



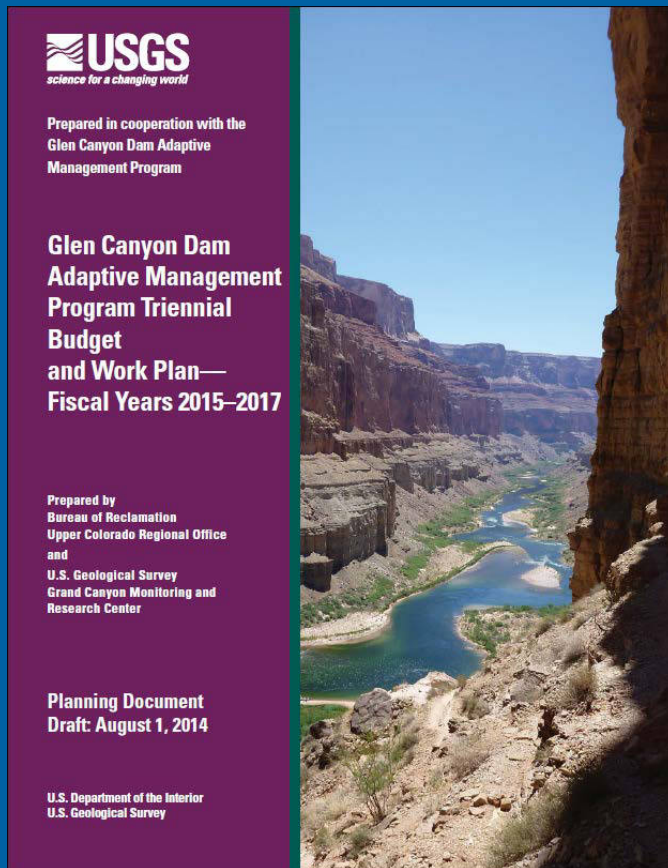
Economic Value of Energy in an Interconnected System: Hydropower at Glen Canyon Dam

Lucas Bair

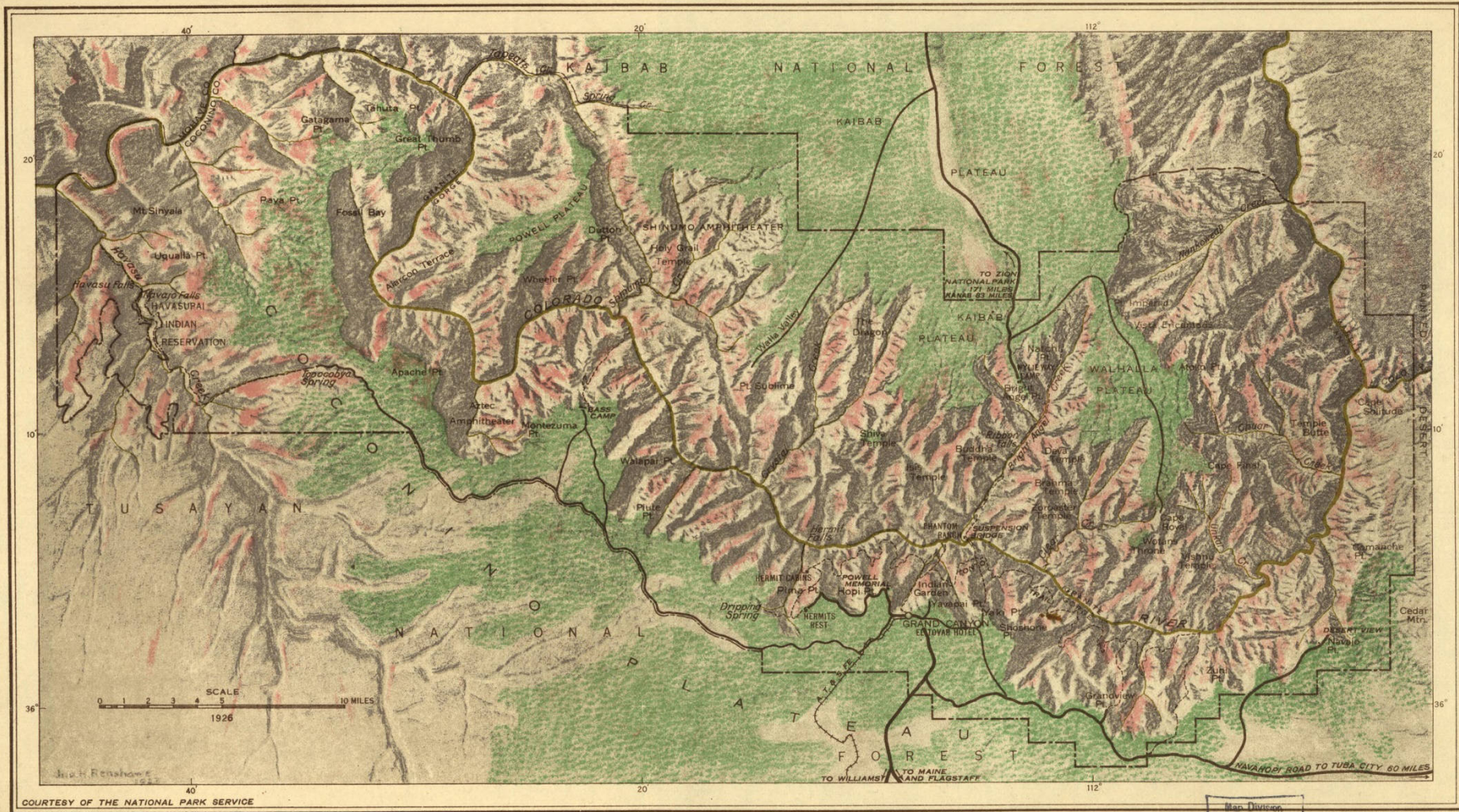
Economist

Grand Canyon Monitoring and Research Center

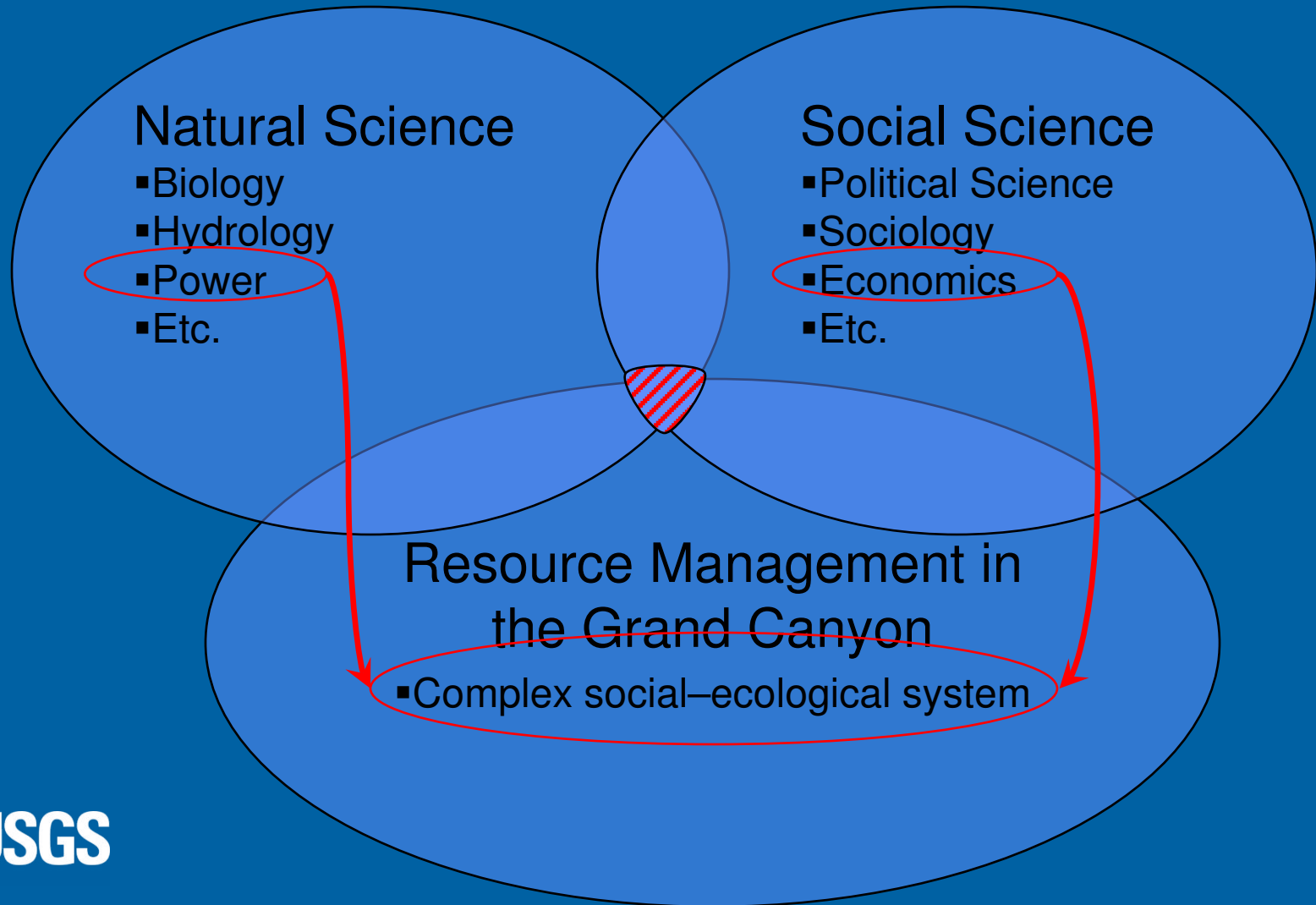
Grand Canyon Monitoring and Research Center



Provide the public and decision makers with relevant scientific information about the status and trends of natural, cultural, and recreational resources found in those portions of Grand Canyon National Park and Glen Canyon National Recreation Area affected by Glen Canyon Dam operations.



