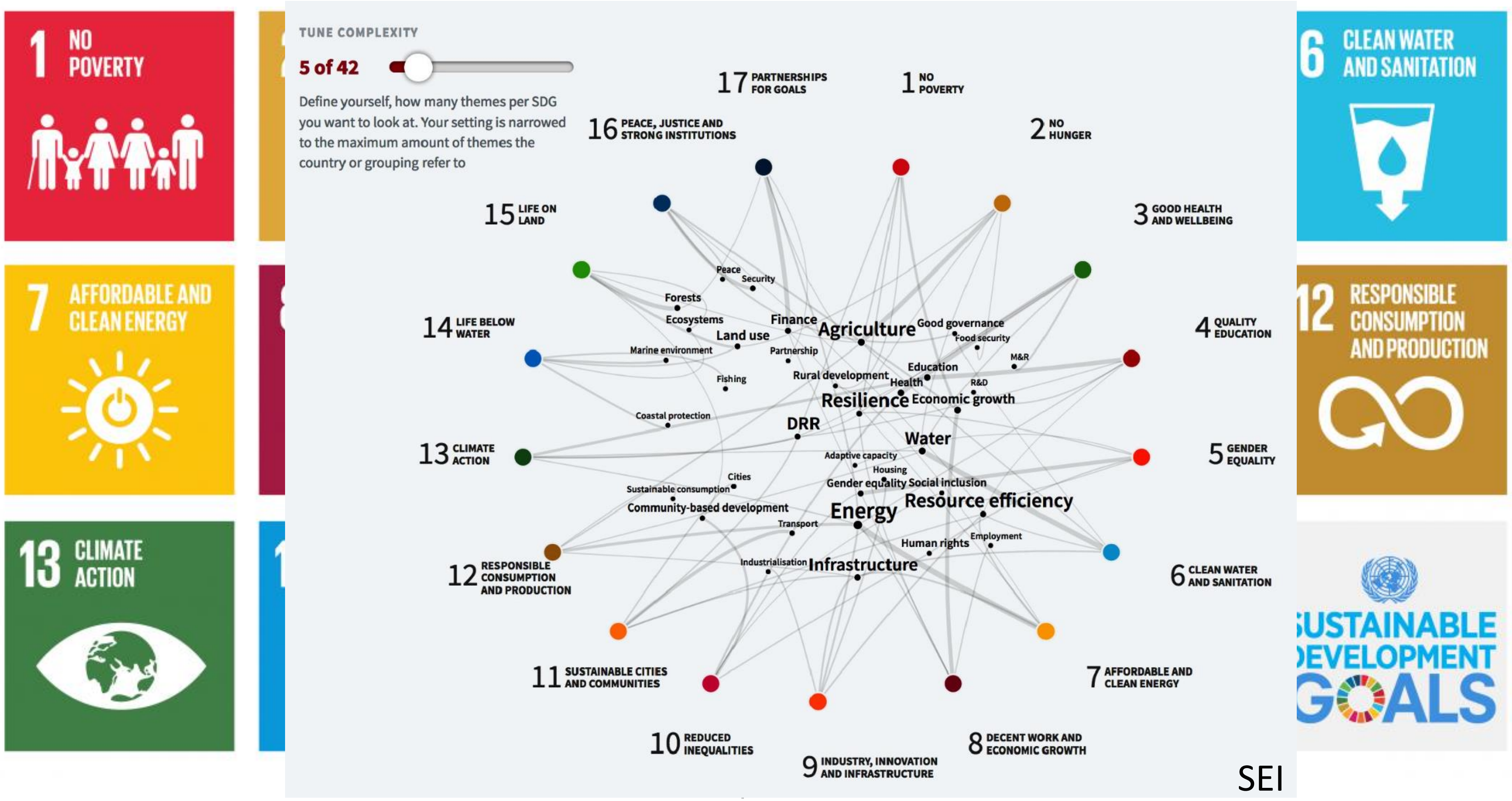
**Bassel Daher**

San Antonio, TX | November 4, 2022

# UN SUSTAINABLE DEVELOPMENT GOALS (SDGs)

SUSTAINABLE DEVELOPMENT GOALS

17 Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity



# UN SUSTAINABLE DEVELOPMENT GOALS (SDGs)

## USA 2021 SDG GLOBAL RANKING

SDG Index Rank: **41** /163

SDG Index Score: 74.5

## SAN ANTONIO 2019 SDG US CITIES RANKING

CITY OF SAN ANTONIO EST. 1718

SDG Index Rank: **51** /105

