ARVIN-FEW: ARizona Value INtegrated Food, Energy, Water Model

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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

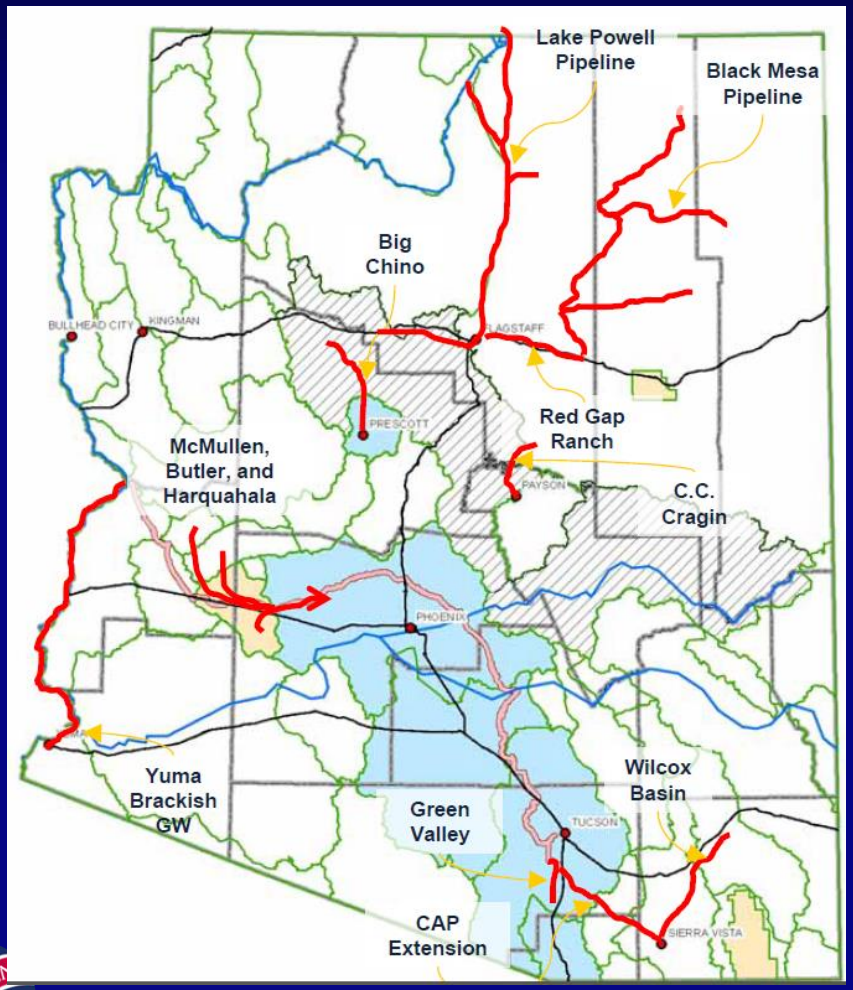
State Level — Legal and Political, Demand, Inter-Planning Area Trans

Planning Area Level — Infrastructure Decisions, Water Conservation

Water Allocation

Econ. & System Security

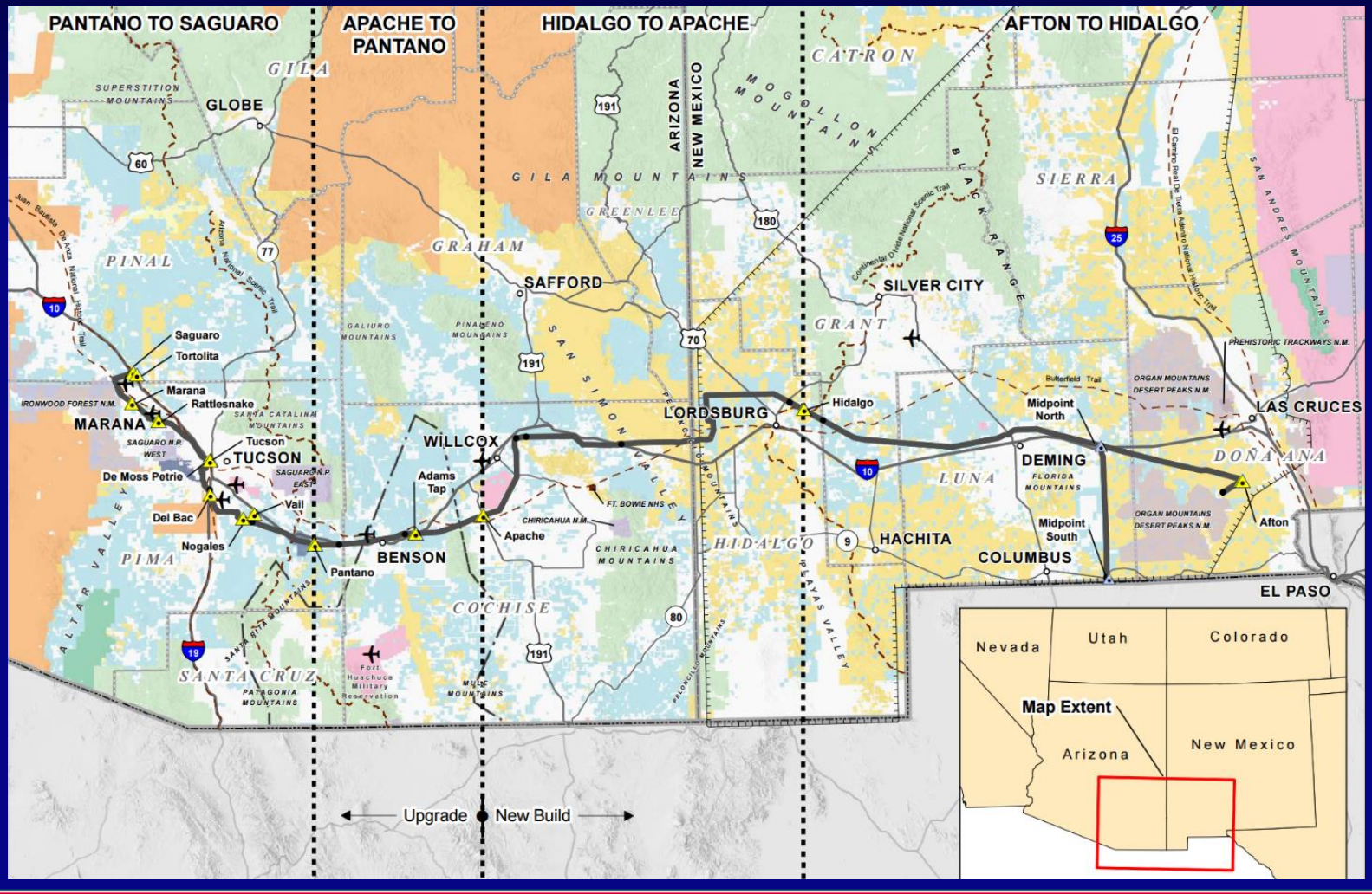
Why Multi-Scale Modeling?



- Groundwater transfer
- Surface water transfer
- Statewide desalination

Source: HDR

Interstate Transmission Lines



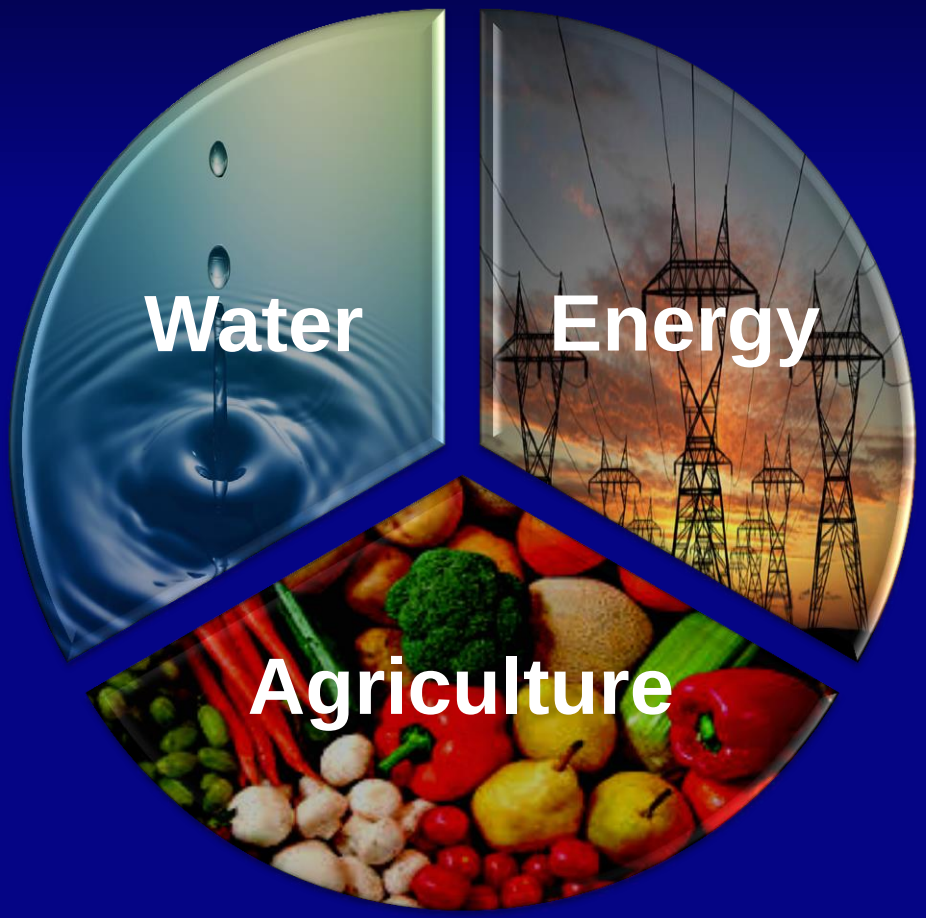
Motivation

- 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.
- Lack of quantitative integrated resource planning model tool

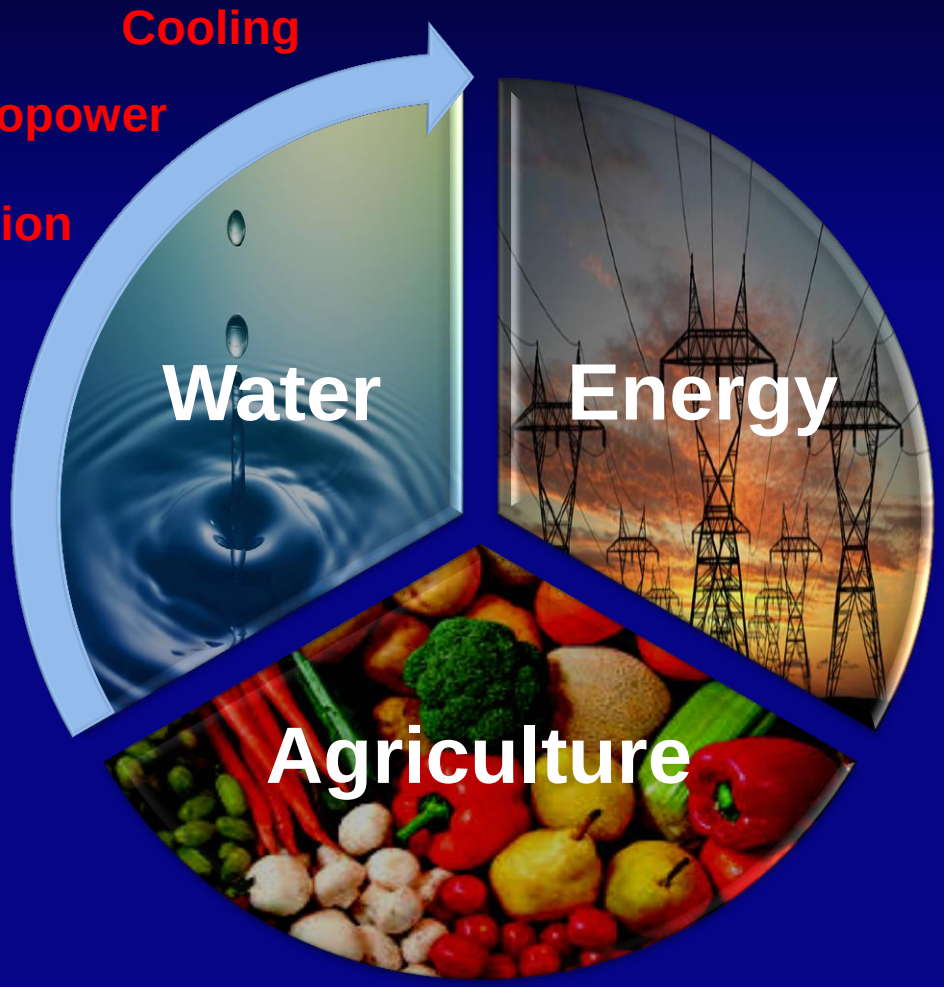
Objectives

- 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
- Provide a broader discussion of our vision for ARVIN

