Data Modeling and Analysis

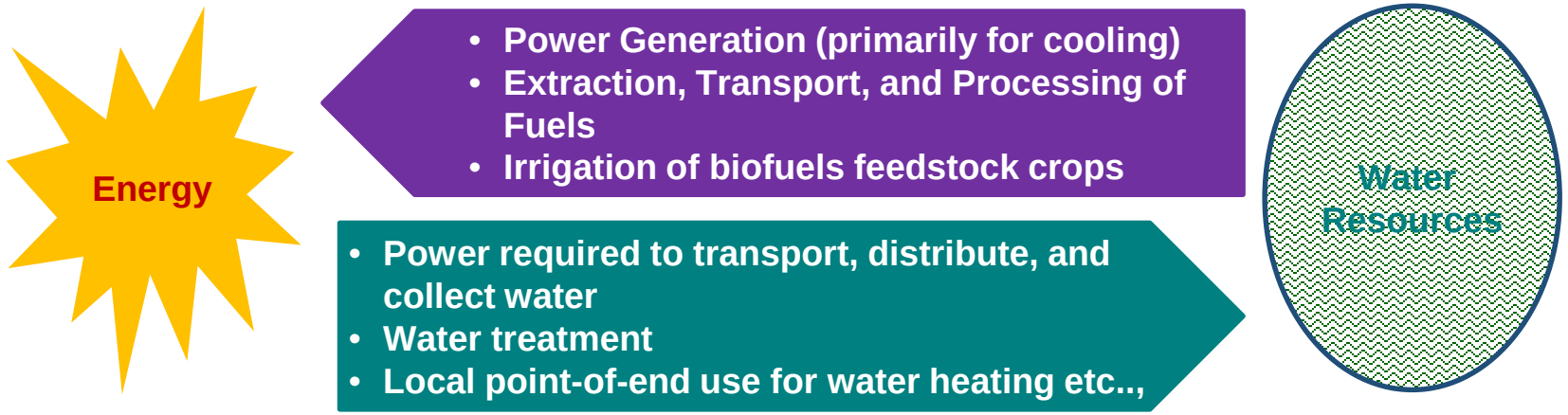
Water Management Program Workshop

Erik Shuster

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY

Water – Energy Interdependency



Power Generation*

- Thermoelectric power generation accounts for a majority of water usage for power generation
  - Nearly 52% of surface fresh water withdrawals
  - A total of 43% of total water withdrawals
- Vulnerable to physical constraints of water availability and regulations limiting access to it
  - Power plants in the US forced to modulate/shutdown power generation during a recent drought in 2012
  - Can constrain the type and location of power plants that can be built

Water Resources

- Water scarcity, variability, and uncertainty are becoming more prominent in the US
  - Population growth
  - Climate change
  - Precipitation profile redistributions
- Environmental impacts and regulations alter water availability profile
- Strong temporal dependence
- Highly localized due to water rights and other region-specific issues

Water – Energy Dependency is one dimension of the larger Water – Energy - Food Nexus

*Sources: 1. US DOE, "The Water – Energy Nexus: Challenges and Opportunities – Overview and Summary," 2014;
2. IEA, "Water for Energy Resource: Is Energy Becoming a Thirstier Resource," Excerpt from the World Energy Outlook 2012.
3. NREL, "Water Constraints in an Electric Sector Capacity Expansion Model," NREL/TP-6A20-64270 , 2015.
4. "The Energy-Water-Food Nexus", D. L. Keairns, R. C. Darton, and A. Irabien, Annu. Rev. Chem. Biomol. Eng. 2016.7:9.1-9.24

Data Modeling and Analysis
Projects/Analyses

- Produced Water Desalination Metrics
- Cooling Technologies Modeling
- Trace Metals Analysis for advanced power plant streams
- Nontraditional Streams
  - Scoping Study and Follow-on Analysis
- Case Studies on Power Plant Water Use Practices and Future Issues
- Eastern States Water Availability
- Water-Energy Integrated Model