The Role of Social and Natural Science in Resource Management



Presentation Outline

- Systems analysis
- Power system analysis
- Economic analysis
- Adaptive management in the Grand Canyon



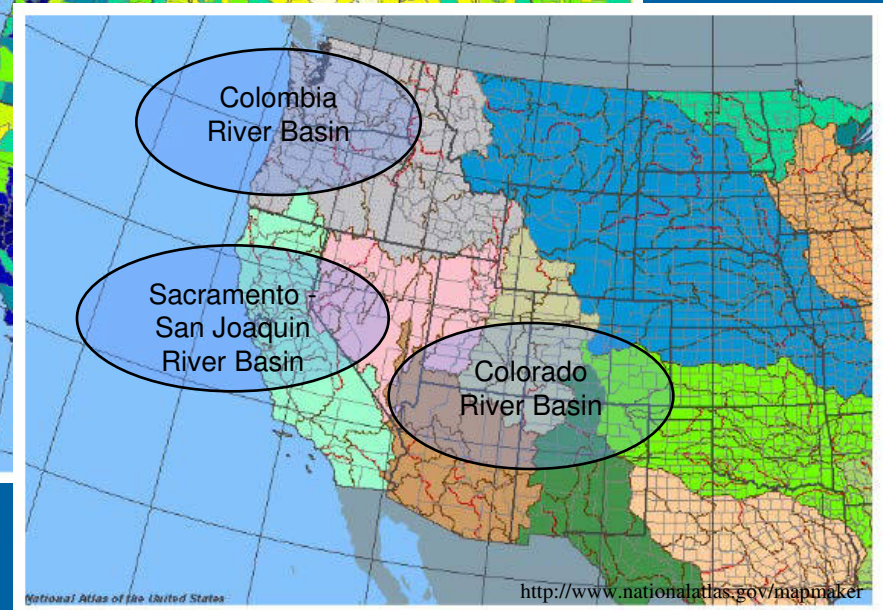
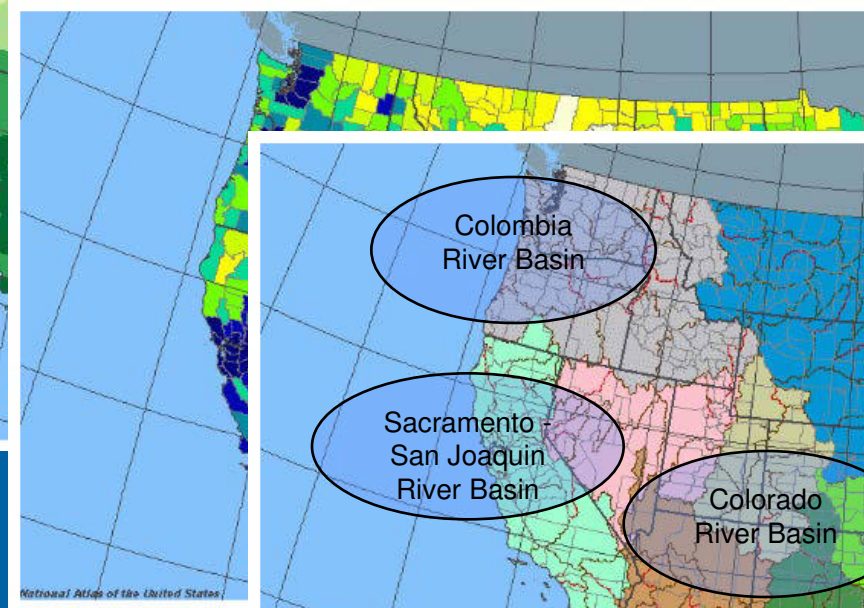
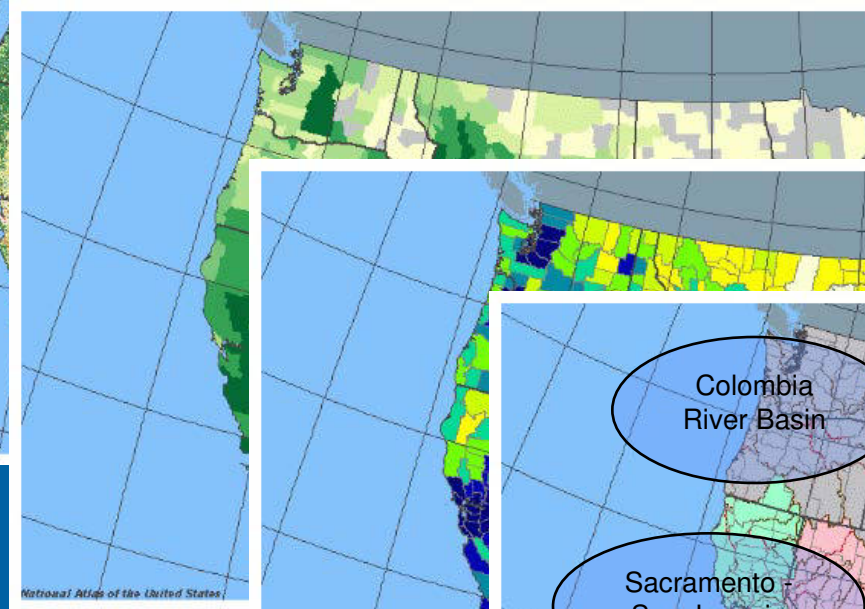
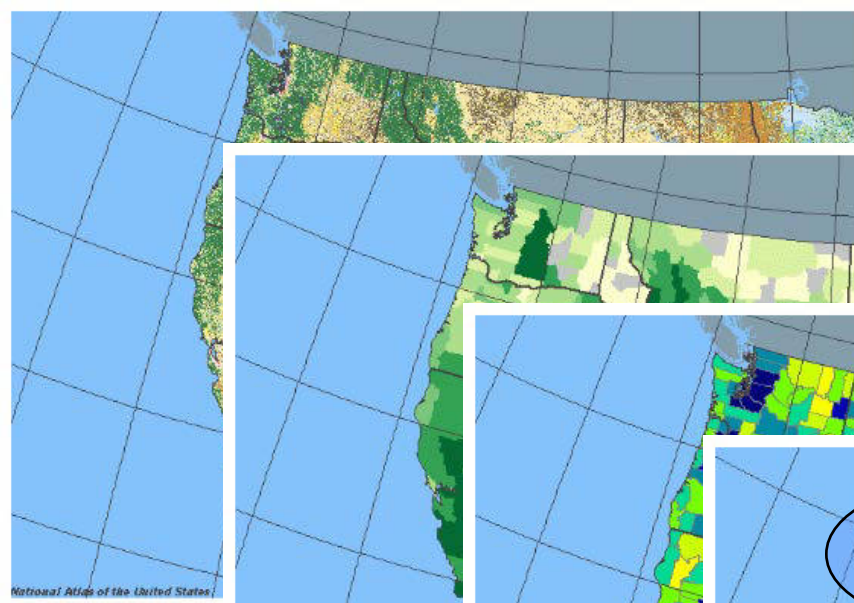
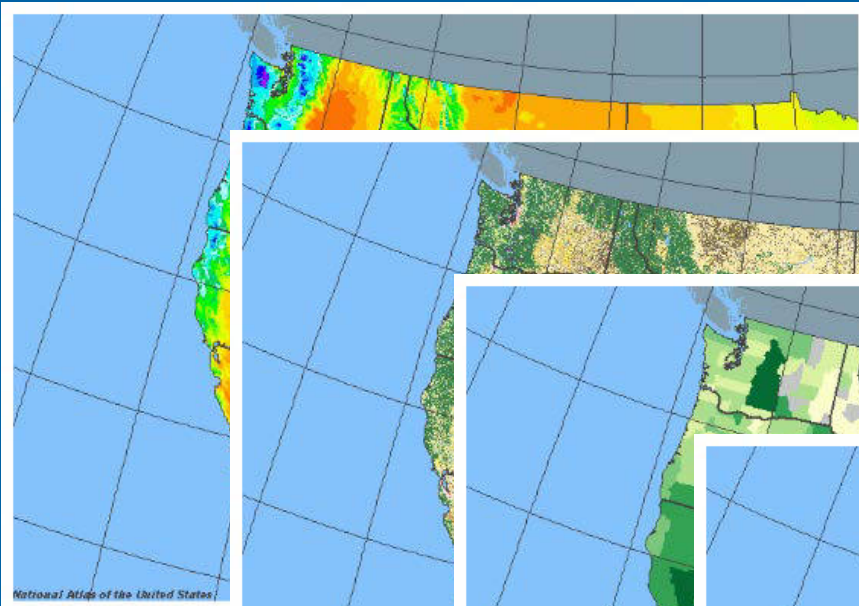
Systems Analysis

Precipitation

Land cover

Irrigated agriculture

Population density

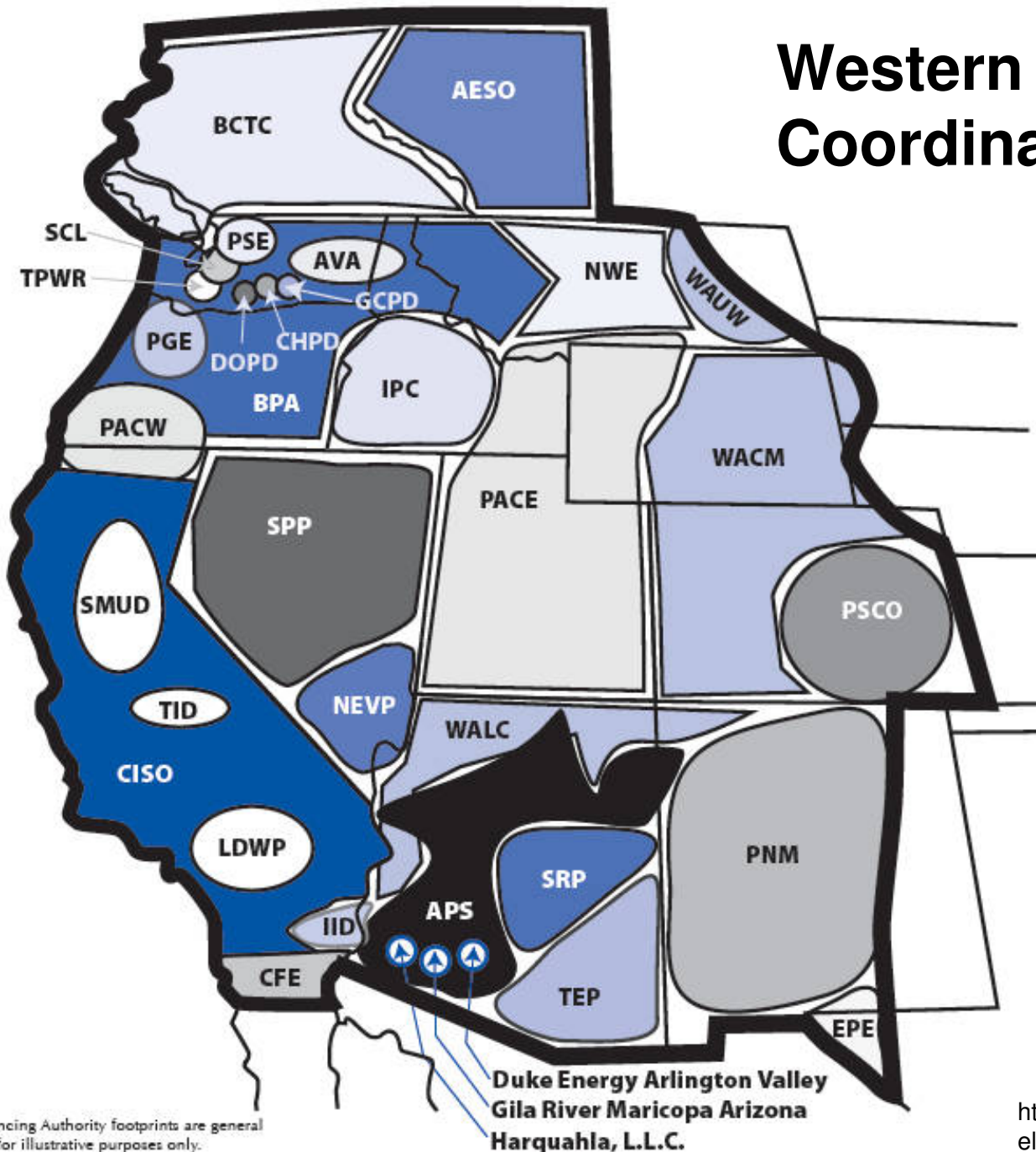


River Basin

Western Electricity Coordinating Council

Balancing Authorities

- 80 million consumers
- Institutional differences
- Geographic disparities
- Hydropower (28 percent)



Balancing Authority footprints are general and for illustrative purposes only.