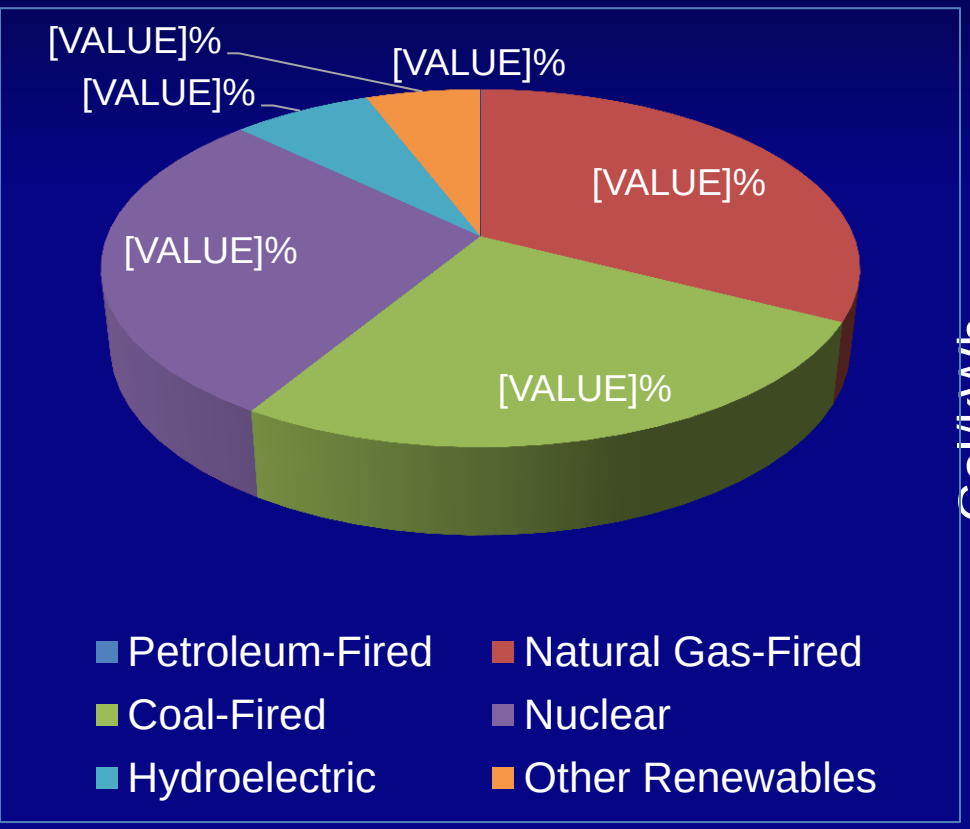
Water, Energy, Agriculture Nexus

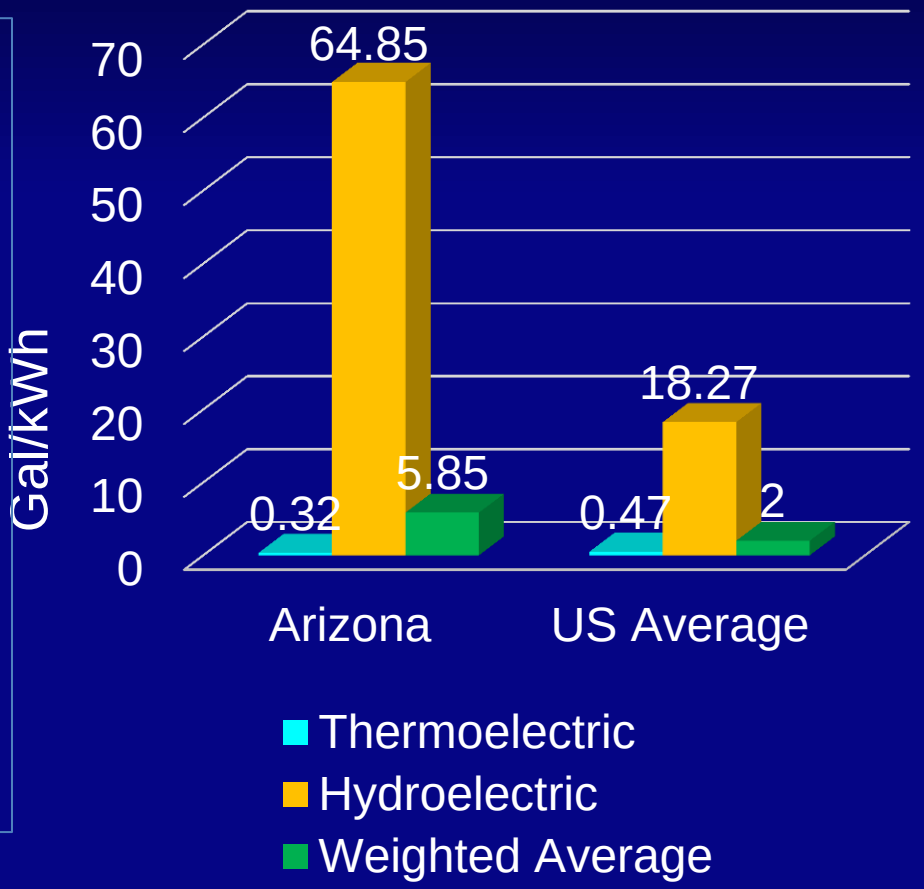


Water → Energy



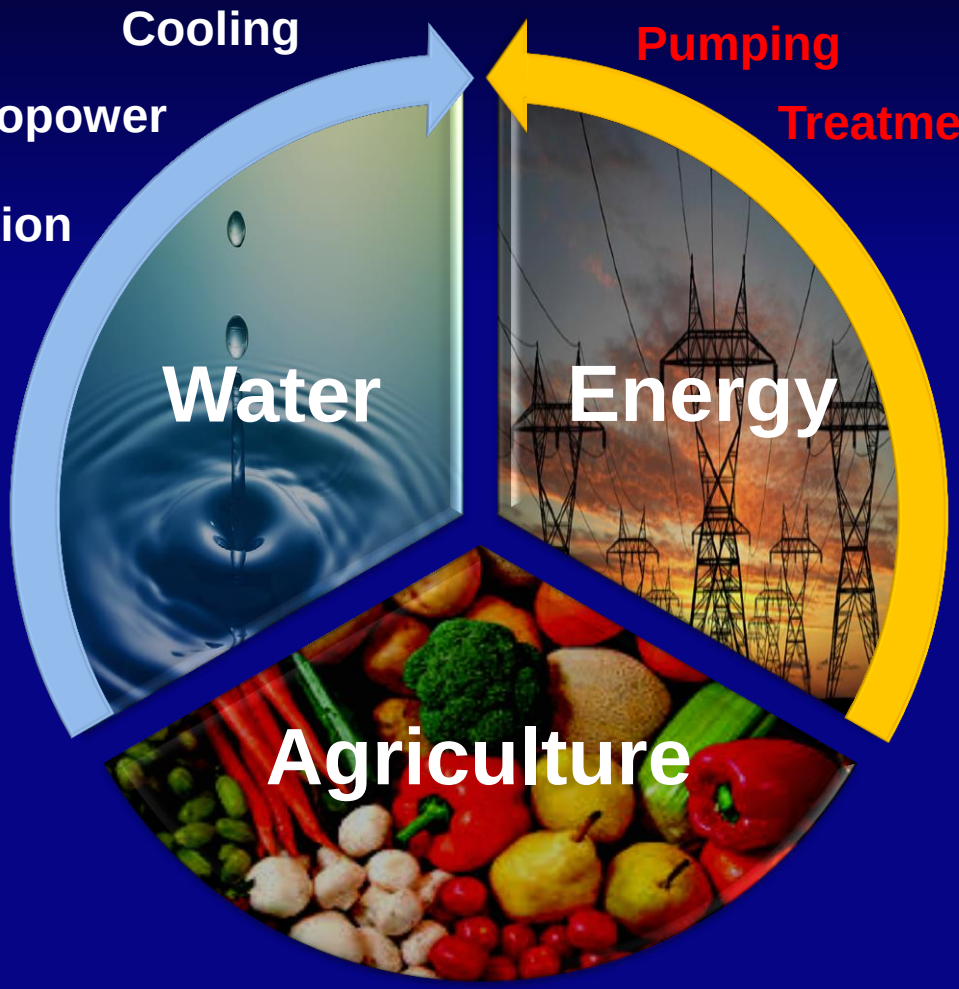
Water Use for Electricity Generation



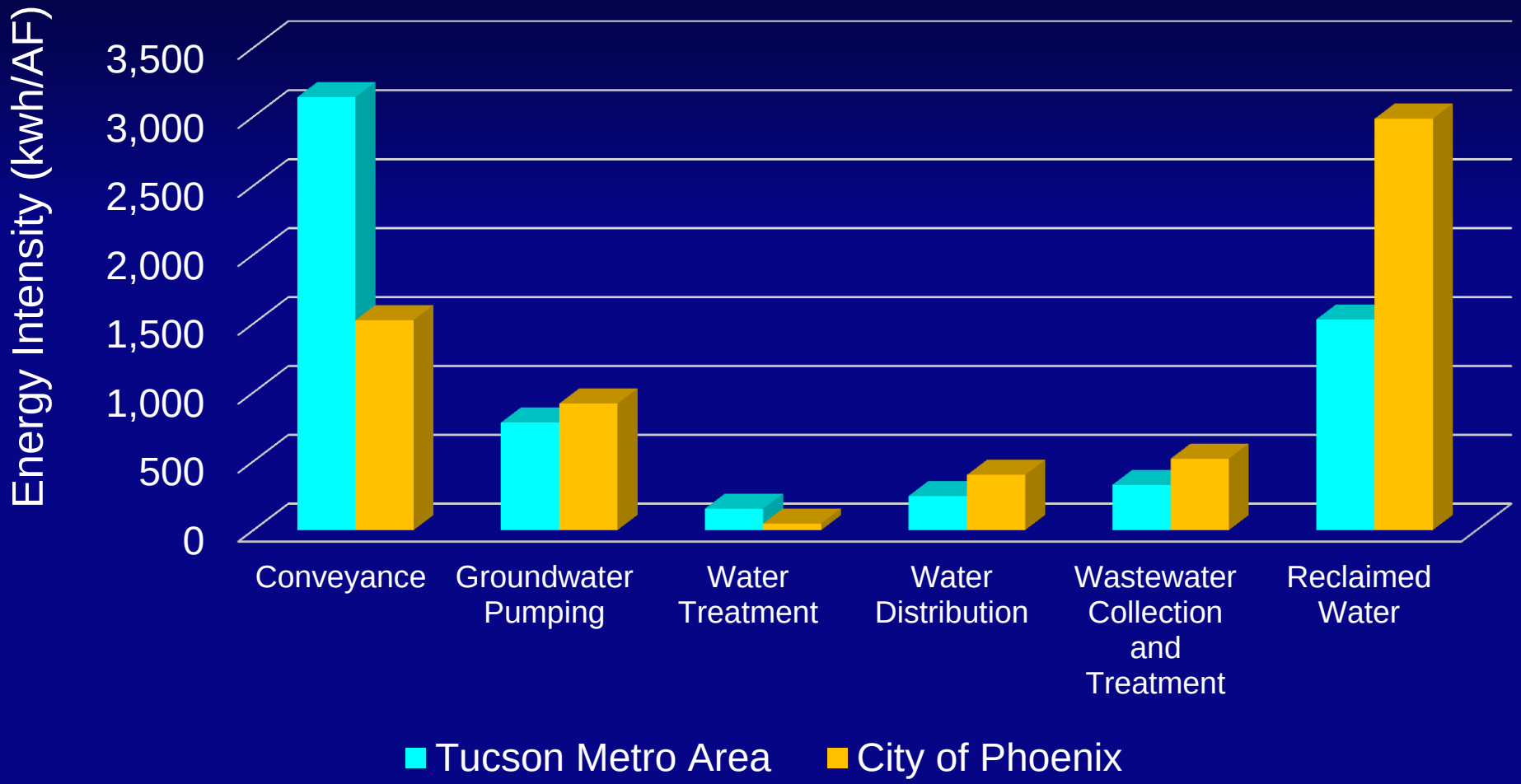


Source: U.S. EIA and National Renewable Energy Laboratory

Energy → Water

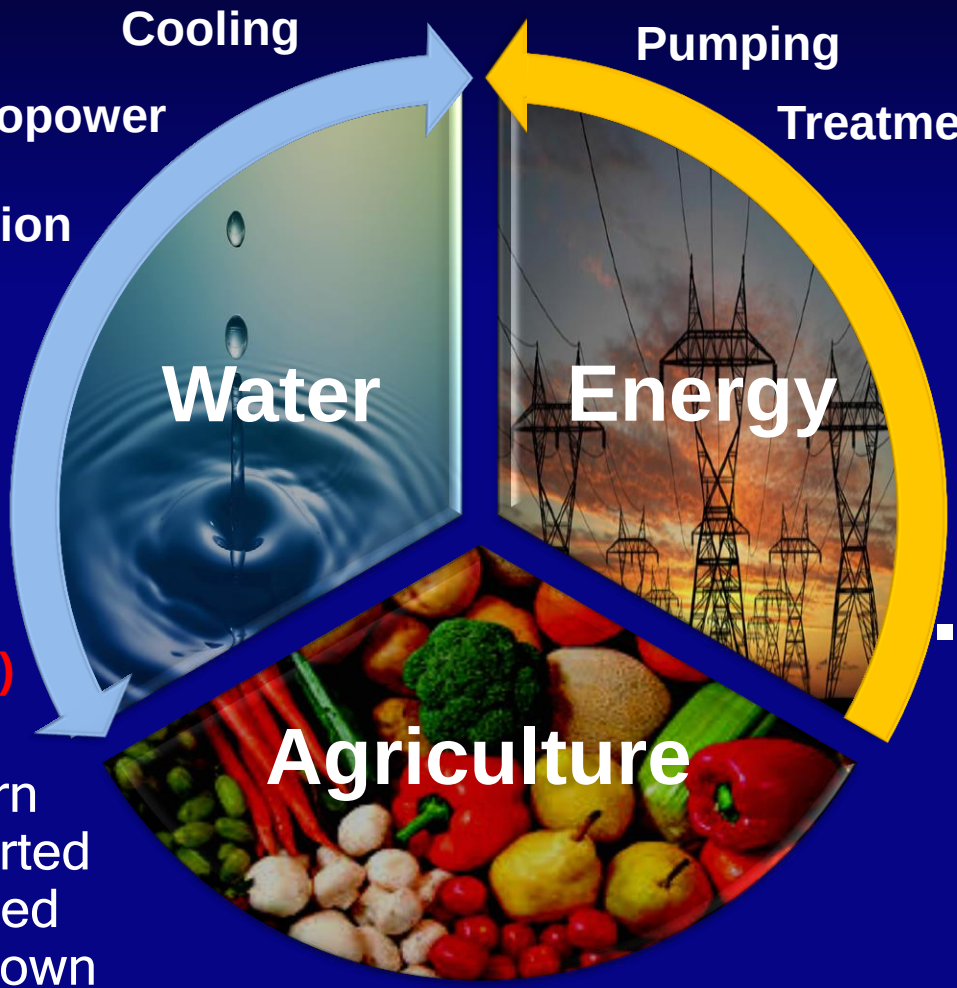


Energy Intensity for Water Service



Source: Hoover, J. J. (2009)

Water → Agriculture



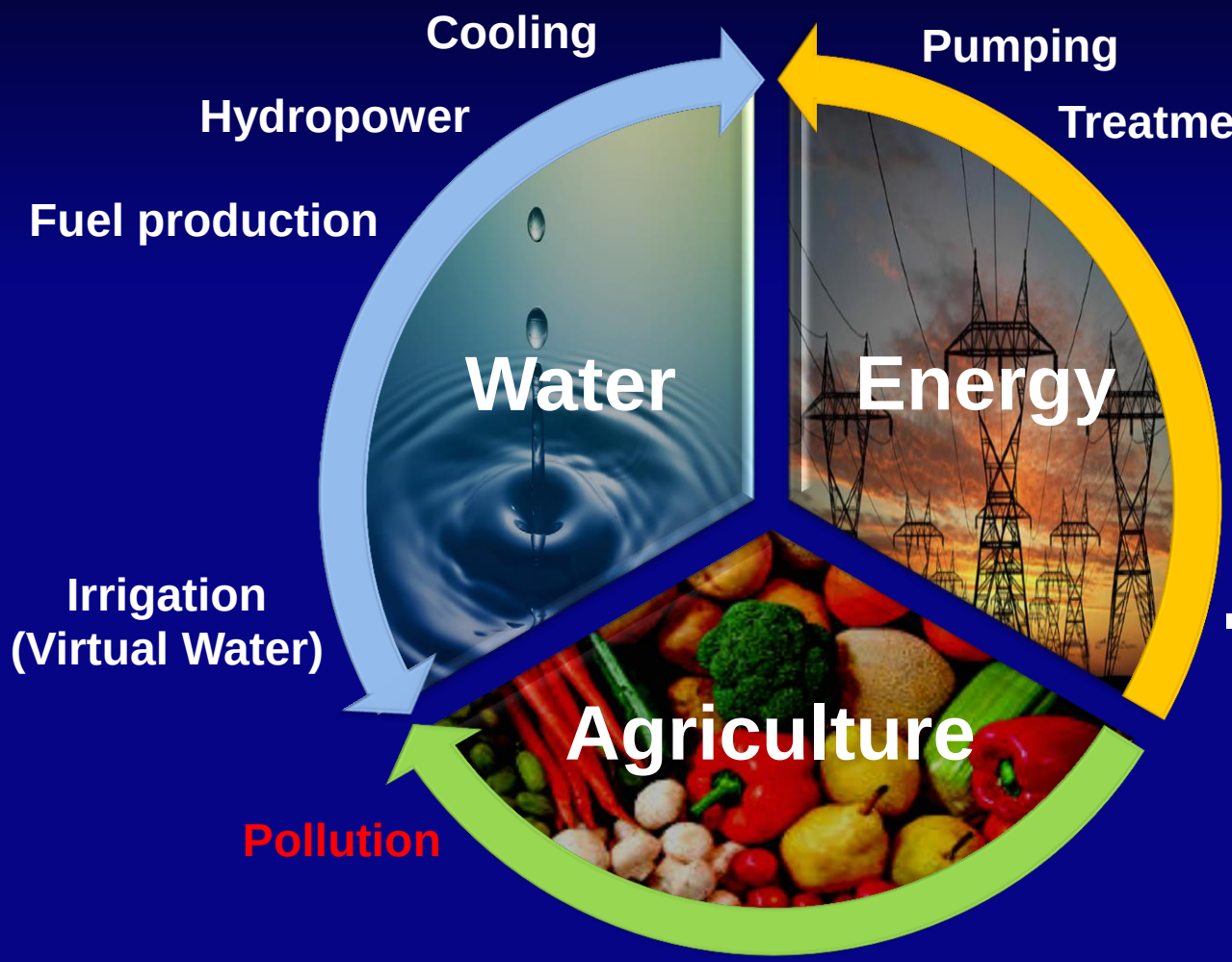
Irrigation (Virtual Water)

- In 2012, roughly 153kAF of western water were exported to China embedded in alfalfa crops grown with irrigation water

- Average 5.16 MAF of water are used by the agricultural water sectors in Arizona (75% of total water use)

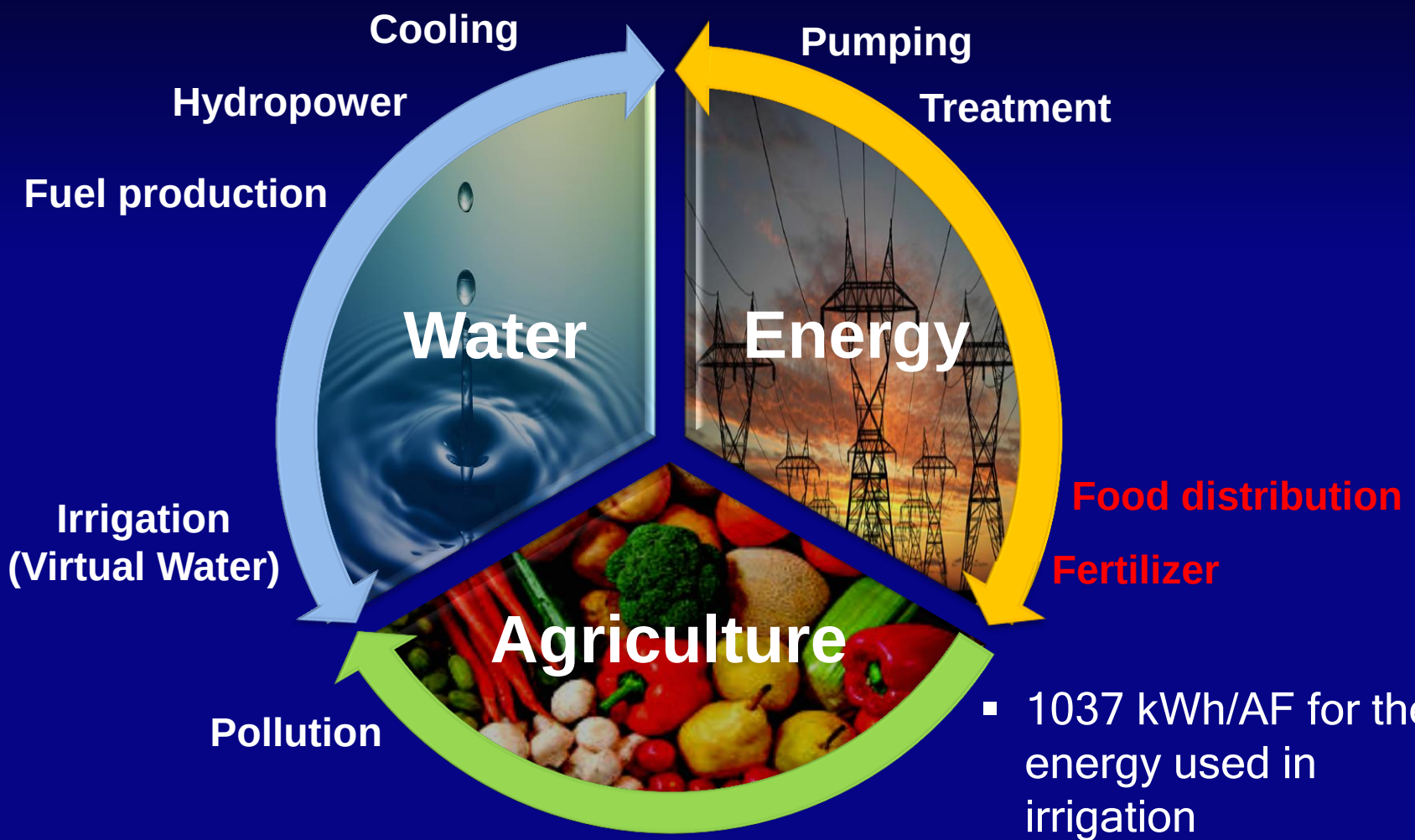
Source: ADWR and Jervey, B. (2014)