Produced Water Desalination Metrics

- **Detailed systems level analyses will be used to develop metrics for desalination of extracted brines from carbon storage reservoirs to manage plume and pressure or produced water from oil/natural gas production**
  - Costs, Performance, Energy, scale, effluent conditions, final conditions
- **NETL R&D membrane work may also be incorporated into this subtask**

Cooling Systems Modeling

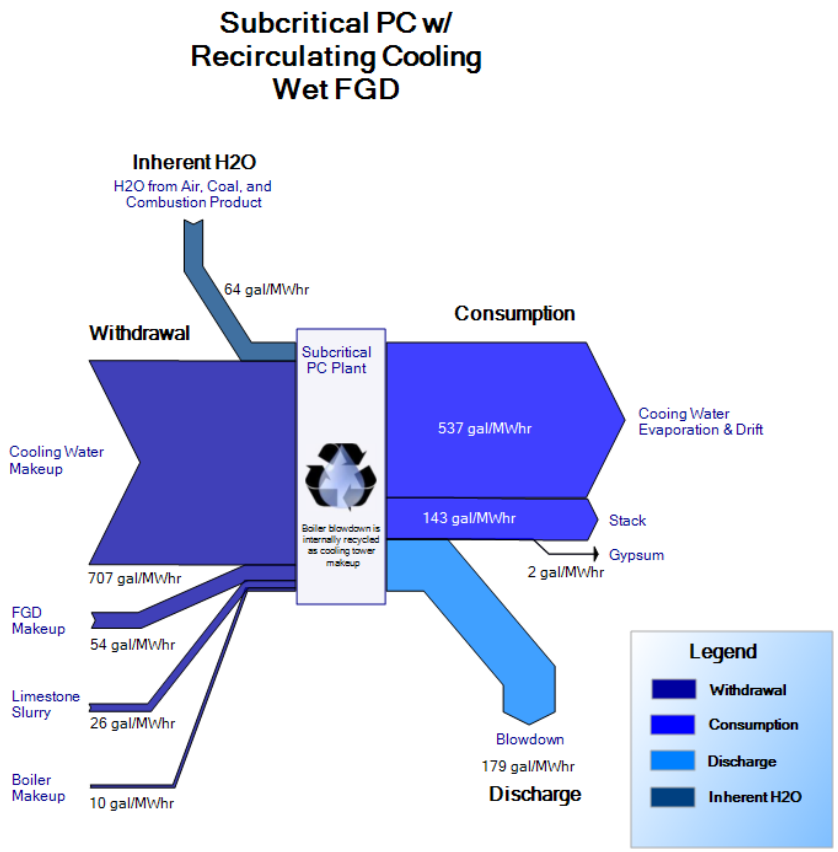
- **Evaluate wet, dry, hybrid cooling technologies for power plants**
  - Develop cost and performance (parasitic power load, water consumption) models
  - Unit operation models should be responsive to changes in ambient conditions
  - Incorporate unit operation blocks into Aspen simulations; compare results against literature

Trace Metals Analysis

- **Characterize trace elements in blowdown streams from advanced power systems**
  - "Coal contains the periodic table" – heavy metals content in blowdown from pulverized coal combustion relatively well known
  - Conduct literature survey to characterize trace elements in process water streams from IGCC, oxycombustion, CCS, chemical looping, etc.

Nontraditional Streams

- Identify and characterize (chemical constituent) process liquid discharge streams from coal plants (conventional, advanced power, and chemical)
- Identify current and future discharge requirements (i.e., effluent guidelines and/or other drivers that influence technology needs at real plants)
- Identify water treatment technologies that can/could achieve required discharge limits (including zero-discharge options)
- Develop cost and performance models of the "quality" that would allow them to be incorporated into NETL techno-economic analyses
- Incorporate the models into the baseline studies



