ARVIN-FEW:
*AR*izona *V*alue *IN*tegrated *F*ood, *E*nergy, *W*ater Model

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WRRC Brown Bag Seminar

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What is ARVIN-FEW?

*AR*izona *V*alue *IN*tegrated *F*ood, *E*nergy, *W*ater Model

- A framework for design and operation of sustainable and robust interdependent infrastructures.
- A large food, energy, and water allocation model that will form the basis of a stand-alone model.
- First constructed as a system dynamics model and it will be transferred to a general network flow optimization model.

Lower Colorado River Scale

Basin Level	Legal Rights Political Decisions Climate

Arizona Scale

Basin Level	Legal Rights Political Decisions Climate
State Level	Legal and Political Demand Inter-Planning Area Transfer

Multiple Planning Area Scale

Basin Level — Legal Rights, Political Decisions, Climate

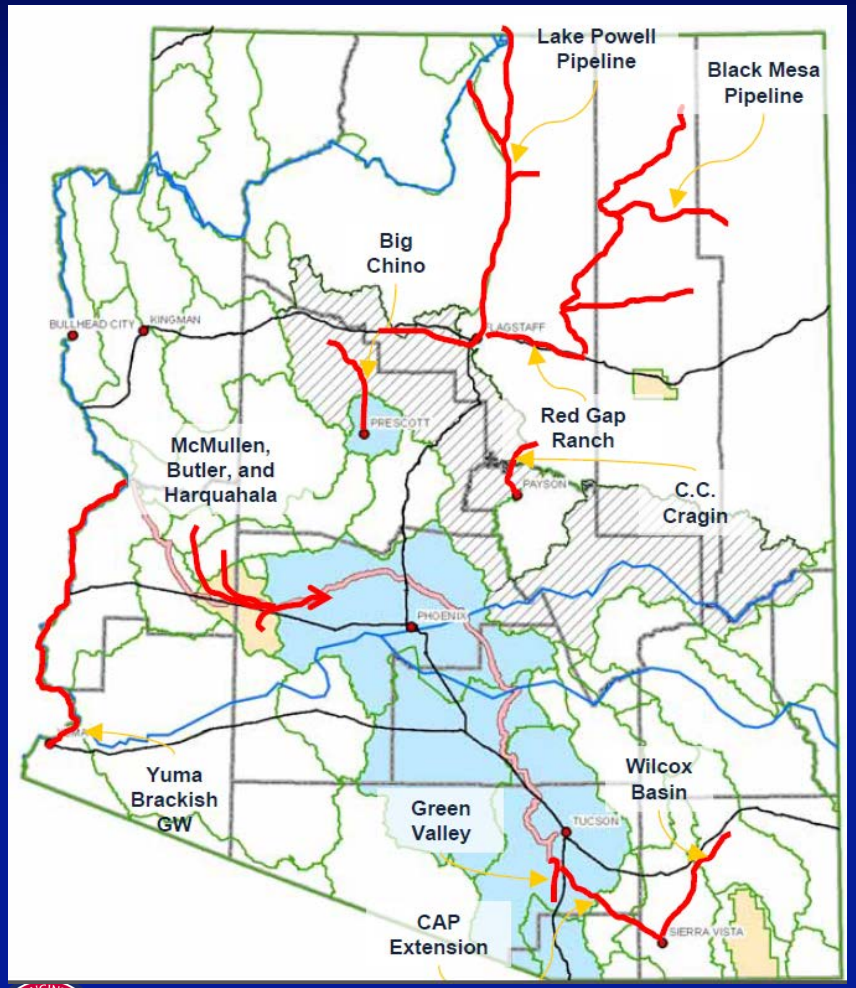
State Level — Legal and Political Dema…, Inter-Planning Area Trans…

Planning Area Level — Infrastructure Decisions, Water Conservation

Water Allocation

Econ. & System Security

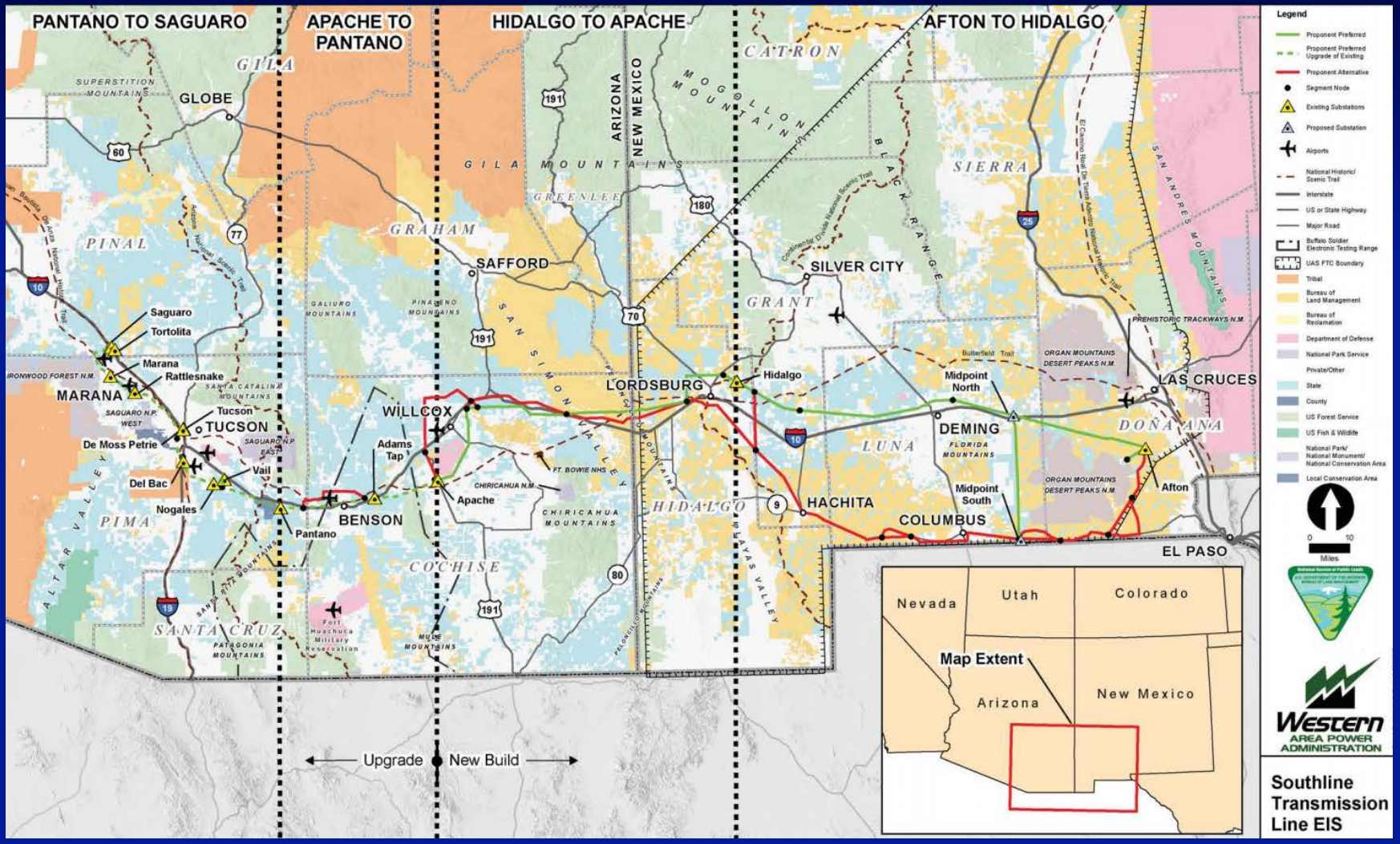
Why Multi-Scale Modeling?



- Groundwater transfer
- Surface water transfer
- Statewide water desalination

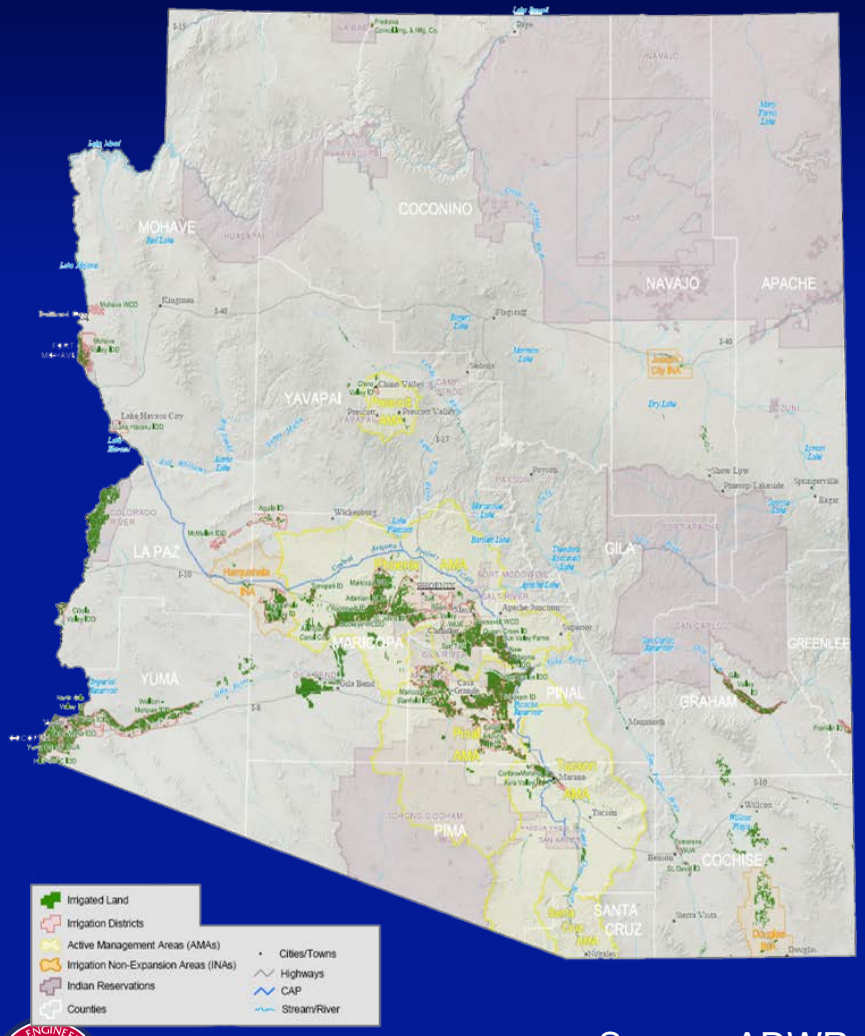
Source: HDR

Interstate Transmission Lines



Source: ENERGY.GOV

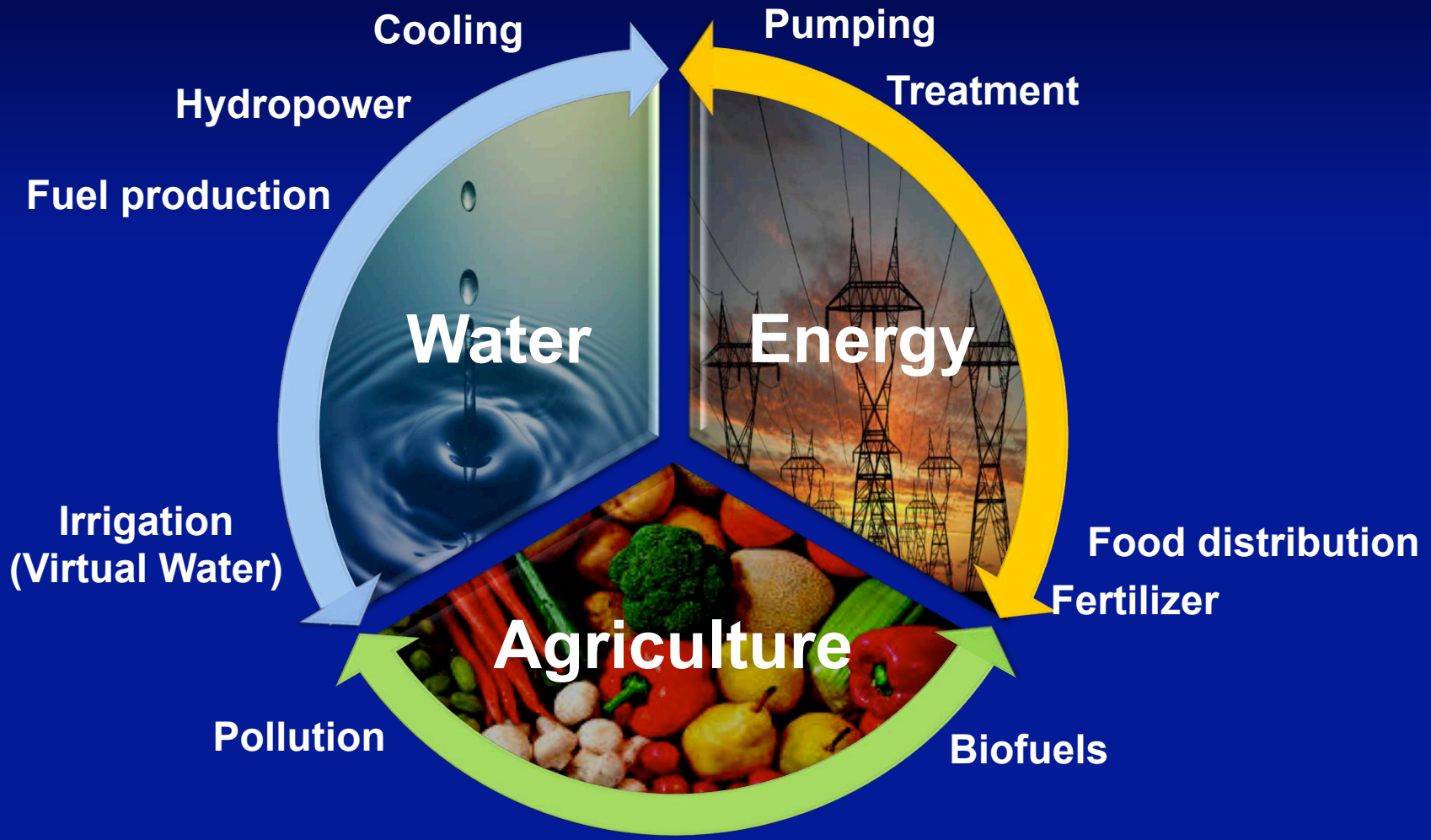
Agriculture in Arizona



- Arizona's agricultural production covers ~900,000 acres
- Annual agricultural water use is ~4.9 million AF accounting for ~70% of the state's water supply
- In 2012, Arizona exported $1.2 billion in agriculture product (virtual water).