SDG Index Score: 48.5

## SAN ANTONIO 2019 SDG US CITIES RANKING PROGRESS


**PERFORMANCE LEGEND**

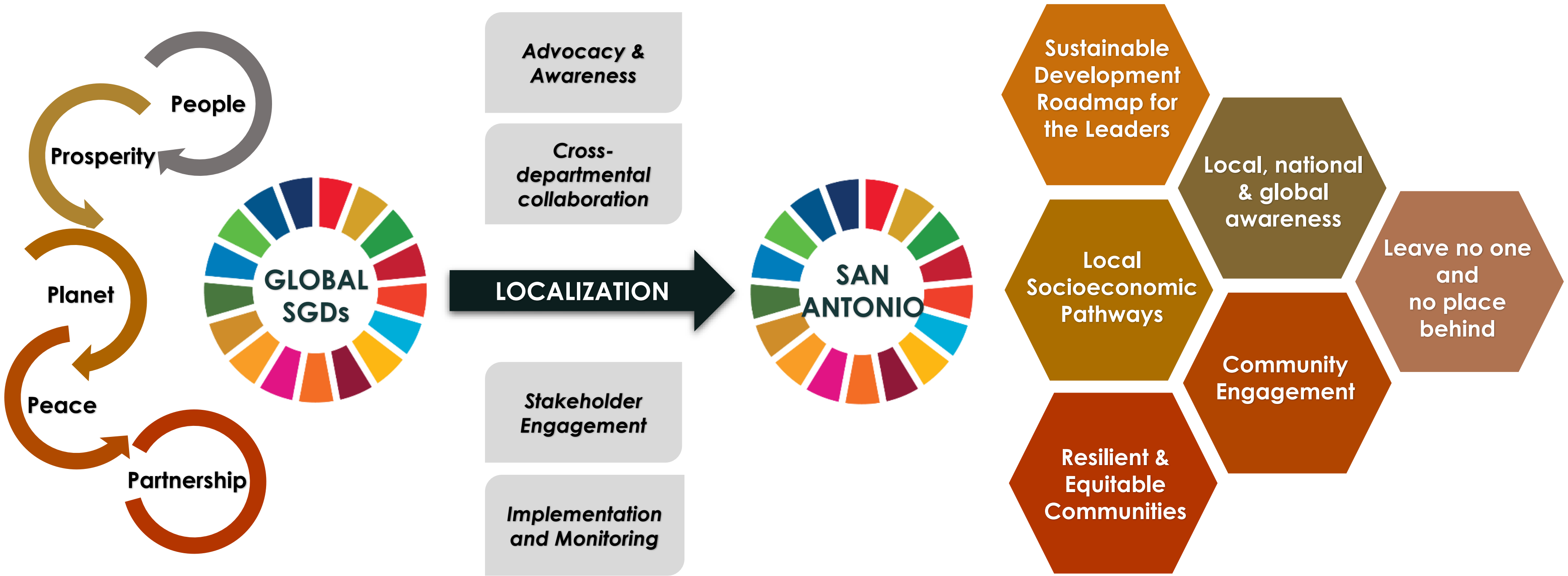
Good | Moderate to Good | Poor to Moderate | Poor | N/A

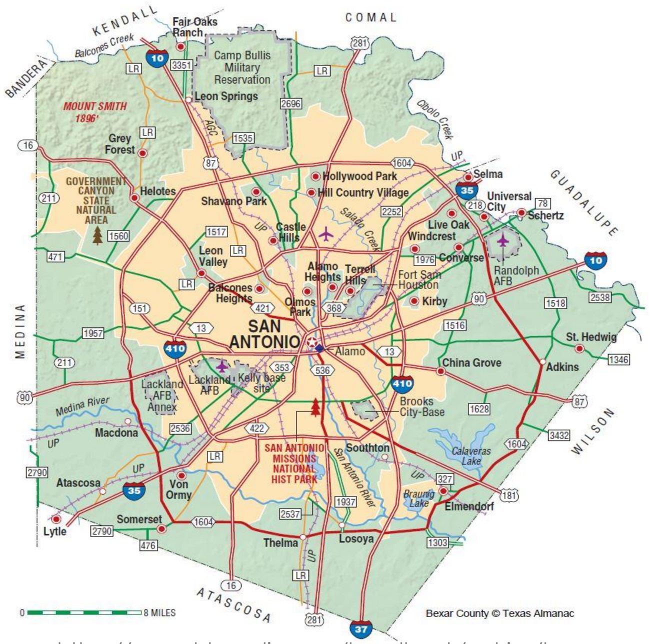


***Source***: The United States Sustainable Development Report, Sustainable Development Resource Network, USA
https://us-states.sdgindex.org/profiles/texas | https://sdsna.github.io/2019USCitiesIndex/2019USCitiesRankings.pdf