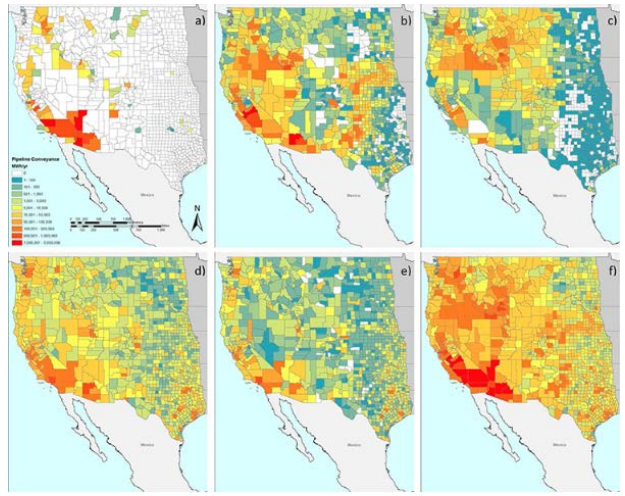
Case Studies on Power Plant Water Use Practices and Future Issues

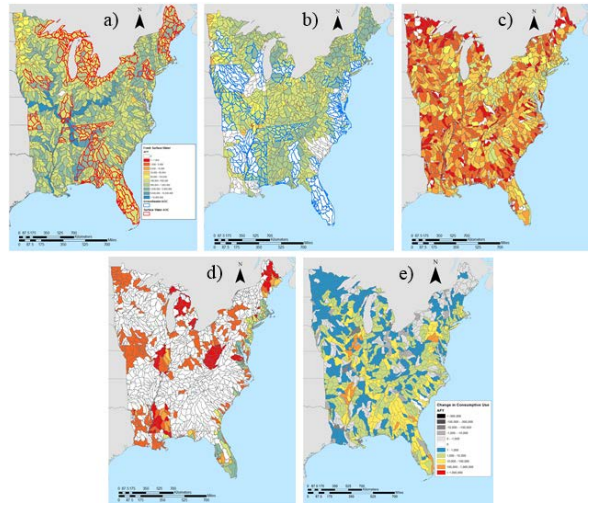
- Develop a case study on power plant water use practices
- Conduct several power plants tours with a primary focus on coal plants and a secondary on natural gas combined cycle plants
- A collaborative effort between NETL and plant staff will be established in order to develop a report based on their water use practices and future issues and concerns regarding plant water

- Water use, measurements, conditions, normal ops, turndown ops, permits, disposal, run off, challenges, issues,…