Upper Colorado River Basin



Colorado River Storage Project
Units and Participating Projects

Colorado River Storage Project

Colorado River Storage Project Act -
Develop Upper Colorado River Basin

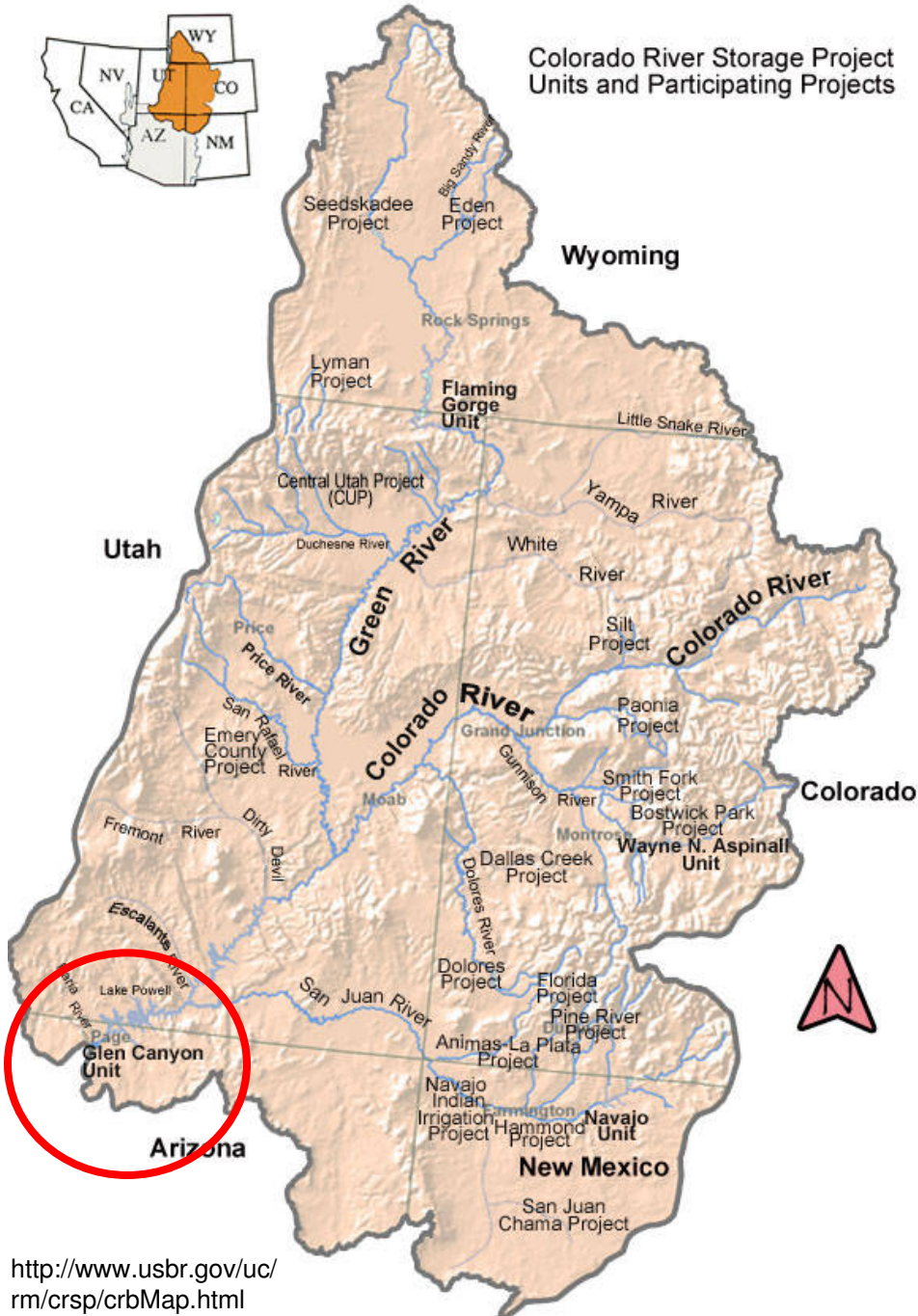
- Water storage
- Energy production
- Flood control



Manage water and related resources in an
environmentally and economically sound
manner.

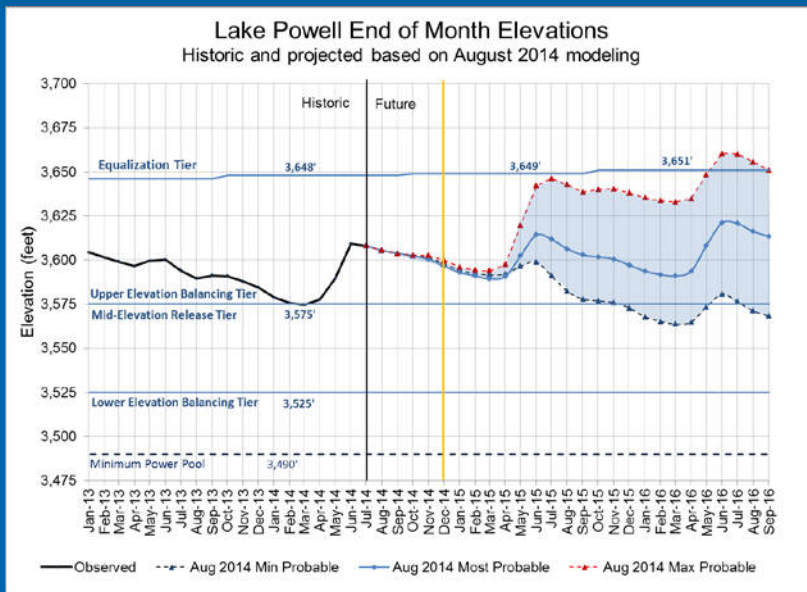


Market and transmit wholesale electricity
from multi-use water projects operated by
the various government agencies (e.g.,
Bureau of Reclamation, U.S. Army Corps of
Engineers).



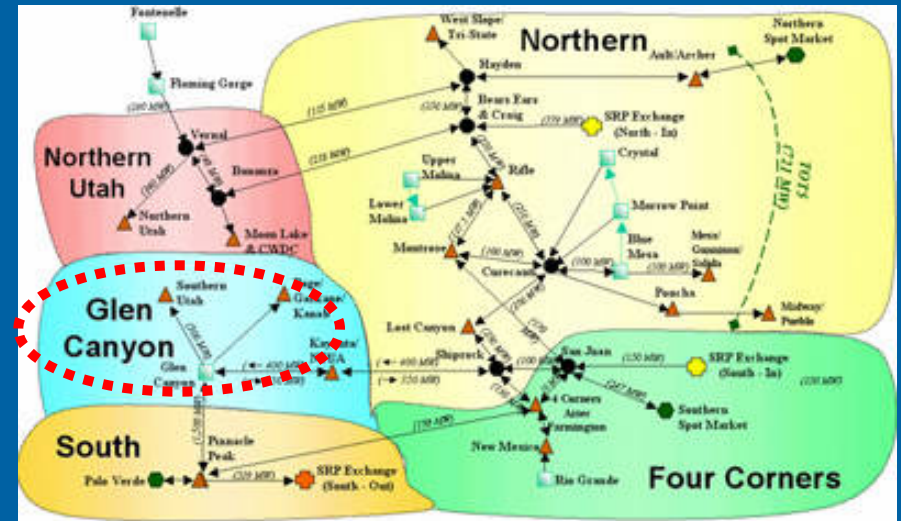
Systems Models - CRSP

Colorado River Simulation System



Generation and Transmission Maximization Model

U.S. Department of Interior, Bureau of Reclamation. August 2014 DOI-DOE Federal Family Call Glen Canyon Operations Coordination August 19, 2014



Glen Canyon Dam



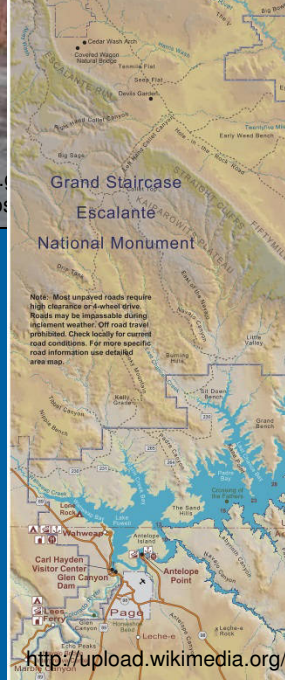
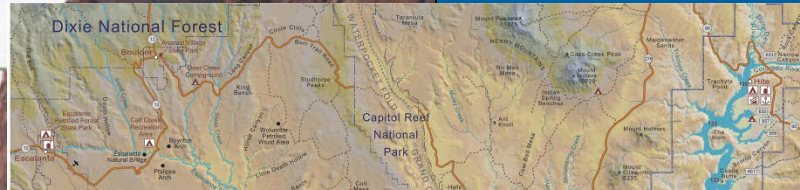
1889