Source: ADWR

Food-Energy-Water Nexus



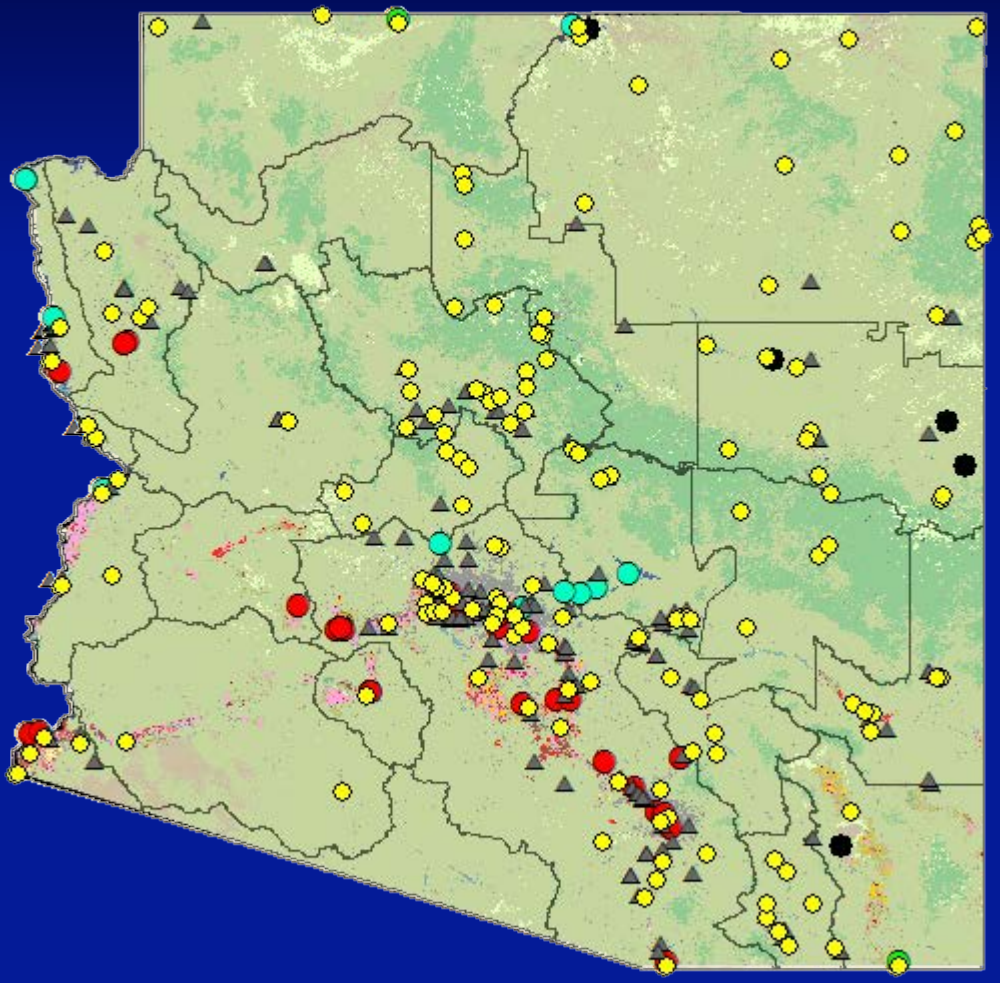
Motivation

- **Imbalance** between water supply and demand
  - The long-term projected imbalance in future supply and demand is about **3.2 million acre-feet** (MAF) by 2060 (USBOR).
  - Arizona could face an annual water supply imbalance in the next decades about 1 MAF (ADWR).
  - Potential management and infrastructure alternatives are proposed by USBOR and ADWR.
- Agriculture is the predominant user of water in Arizona
- Increasing energy demand
- Lack of **quantitative integrated resource planning model tool**

Presentation Goals

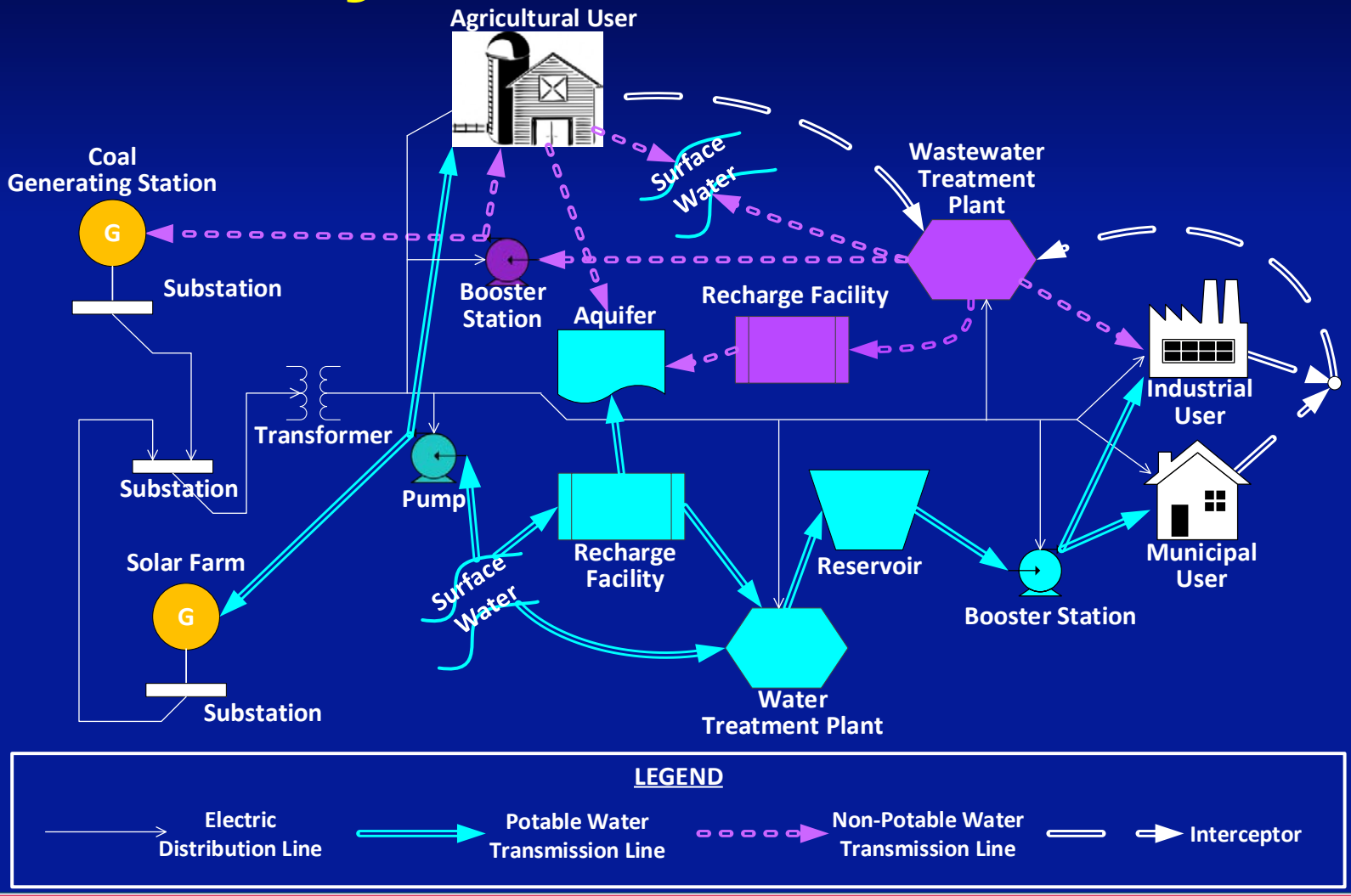
- Find a coordinated approach to solution of the multi-scale problem
- Introduce ARizona Value INtegrated Food, Energy, and Water Model (ARVIN-FEW)
- ARVIN-FEW applications
- Motivate a broader discussion of our vision for ARVIN-FEW

ARVIN's Modeling Coverage

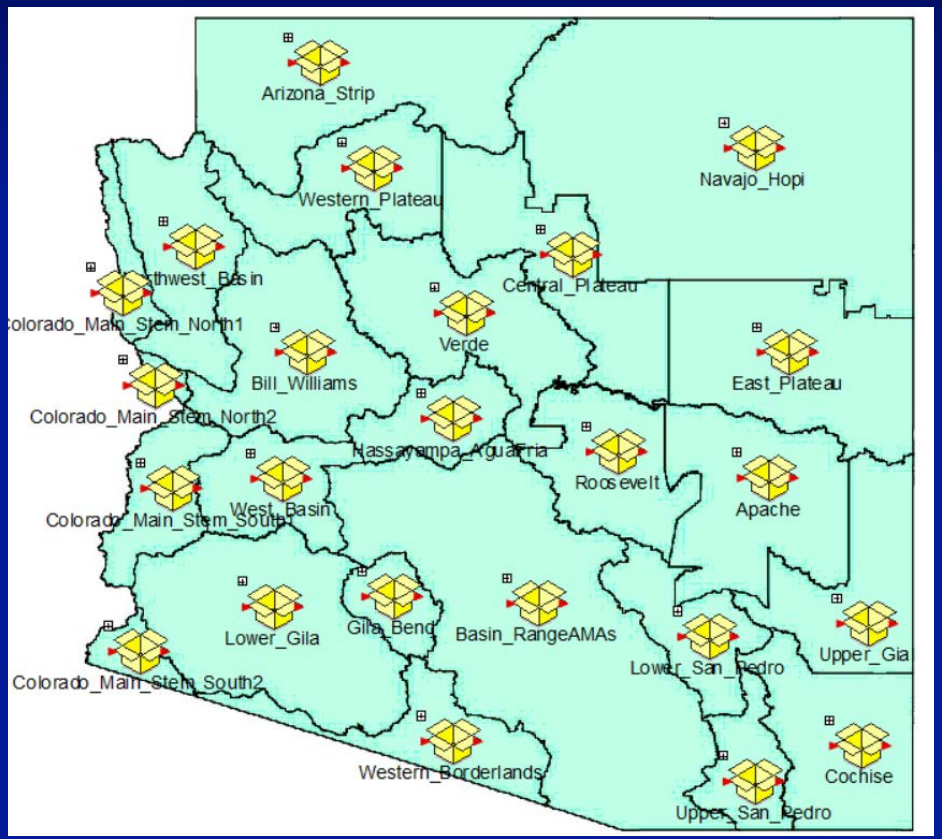


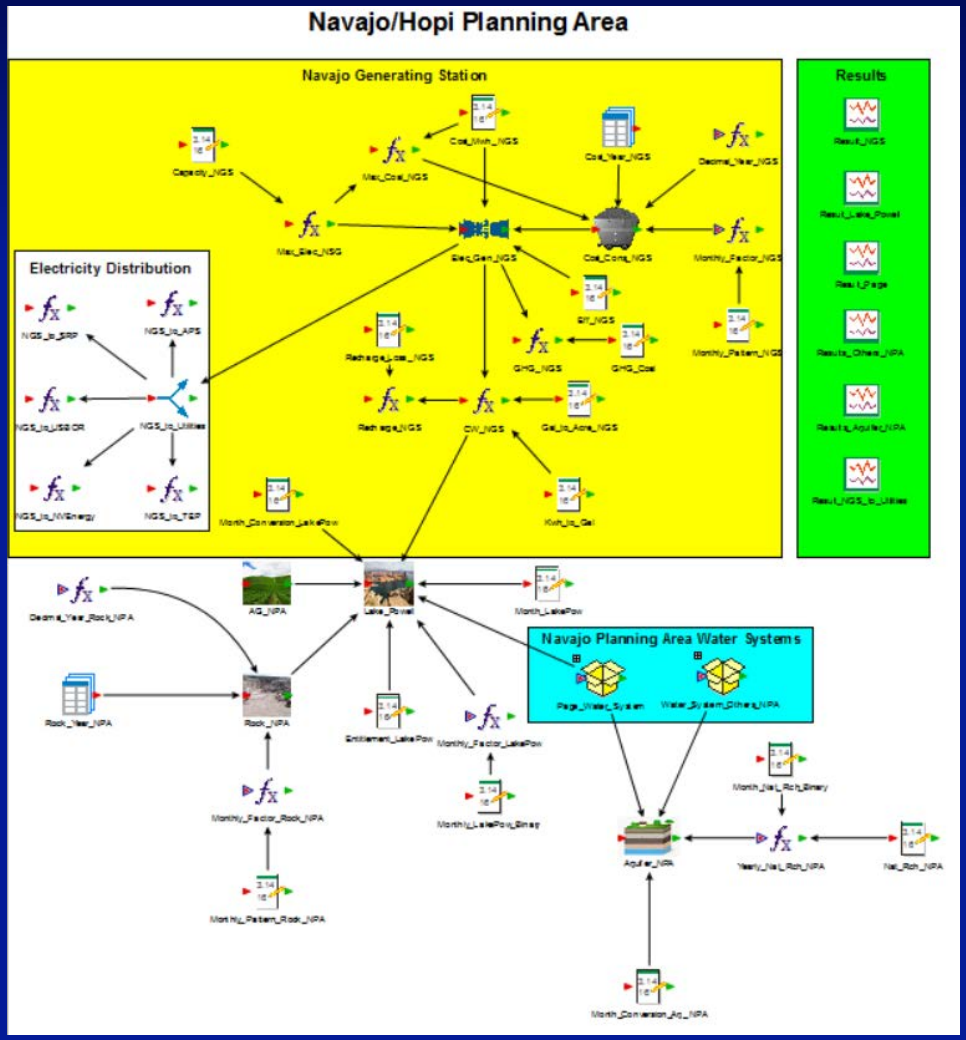
- 22 Strategic Planning Areas
- 151 cities (70 cities with pop.≥ 5000)
- Power plants
  - 5 coal generating stations
  - 11 hydroelectric generating stations
  - 31 natural gas stations
- Mines
- Agriculture
  - Crop pattern