Agriculture → Water



- Nutrient runoff from agricultural lands lead to river, stream, and groundwater impairment

Energy → Agriculture

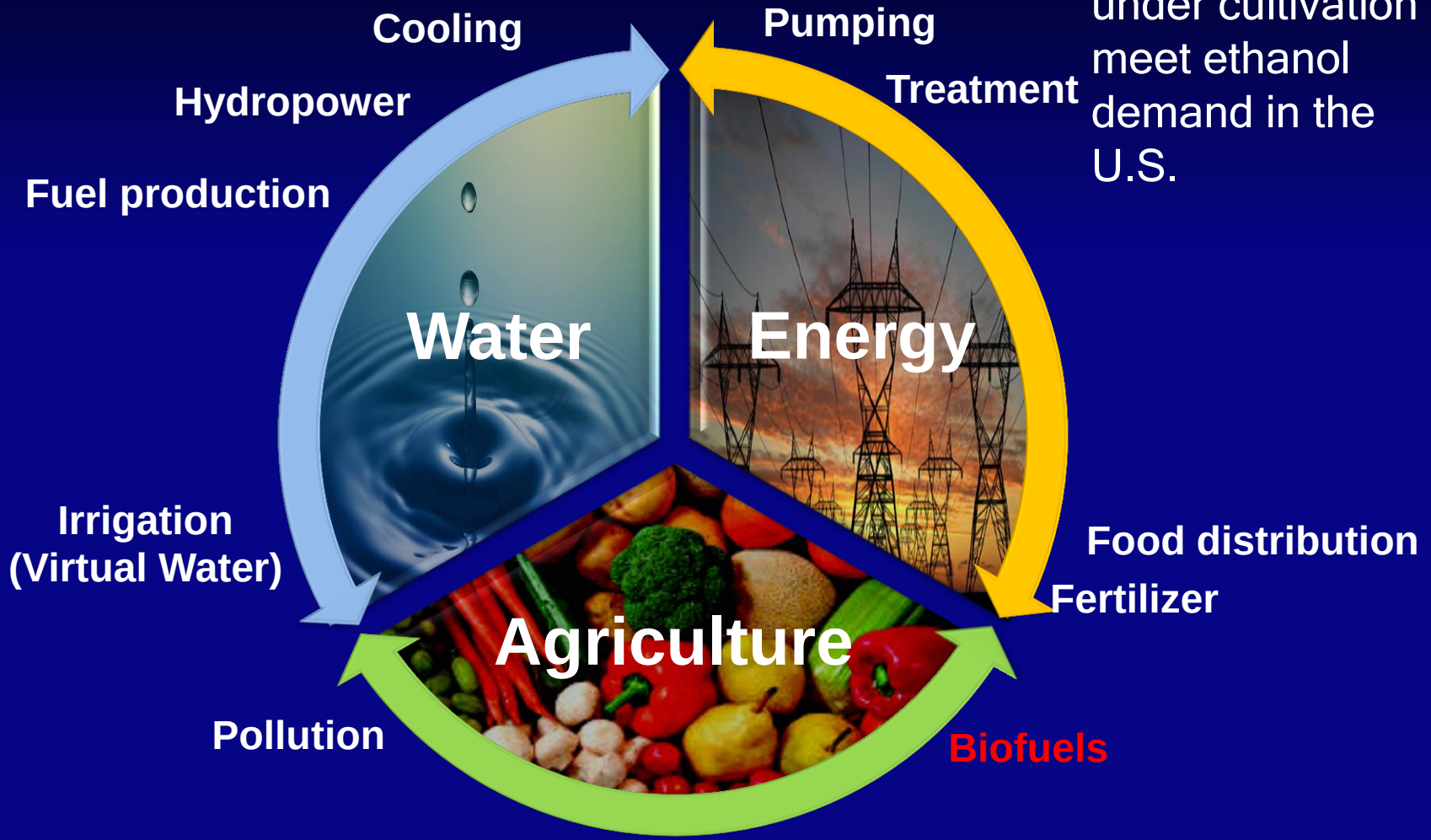


- 1037 kWh/AF for the energy used in irrigation

Source: Wateright, (2008)

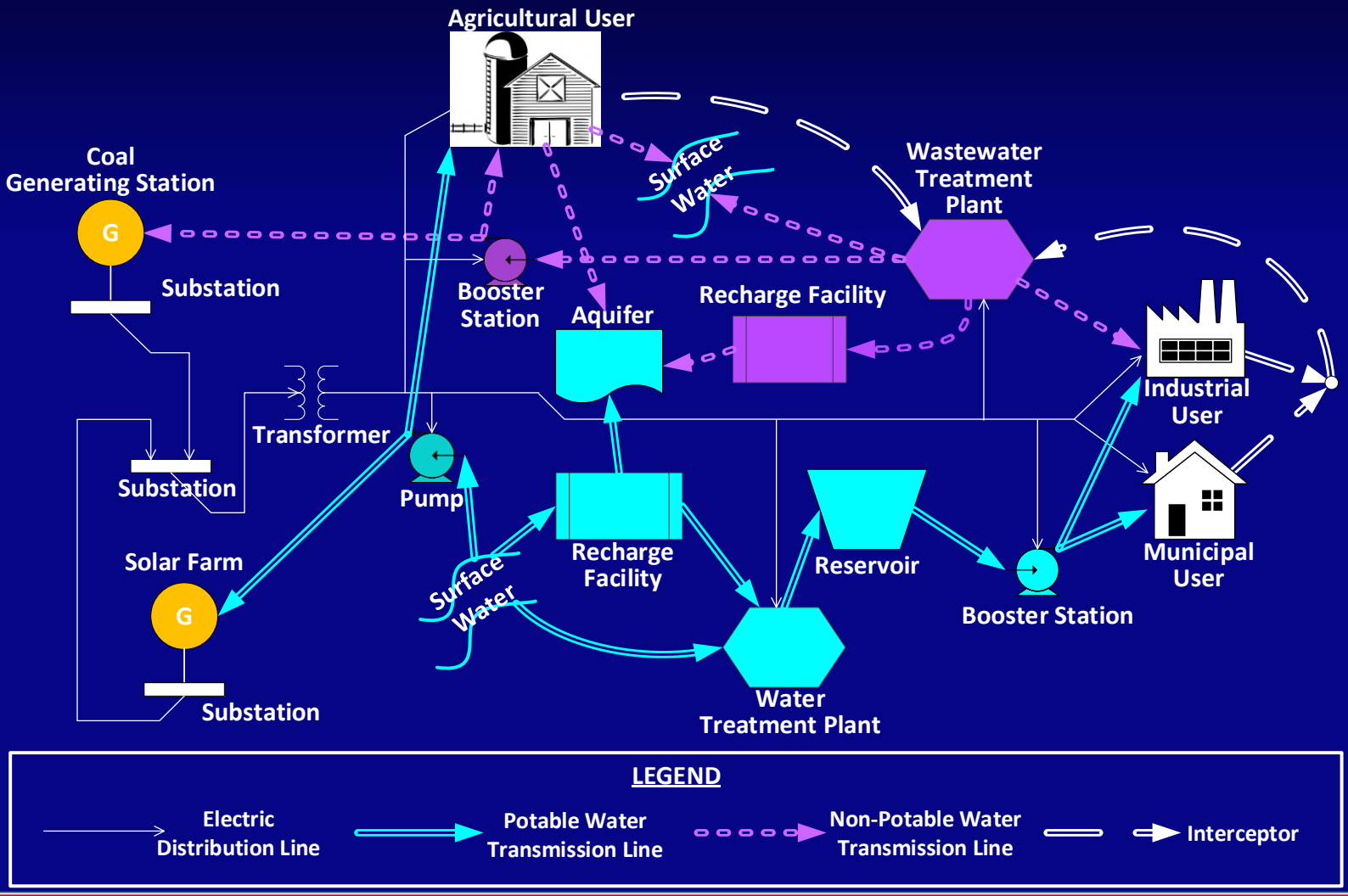
Agriculture → Energy

- 11 million more hectares of sugar cane and corn need to be brought under cultivation to meet ethanol demand in the U.S.

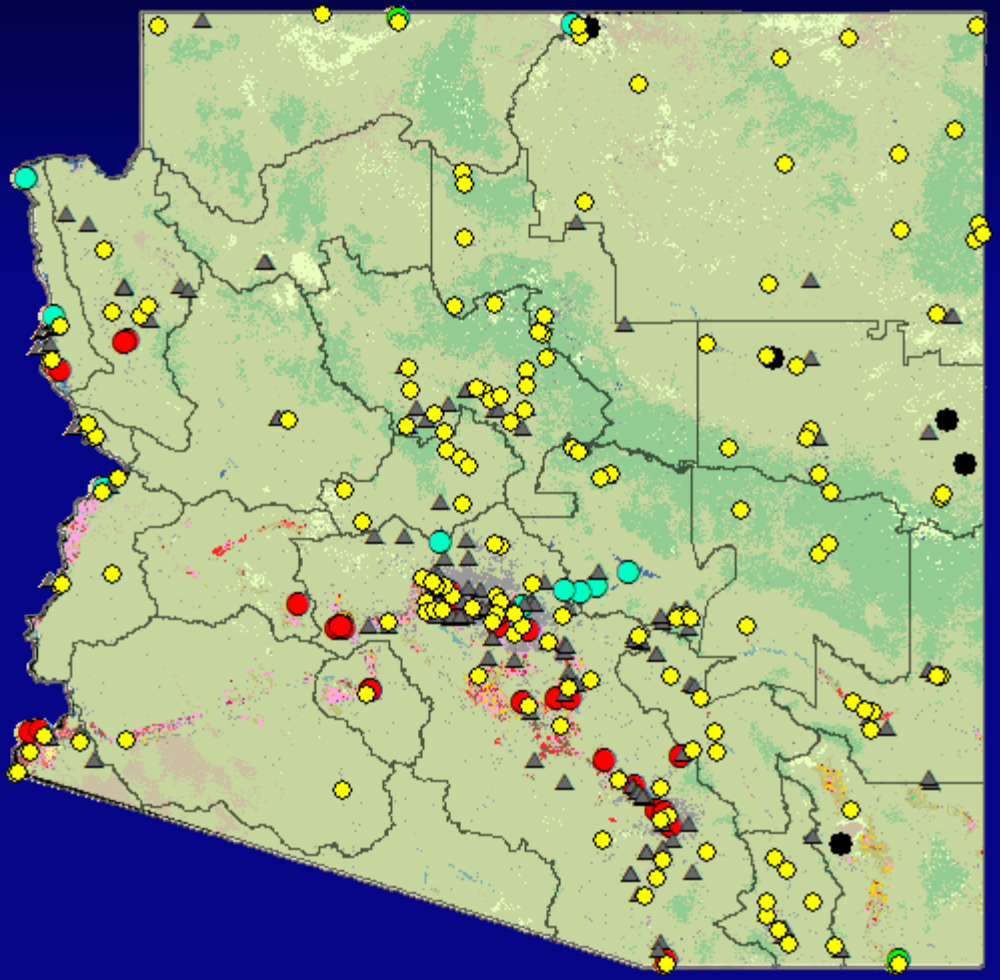


Source: CGIAR

Food, Energy, Water Networks

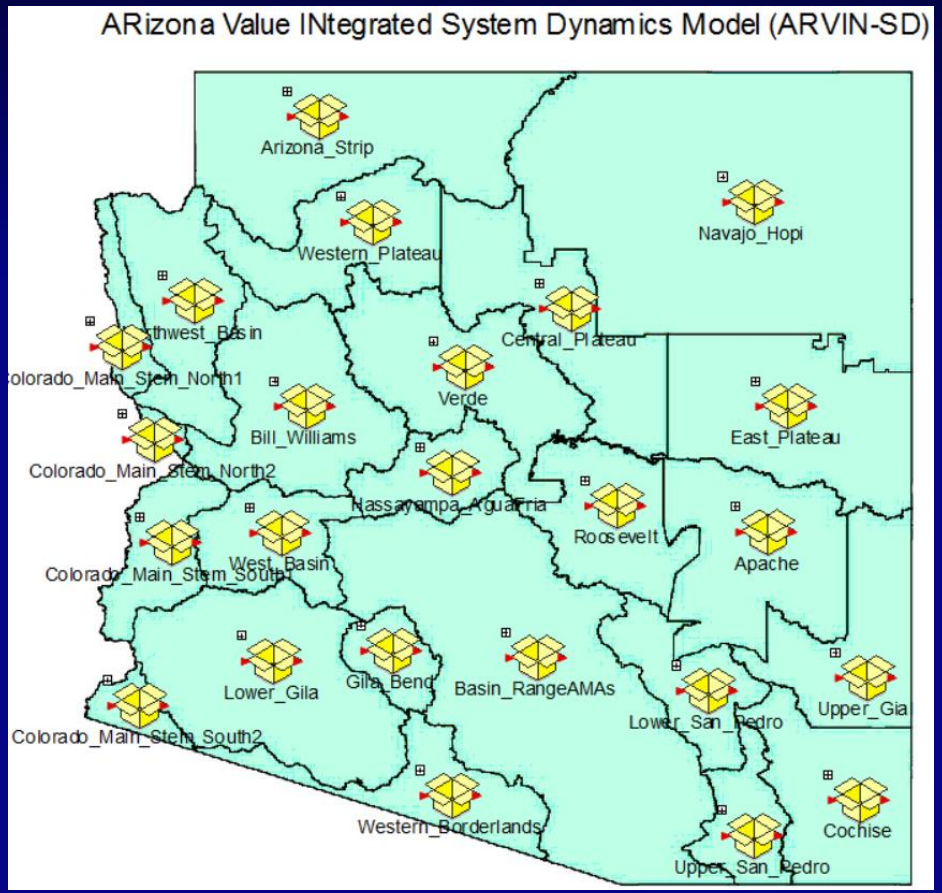


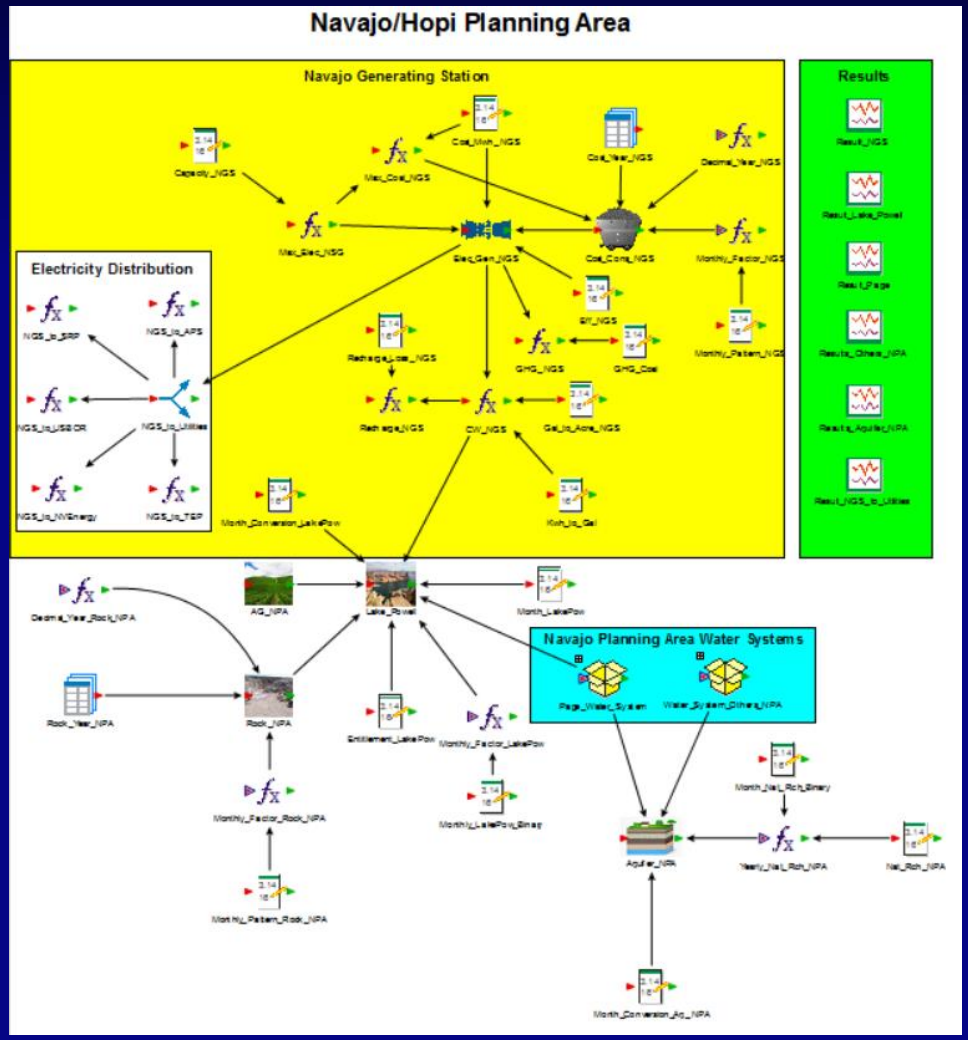
ARVIN's Modeling Coverage



- 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
  - Transmission/Distribution lines
  - Substations
- Mines
- Crop pattern