1992

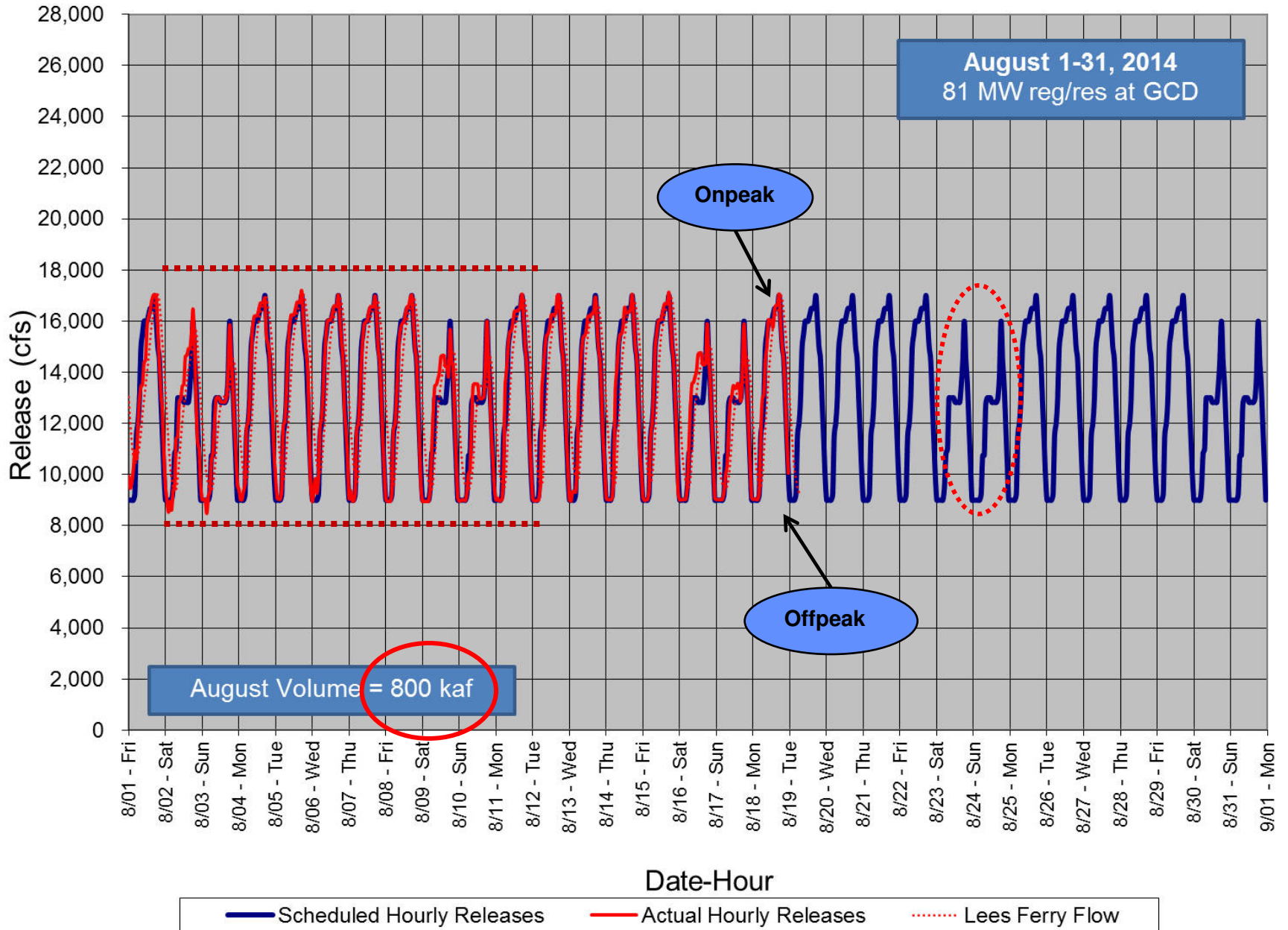
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<http://www.paztcn.wr.usgs.gov/photography/repeat-photo/>

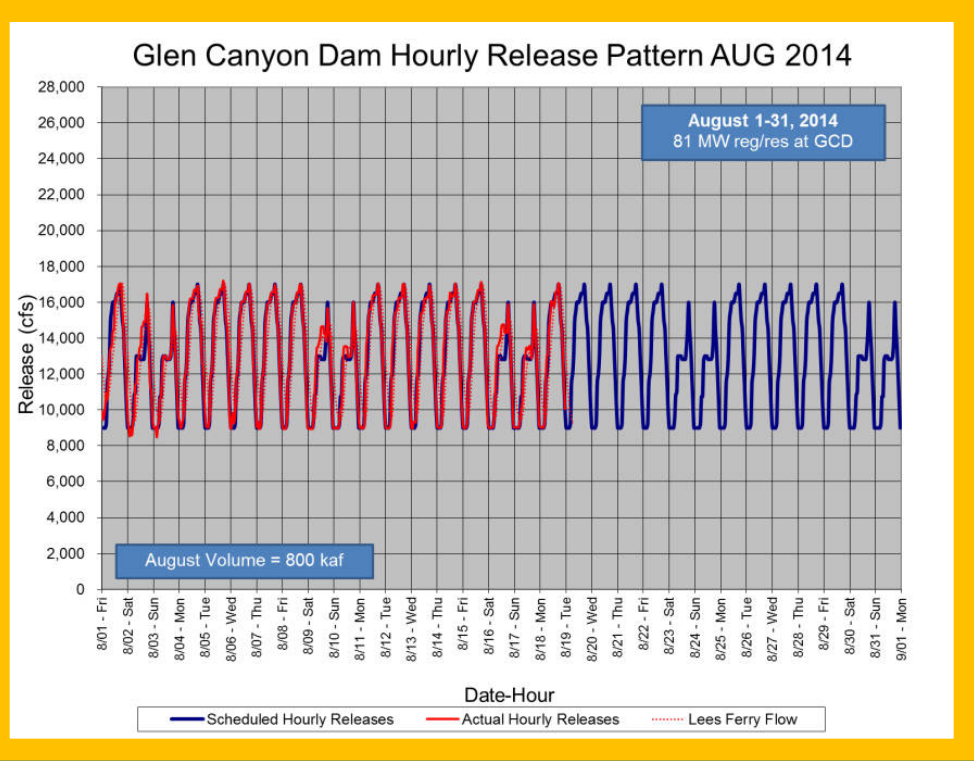
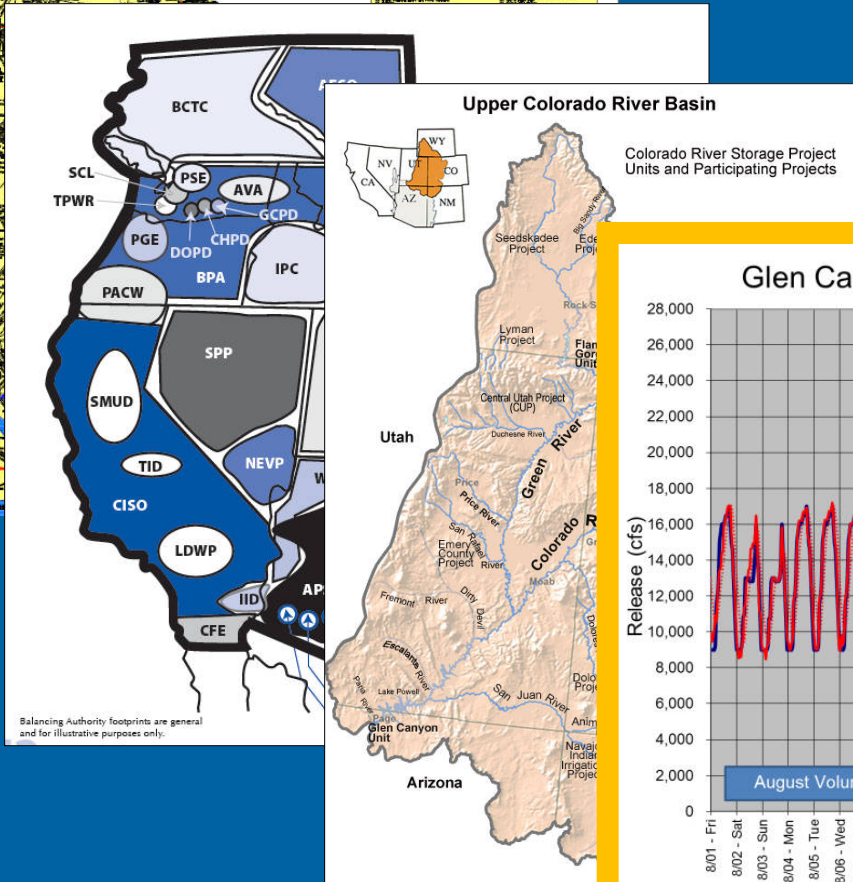
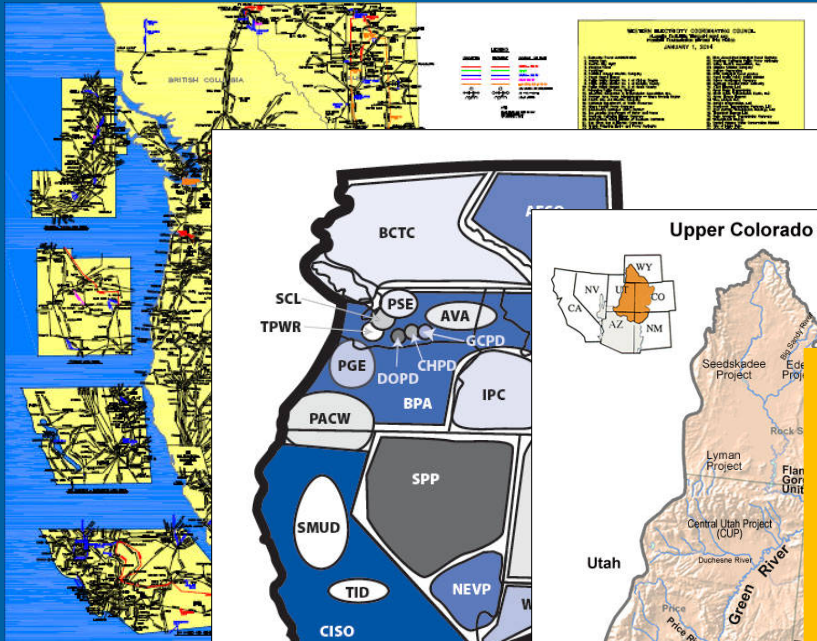


<http://upload.wikimedia.org/>

Glen Canyon Dam Hourly Release Pattern AUG 2014



Power System Analysis





What is Economics?

- **Study of the allocation of scarce resources among competing uses**
 - Market economy
 - Aggregation of economic agents
 - Profit maximizing firms and utility maximizing consumers
- **Goods and services not traded in market**
 - Economic principles for allocating resources among competing uses
 - Evaluate trade-offs (opportunity cost)
 - Example: water supply; water quality; energy; ecosystem attributes; recreation; flood control; navigation