System Dynamics Representation of FEW Systems



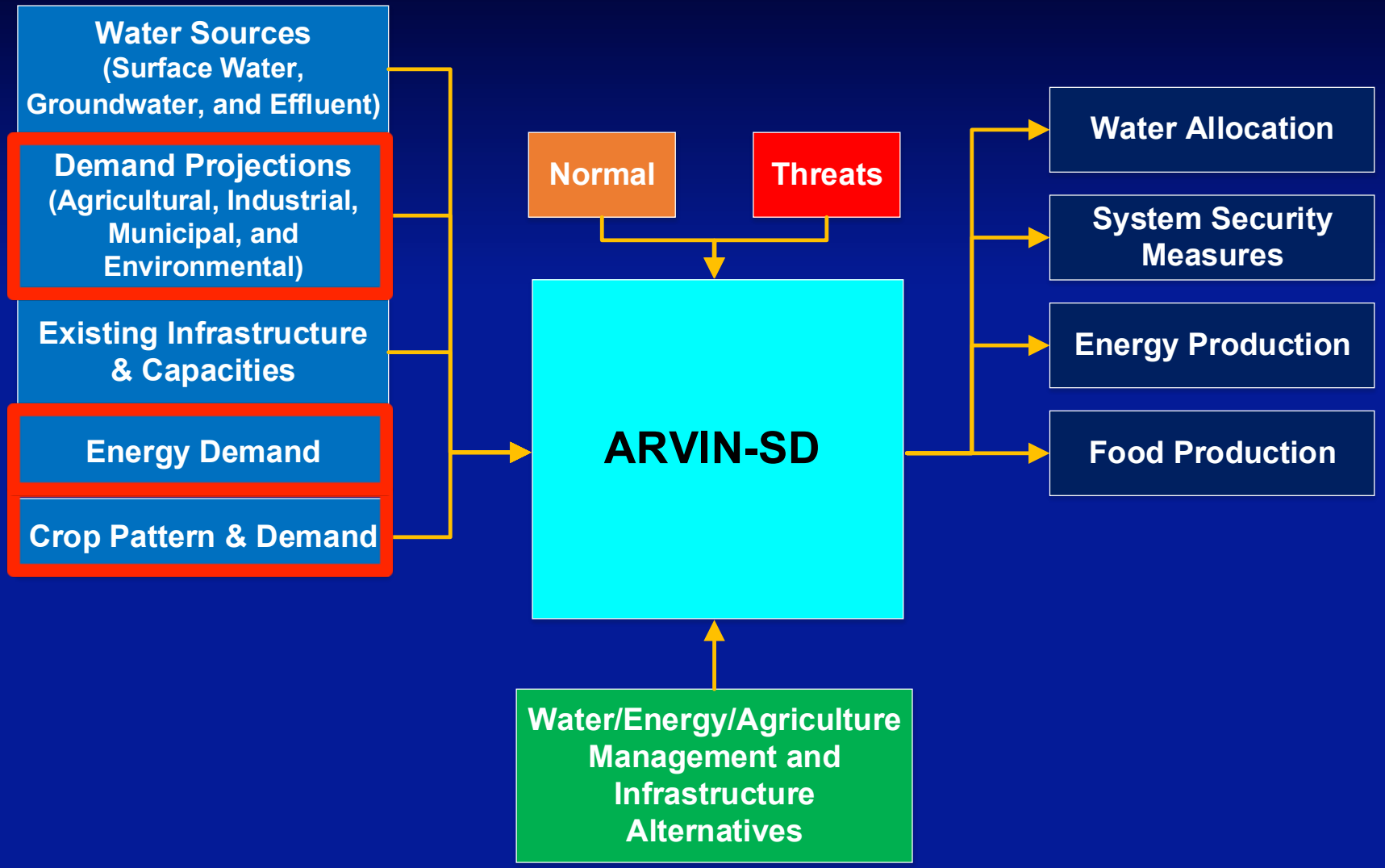
ARVIN-FEW SD



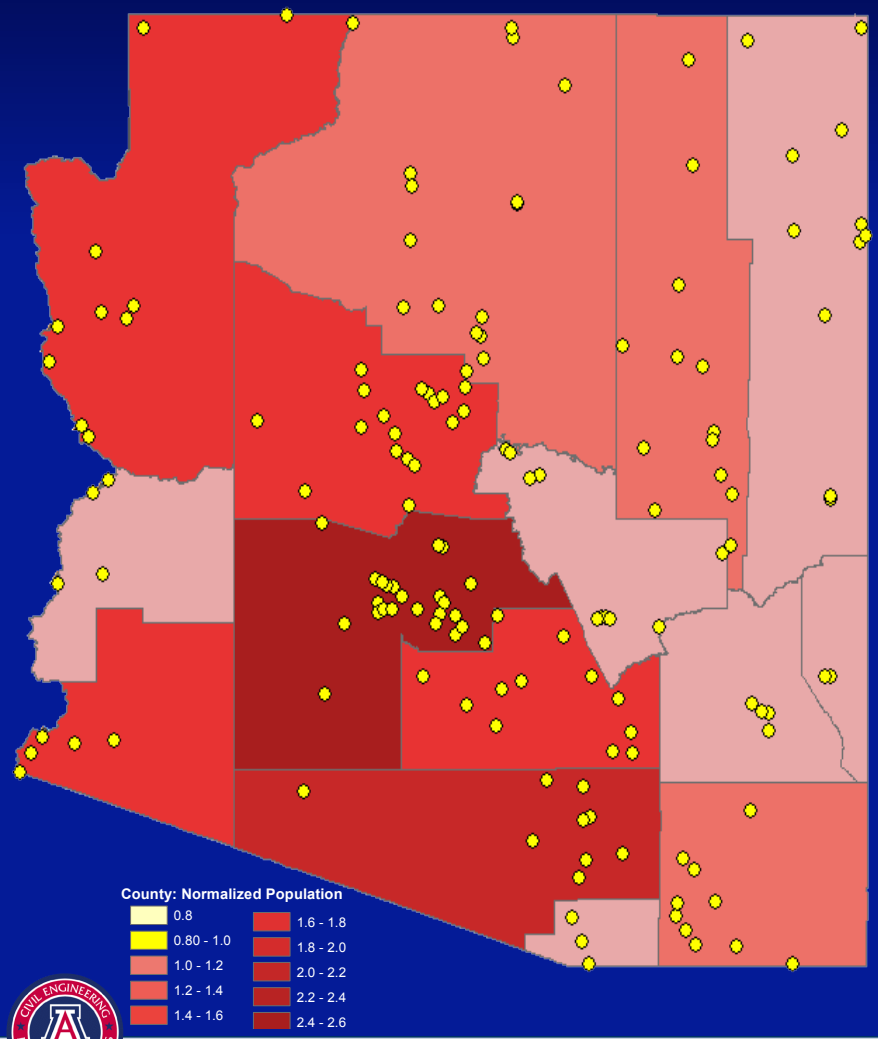


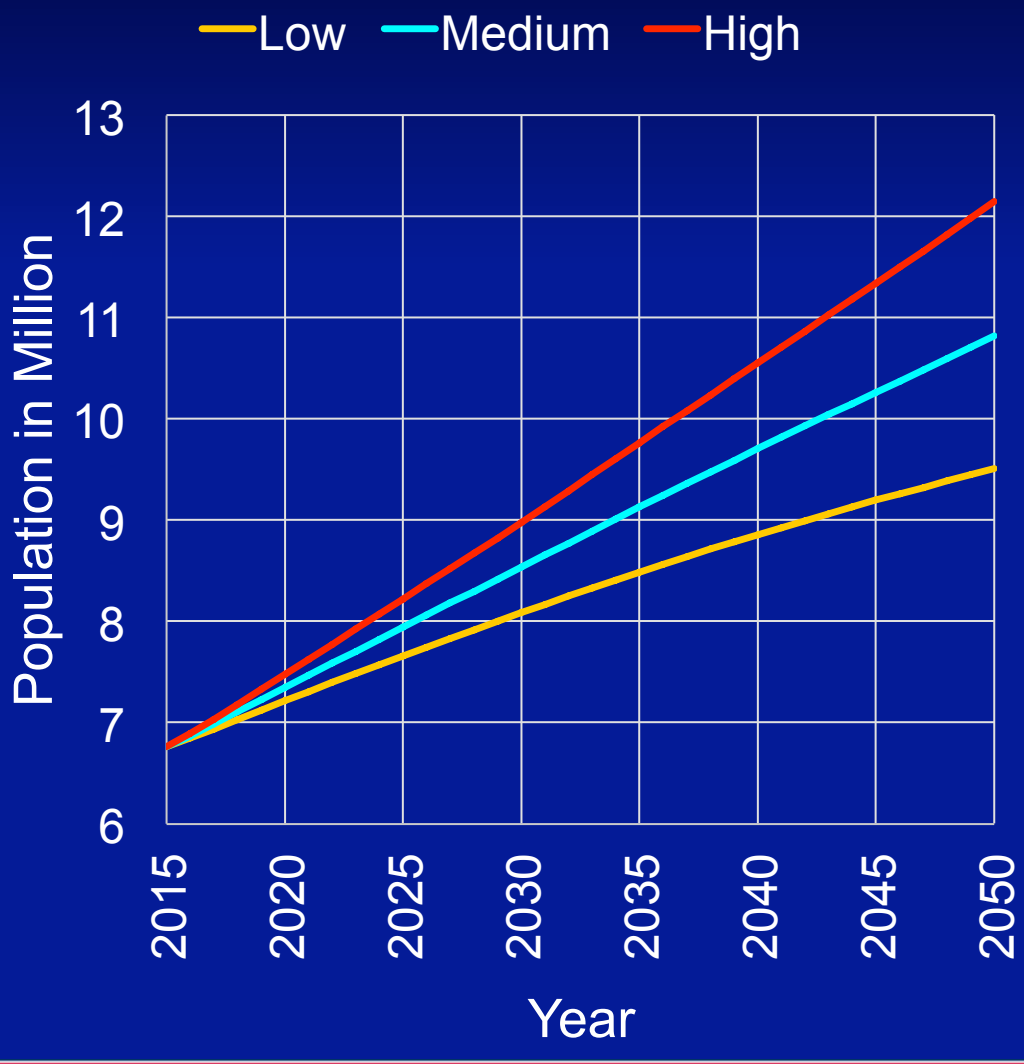
GoldSim

ARVIN-FEW SD Structure

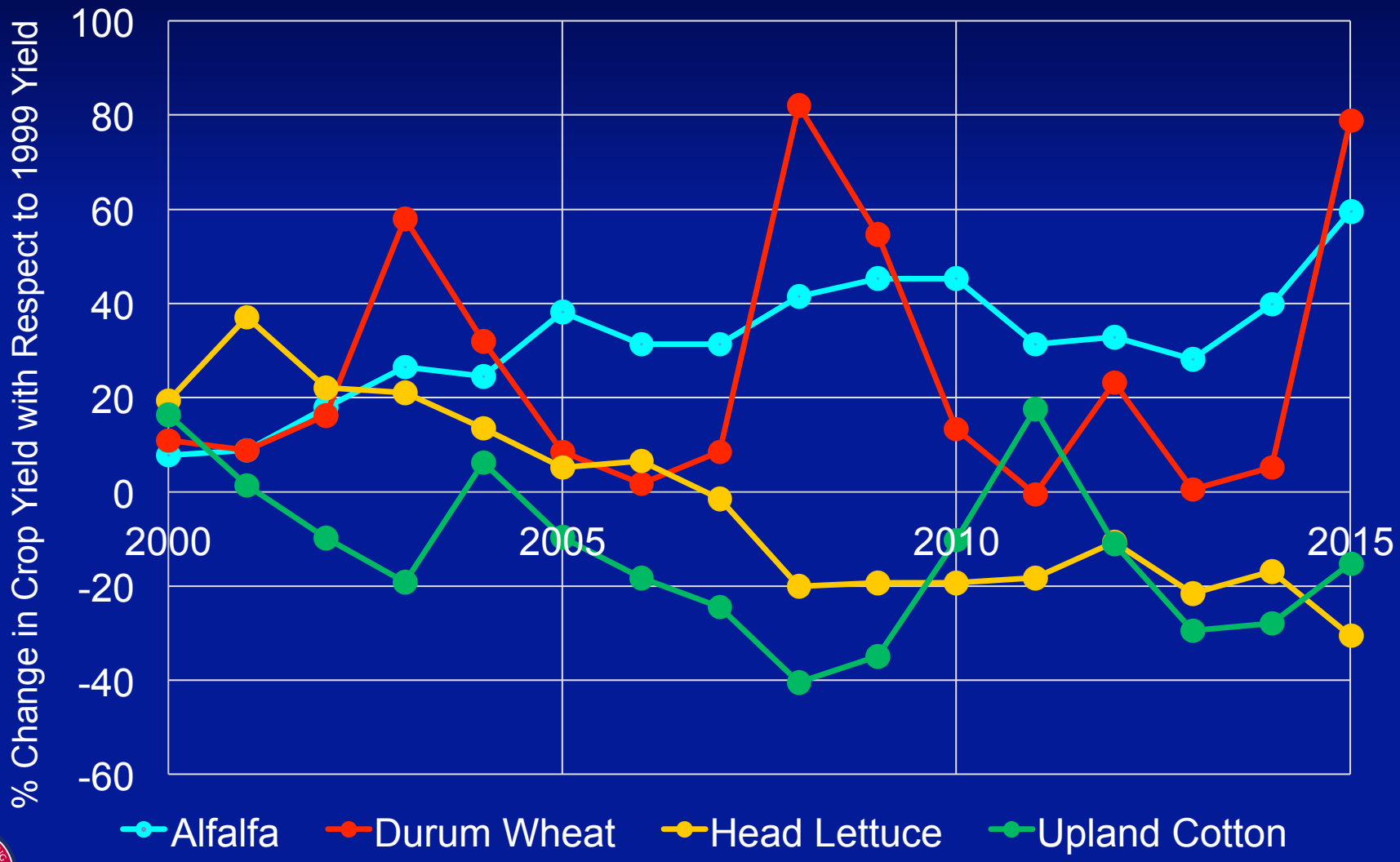


Population Growth Scenarios in AZ

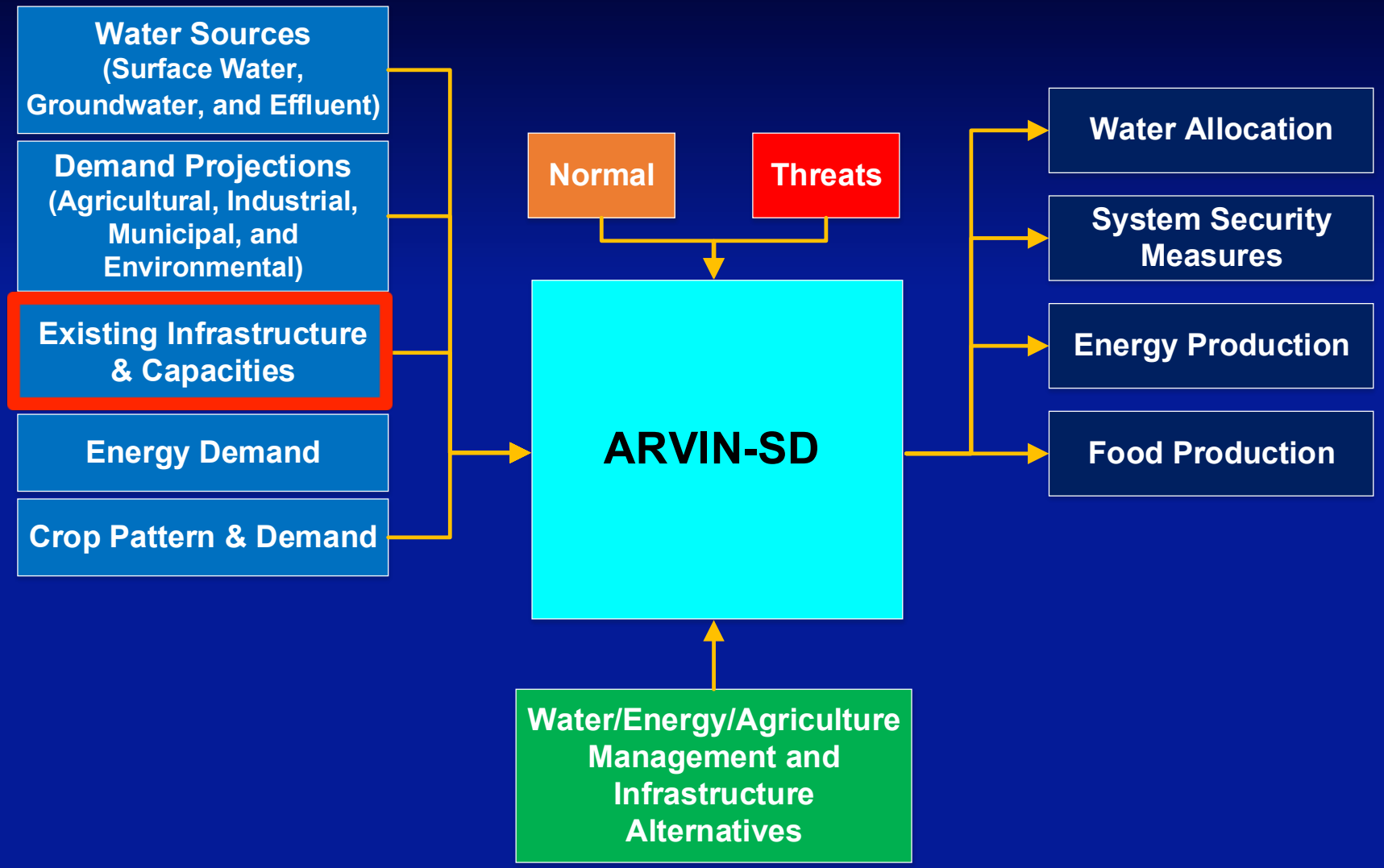




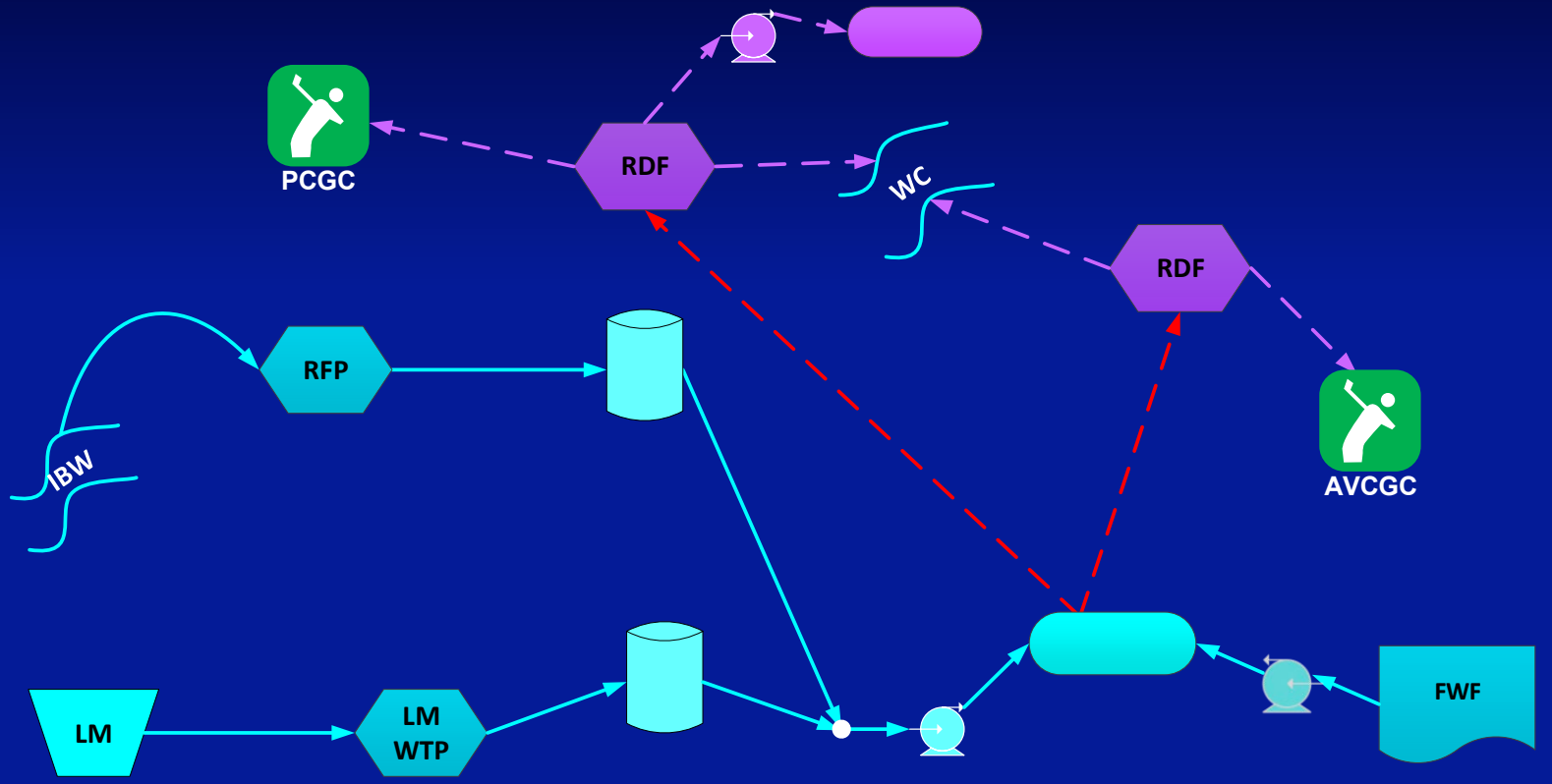
Historical Crop Yield



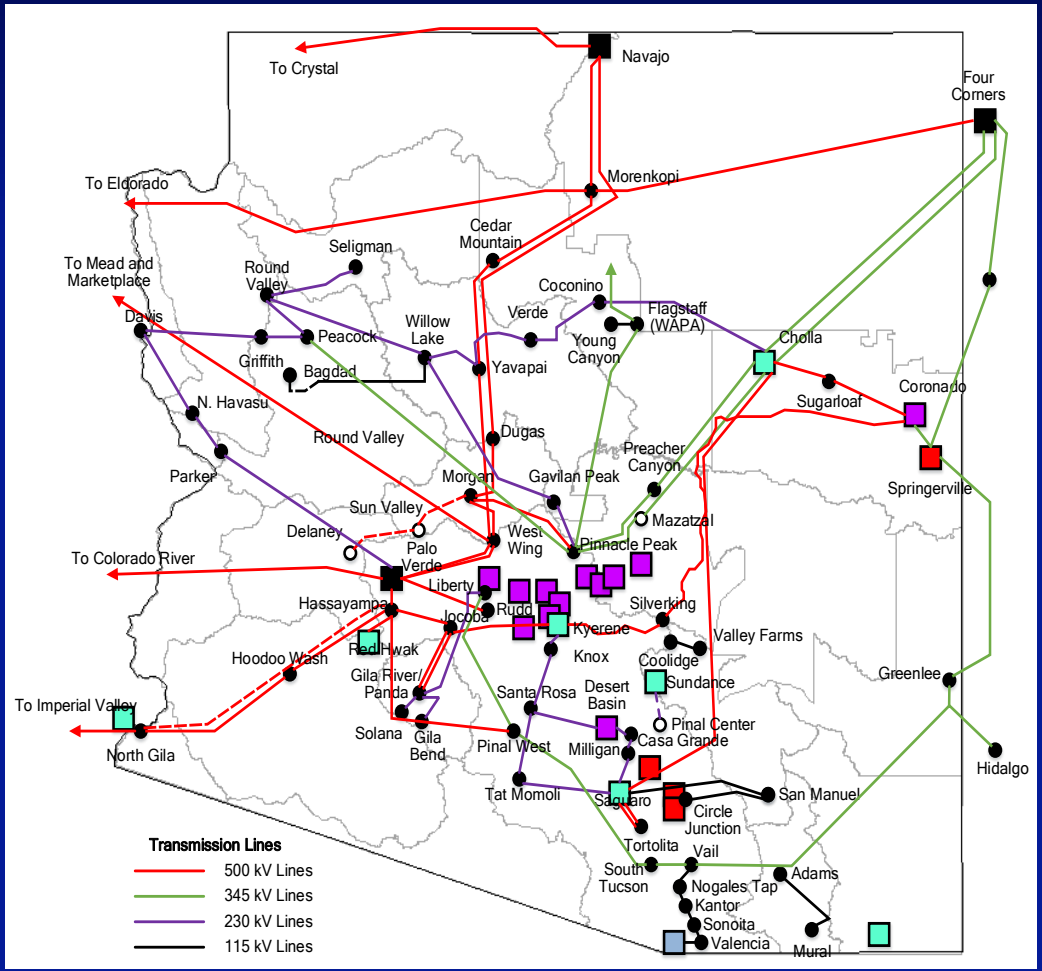
ARVIN-FEW Structure



Municipal Water Supply System

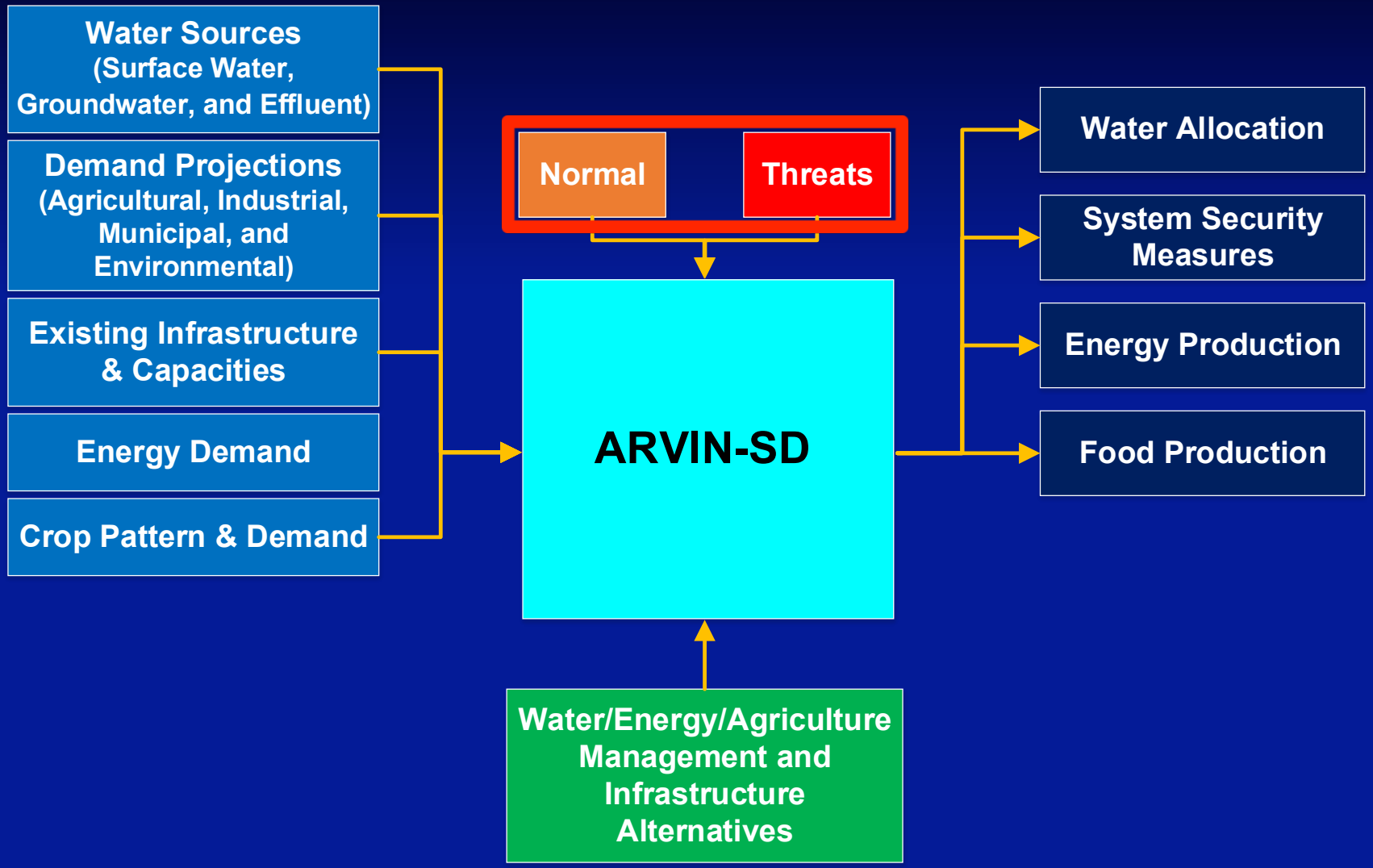