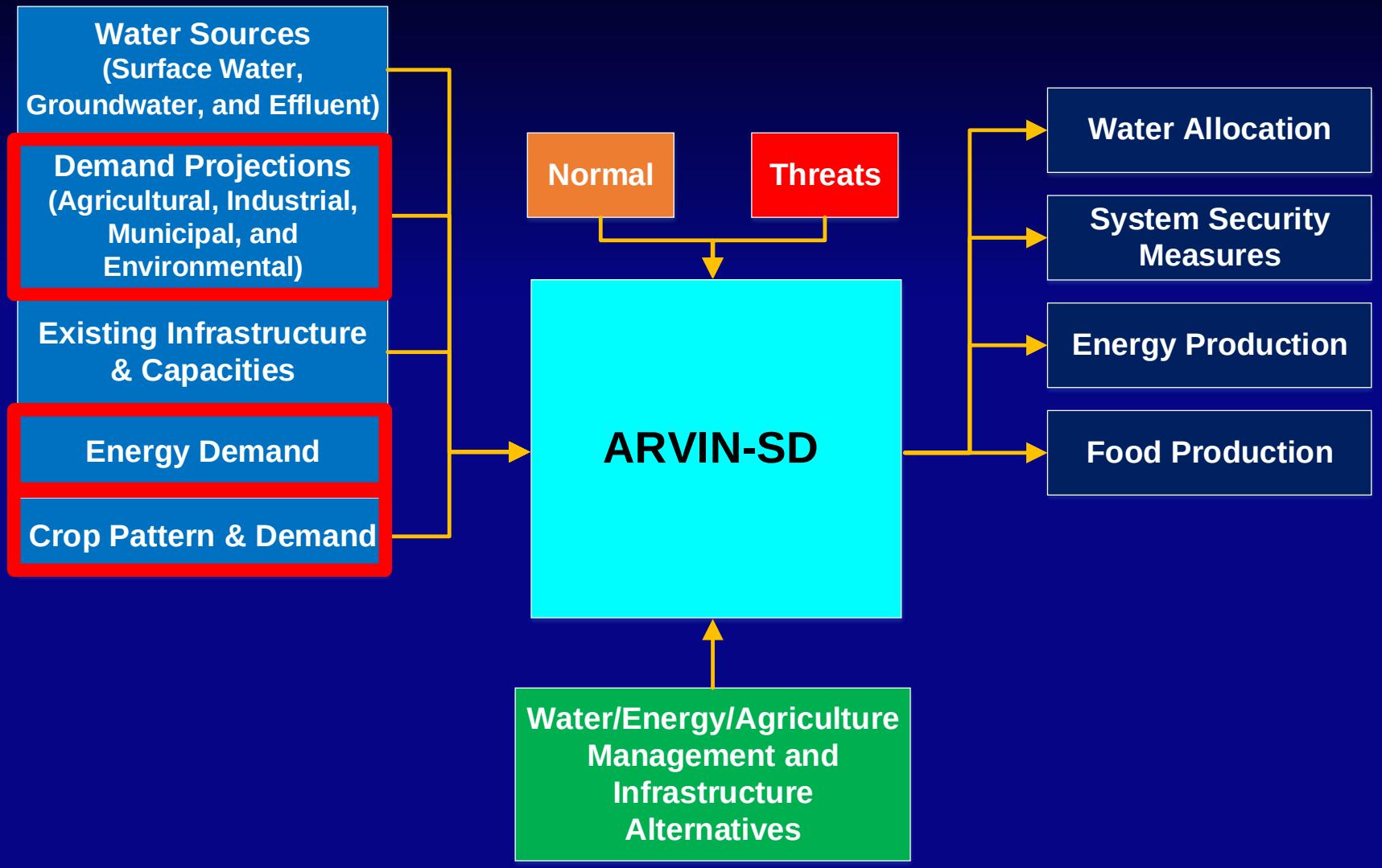
ARVIN-SD



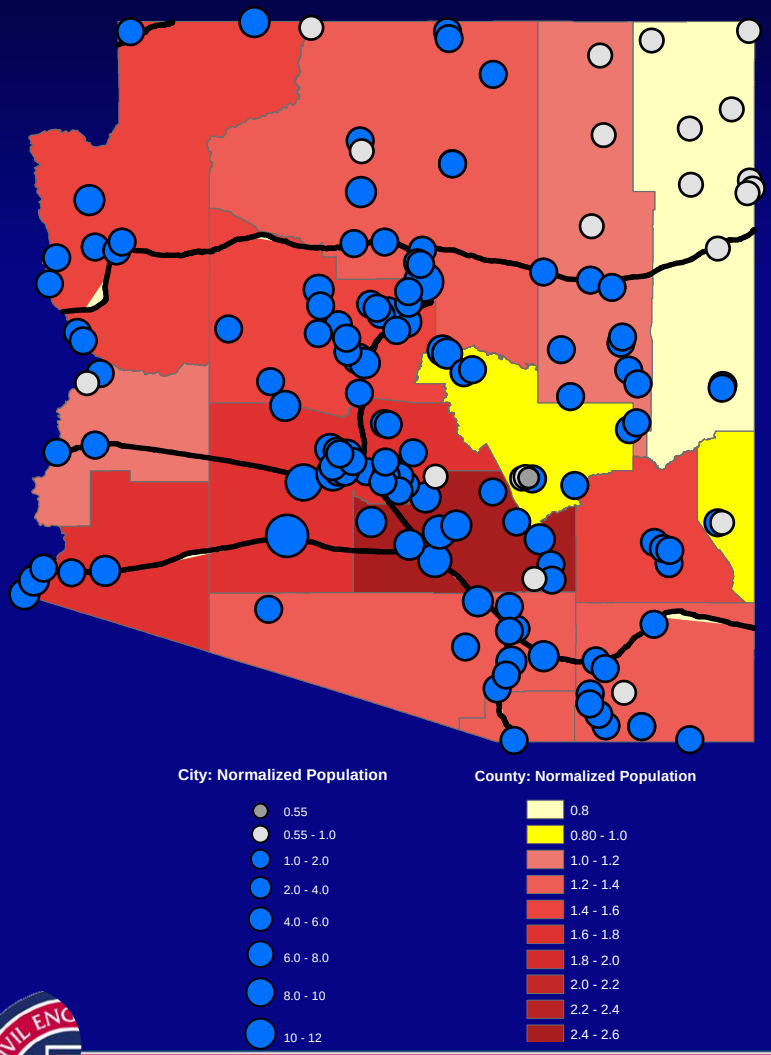


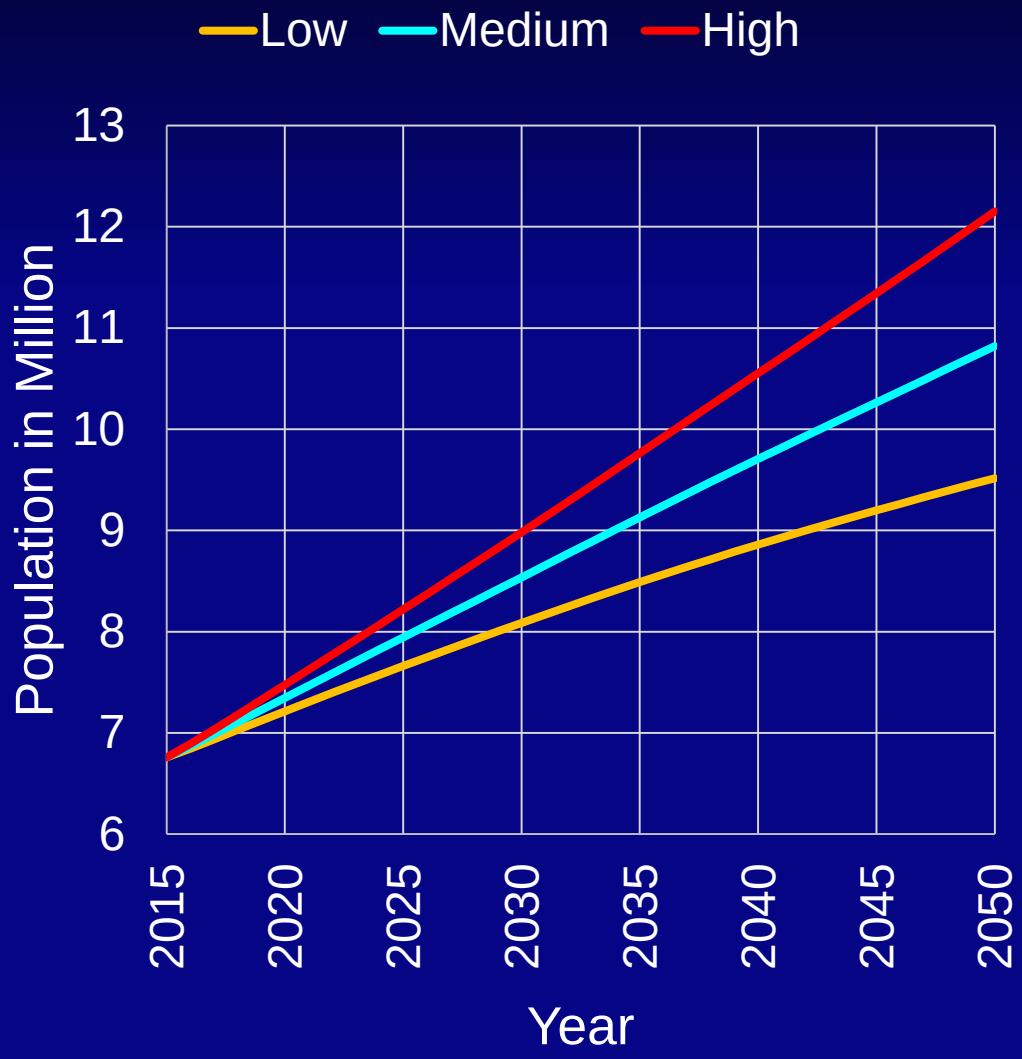
GoldSim

ARVIN-FEW Structure

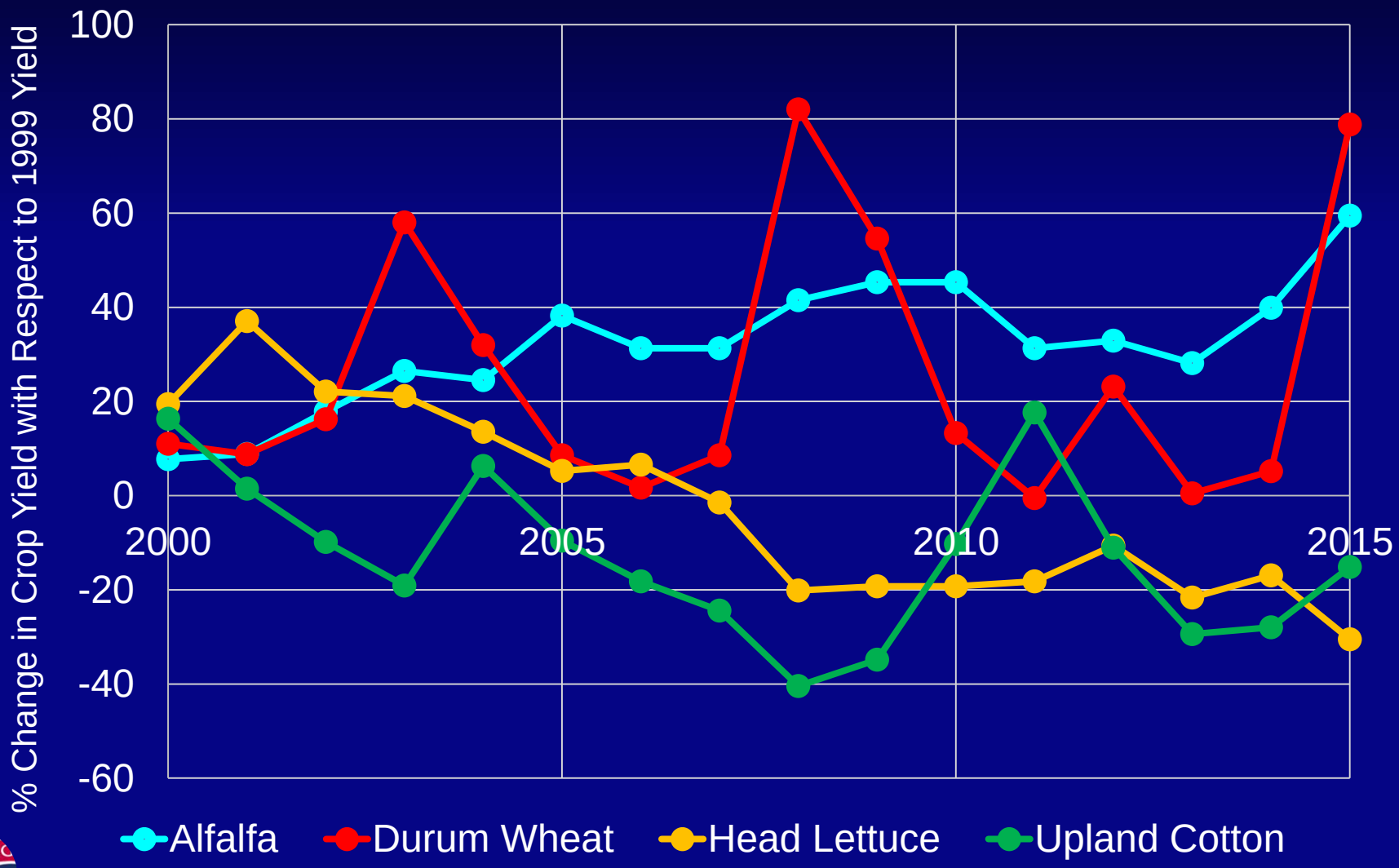


Population Growth Scenarios in AZ

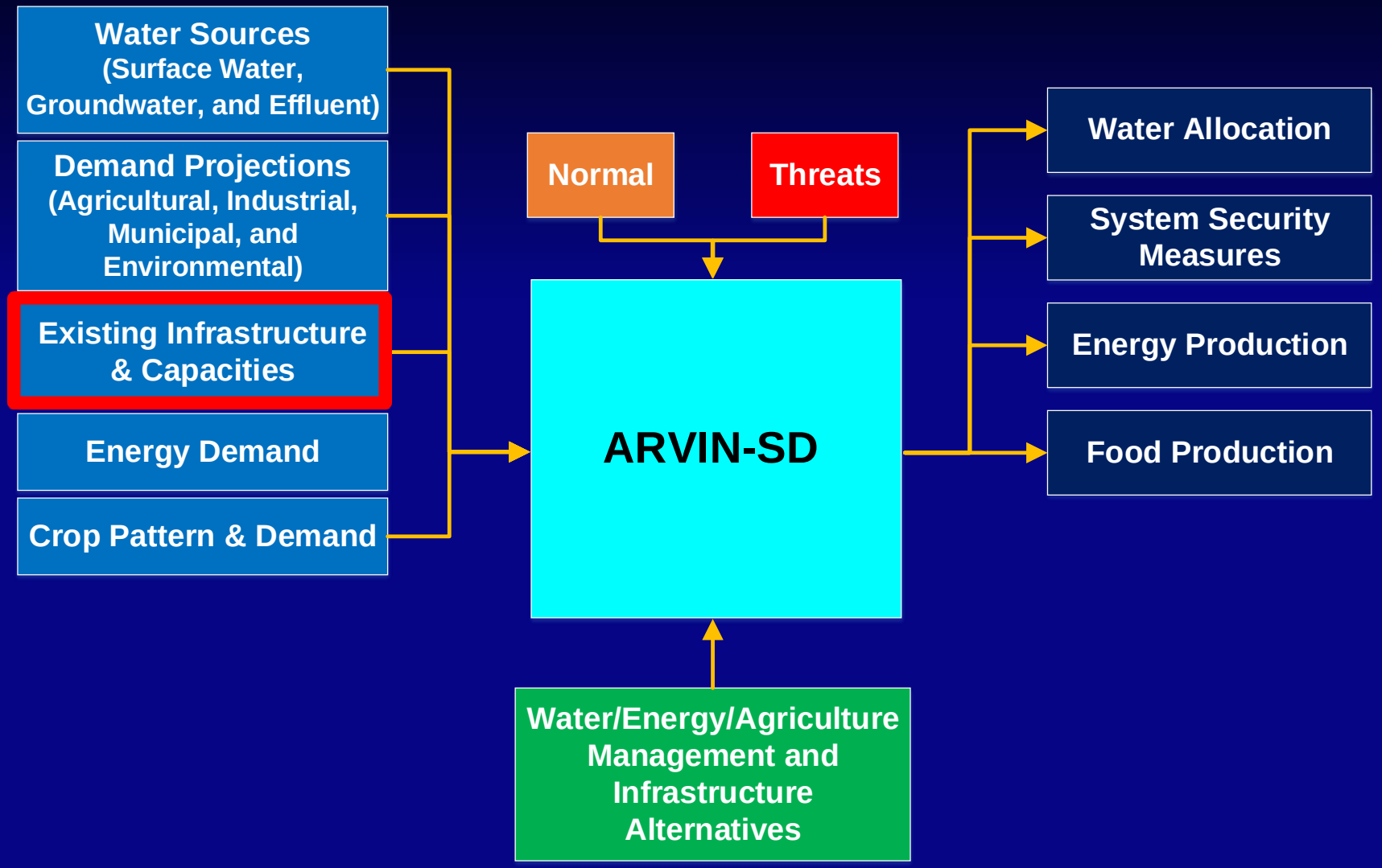




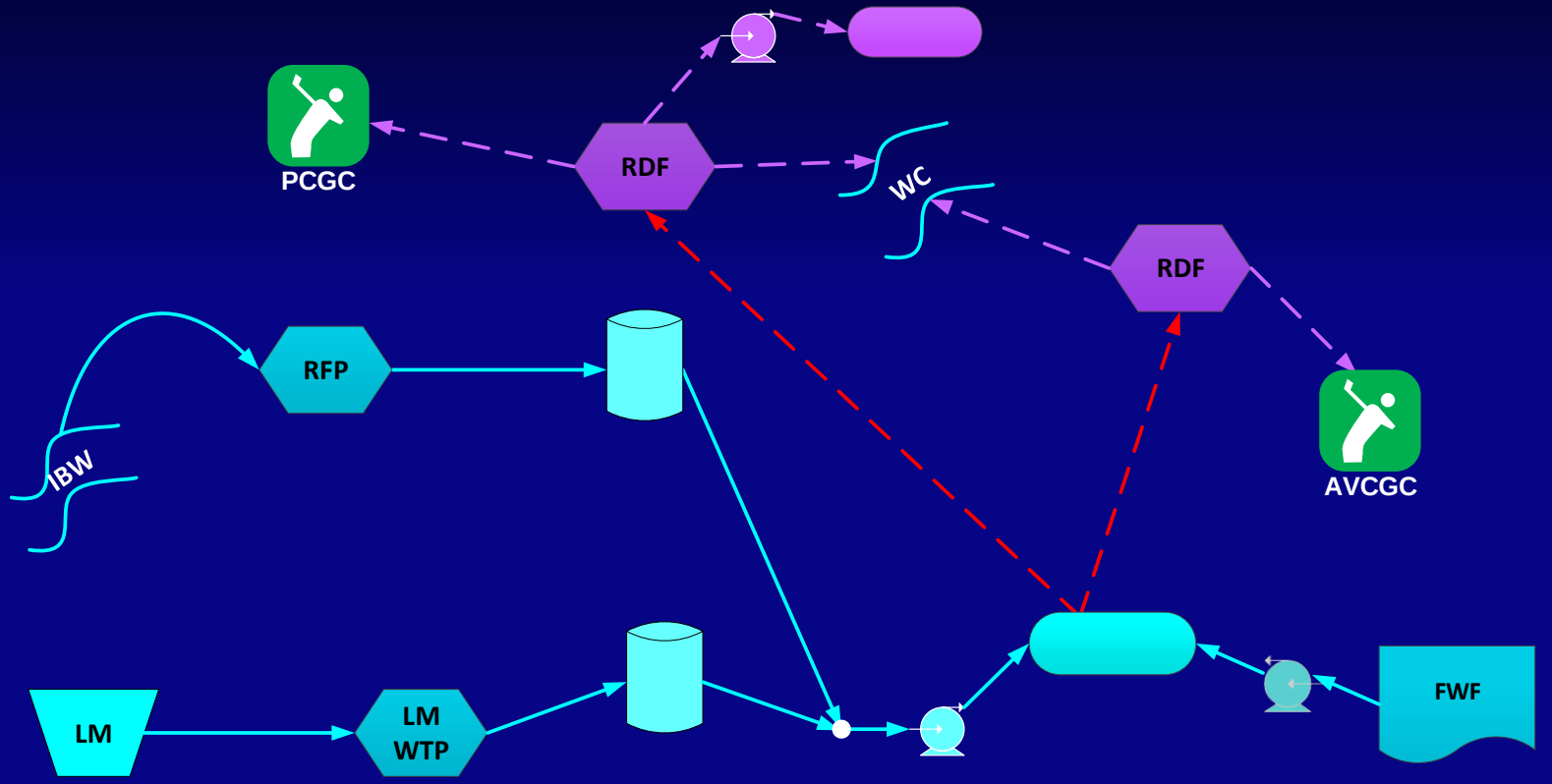
Crop Pattern and Demand



