Synapse
Energy Economics, Inc.

Co-Benefits of Renewable Energy and Energy Efficiency in Utah

Air Quality, Health and Water Benefits
A Report to the State of Utah

March 15, 2010

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Introduction and Scope

- Client group
  - State Energy Program
  - Division of Public Utilities
  - Division of Air Quality
  - Committee of Consumer Services
  - Governor's Energy Advisor
- Purpose
  - Tier I: Develop and apply methods of estimating health and water co-benefits of alternative energy
  - Tier II: Identify and discuss impacts on natural gas prices and regional haze
  - Scenario analysis

Punchline

- Fossil generation in Utah today
  - Consumes **74,000 acre feet** of water per year
  - Regionally, results in **200 premature deaths** and 350 hospital admissions each year
  - Costs society between **$1.7** and **$2.0 billion** each year
  - Vast majority of impacts from coal-fired generation
- Utah is a net power exporter
  - Reducing demand in-state does not substantially impact coal generation
  - Energy efficiency (EE) and renewable energy (RE) projects displace gas-fired generators
- Co-benefits range from **$26**/MWh to a *cost* of -**$4**/MWh
- Replacing the least efficient coal generators in Utah yields a co-benefit of **$69** - **$79**/MWh

- Externalities

  "activities of one agent that affect the wellbeing of another agent, and occur outside the market mechanism" – National Academies of Science

  Costs (or benefits) imposed on society, not borne by utility owners or ratepayers