Electric Power Distribution Network

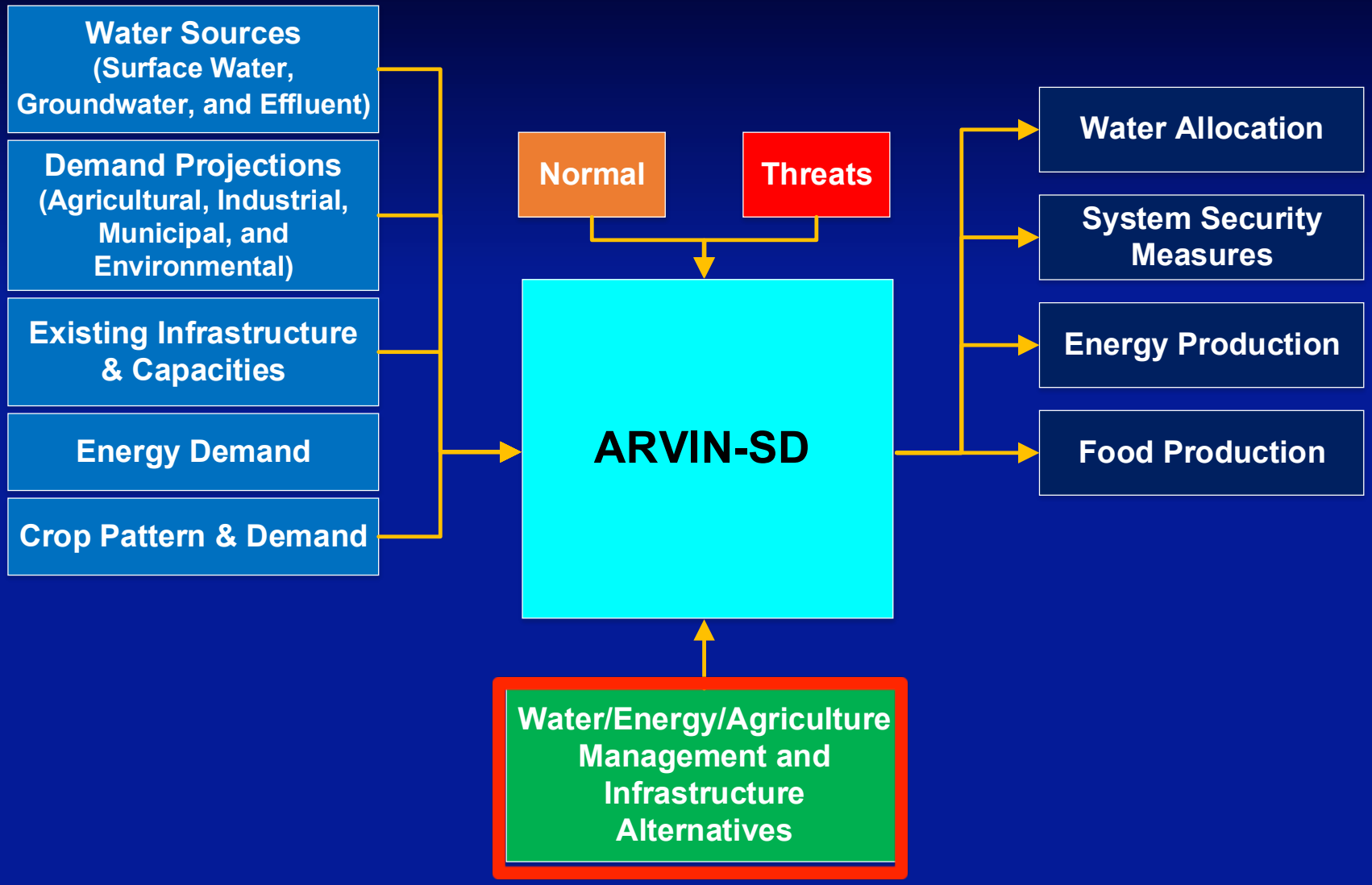


- Electricity utilities
- Power plants
  - Coal
  - Gas
  - Nuclear
  - Hydroelectric
- Transmission lines
- Distribution lines
- Substations

ARVIN-FEW Structure



ARVIN-FEW Structure



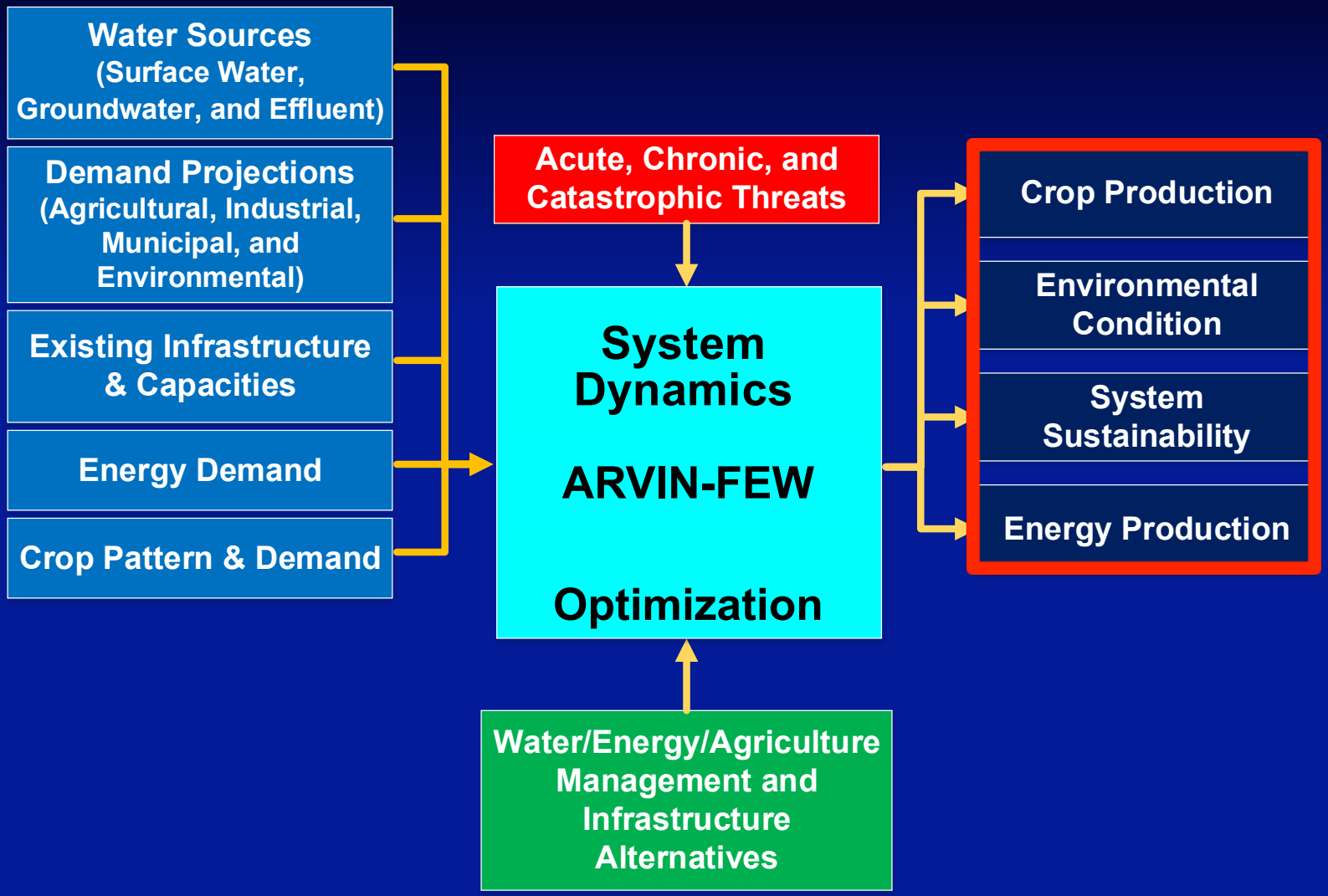
Potential Management Alternatives

- Water conservation
  - Rainwater harvesting
  - Graywater reuse
  - Demand reduction
- Reclaimed water reuse
- New infrastructure
- In-state water transfers
- Supply importation