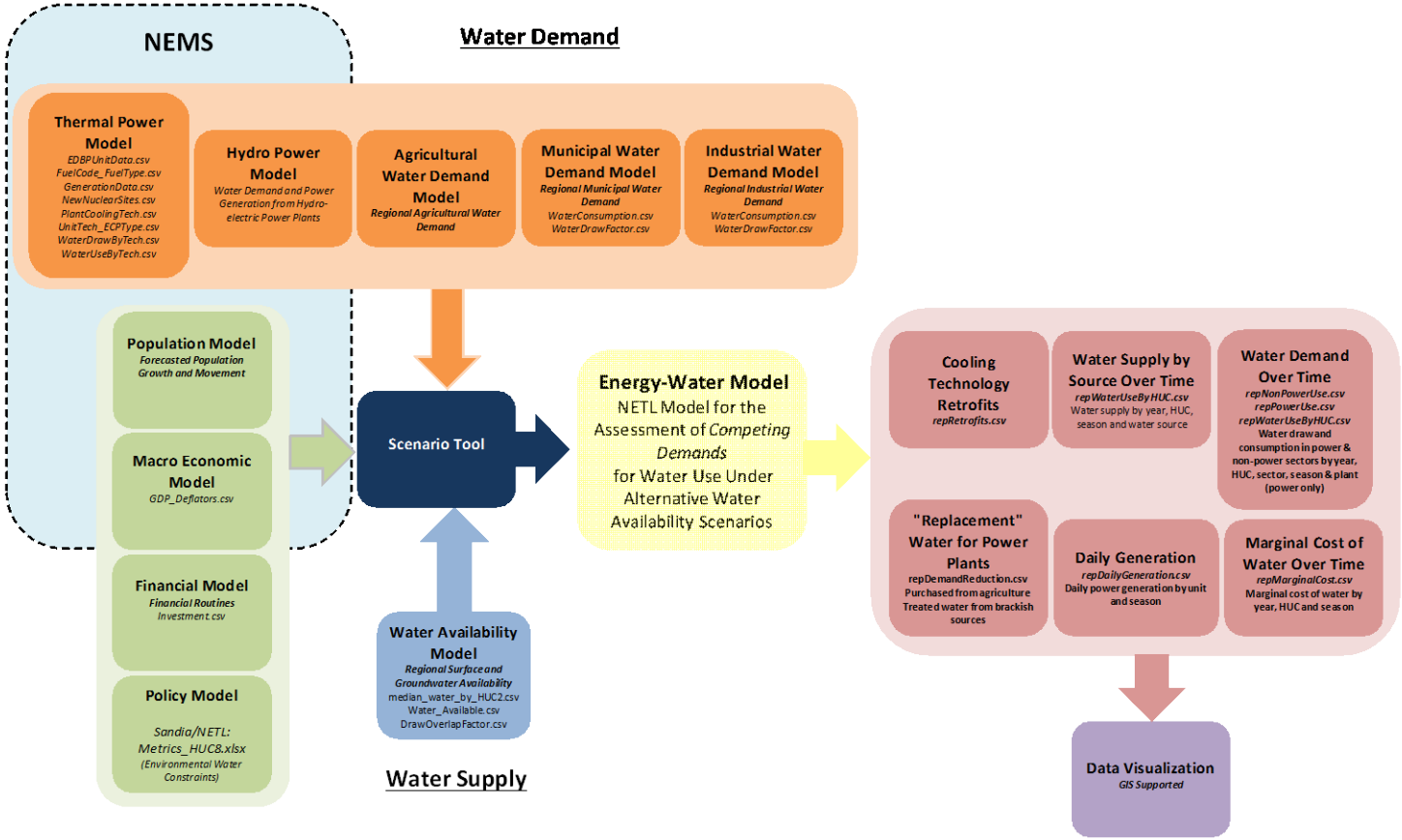
Sandia Eastern Water Availability Data

- Original 17 Western States
- NETL funding for 31 Eastern States
- HUC-8 watershed level
- Fresh surface, fresh ground, municipal waste, brackish ground water