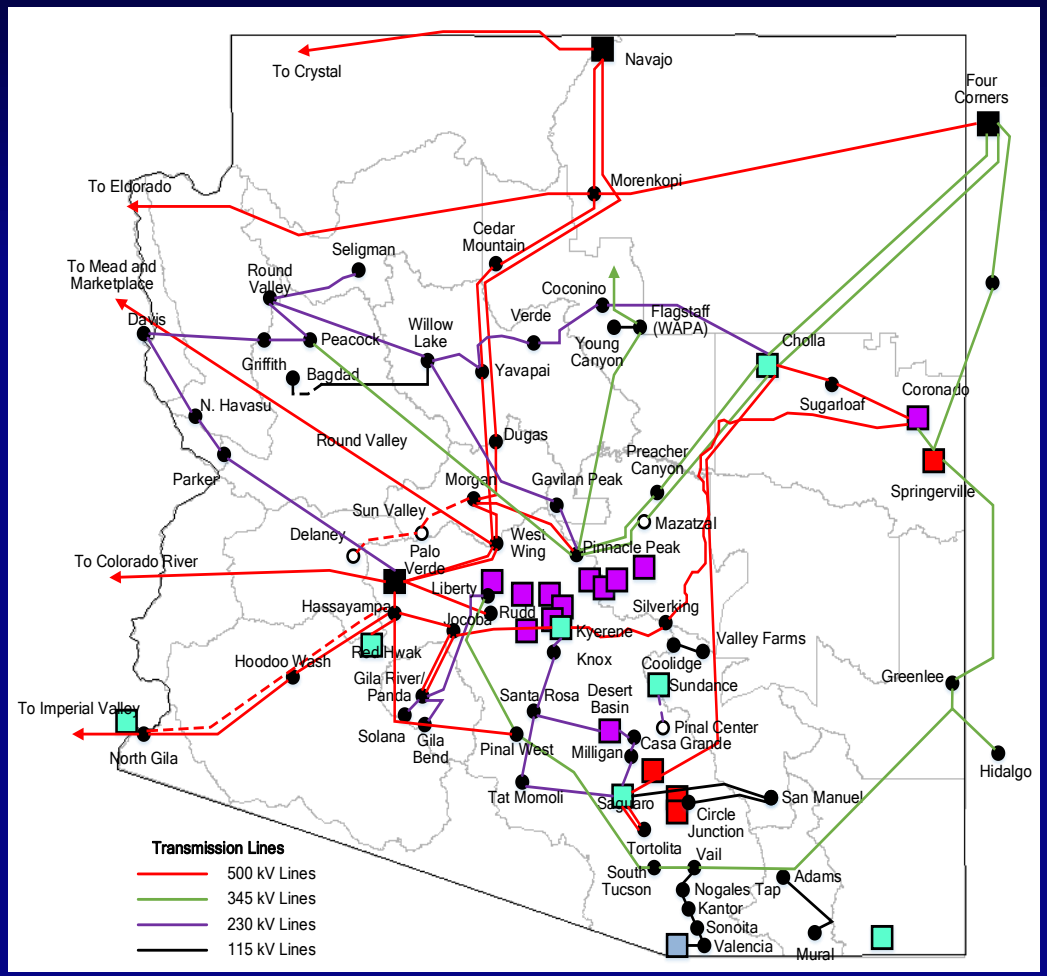
ARVIN-FEW Structure



Water Supply System

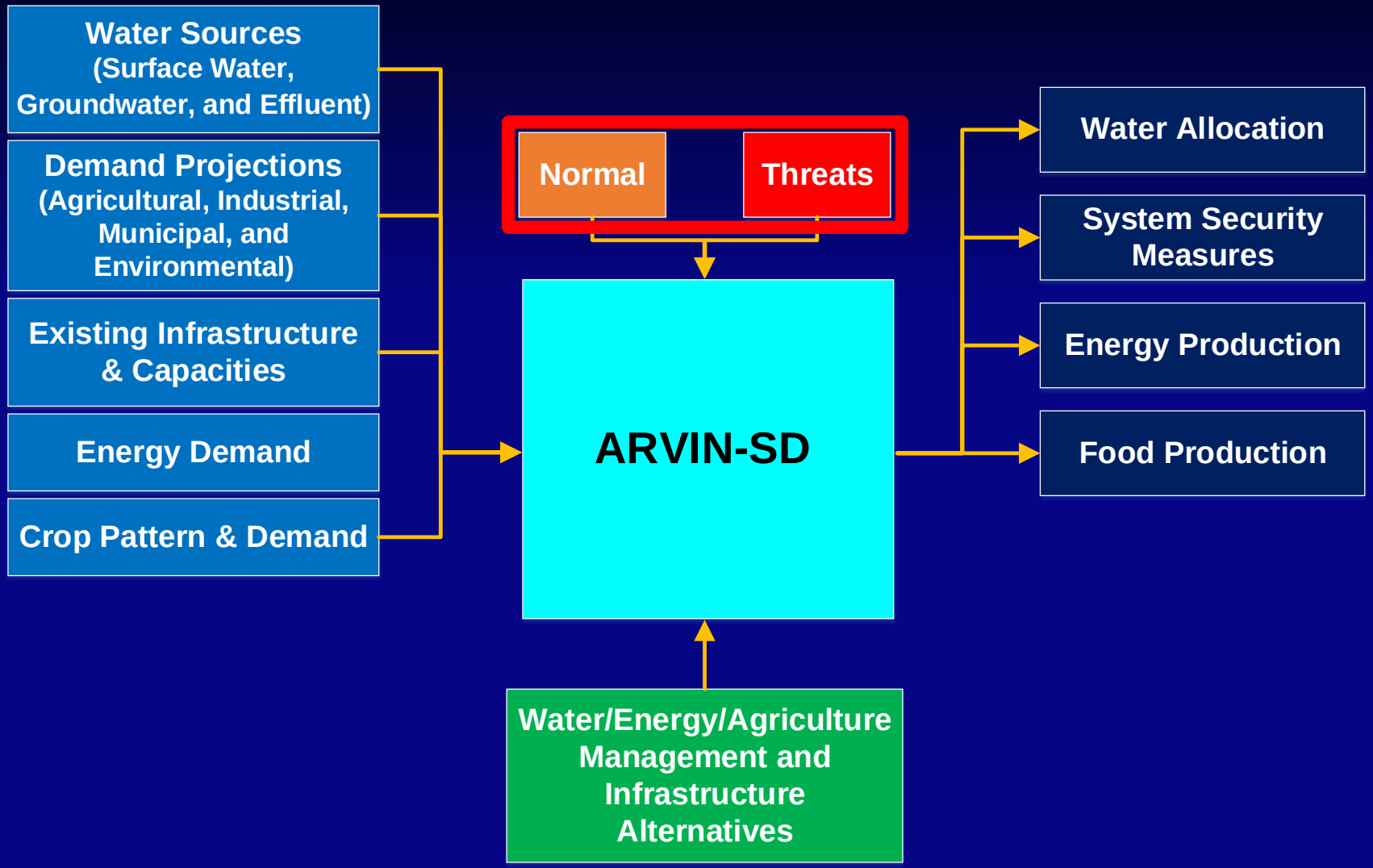


Electric Power Distribution Network

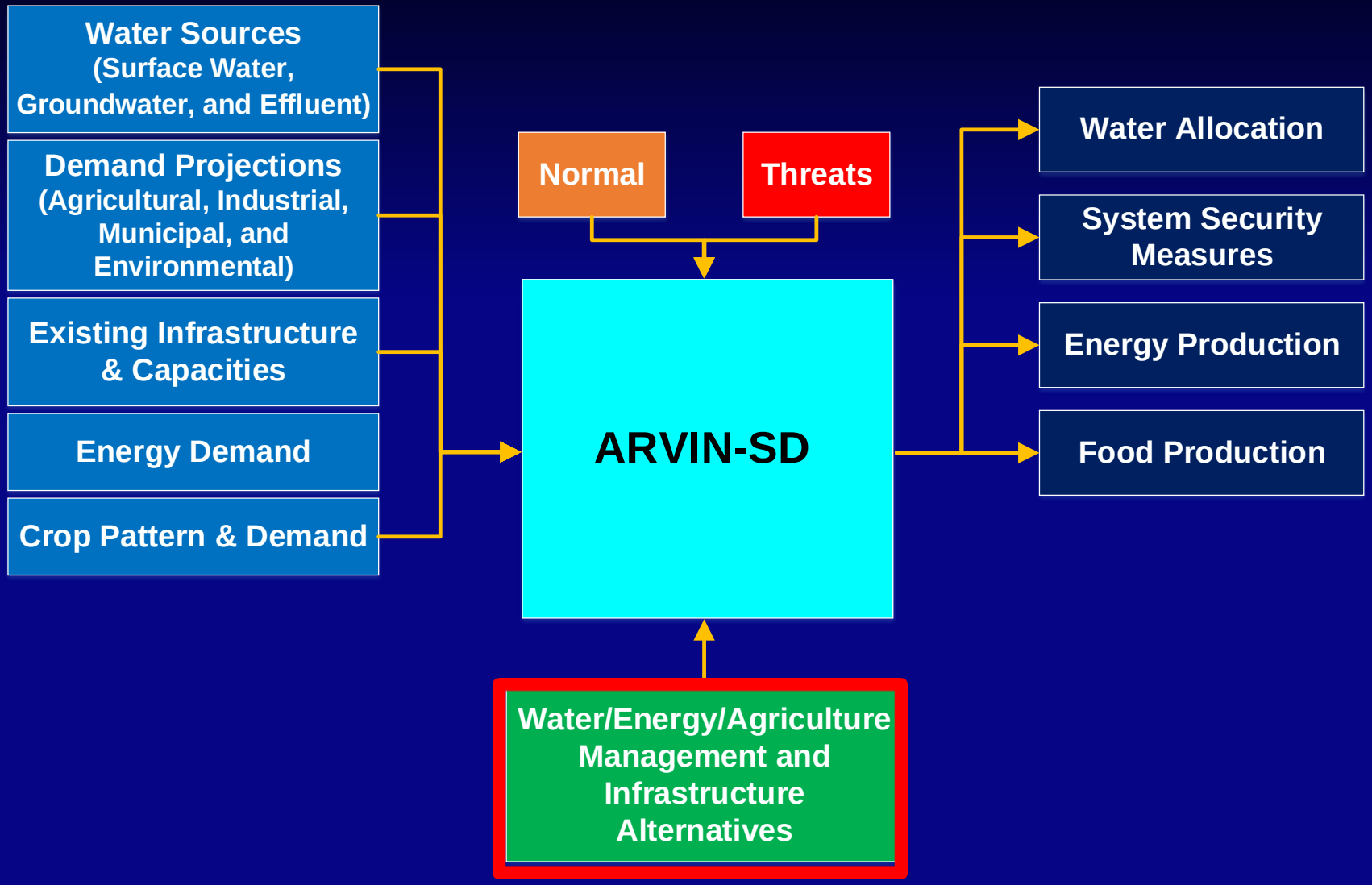


- Electricity utilities
- Power plants
  - Coal
  - Gas
  - Nuclear
  - Hydroelectric
- Transmission lines
- Distribution lines
- Substations