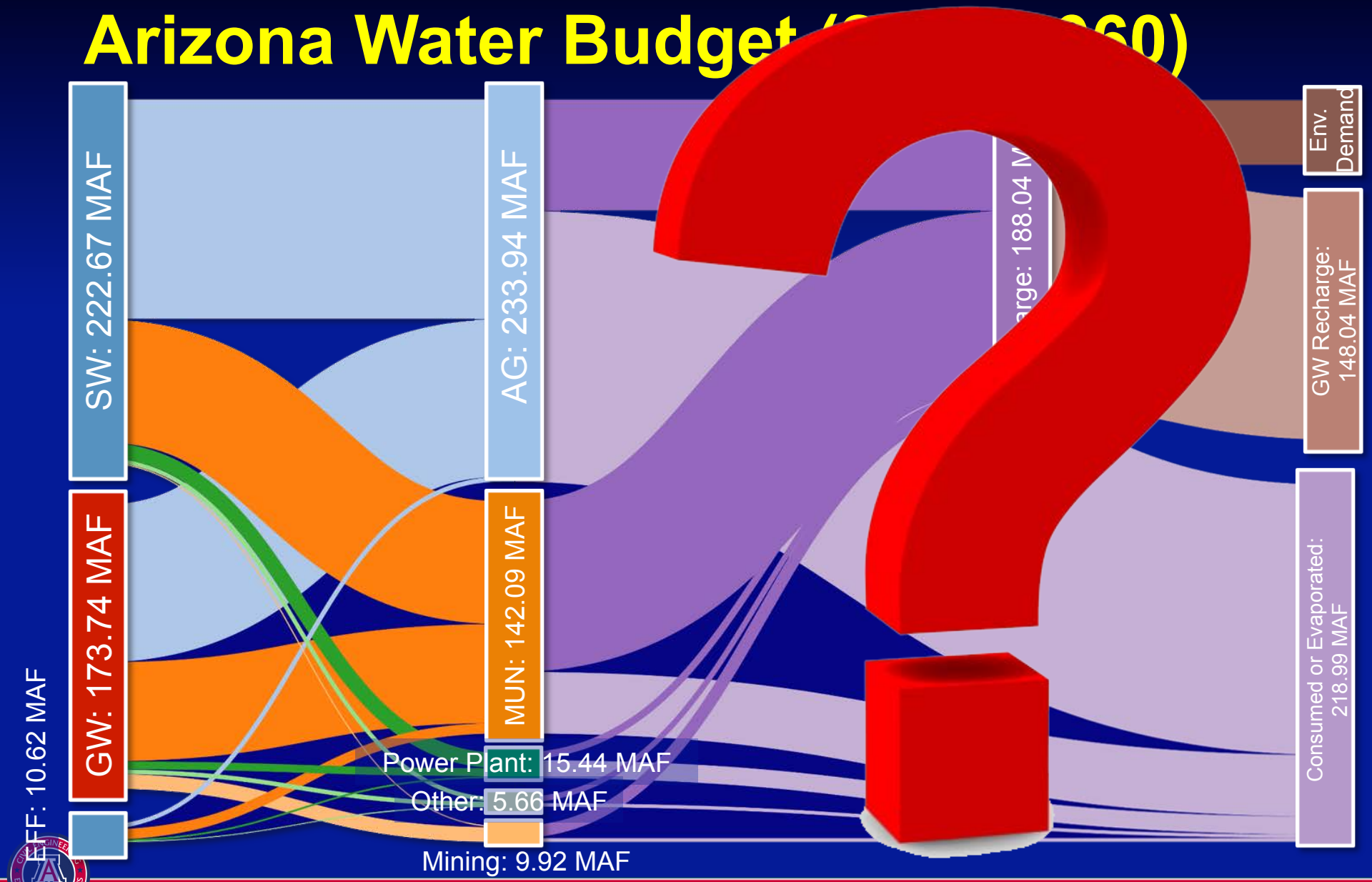
- Renewable energy
- Low water cooling
- Increasing efficiency
- Development of new transportation system

- Alternative crop pattern
- Efficient irrigation system
- Water market
- Controlled environment agriculture

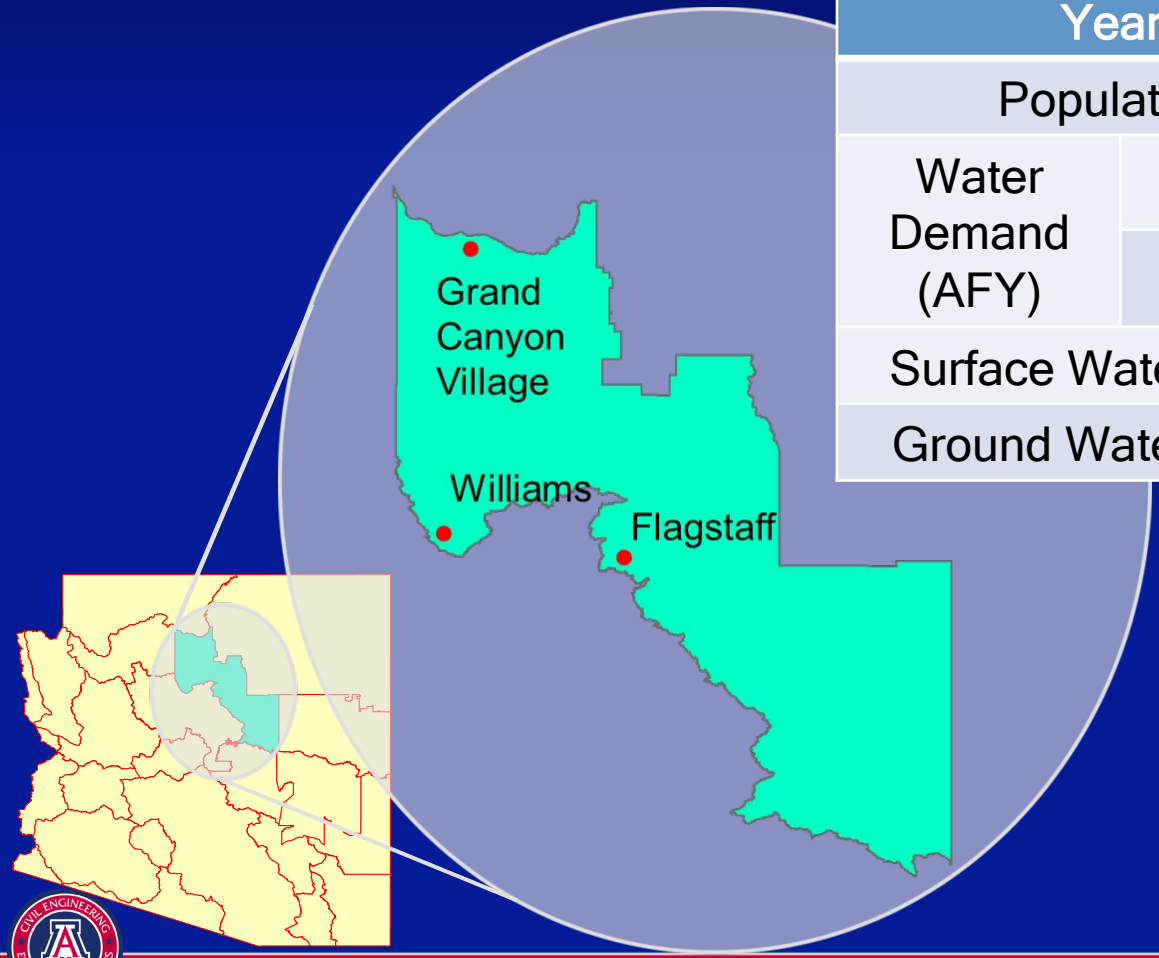
ARVIN-FEW Structure



Arizona Water Budget (2[illegible]60)



Case Study 1: Central Plateau PA

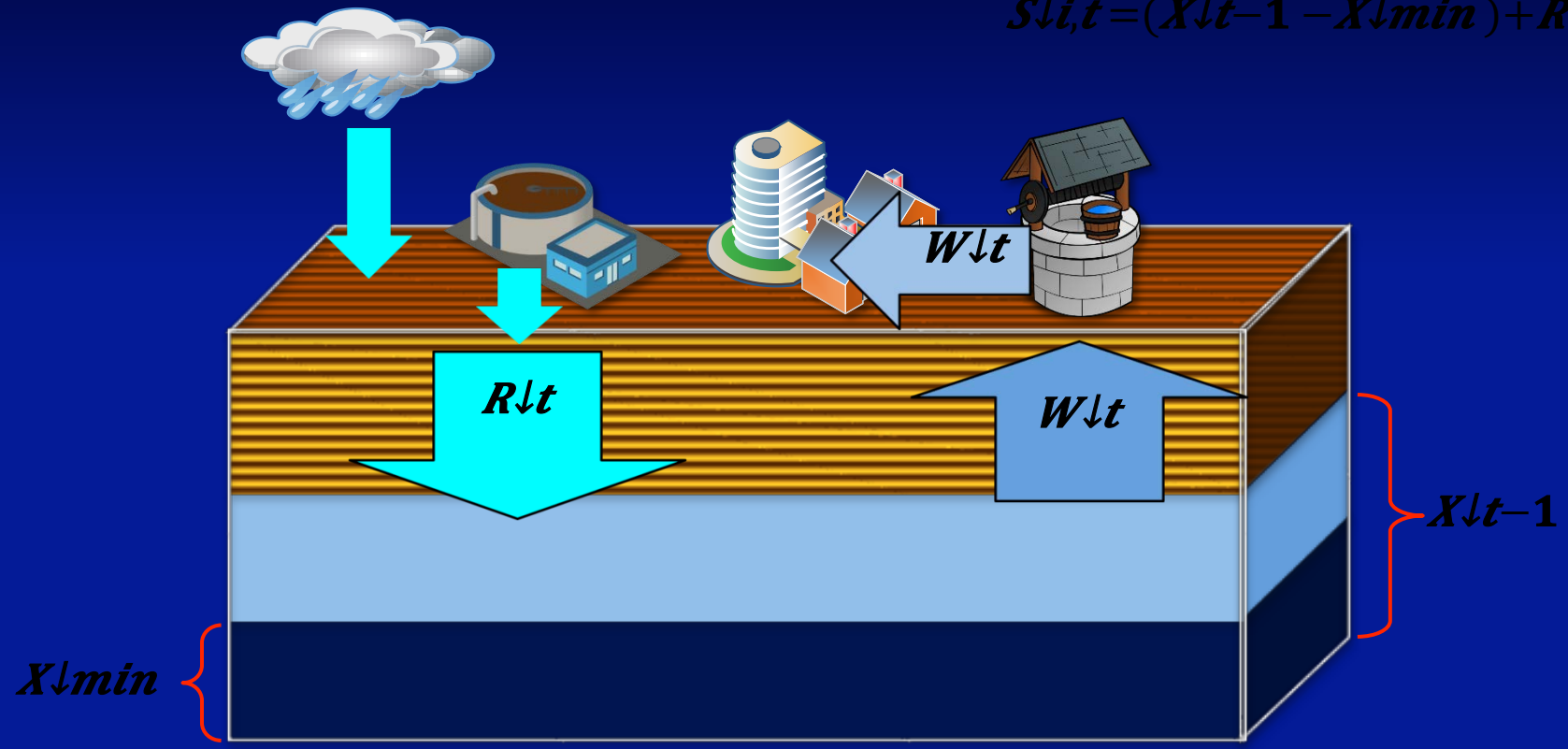


Year		2010	2060
Population		66,470	135,850
Water Demand (AFY)	MU	8,414	17,196
	IND	1,410	1,410
Surface Water (AFY)		2,242	
Ground Water (AFY)		8,800 (safe-yield)	

Note
MU : Municipal
IND: Industrial
AG : Agricultural

Sustainability Indicator

$$S_{i,t} = (X_{t-1} - X_{min}) + R_t / W_t$$

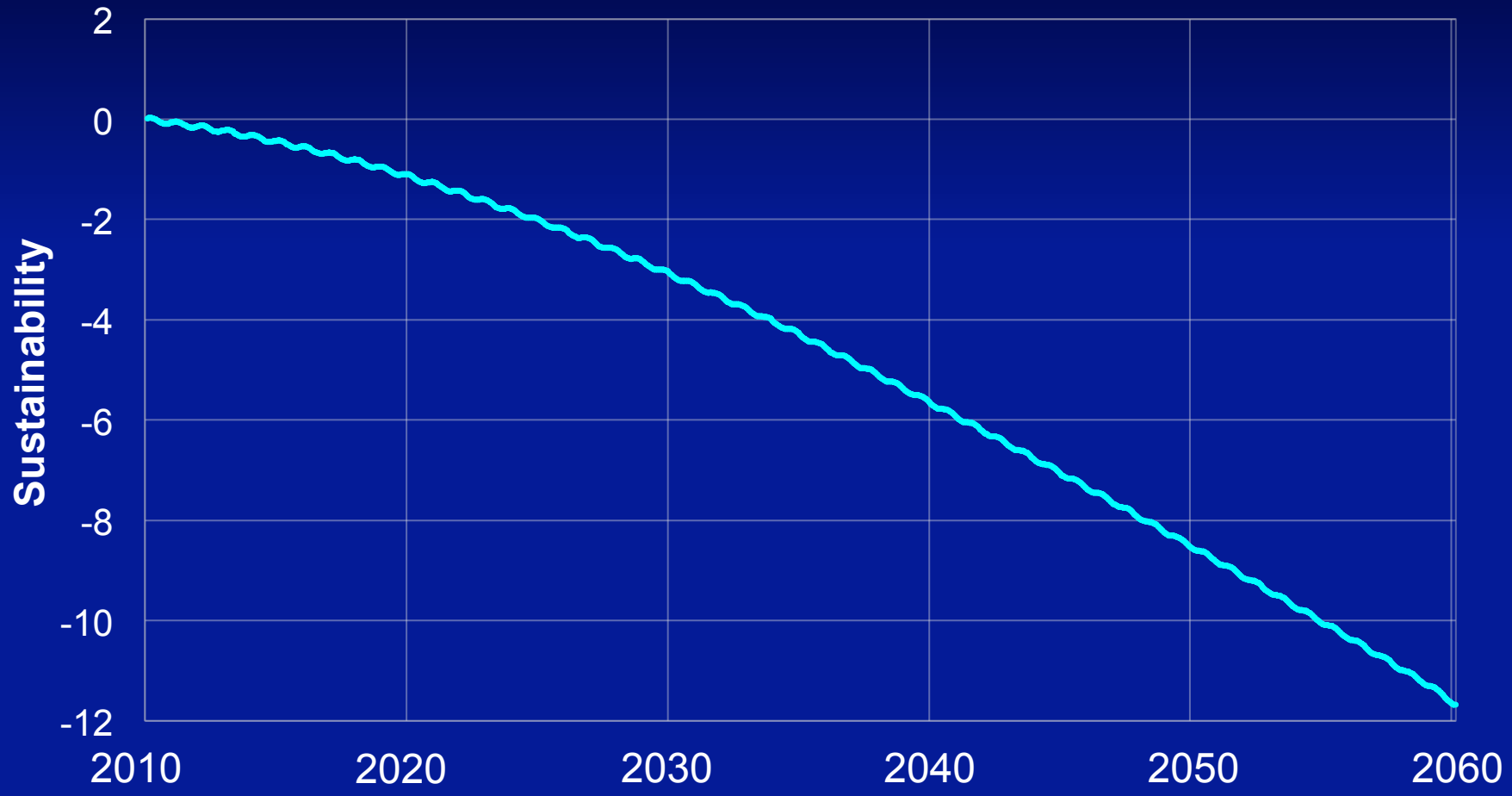


- Safe yield goal → pump usage=recharge credit

→ $S_{i,t} \geq 1$

Huizar et al. (*In Review*)

Sustainability of the Central Plateau



Potential Water Conservation Options

Potential Alternatives for the Central Plateau Planning Area

Water Importation

- ☐ Red Gap Ranch Project
  - Available Supply (AFY): 8000
- ☐ Wetern Navajo Pipeline Project
  - Available Supply (AFY): 8000

Water Importation
City of Flagstaff can obtain groundwater from the C-Aquifer by the Red Gap Ranch Project starting from 2030.