Water-Energy Integrated Model



Motivation

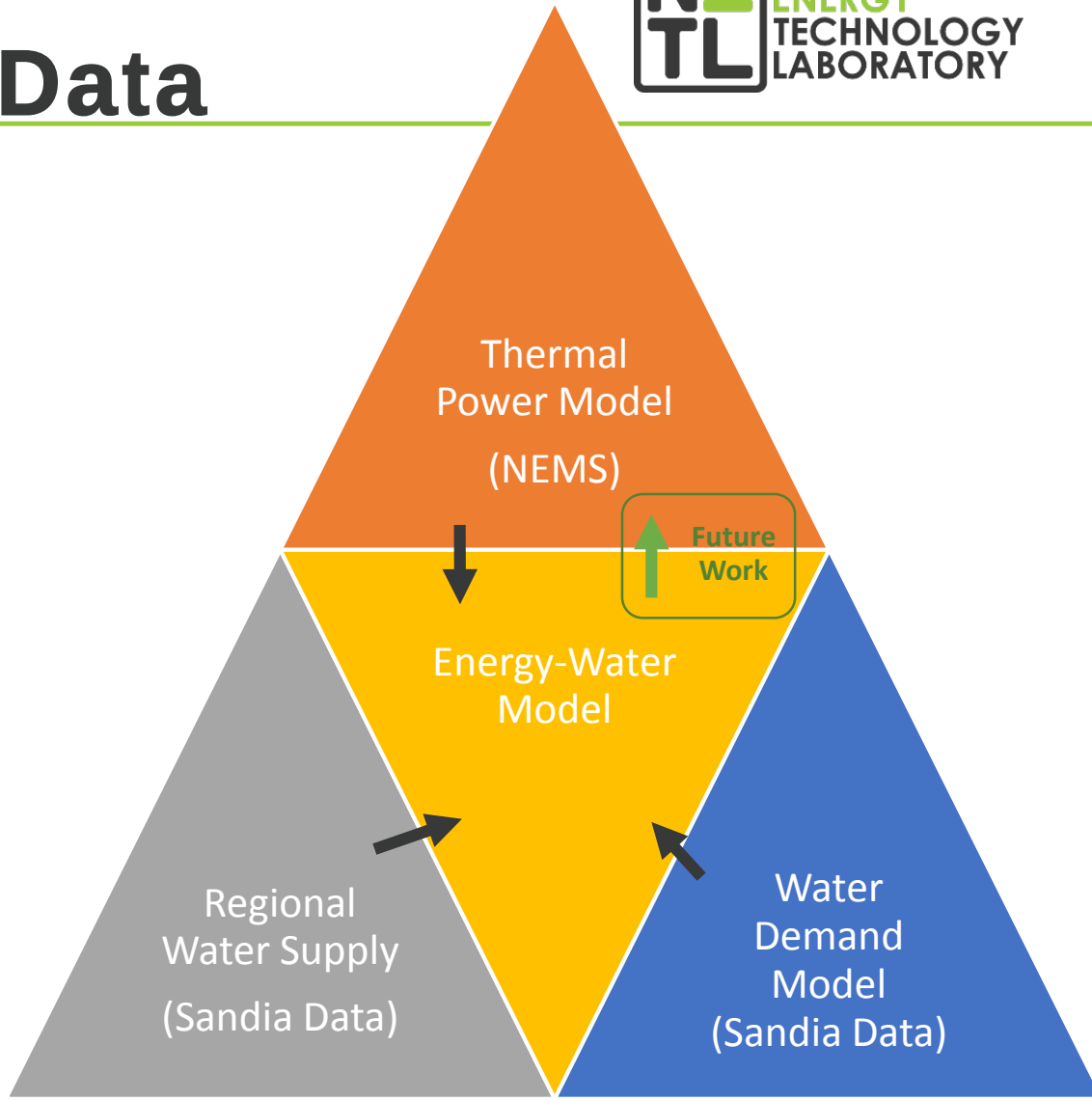
- **Water – Energy interdependency is an important factor that has to be taken into consideration in the deployment of power generation technologies**
  - Siting considerations
  - Environmental considerations
  - Technology considerations
  - Municipal, Industrial, and Agriculture considerations
- **Current energy capacity forecasting tools such as NEMS do not adequately take into account potential water constraints in deployment considerations**

Objectives

- **Develop tools and metrics that inform electric power generation design choices related to water availability and the cost of power plant water utilization**
- **Explore electric power technology options and use results to**
  - Inform R&D
  - Mitigate the impact of adverse water availability conditions on current and projected future thermoelectric electric power generation capacity

Prototype Model Design and Data

- Time Period: 2012 to 2040
- Regions: HUC 8 – Hydrologic Unit Code (8 digits 2,200 HUs, 700 mi^2)
- Model Objective Function: Minimize the total cost of satisfying water demand in each HUC 8