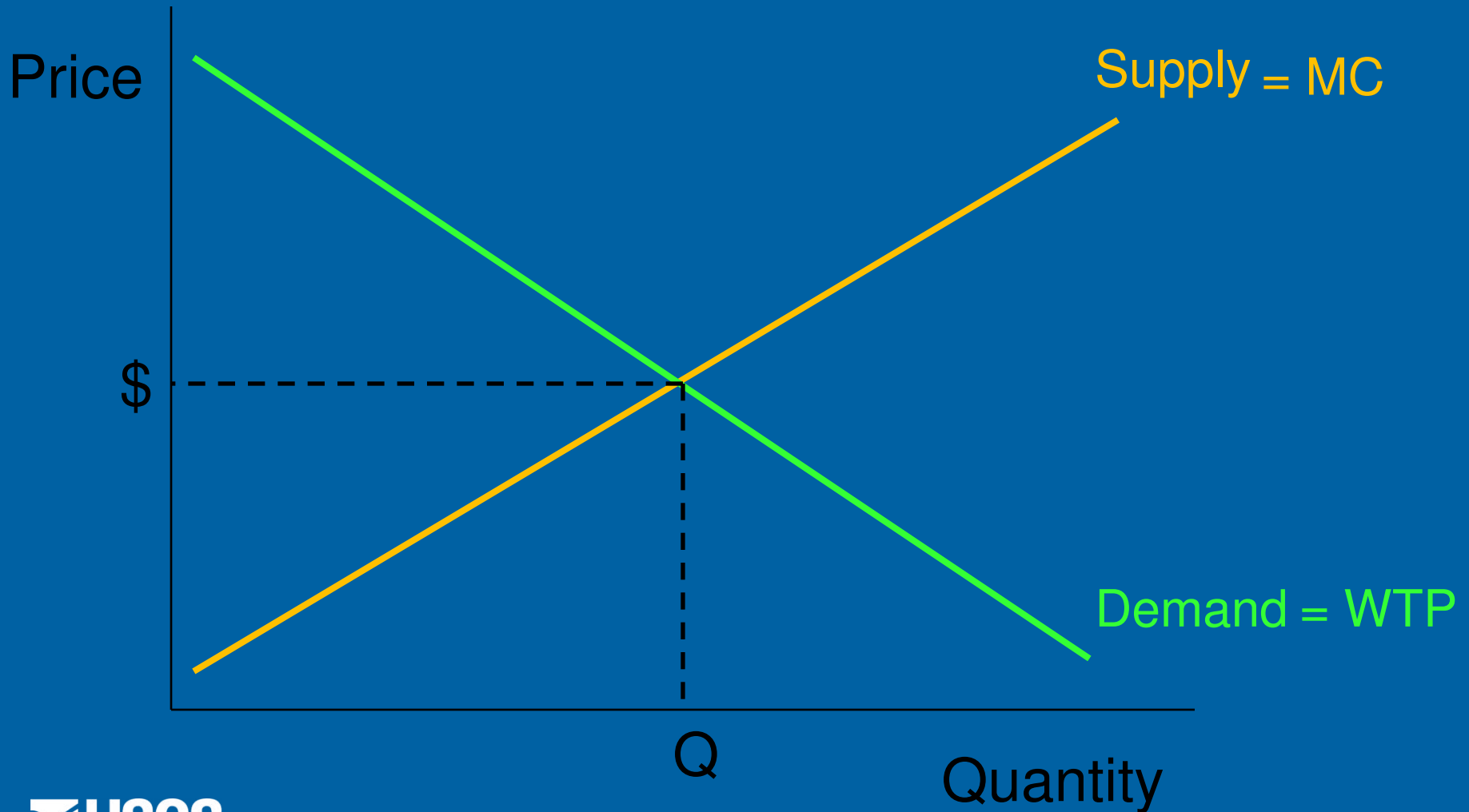
Benefit-Cost Analysis

- **Measure of economic efficiency**
 - Increase in social welfare (benefit)
 - Decrease in social welfare (cost)
- **Baseline condition compared to condition under management action**
- **Discounting and planning horizon**
 - Time value of money

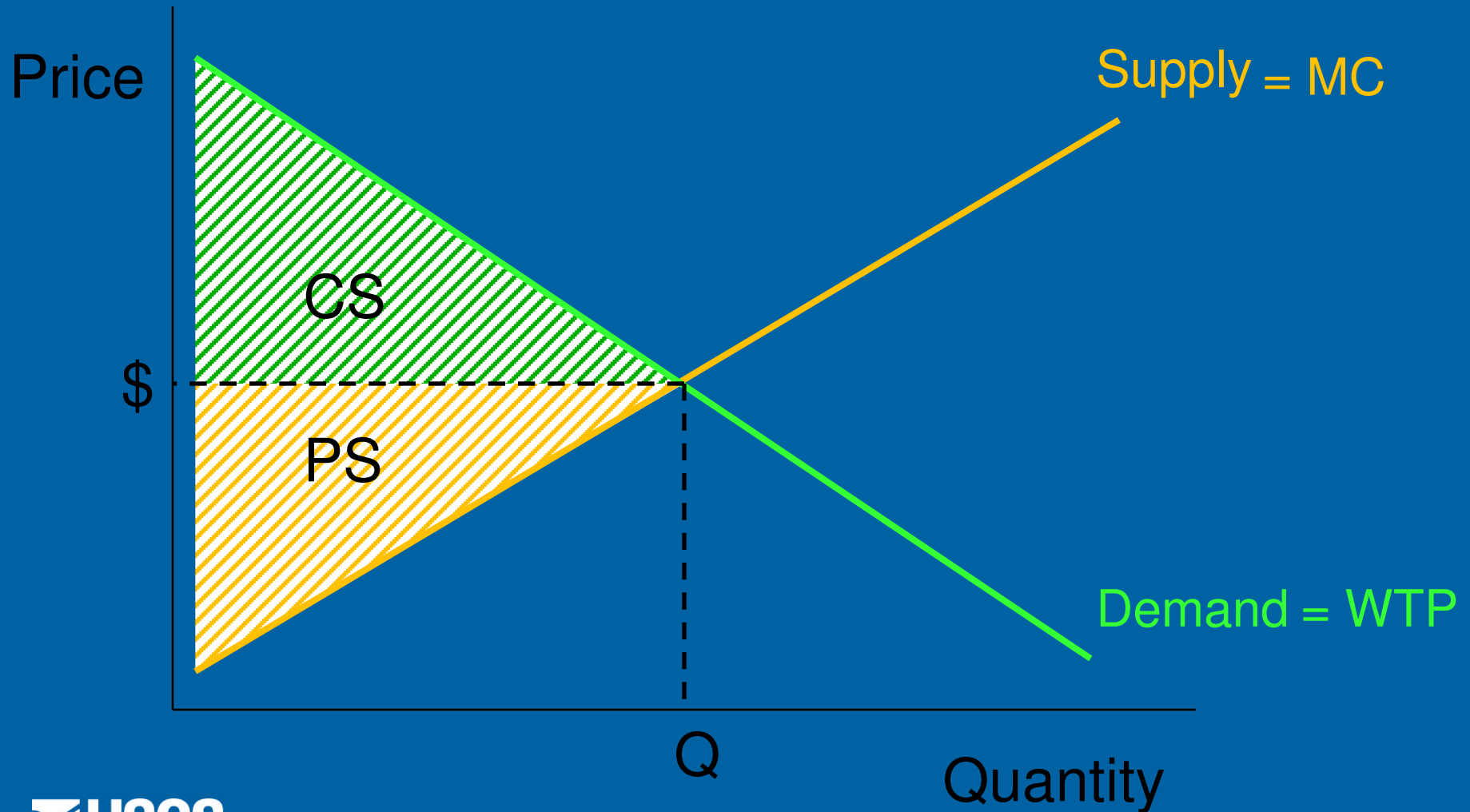
Economic Benefits and Costs

- **Economic cost is foregone opportunity of use in other sectors on the economy**
 - Labor
 - Capital
 - Resource inputs (e.g., water)
- **Economic benefit is willingness to pay, or demand, for a good or service**
 - Demand is a function of price
 - Individual income (fixed)
 - Prices of all others goods and services (fixed)

Economic Supply and Demand

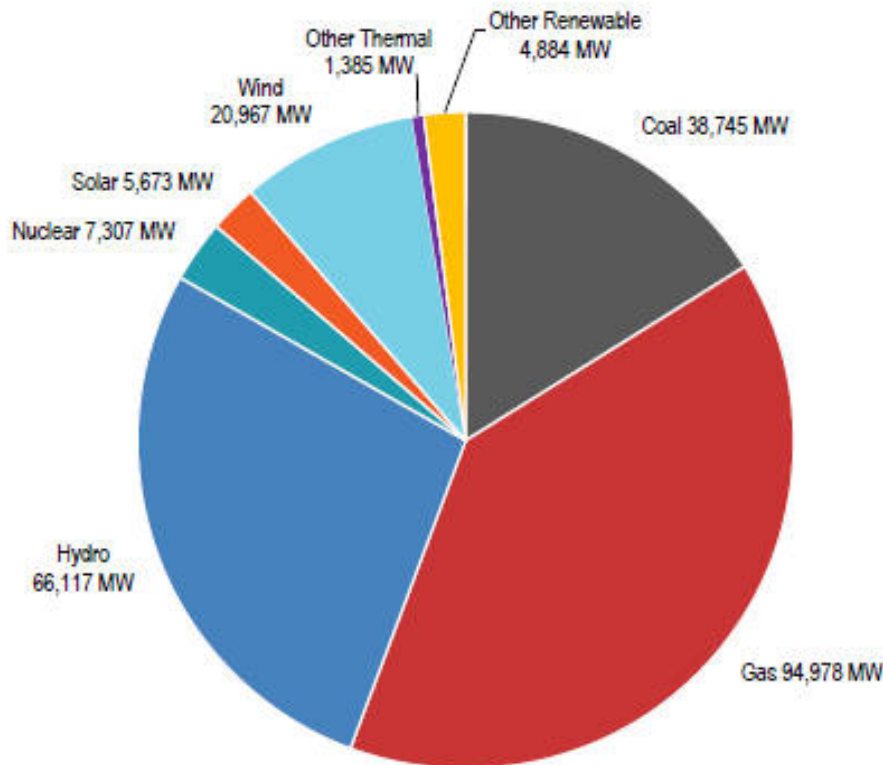


What is Economic Value?