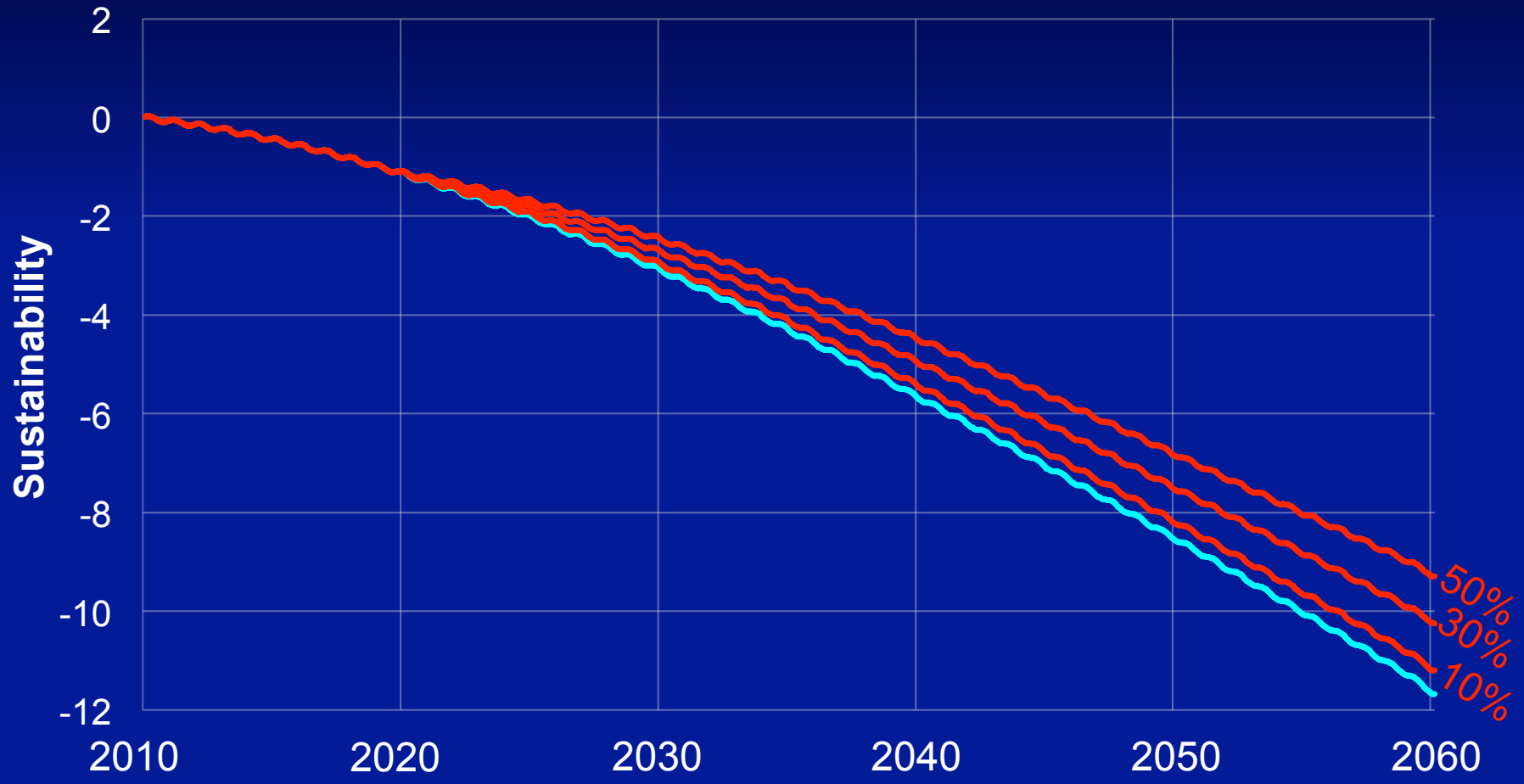
City of Flagstaff can obtain surfacewater

Water Conservation

- ☑ Rainwater Harvesting
  - Adopotation Rate: 0 — 50 — 100
  - Roof Size (ft^2): 2079
- ☑ Reclaimed Water Reuse
  - Percent Use: 0 — 10 — 100
- ☑ Demand Reduction
  - Percent Reduction: 0 — 10 — 100

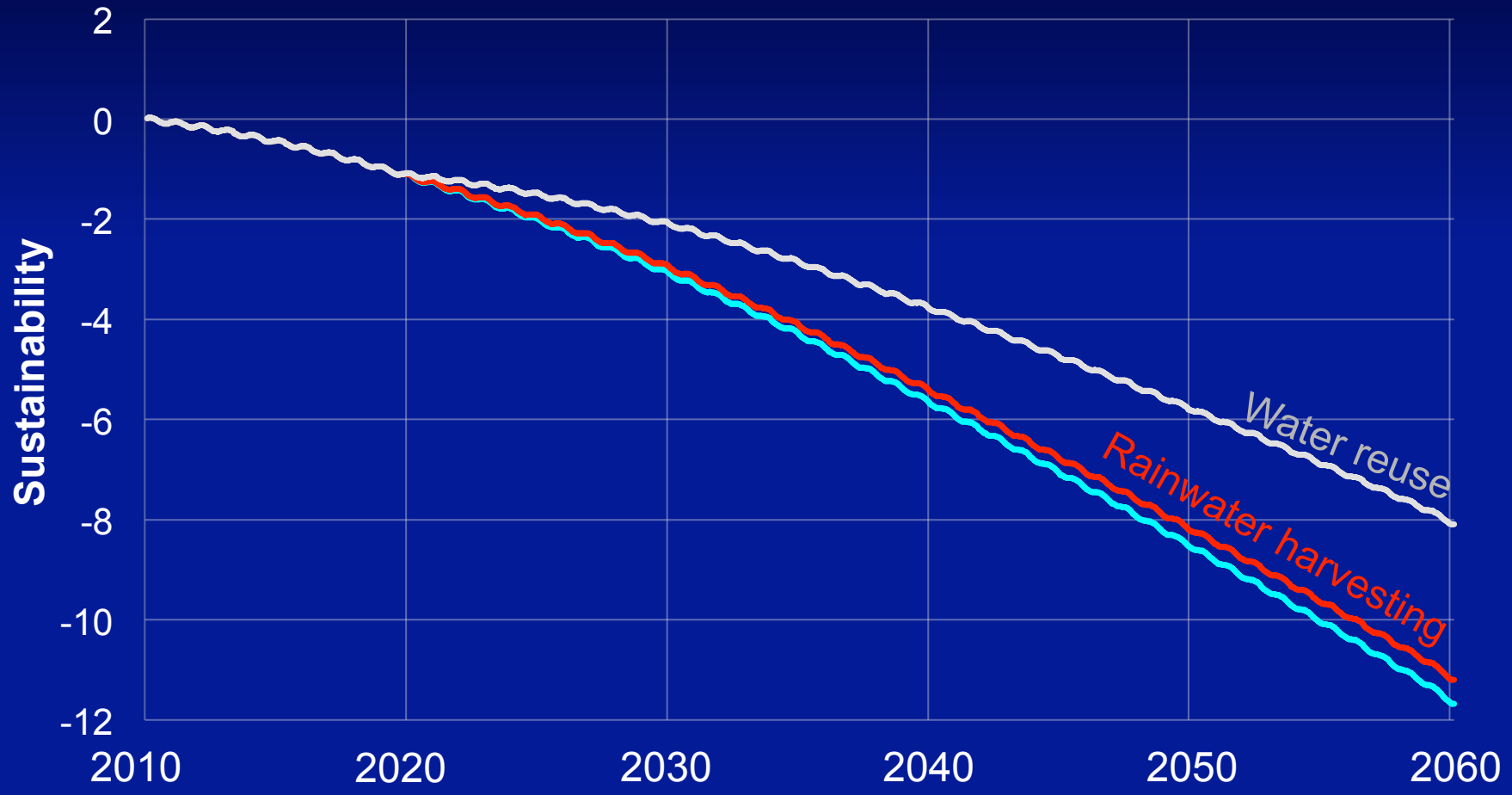
Result Graphs | Browse Model | Run Model

Rainwater Harvesting



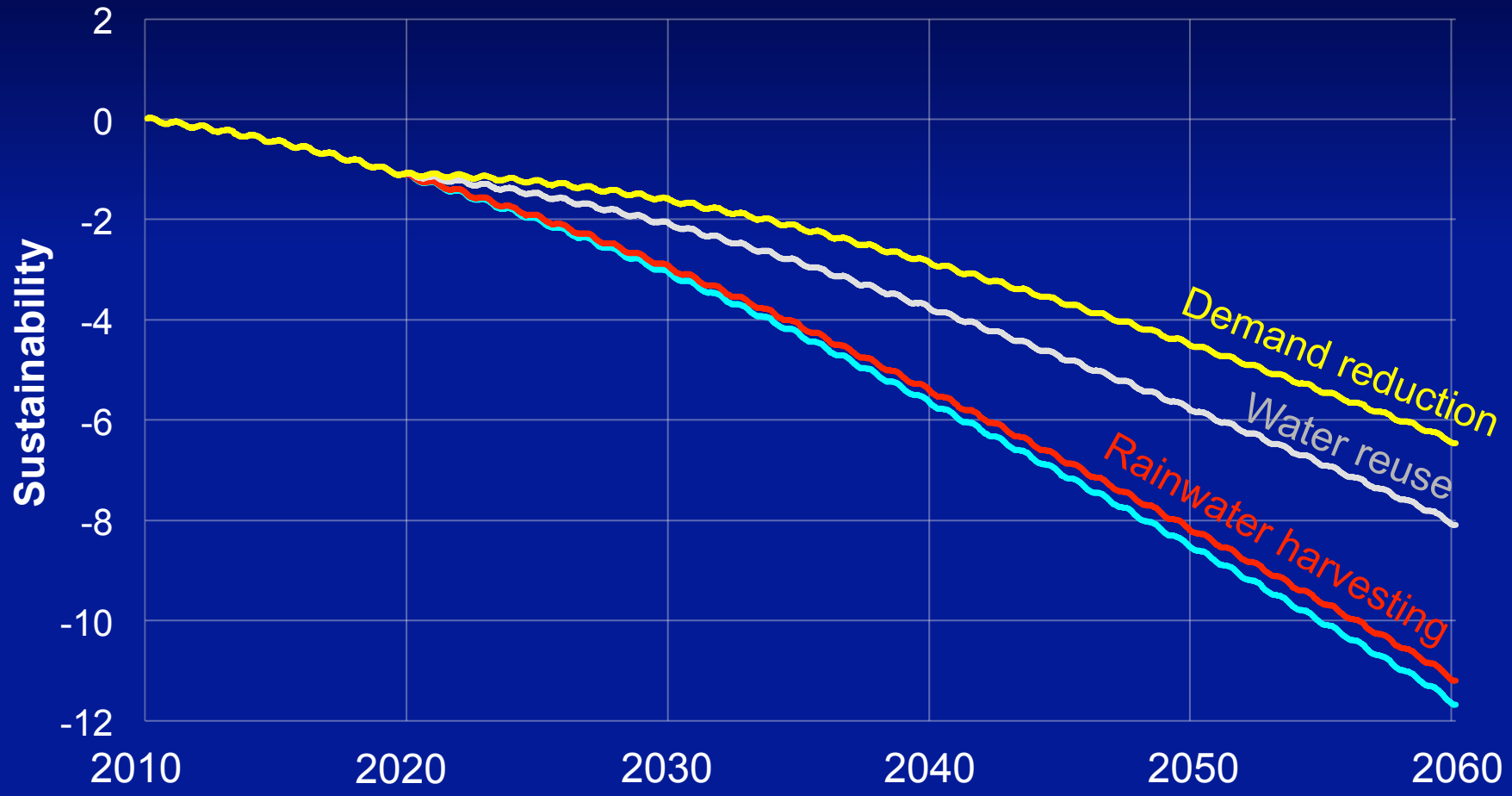
- Rainwater harvesting: 2,079 ft^2 roof size and 10, 30, and 50% adoption rates

Water Reuse



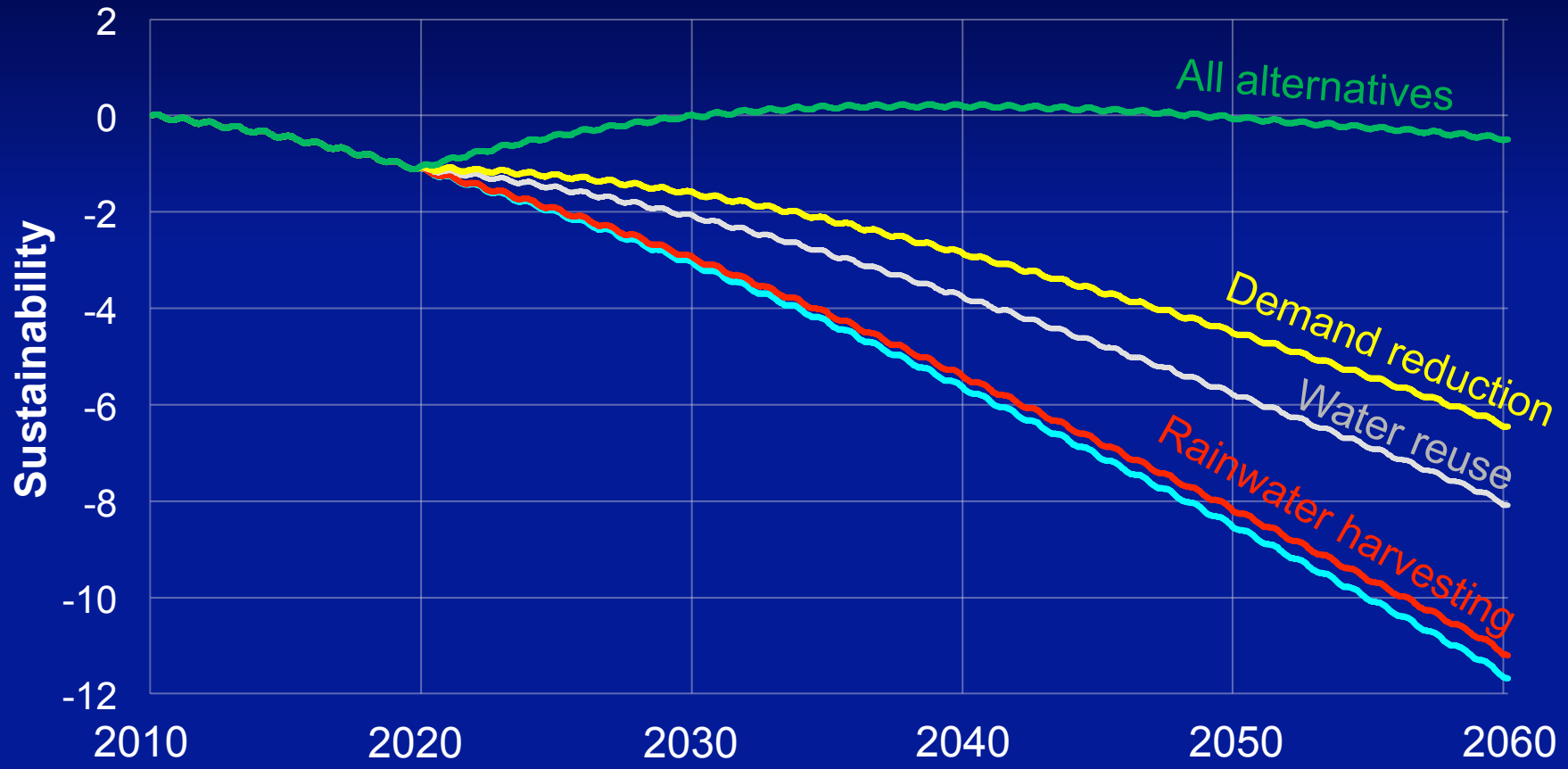
- Water reuse: 10% increase in reclaimed water use

Demand Reduction



- Demand reduction: 10% decrease in total demand

All Alternatives



- Rainwater harvesting: 2,079 ft^2 roof size and 10% adoption rates
- Water reuse: 10% increase in reclaimed water use
- Demand reduction: 10% decrease

Potential Instate Water Importation

Potential Water Conservation Options

Potential Alternatives for the Central Plateau Planning Area

Water Importation

- [x] Red Gap Ranch Project
  - Available Supply (AFY): 8000
- [x] Wetern Navajo Pipeline Project
  - Available Supply (AFY): 8000