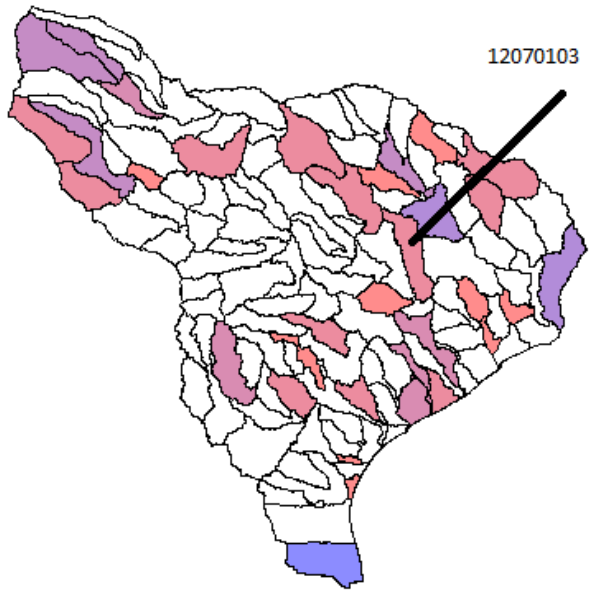


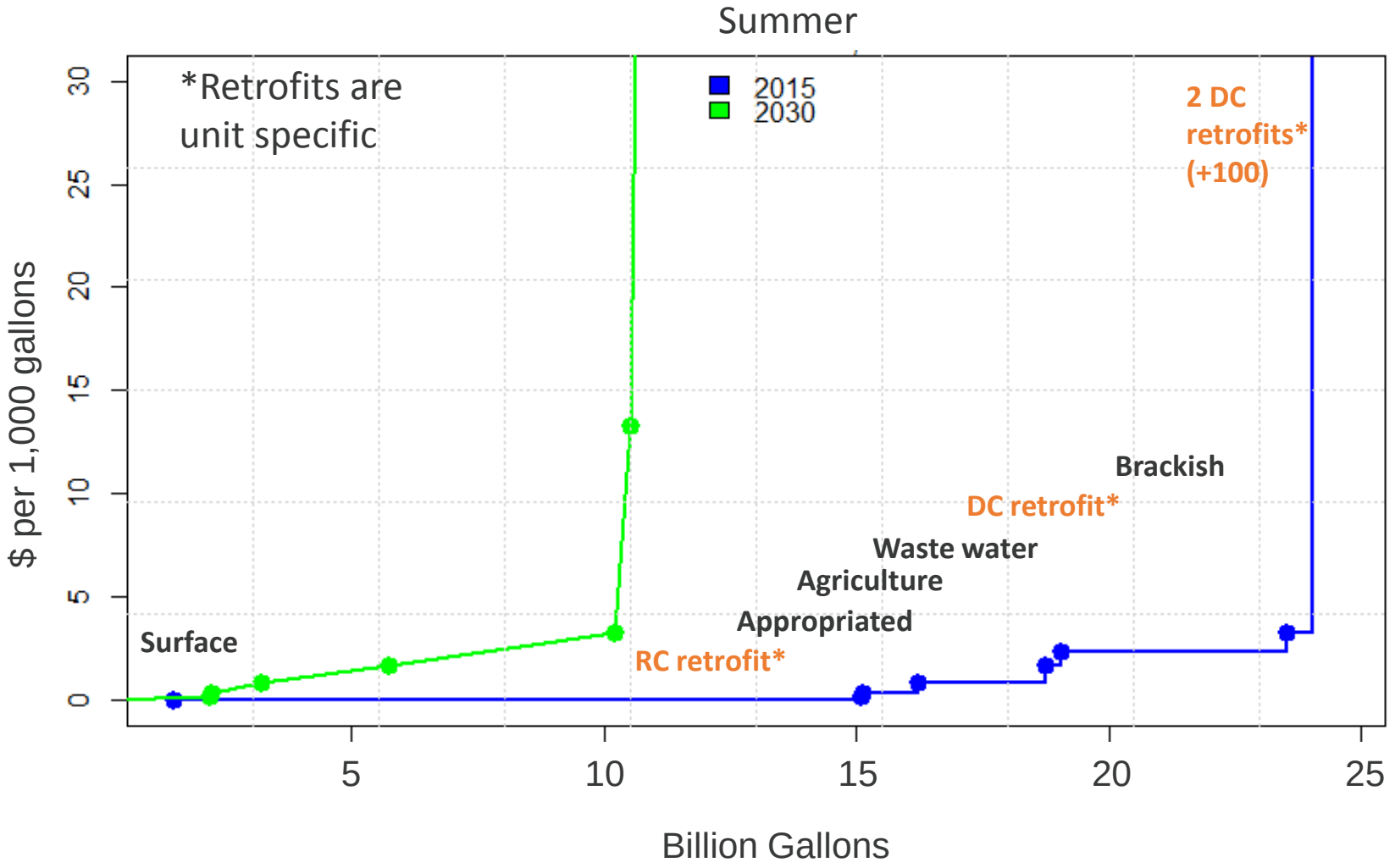
Model Design

- **Multi-period seasonal planning model**
- **Prototype model developed in GAMS**
  - General Algebraic Modeling System – Linear programming model
- **Optimizes to minimize the cost of satisfying the demand for water**
- **LP performs an economic trade-off between purchasing water at various costs from constrained water sources or spend capital to retrofit power plants with less intensive water cooling technologies**
  - Appropriated water
  - Impaired water (waste or bine waters)
  - Purchase from Ag
  - Retrofit cooling system to recirculating or dry cooling