ARVIN-FEW Structure



ARVIN-FEW Structure



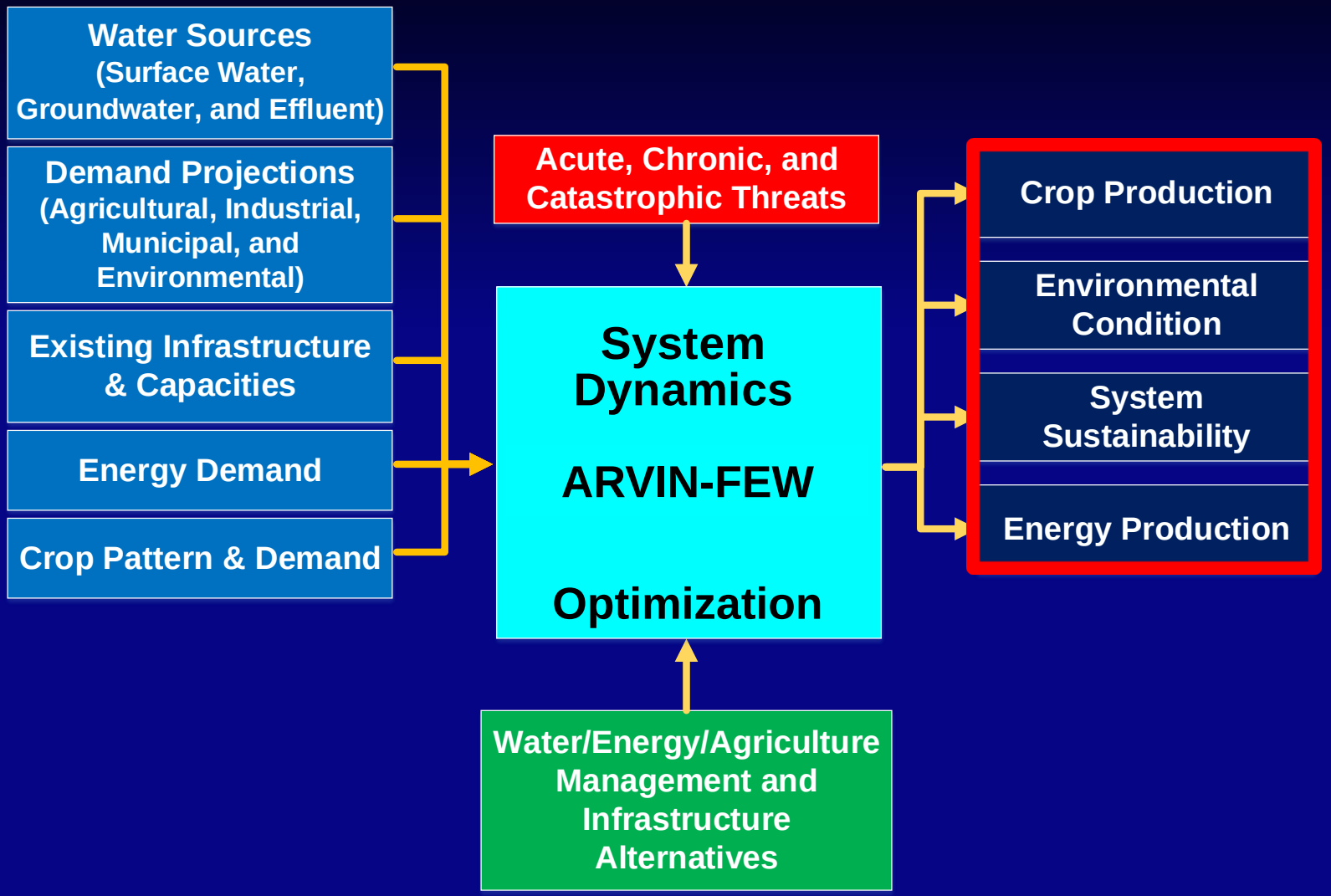
Potential Management Alternatives

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

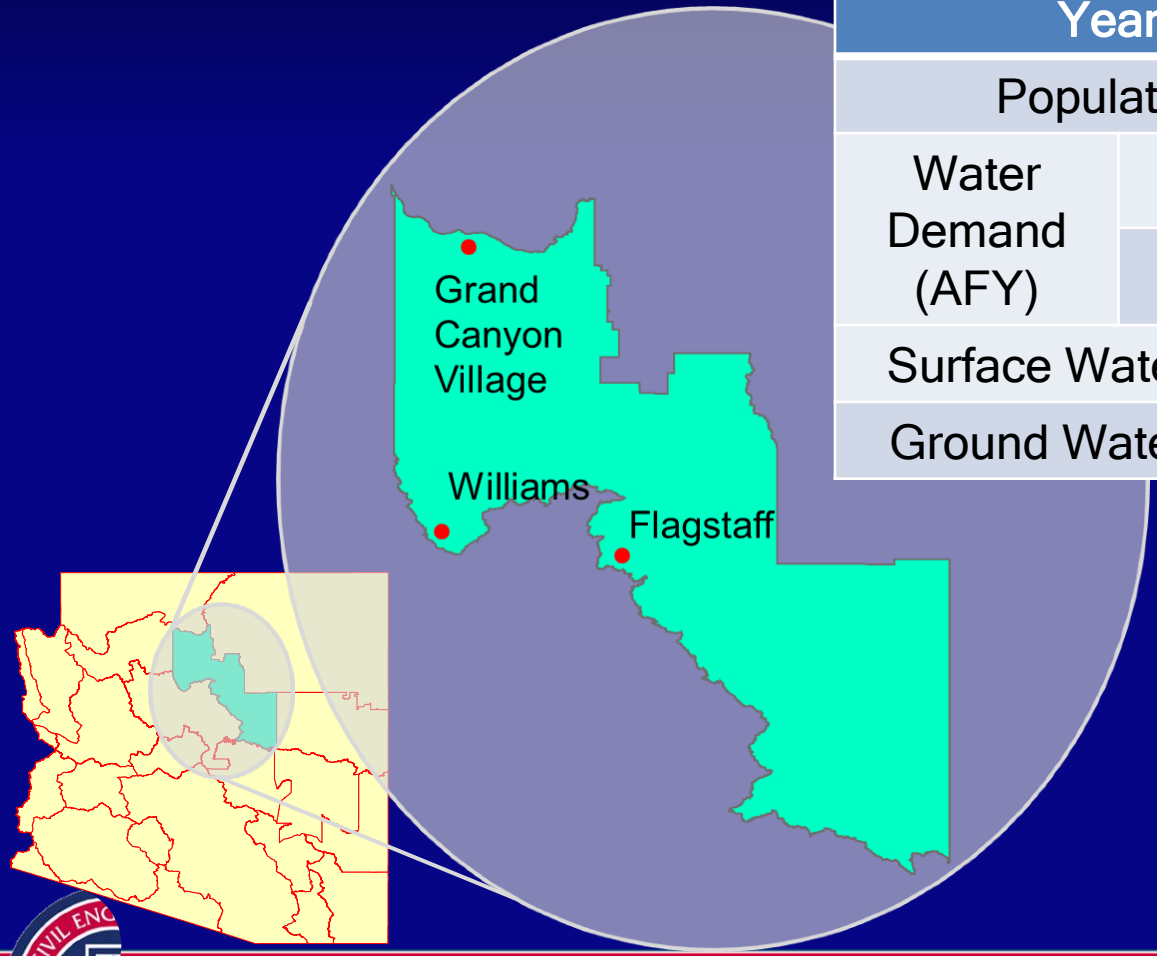
- Renewable energy
- Low water cooling
- Increasing efficiency
- Development of new transportation system

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

ARVIN-FEW Structure



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

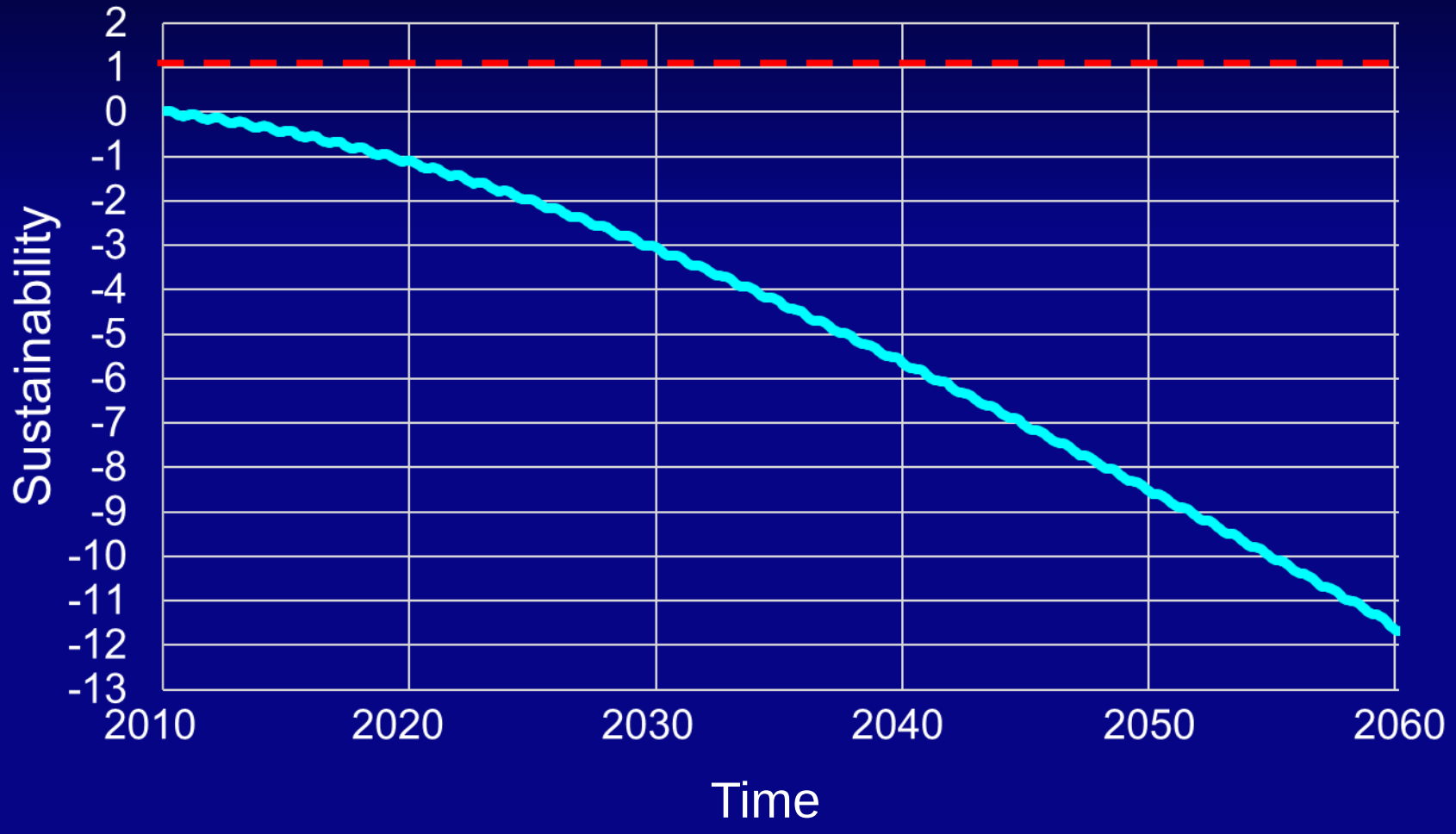
- Describe long term ability of water supply to maintain satisfaction state
- $Sustainability_{i,t} = \frac{X_{t-1} + R_t - X_{min}}{W_t}$

Acronym

i = groundwater basin i
X_{t-1} = amount of water storage at the end of previous year
X_{min} = minimum allowable groundwater storage
R_t = amount of renewable supply in current year
W_t = Groundwater withdrawl in current year

- Safe yield goal $\rightarrow$ pump usage=recharge credit
$\rightarrow Sustainability_{i,t} \geq 1$

Sustainability of the Central Plateau Planning Area (PA)



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

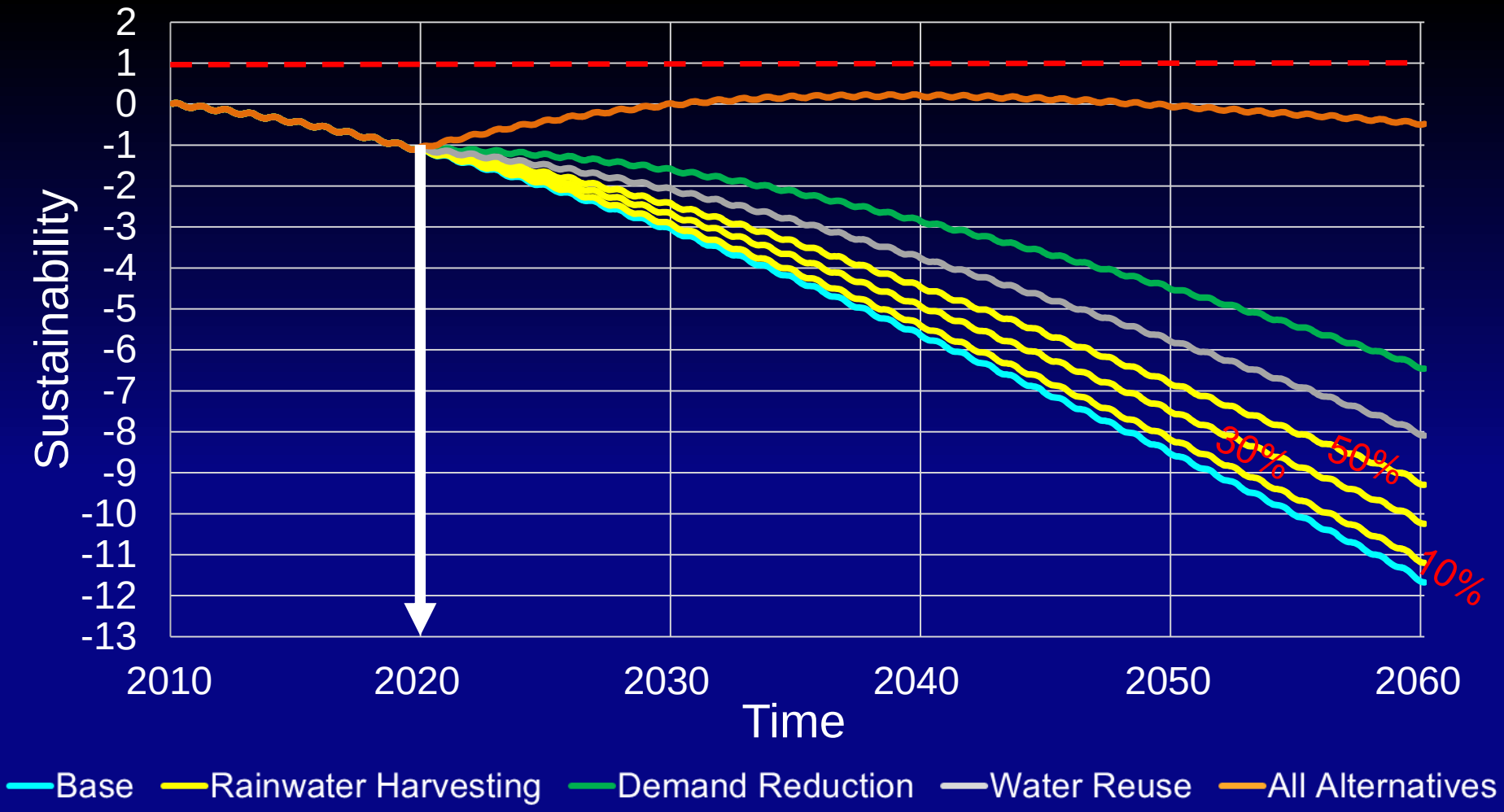
Water Importation
City of Flagstaff can obtain groundwater from the C-Aquifer by the Red Gap Ranch Project starting from 2030.

City of Flagstaff can obtain surfacewater

Water Conservation

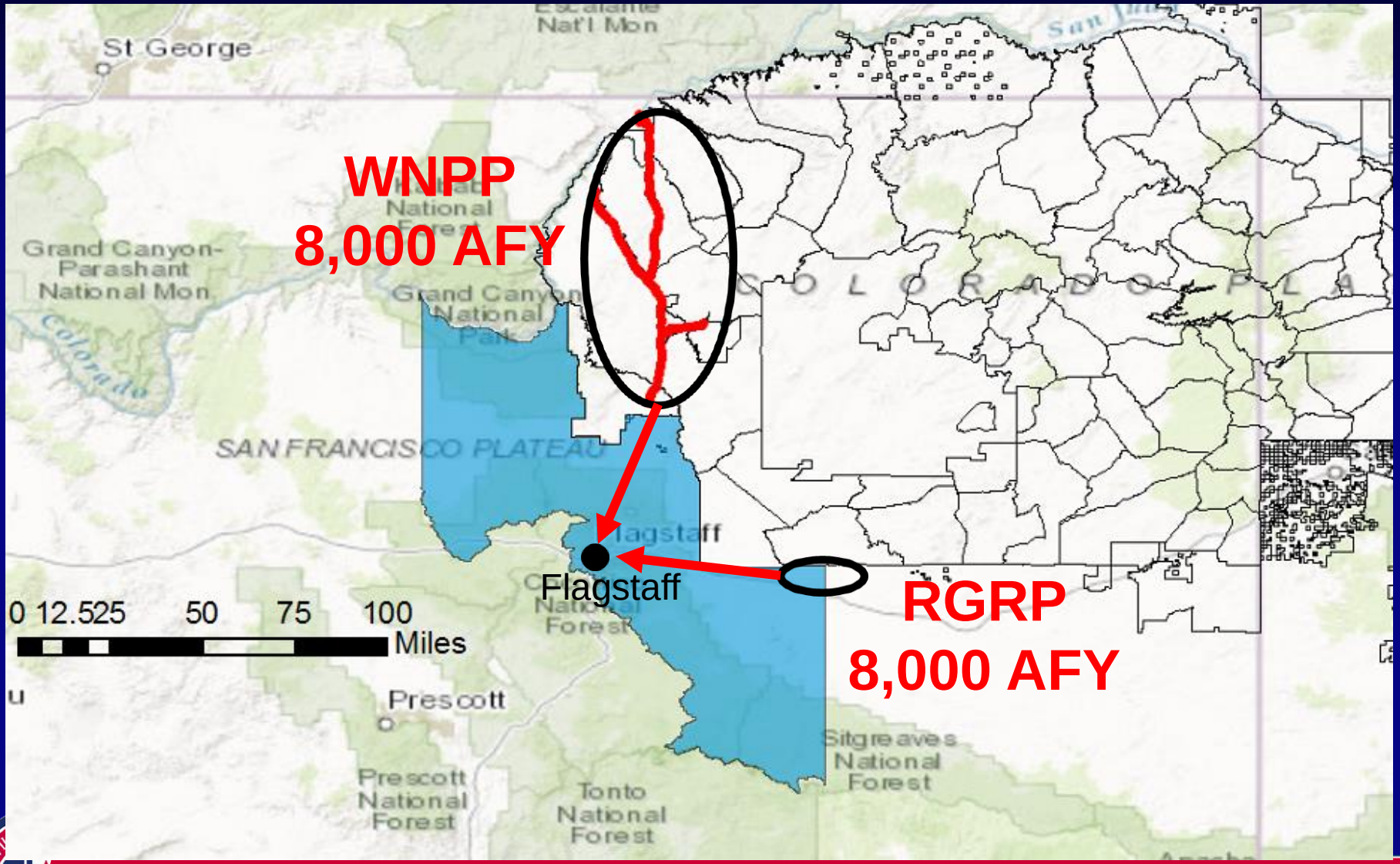
- [x] Rainwater Harvesting
  - Adopotation Rate: 0 — 50 — 100
  - Roof Size (ft^2): 2079
- [x] Reclaimed Water Reuse
  - Percent Use: 0 — 10 — 100
- [x] Demand Reduction
  - Percent Reduction: 0 — 10 — 100

Result Graphs | Browse Model | Run Model



- Rainwater harvesting: 2,079 ft^2 roof size and 10, 30, and 50% adoption rates
- Demand reduction: 10% decrease
- Water reuse: 10% increase in reclaimed water use