Water Importation
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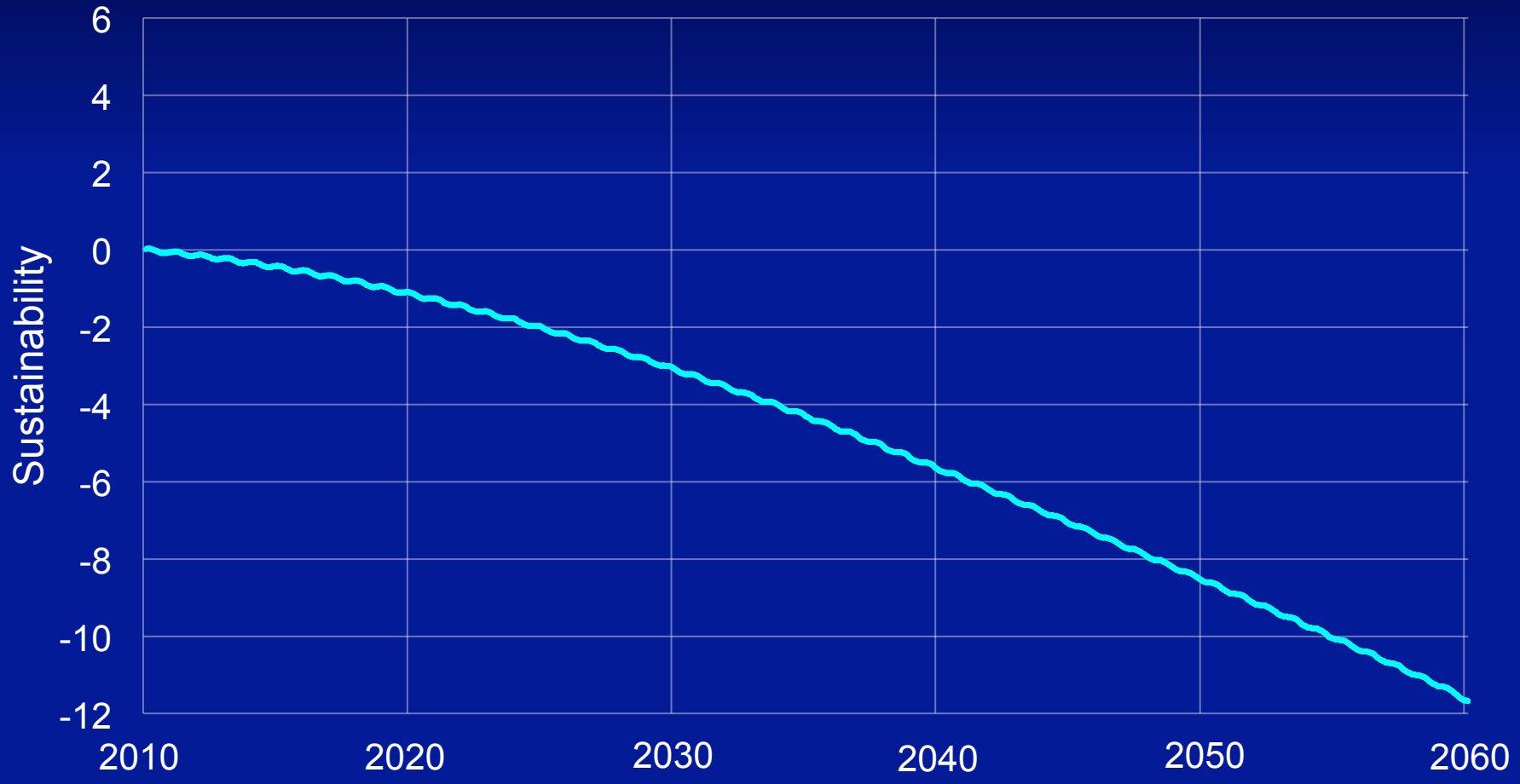
Water Conservation

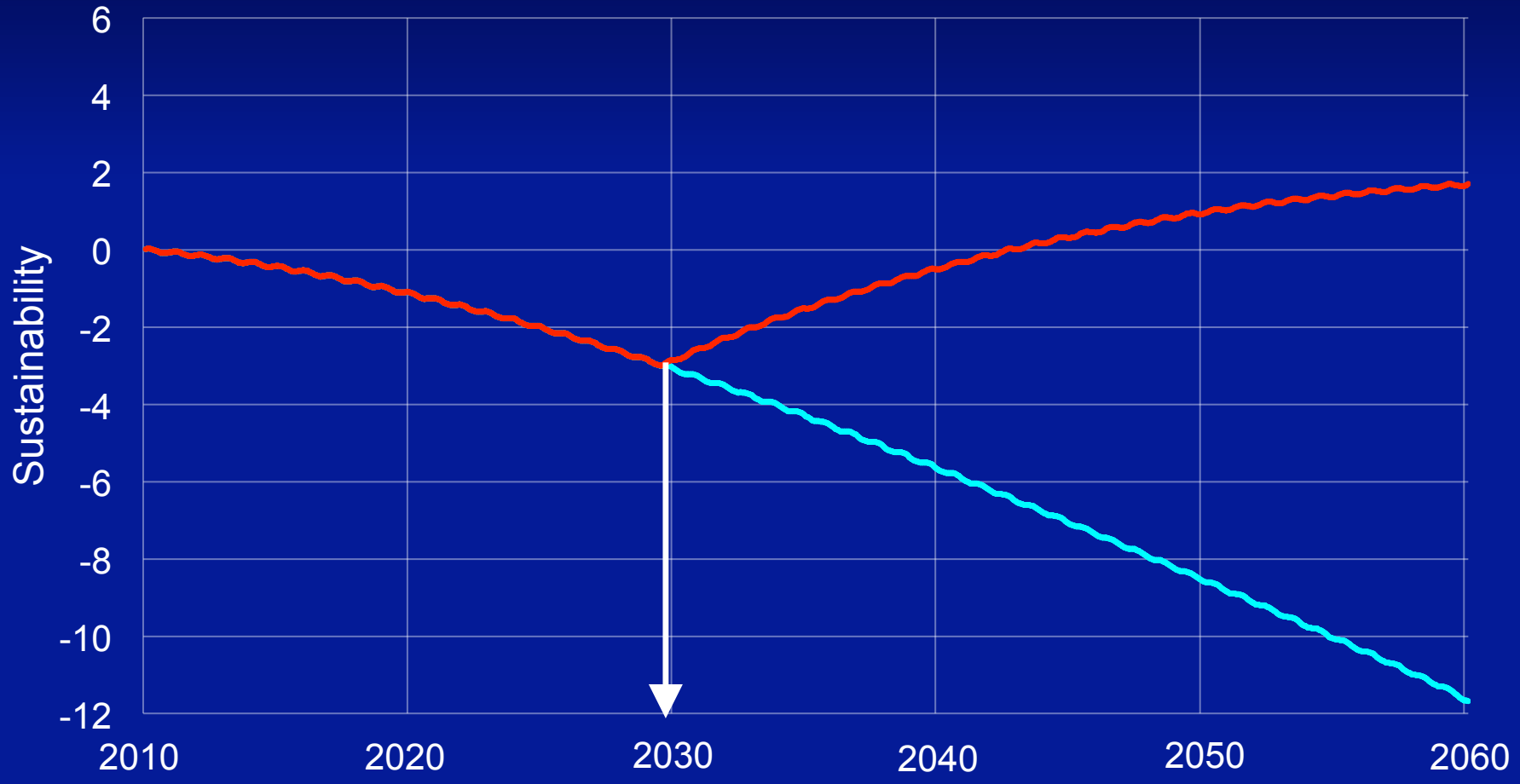
- [ ] Rainwater Harvesting
  - Adopotation Rate: 0 — 50 — 100
  - Roof Size (ft^2): 2079
- [ ] Reclaimed Water Reuse
  - Percent Use: 0 — 10 — 100
- [ ] Demand Reduction
  - Percent Reduction: 0 — 10 — 100