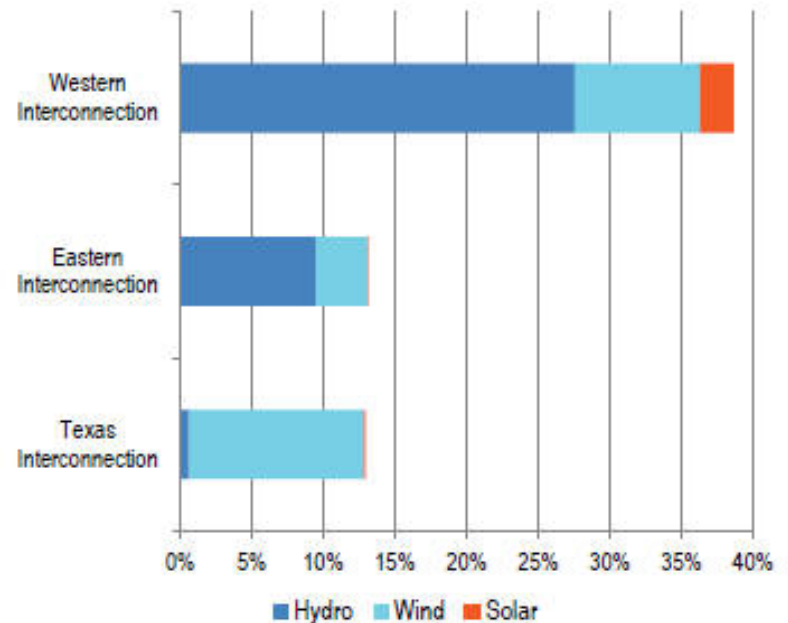




2013 Western Interconnection Resource Portfolio



2013 Weather-Dependent Resources
Percentage of Resource Portfolio*

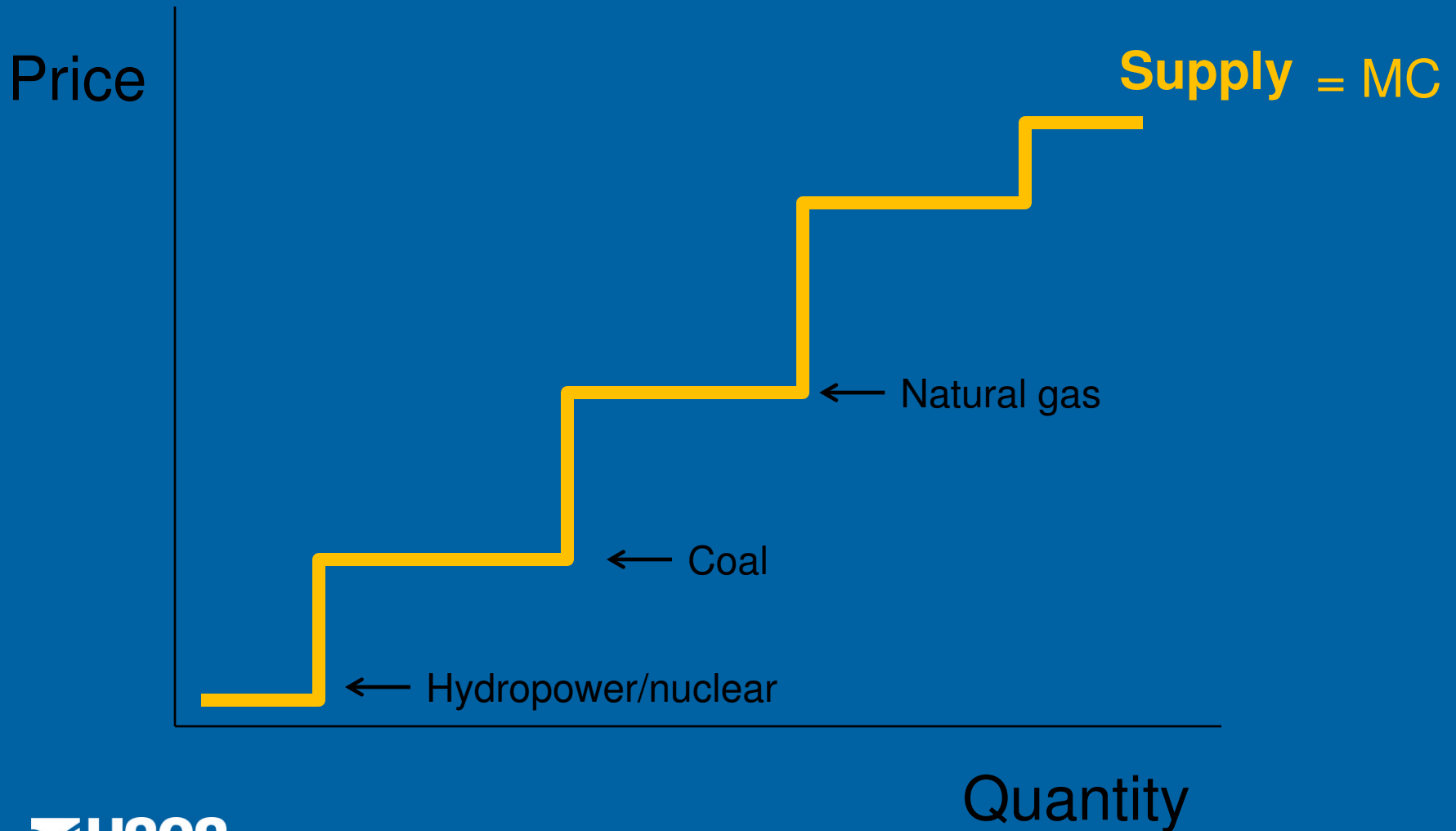


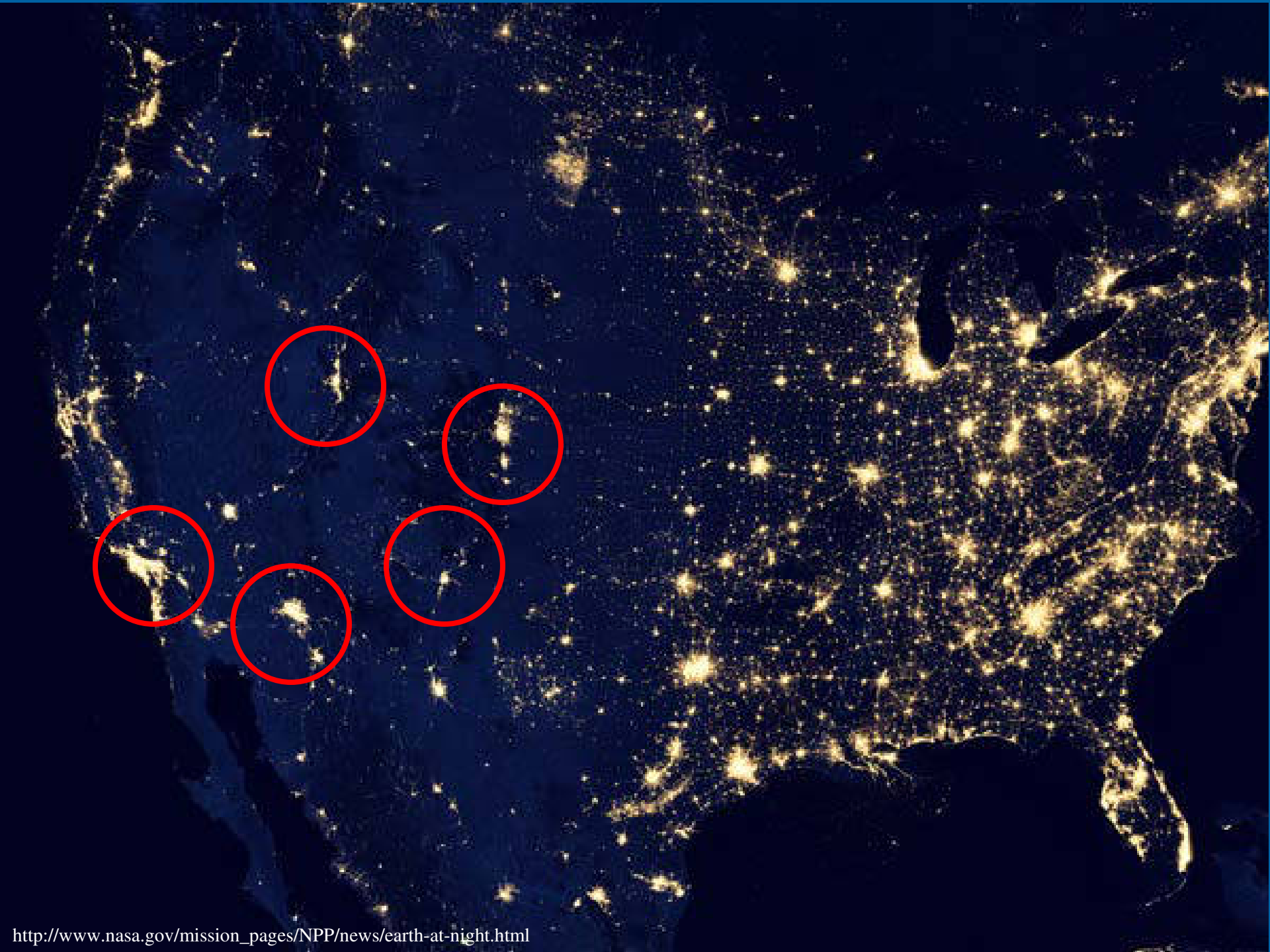
*Weather-dependent resources include hydro, wind and solar generation.

WECC used nameplate capacity for wind and solar resources. Expected summer maximum capacity was used for all other resources when the data was available, otherwise nameplate was used.