# UN SUSTAINABLE DEVELOPMENT GOALS (SDGs)

## SUSTAINABLE DEVELOPMENT GOALS LOCALIZATION FOR SAN ANTONIO




https://www.tshaonline.org/handbook/entries/bexar-county

# TRACKING SAN ANTONIO POLICIES/PROGRAMS

**BENEFITS OF TRACKING** → ASSESSING EXISTING POLICIES/PROGRAMS VS THE CITY'S NEEDS — PROPER ALLOCATION OF RESOURCES TO THE RIGHT COMMUNITY IN NEED — MONITORING & ASSESSING EFFECTIVENESS OF POLICIES/PROGRAMS

SA2020


SA CLIMATE READY

| MITIGATION | ADAPTATION |
| --- | --- |
| Actions to reduce or prevent emissions from greenhouse gases | Actions that help to reduce the negative effects of climate change |
| EXAMPLE: | EXAMPLE: |
| Increasing renewable energy | Flood-proofing roadways & critical infrastructure |
| Reducing energy use in buildings | Developing a community wildfire protection plan |
| Increasing cleaner and more efficient vehicle use | Increasing tree canopy |

*SA2020 drives progress toward a shared Community Vision for San Antonio through research, storytelling, and practice*
*Est. 2010*

*Implementation of SA Climate Ready means a more equitable, safe, affordable, and prosperous future for all San Antonians*
*Est. 2017*

# UN SDG TRACKING FOR SAN ANTONIO

CITY OF SAN ANTONIO EST. 1718

SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY | 2 ZERO HUNGER | 3 GOOD HEALTH AND WELL-BEING | 4 QUALITY EDUCATION | 5 GENDER EQUALITY | 6 CLEAN WATER AND SANITATION | 7 AFFORDABLE AND CLEAN ENERGY | 8 DECENT WORK AND ECONOMIC GROWTH | 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | 10 REDUCED INEQUALITIES | 11 SUSTAINABLE CITIES AND COMMUNITIES | 12 RESPONSIBLE CONSUMPTION AND PRODUCTION | 13 CLIMATE ACTION | 14 LIFE BELOW WATER | 15 LIFE ON LAND | 16 PEACE, JUSTICE AND STRONG INSTITUTIONS | 17 PARTNERSHIPS FOR THE GOALS

## PROCESS

- Establish baseline of current policies and programs
- Collect high quality data
- Implement dashboard for regular tracking
- Match current policies and programs to SDGs and identify gaps
- Create nexus solutions for WEF resources, climate change & sustainable communities
- Synergy and trade-off analysis for efficient policies & program design

## WORK COMPLETED

**01** Identified goals related to WEF resources, poverty, climate change, & sustainable cities

**02** Created methodology to identify high quality data sources

**03** Established multiple indicators to track the localized targets

**04** Identified data sources for the indicators and creating a data tracking dashboard

# UN SDG TRACKING FOR SAN ANTONIO

***Complements*** the Office of Sustainability's ***SA Climate Ready SDG*** *initiative*

***Assists*** *the* ***City of San Antonio*** *to be an* **exemplary champion** *for implementing nexus programs*

*Supports* ***San Antonio*** *to be more* ***equitable, environmentally sustainable,*** *and* ***economically successful***

## STAKEHOLDER ENGAGEMENT

Active guidance in establishing the UN SDG tracking for San Antonio

Verification of identified data sources and information on data gaps

Input in design of nexus solutions to improve WEF resources, eliminate poverty, tackle climate change disasters and create sustainable communities

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WEF NEXUS INITIATIVE

# Closing Remarks

***Mirley Balasubramanya***
Chair, Department of Mathematical, Physical, and Engineering Sciences,
College of Arts and Sciences,
TAMU-San Antonio

San Antonio, TX | November 4, 2022

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# Adjournment

*Thank You*