Marginal Cost Supply Curve for Water
in HUC 12070103 – Navasota, Texas

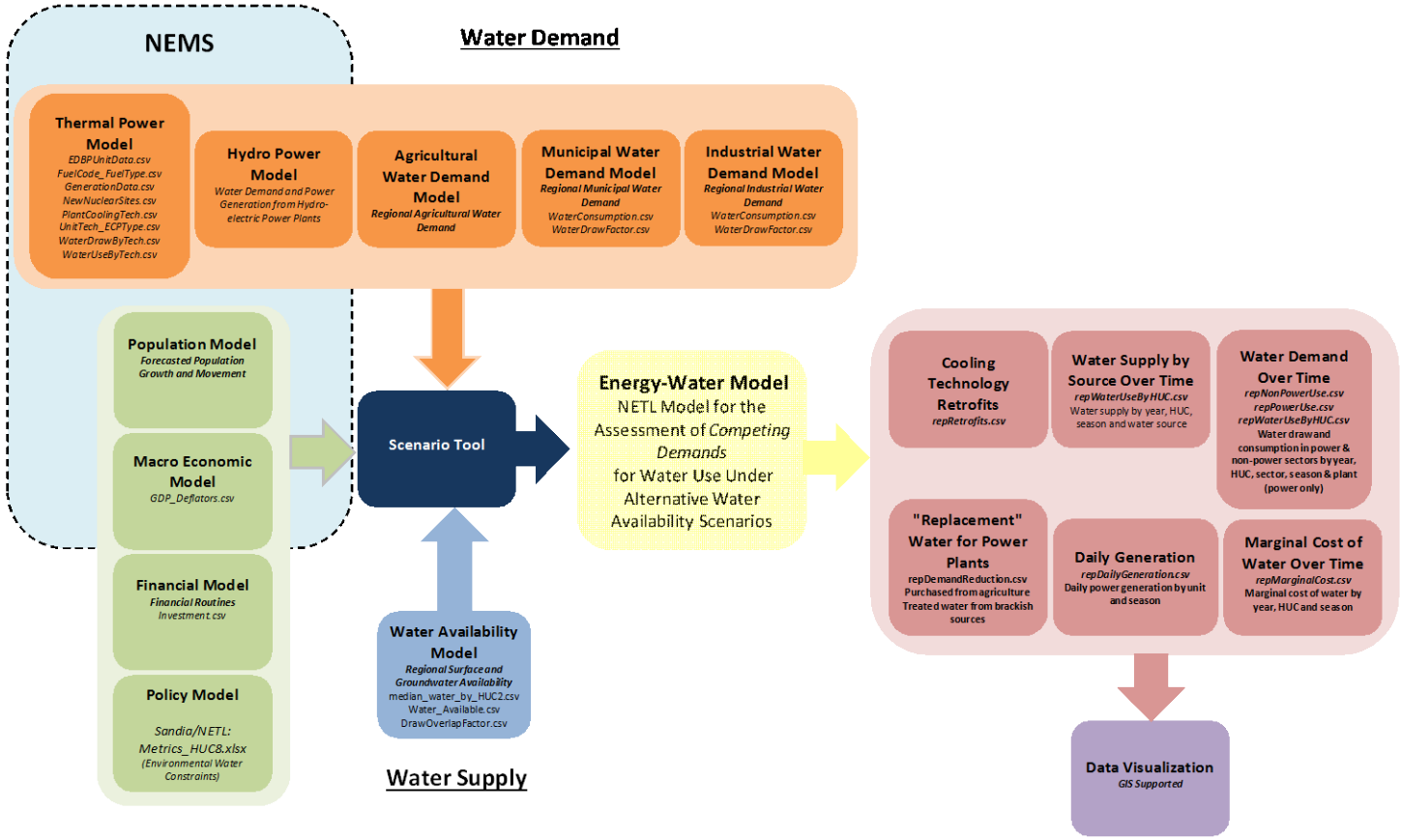
Forecast cost of water from alternative sources in this HUC8 region.