GENERATION

Economic Value of Energy

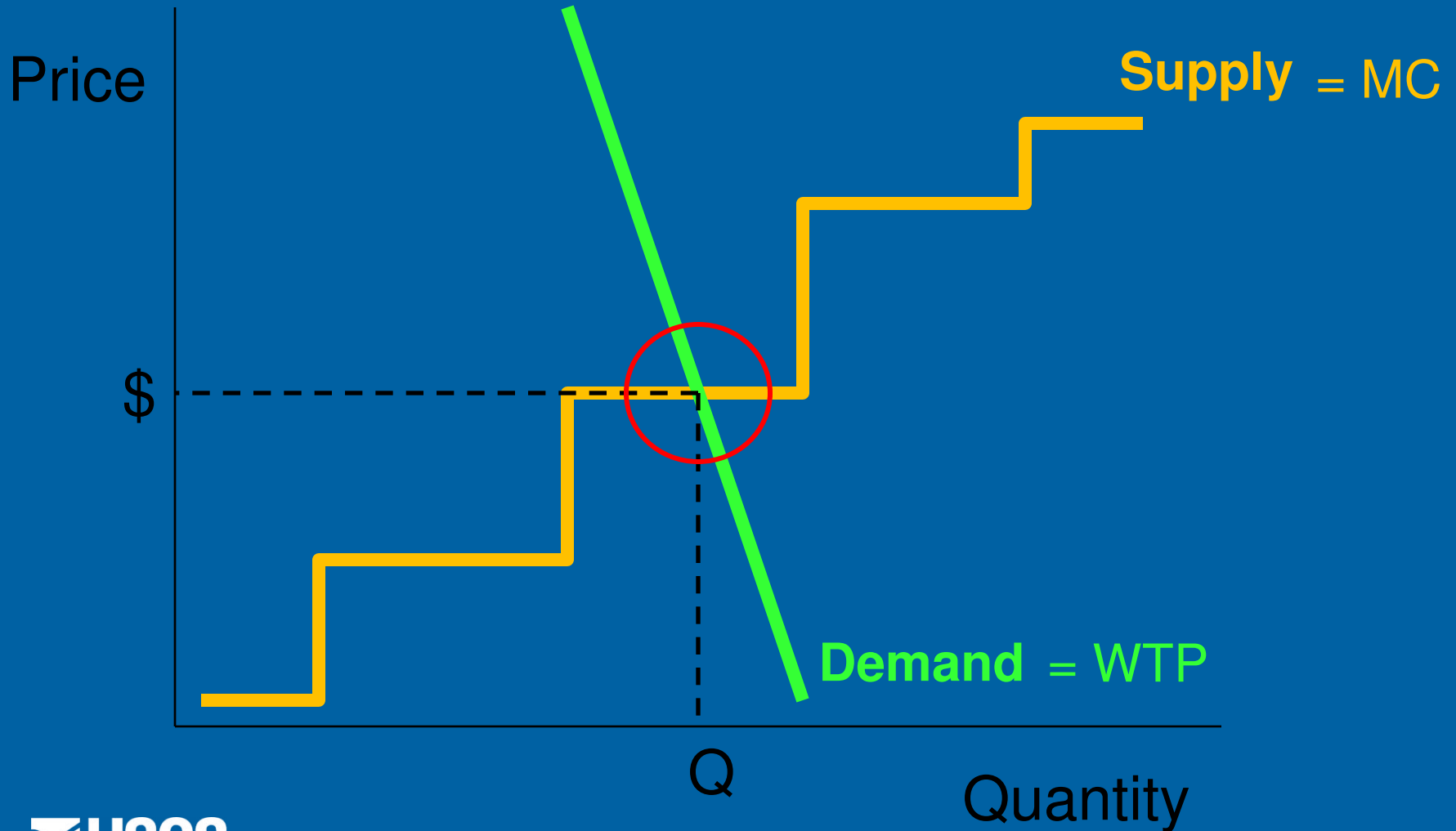




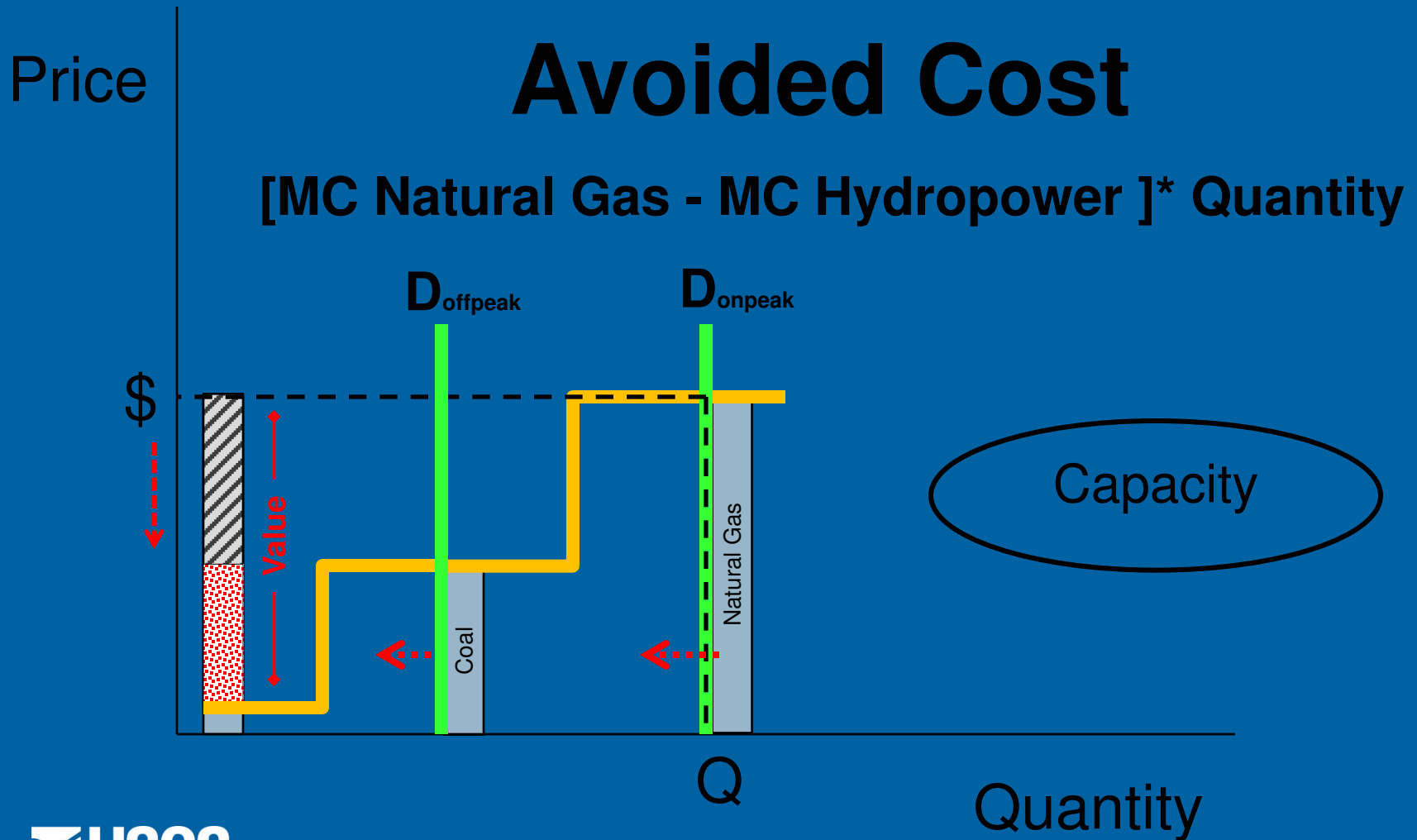
Comparison of Actual to Forecasted Peak Demand 2009-2013



Economic Value of Energy



Economic Value of Energy



Economic Value of Energy

- Value of energy (hydropower)

- $\sum_t [q_t (mc_{ct} - mc_h)] \quad mc_{ct} = p_{ct}$

- Alternative (q'_t) – Base (q_t)

- $\sum_t [q'_t (mc'_{ct} - mc_h)] - \sum_t [q_t (mc_{ct} - mc_h)]$

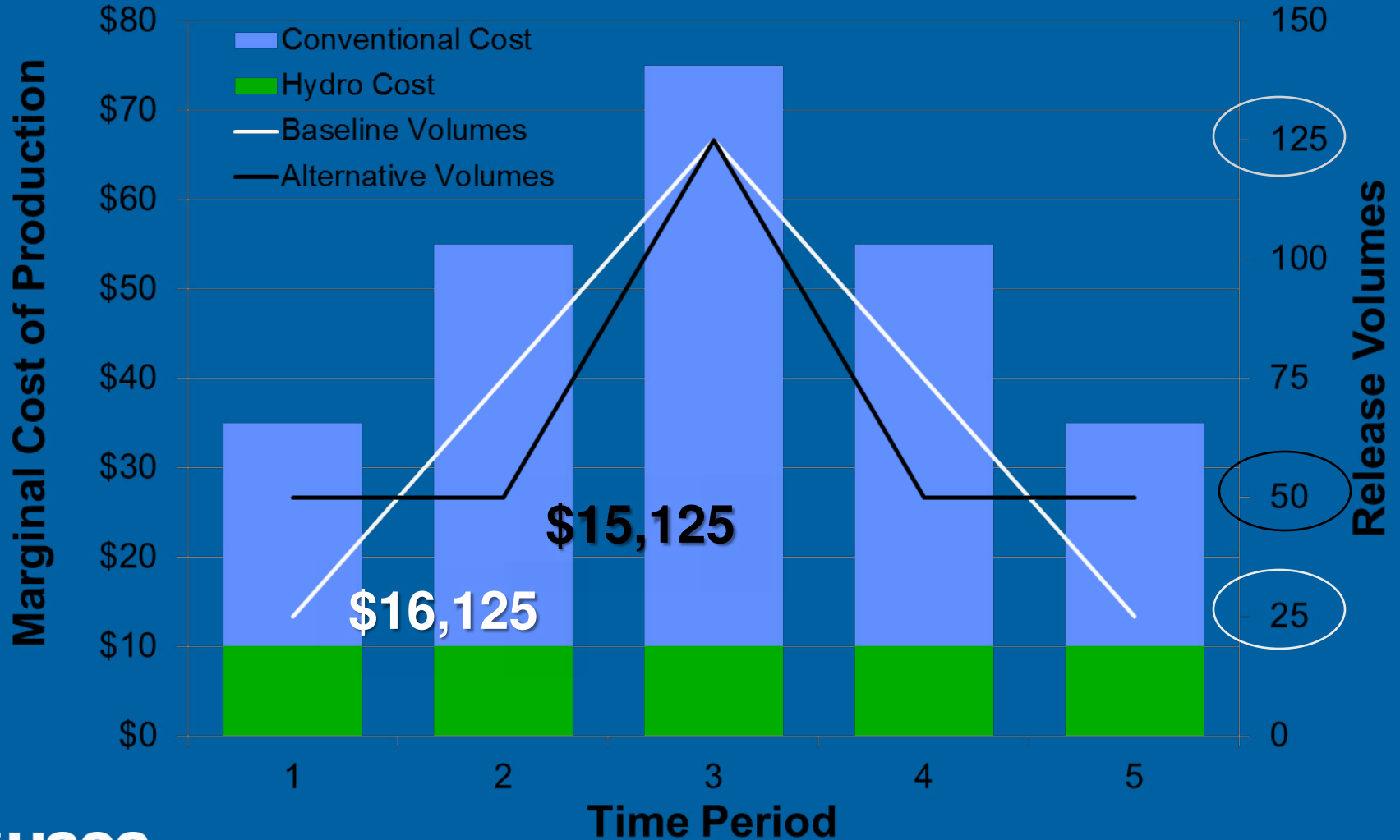
- $\sum_t [q'_t mc'_{ct} - q'_t mc_h] - \sum_t [q_t mc_{ct} - q_t mc_h]$

- $\sum_t [q'_t mc'_{ct}] - \sum_t [q'_t mc_h] - \sum_t [q_t mc_{ct}] + \sum_t [q_t mc_h]$