Result Graphs | Browse Model | Run Model

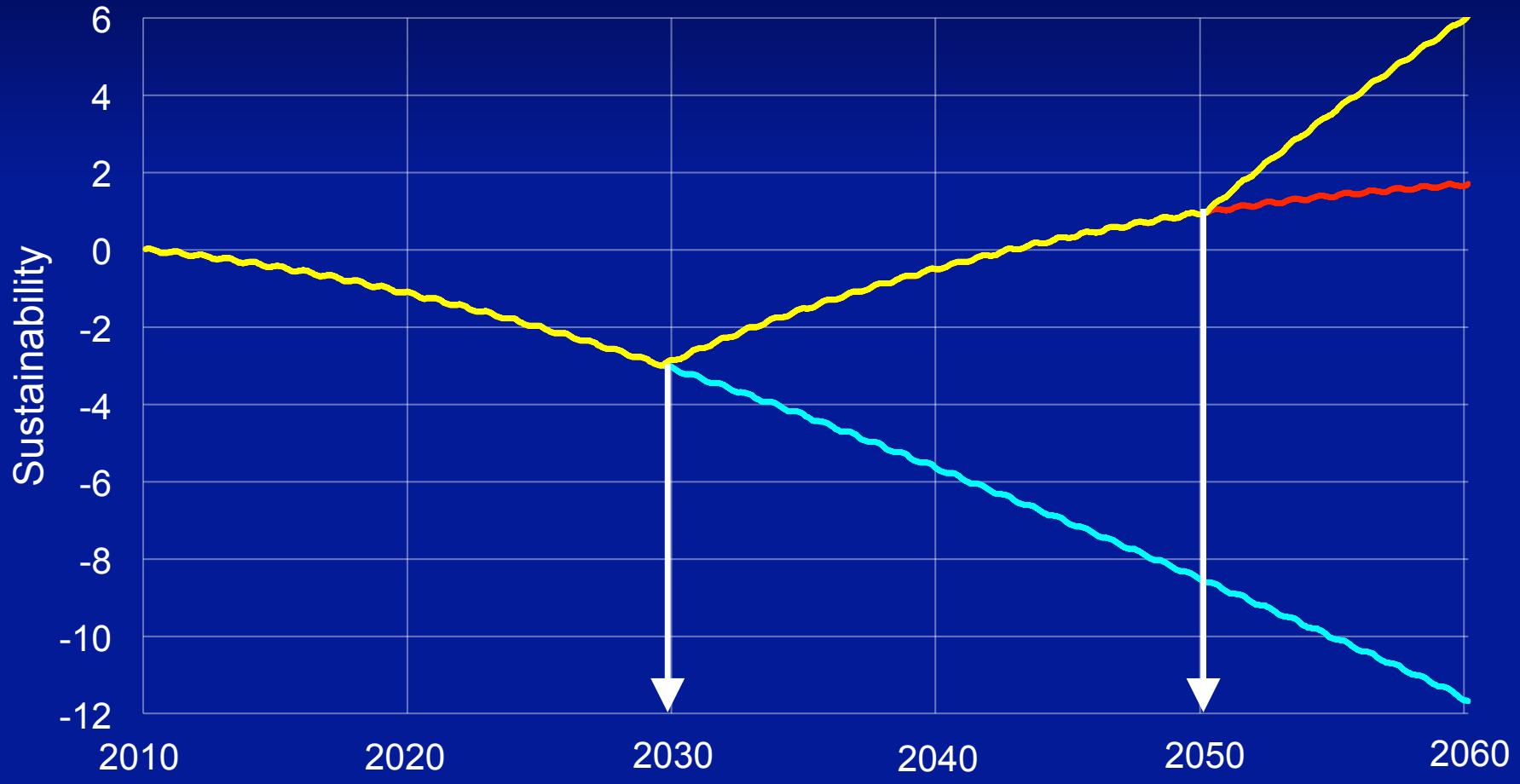
Base Condition



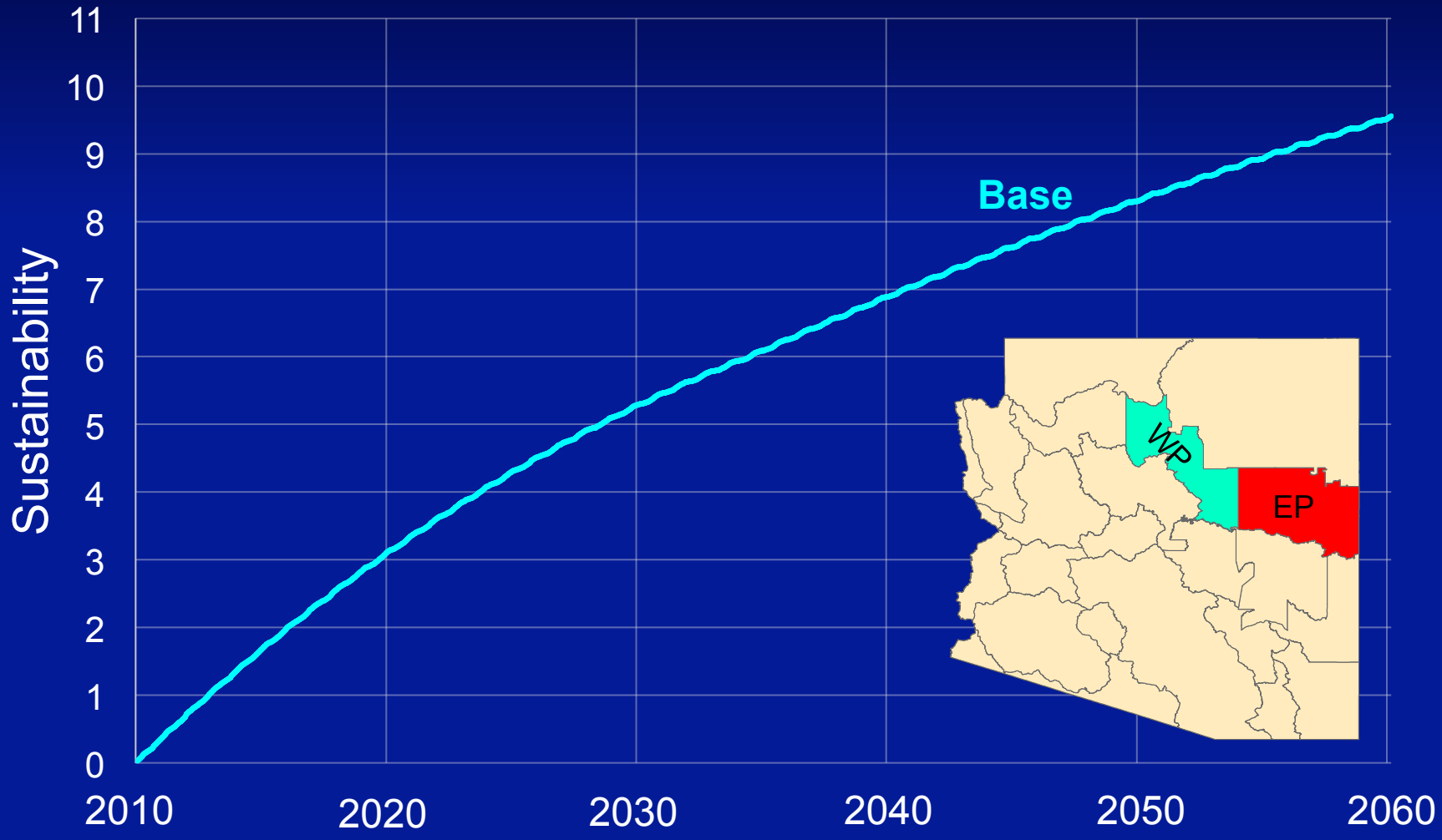
Instate Water Importation RGRP



Instate Water Importation RGRP+WNPP



Inter-Planning Area Impacts: Sustainability of the Eastern Plateau



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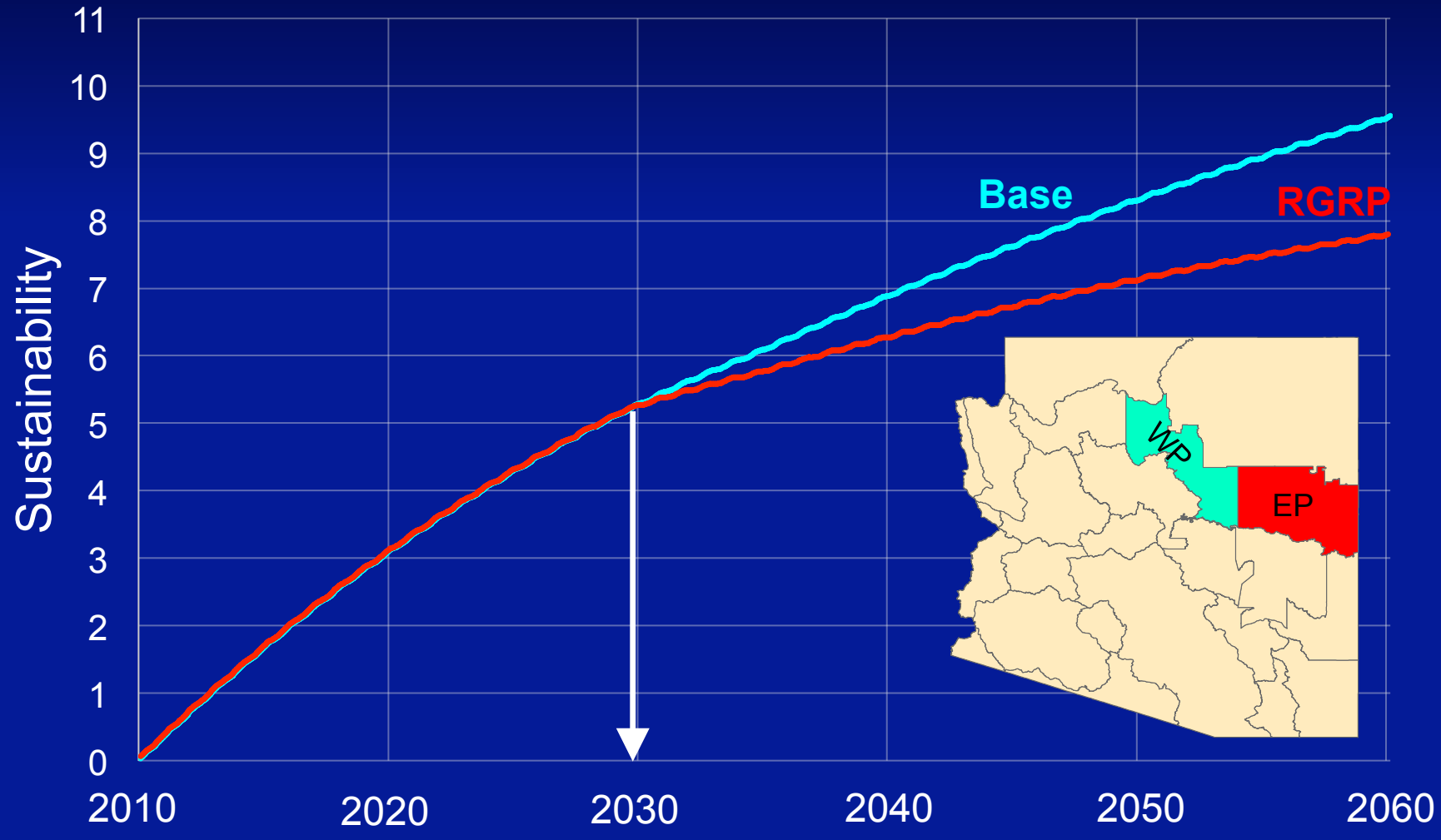
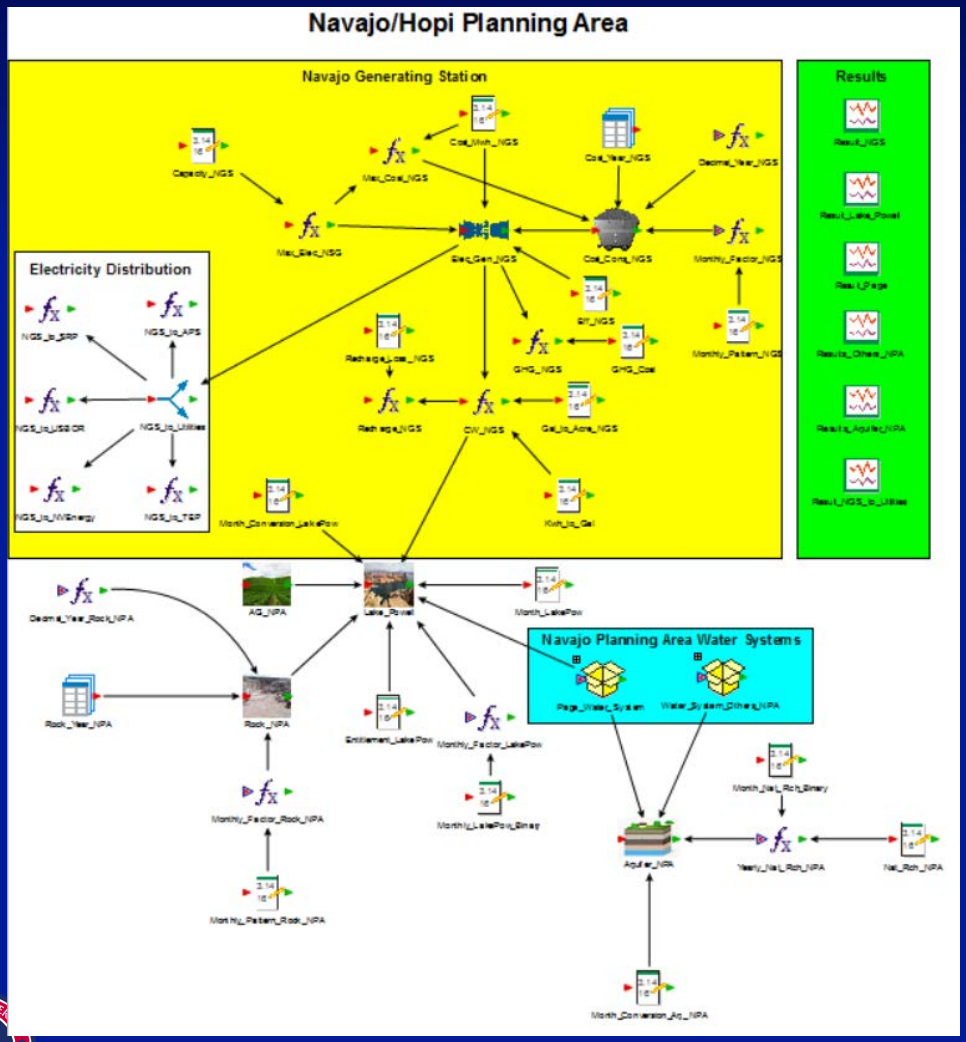
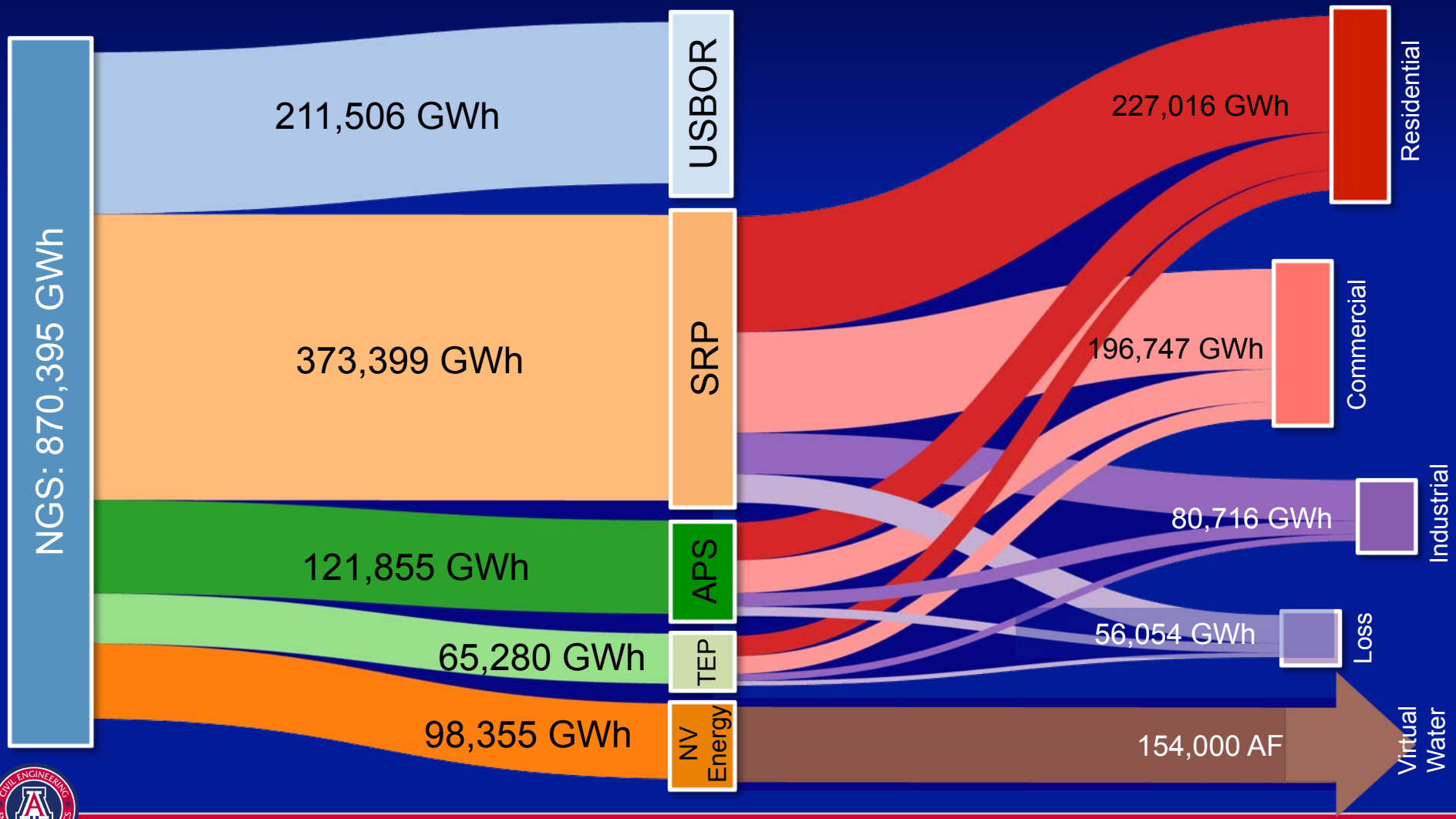


Case Study 2: Navajo/Hopi PA

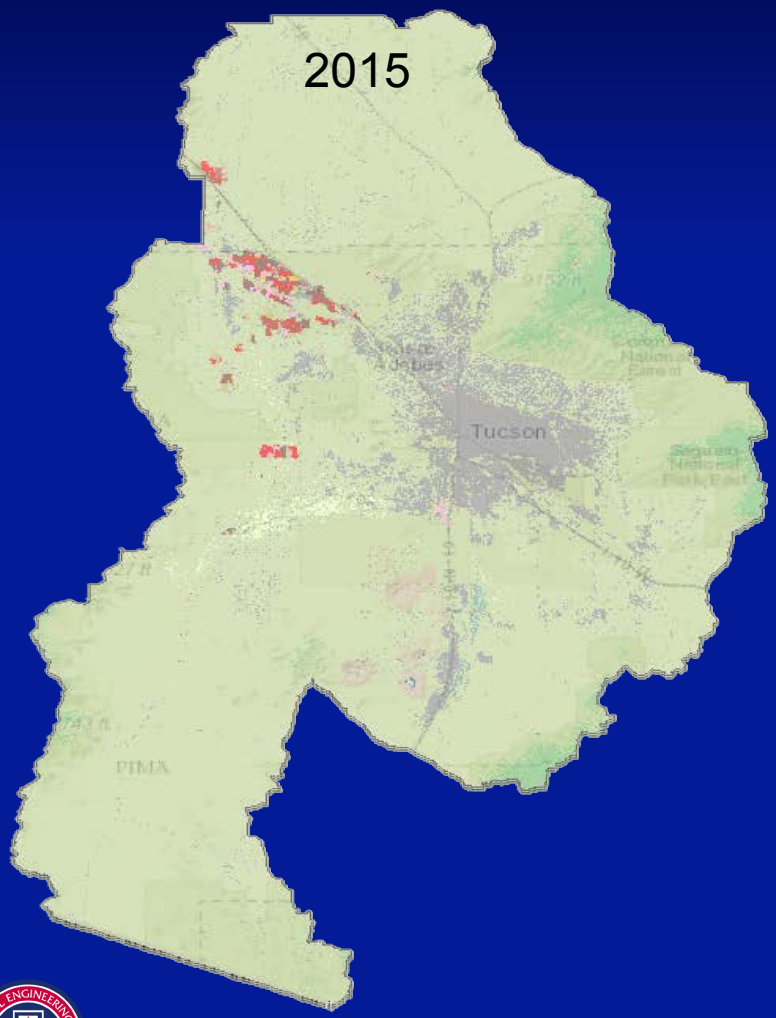


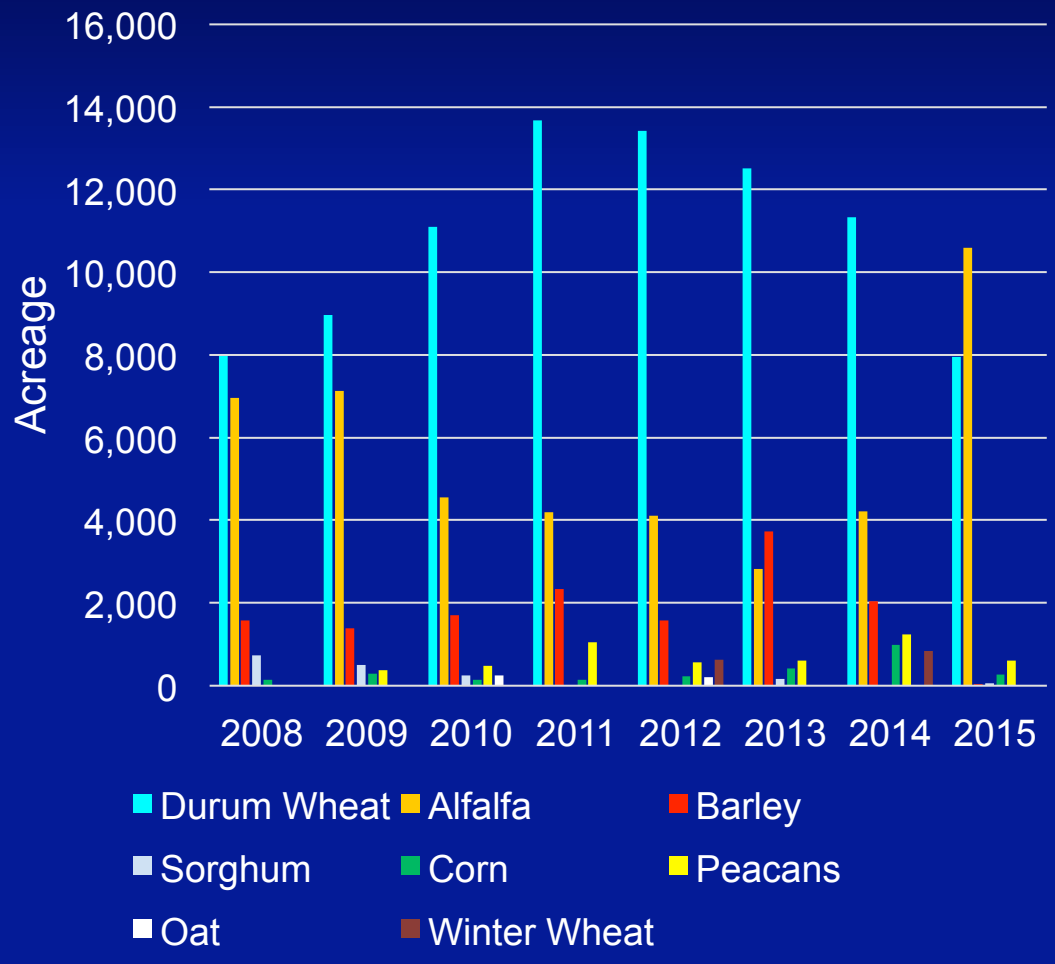
- Municipal water demand
- Agricultural water demand
- Industrial water demand
  - Golf course
  - Navajo generating station
  - Mines (rock production)
- Electricity generation
- Greenhouse gas emission due to electricity generation

Electricity Distribution of NGS Production



Tucson AMA Crop Patterns and Acres





Summary

- Imbalance in future supply and demand is inevitable.
- Arizona statewide management tool is under development to supply quantitative decision making support and bridge the gap between water supply and demand.
- ARVIN-FEW system dynamics model is used to investigate the impact of potential alternatives on system sustainability.