Potential Instate Water Importation



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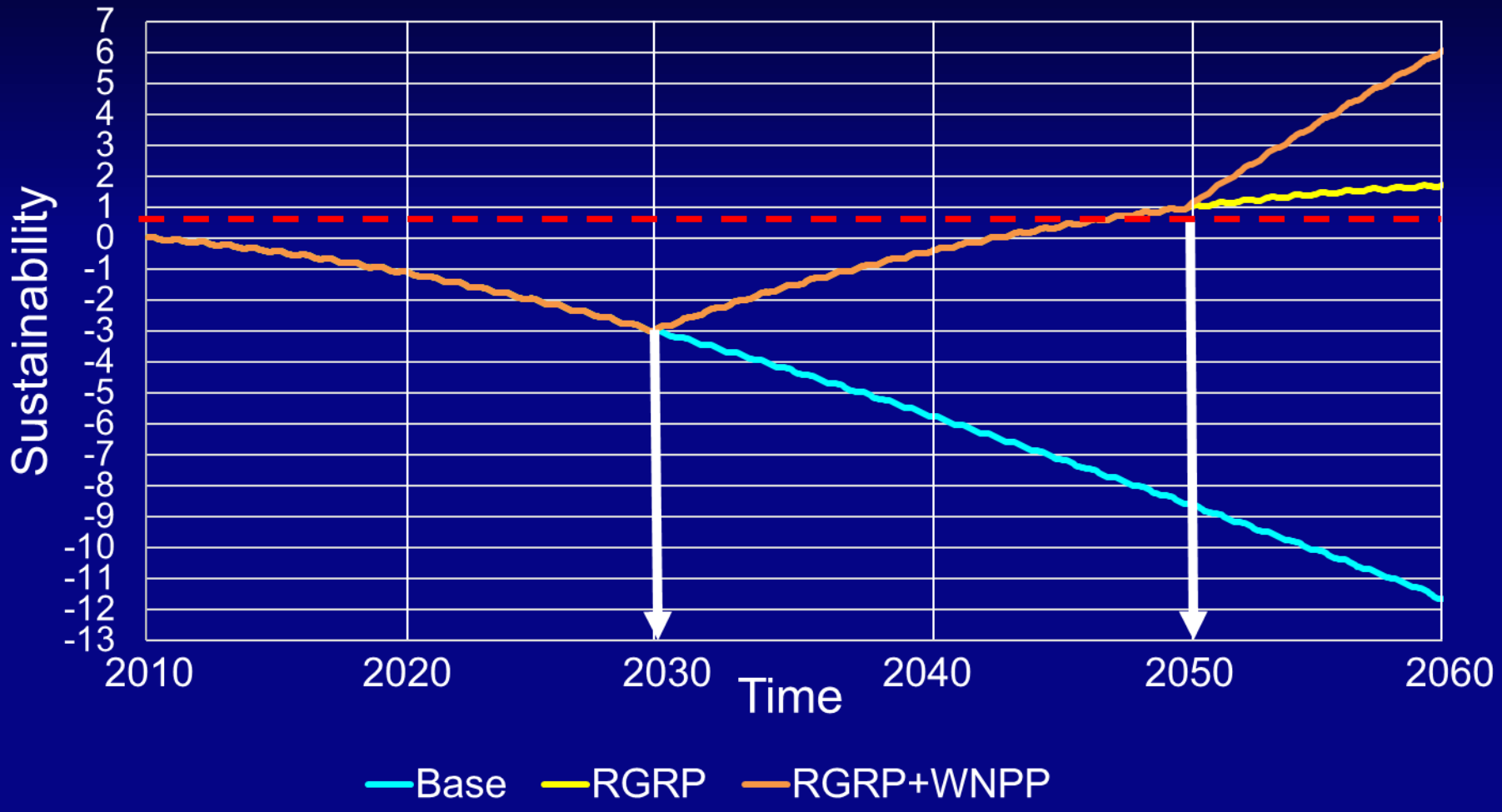
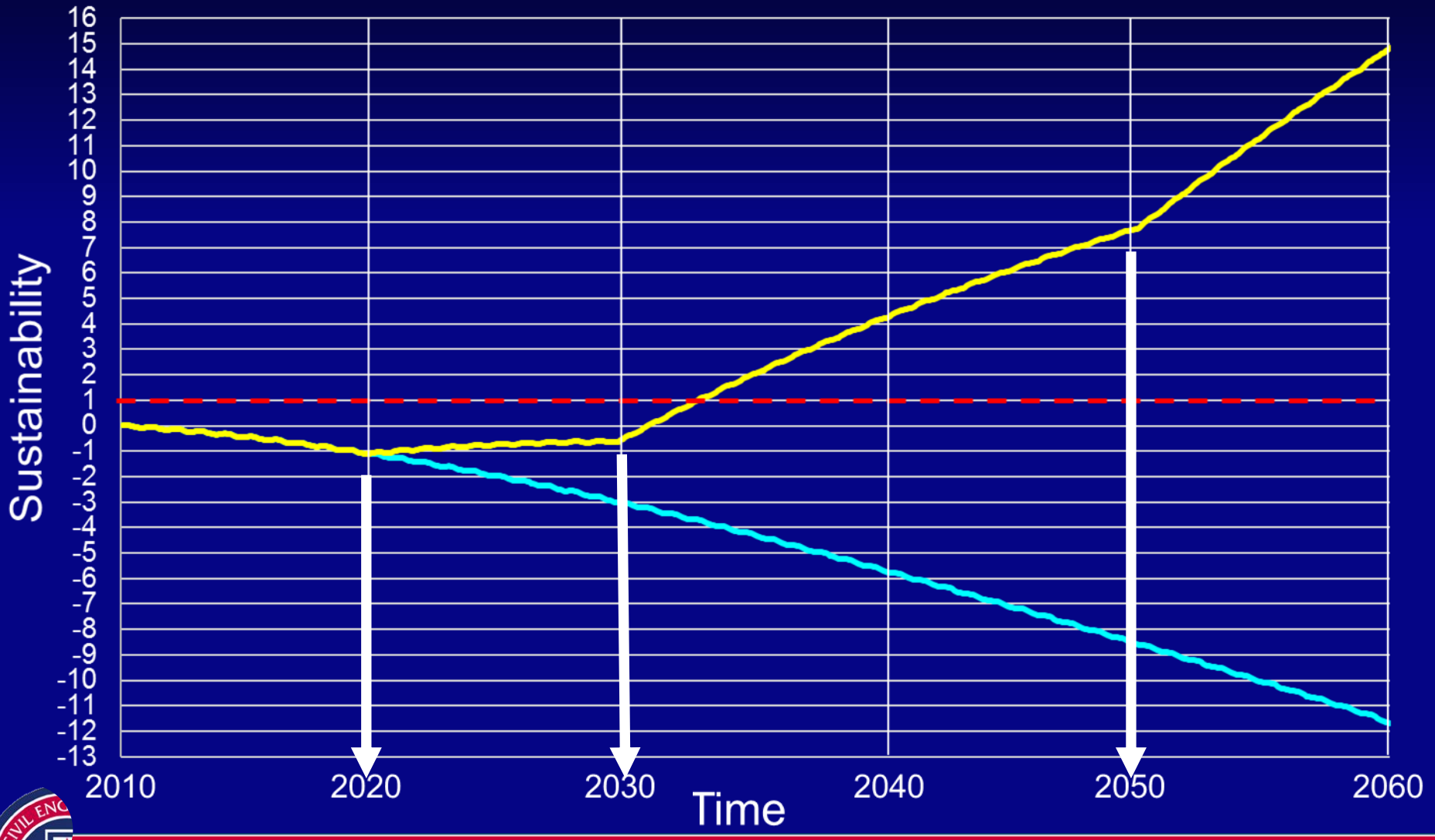
Result Graphs | Browse Model | Run Model