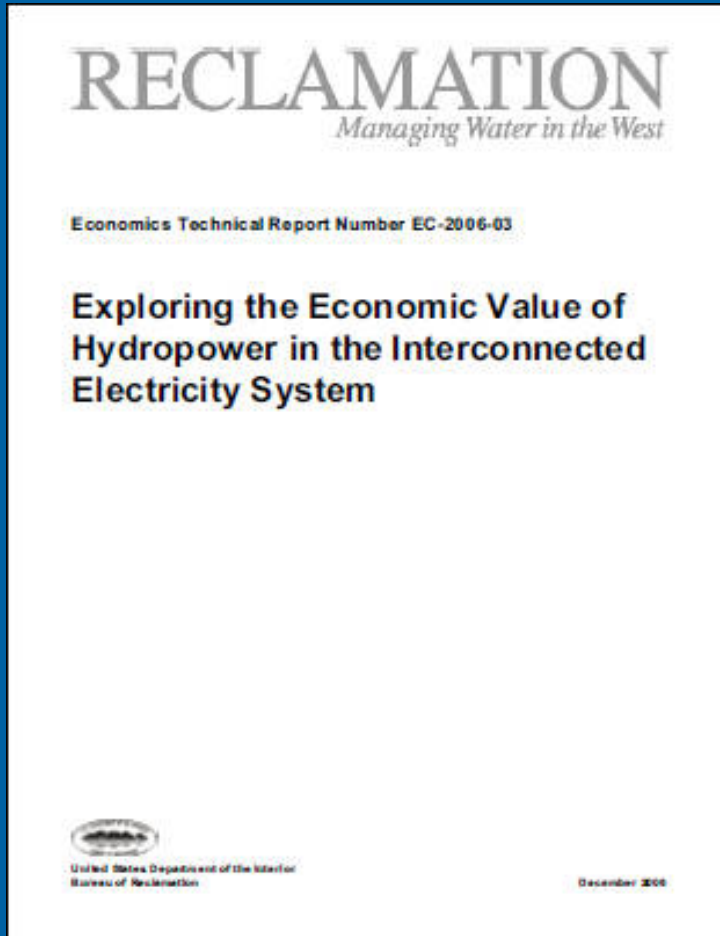
- $\sum_t [p_{ct} (q'_t - q_t)]$

Economic Value of Energy

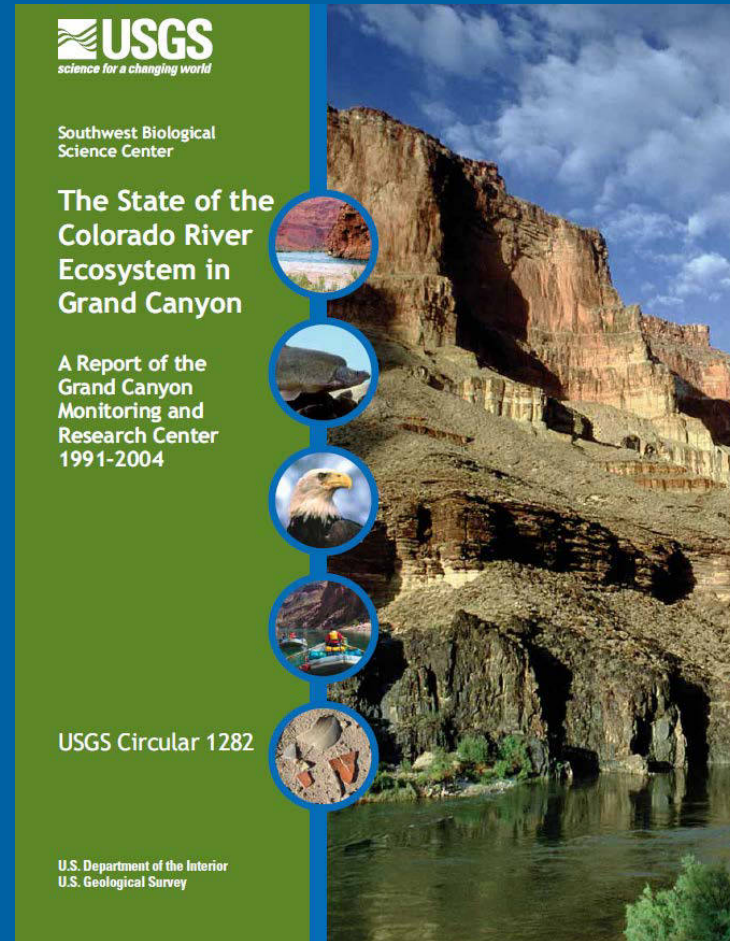
Total Volume = 325
 Max. = 125
 Min. = 25



Resources



<http://www.usbr.gov/pmts/economics/reports/TMEC0603.pdf>

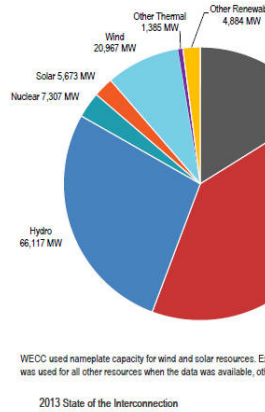


<http://pubs.usgs.gov/circ/1282/c1282.pdf>

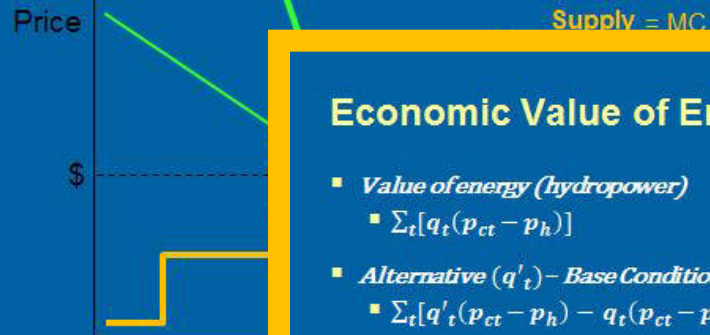


Economic Analysis

2013 Western Interconnection Resource Portfolio

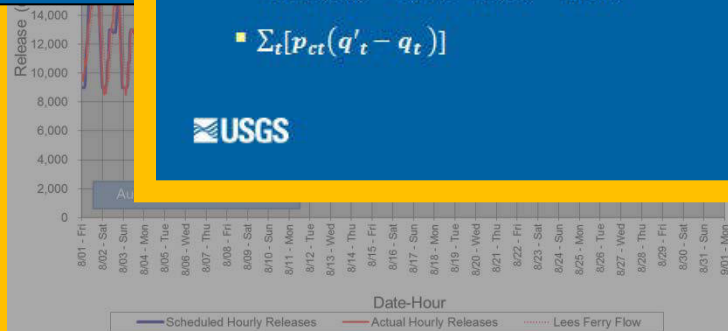


Economic Value of Energy

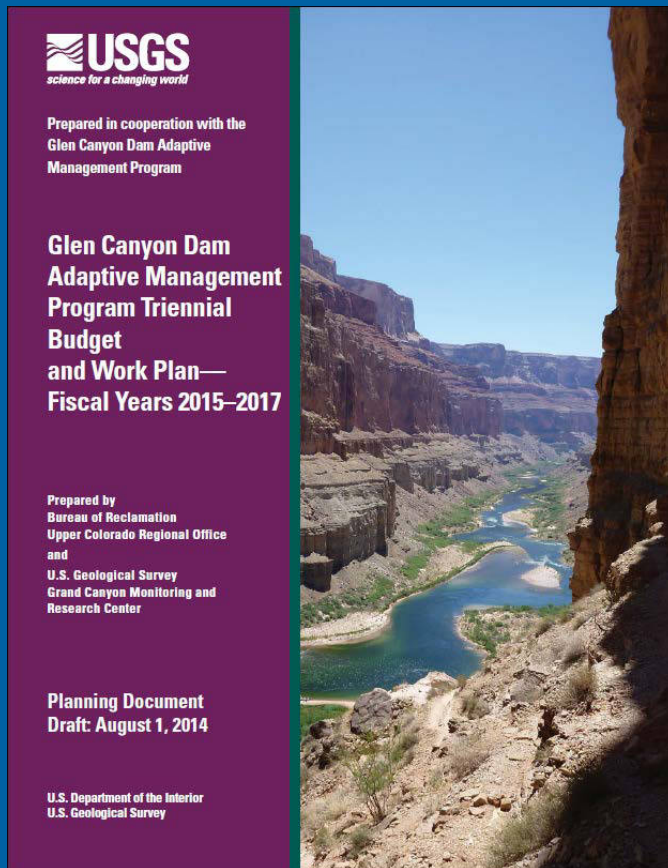


Economic Value of Energy

- *Value of energy (hydropower)*
 - $\sum_t [q_t(p_{ct} - p_h)]$
- *Alternative (q'_t) - Base Conditions (q_t)*
 - $\sum_t [q'_t(p_{ct} - p_h) - q_t(p_{ct} - p_h)]$
 - $\sum_t [(q'_t p_{ct} - q'_t p_h) - (q_t p_{ct} - q_t p_h)]$
 - $\sum_t [q'_t p_{ct} - q_t p_{ct} + q'_t p_h - q_t p_h]$
 - $\sum_t [p_{ct}(q'_t - q_t)]$



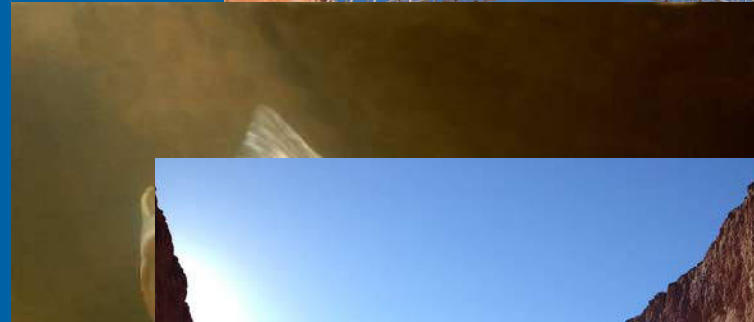
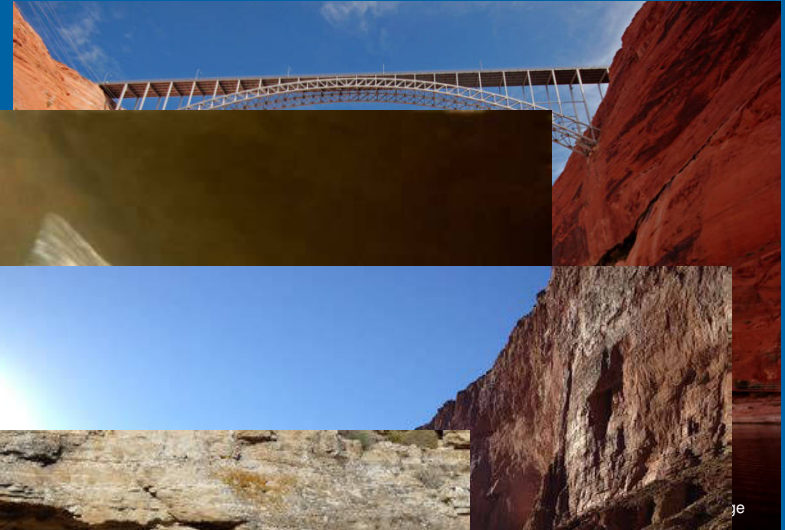
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Resources of Economic Value

- Hydropower
- Ecosystem
 - Native fish
 - Riparian habitat
- Recreation
 - Angling
 - Rafting
- Cultural



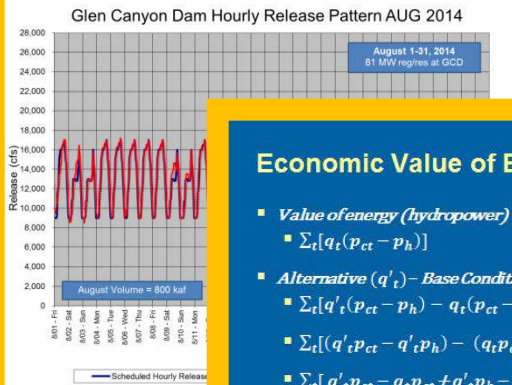
Economics of Adaptive Management

- Management actions and associated costs
 - Dam operations (trout management flows)
 - Temperature control device
- Hypotheses about resource outcomes
 - Predictive models
- Excepted benefit of resource outcomes
- Updating hypotheses
 - Value of information

Computational Economics

- **Mathematical Programming**
 - Optimization or simulation with a series of models
 - Learning through system models
 - Value of information associated with learning
- **Example**
 - Humpback chub management
 - Cost-effective management to meet humpback chub recovery goals
- **Interdisciplinary collaboration**

Resource Management



Economic Value of Energy

- *Value of energy (hydropower)*
 - $\sum_t [q_t(p_{ct} - p_h)]$
- *Alternative (q'_t) - Base Conditions (q_t)*
 - $\sum_t [q'_t(p_{ct} - p_h) - q_t(p_{ct} - p_h)]$
 - $\sum_t [(q'_t p_{ct} - q'_t p_h) - (q_t p_{ct} - q_t p_h)]$
 - $\sum_t [q'_t p_{ct} - q_t p_{ct} + q'_t p_h - q_t p_h]$
 - $\sum_t [p_{ct}(q'_t - q_t)]$



Computational Economics

- **Stochastic Dynamic Programming**
 - Optimization of a series of predictive models
 - Update hypothesis through statistical methods
 - Value of information
- **Example**
 - Humpback chub and rainbow trout interactions
 - Cost-effective trout management to meet humpback chub recovery goals
- **Interdisciplinary collaboration**
- **Computational limitations**



A scenic landscape featuring a dirt path leading through a valley. On the left, a large, gnarled tree with vibrant yellow autumn foliage stands prominently. The path is flanked by various green and yellow shrubs and bushes. In the background, rugged, layered mountains rise under a clear blue sky. The overall atmosphere is bright and natural.

Questions?