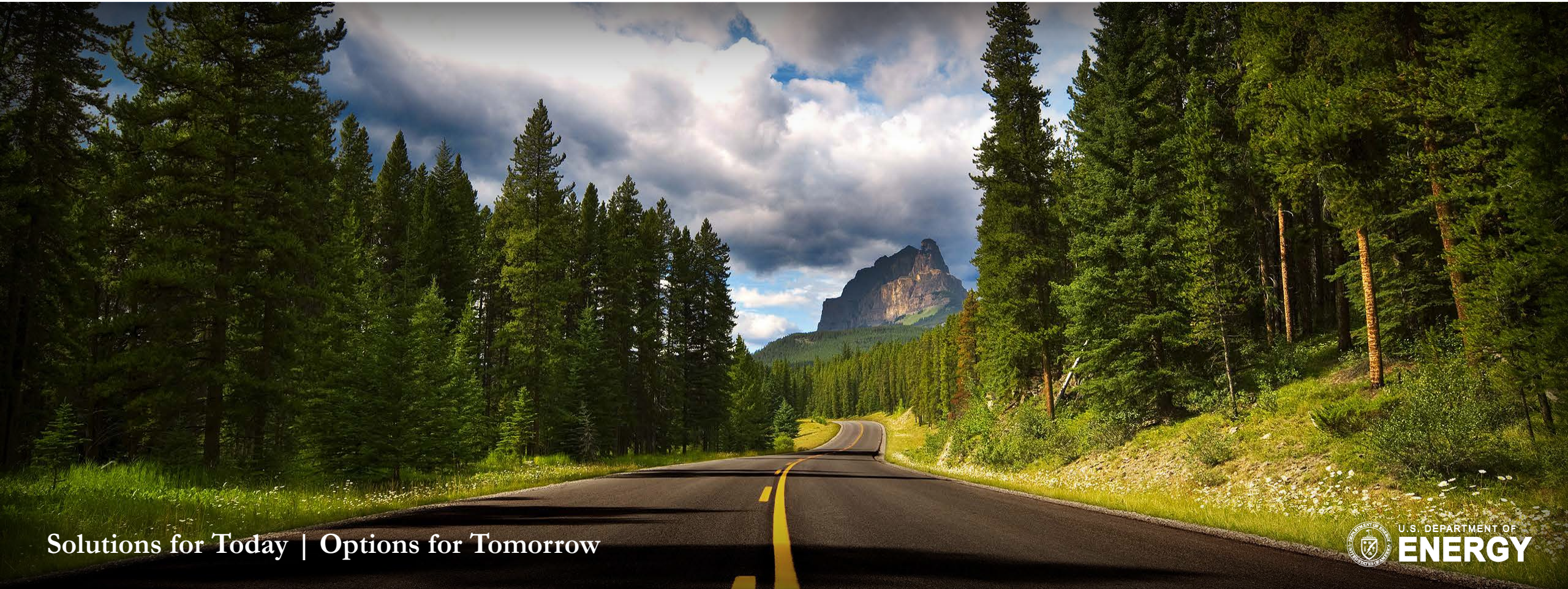


Future Work

- Add data for missing Eastern States
- Update water availability and water demand projections
- Develop and incorporate Drought Scenarios
- Refine cooling system impacts on costs and performance
- Integrate prototype model into EIA's NEMS for a two-way coupled model
  - CF, build, import, purchase water, retrofit cooling technology



Thank you


Solutions for Today | Options for Tomorrow
U.S. DEPARTMENT OF ENERGY