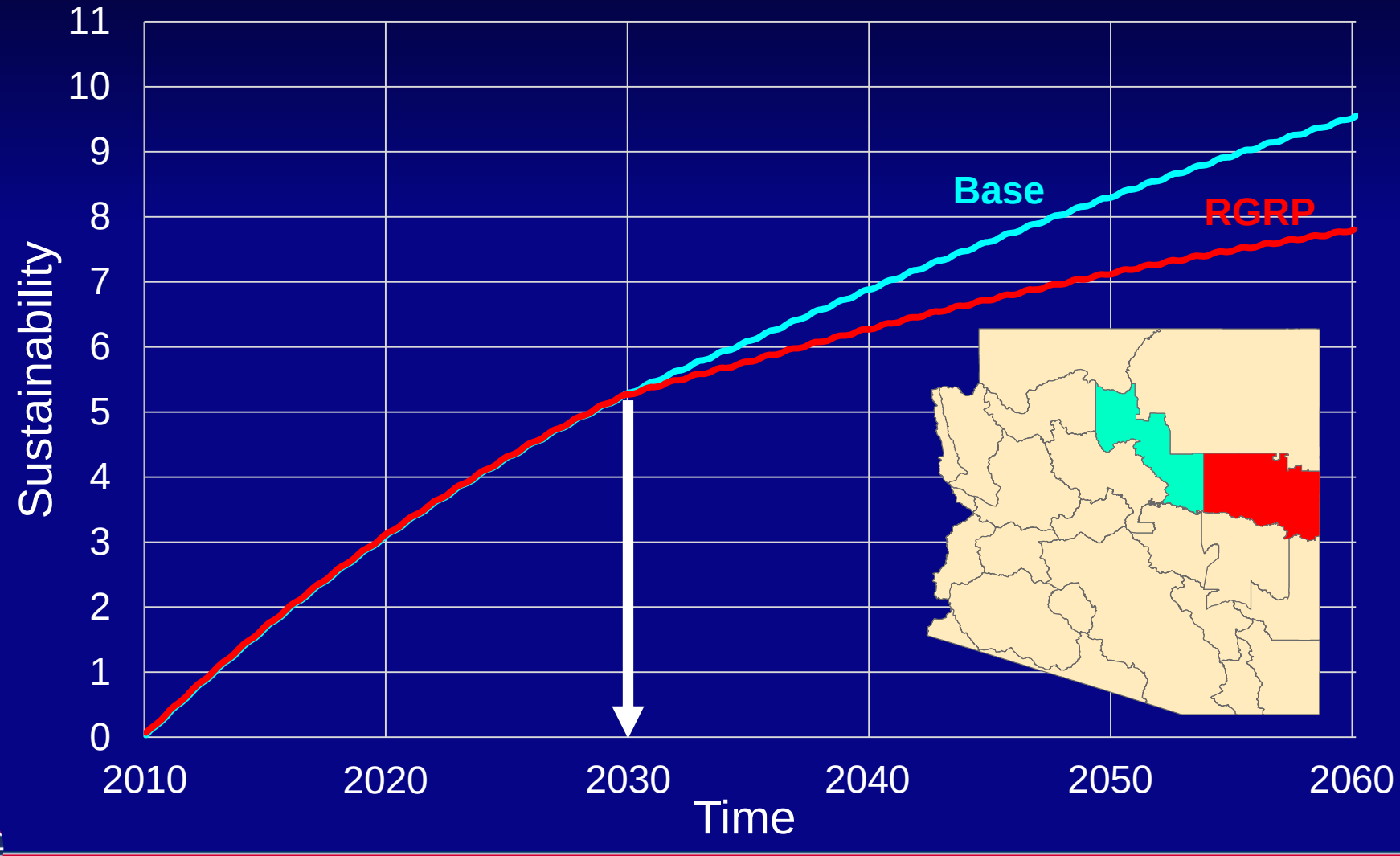
Instate Water Importation



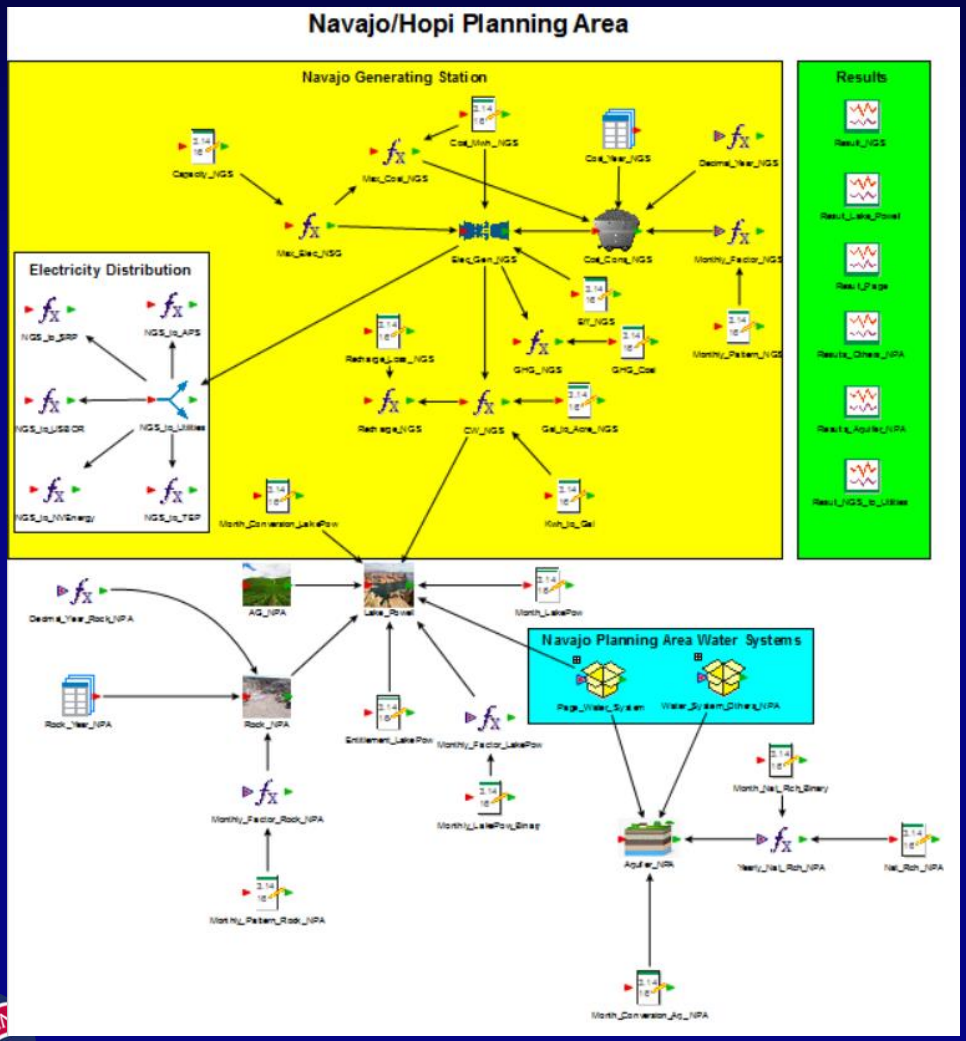
All Alternatives & Water Importation



Inter-Planning Area Impacts: Sustainability of the Eastern Plateau



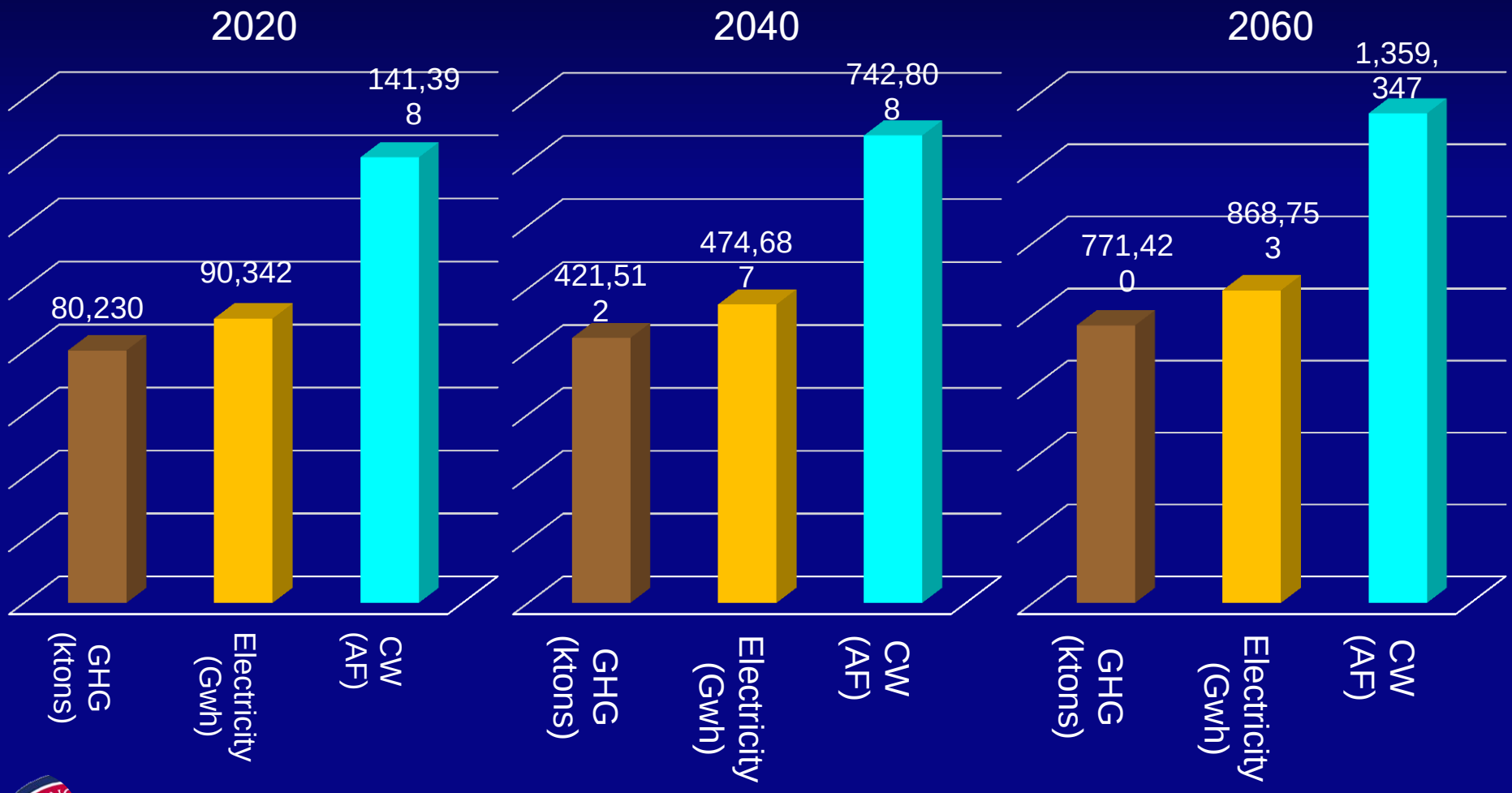
Case Study 2: Navajo/Hopi PA



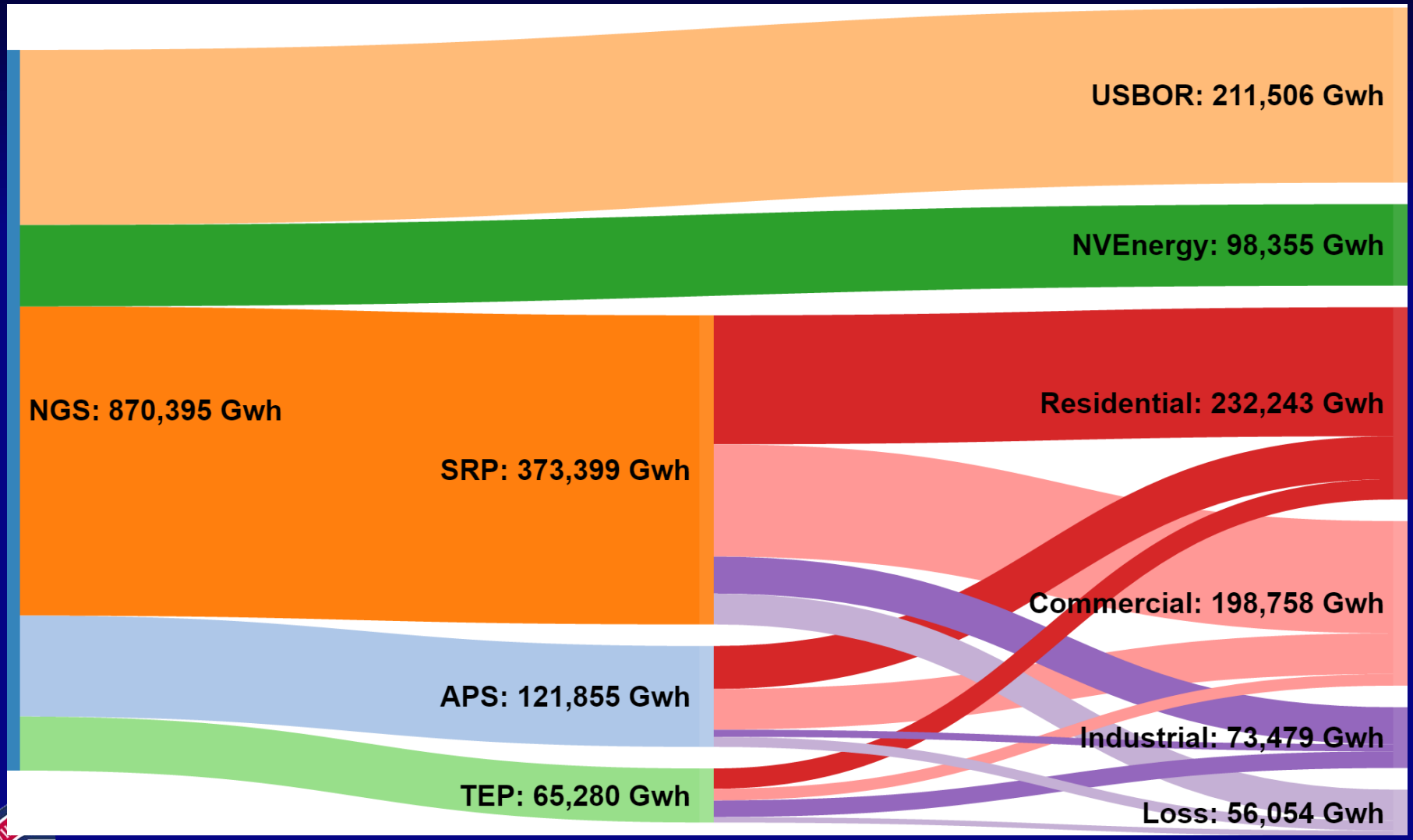
- Municipal water demand
- Agricultural water demand
- Industrial water demand
  - Golf course
  - Navajo generating station
  - Mines (rock production)
- Electricity generation
- Greenhouse gas emission due to electricity generation

Navajo Generating Station:

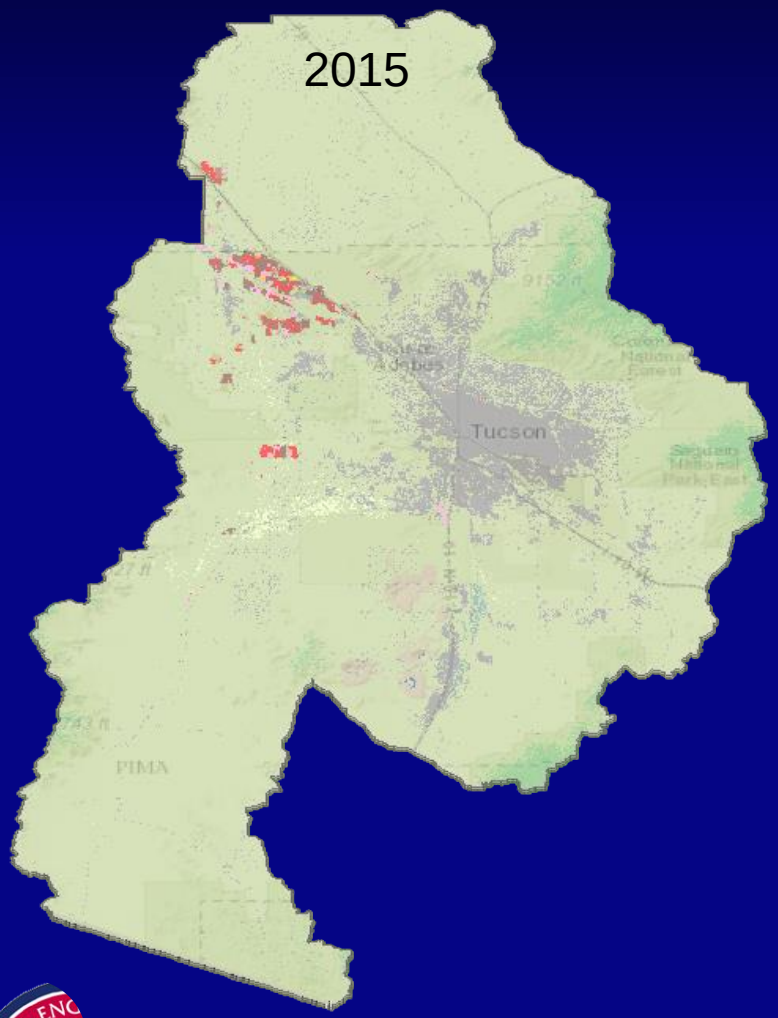
Greenhouse Gas (GHG), Electricity, and Cooling Water (CW)

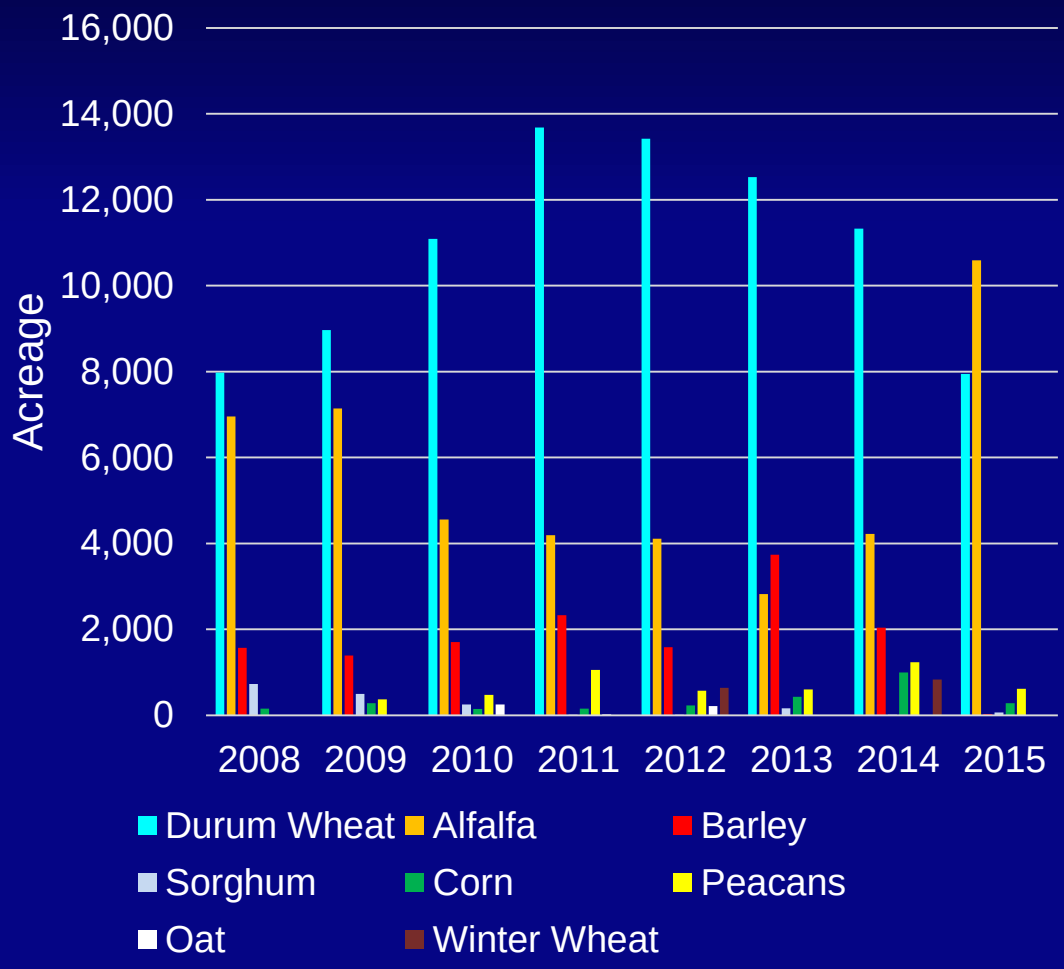


Electricity Distribution

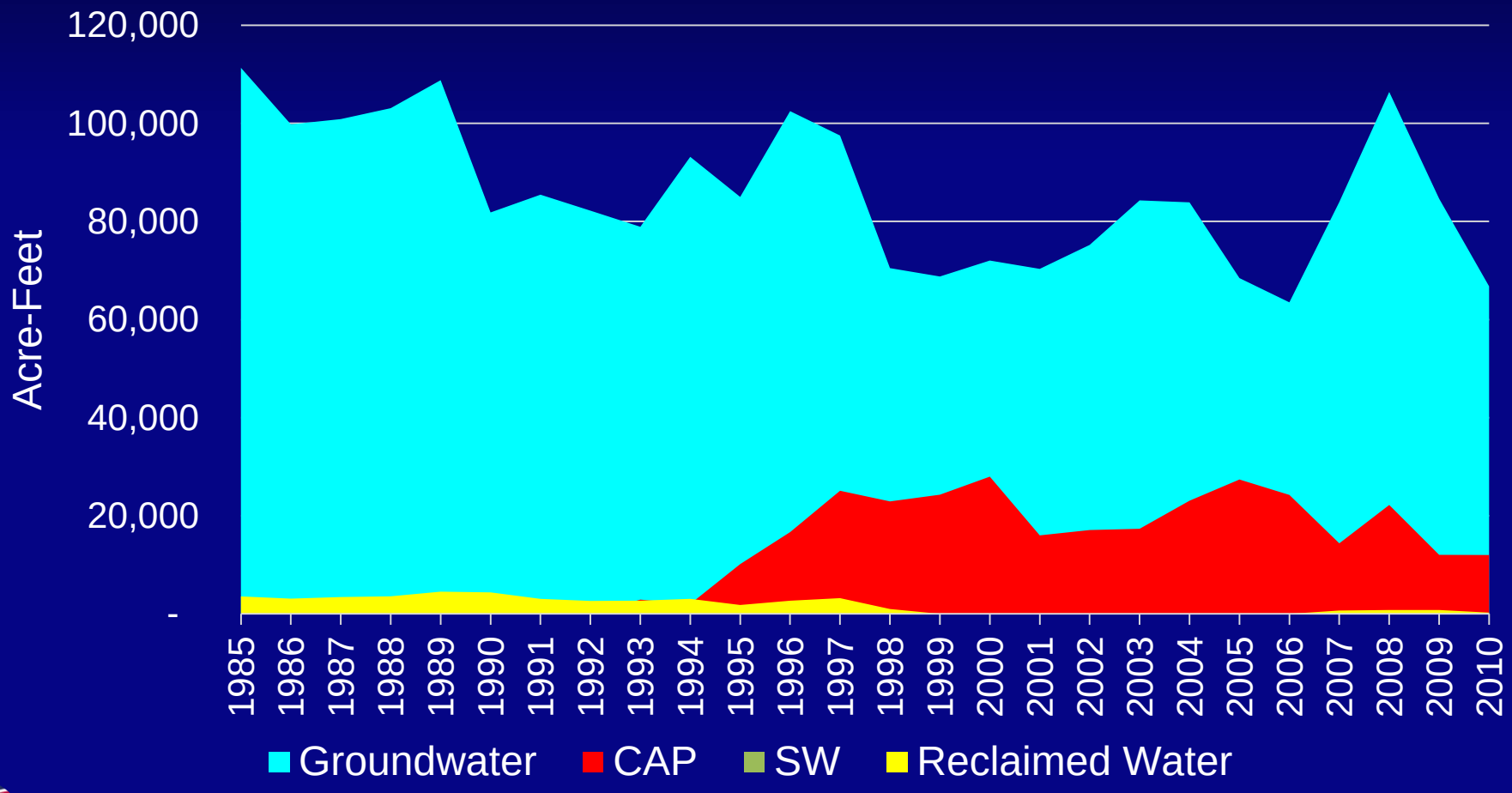


Tucson AMA Crop Patterns and Acres





Tucson AMA Total Agriculture Water Demand by Source Supply 1985-2010

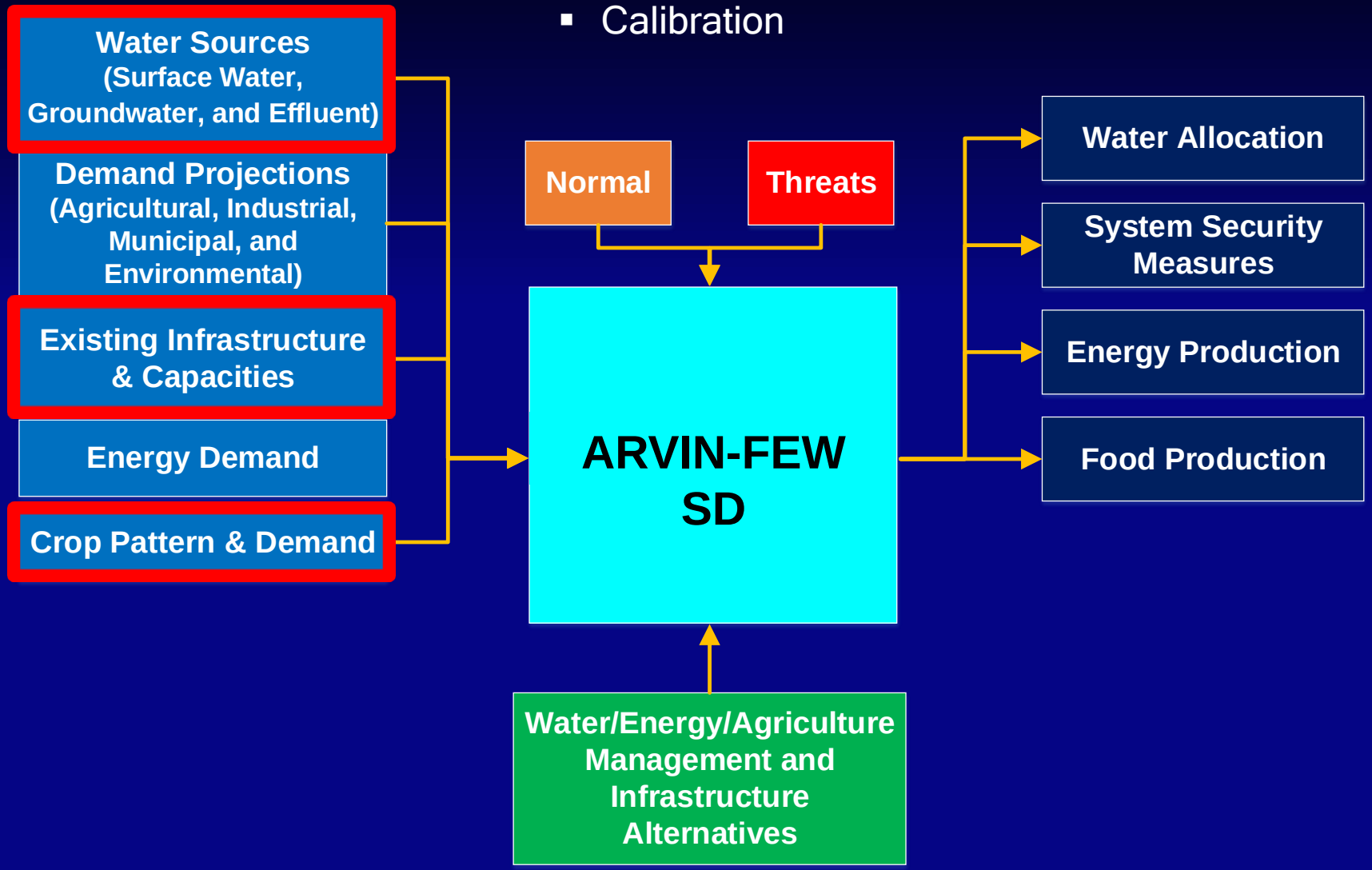


Summary

- 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.

Future Work

- Improve water supply and demand data and allowable groundwater withdrawals
- Develop ARVIN for AZ agriculture system
- Calibration



ARVIN-FEW OPT Structure