- Co-Benefits

  Externalities *avoided* by actions which reduce impacts on society

- Physical or monetized

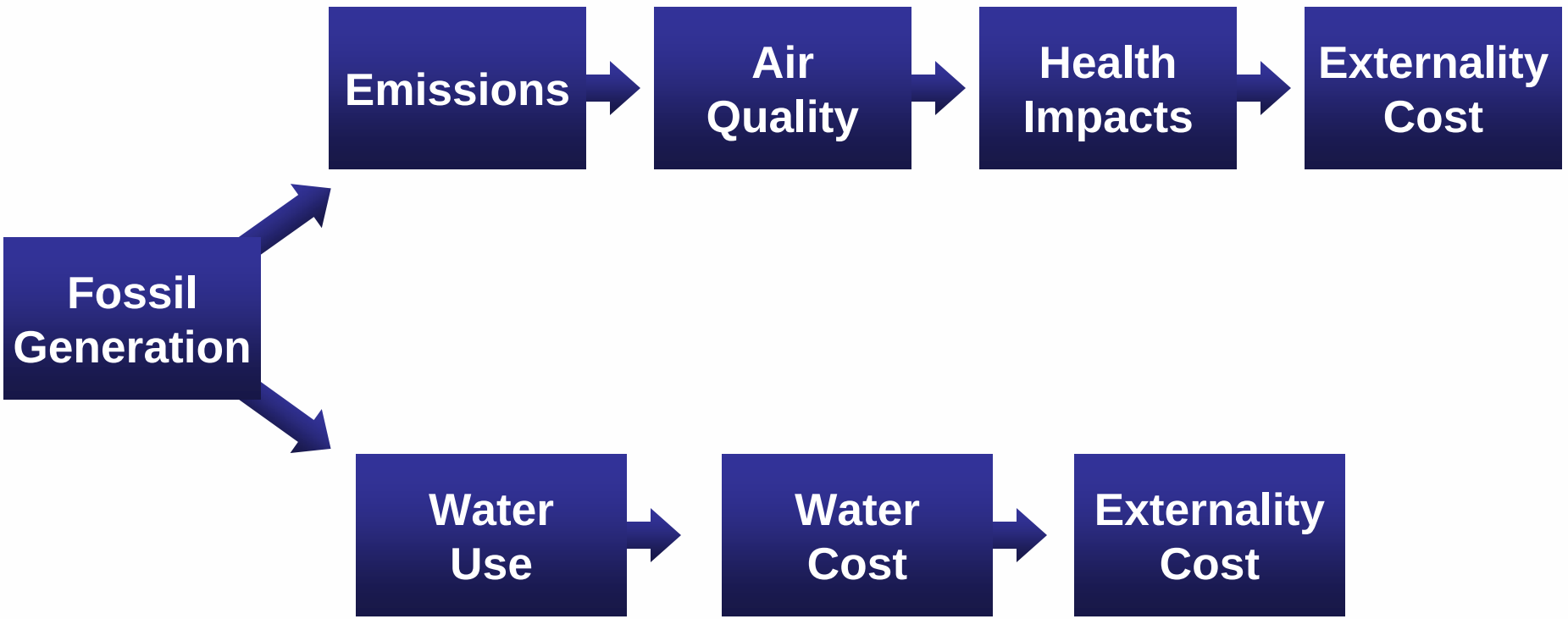
Direct and Indirect Costs of Generation

Considered in Planning?	Costs and Benefits: Direct	Costs and Benefits: Indirect
Yes	• Capital • Fuel • O&M • Transmission • Capacity • Reliability • Environmental regulation	• Employment • Tax basis • Future environmental regulations
No	• Economic impacts and ripple effects • Price effects	• **Health impacts** • **Water consumption** • Land use • Ecosystem and climate impacts • Visibility • Waste storage / disposal • Upstream impacts • Resource availability

Monetize health and water co-benefits of energy efficiency (EE) and renewable energy (RE)

A. Determine current and future externalities
B. Estimate cost of externalities
C. Calculate externalities avoided by EE and RE scenarios
D. Express co-benefits in cost of energy terms ($/MWh)

Approach



Approach

Baseline Scenario

-

Alternative Scenario

=

Co-Benefit

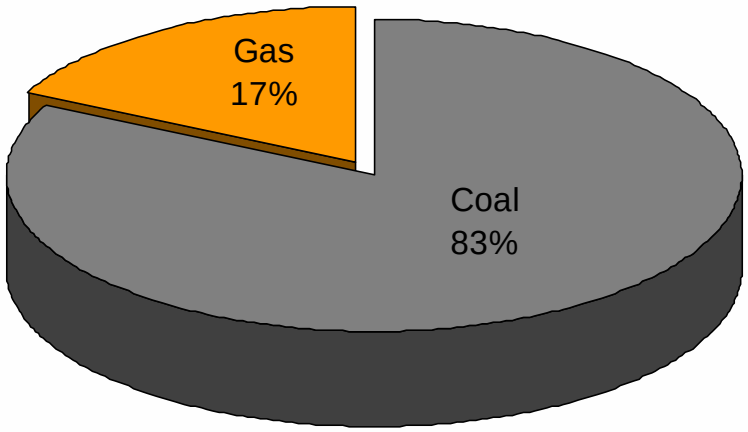
Renewable Energy and Energy Efficiency Scenarios

Spanish Fork. Source: Panoramio

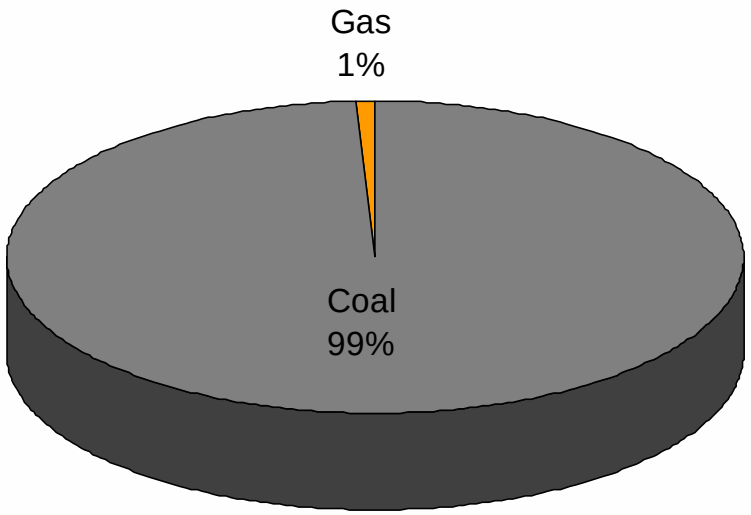
- Energy Efficiency (EE)
- Wind, UT and WY
- Solar Photovoltaics
- Concentrating Solar Power
- Geothermal
- Replacement scenarios
  - EE and gas
  - EE, RE, and gas

Displaced Emissions
Utah's Fossil Generators

- Bonanza
- Carbon
- Hunter
- Huntington
- Intermountain
- Lake Side
- Currant Creek
- Gadsby
- West Valley
- Nebo
- Millcreek

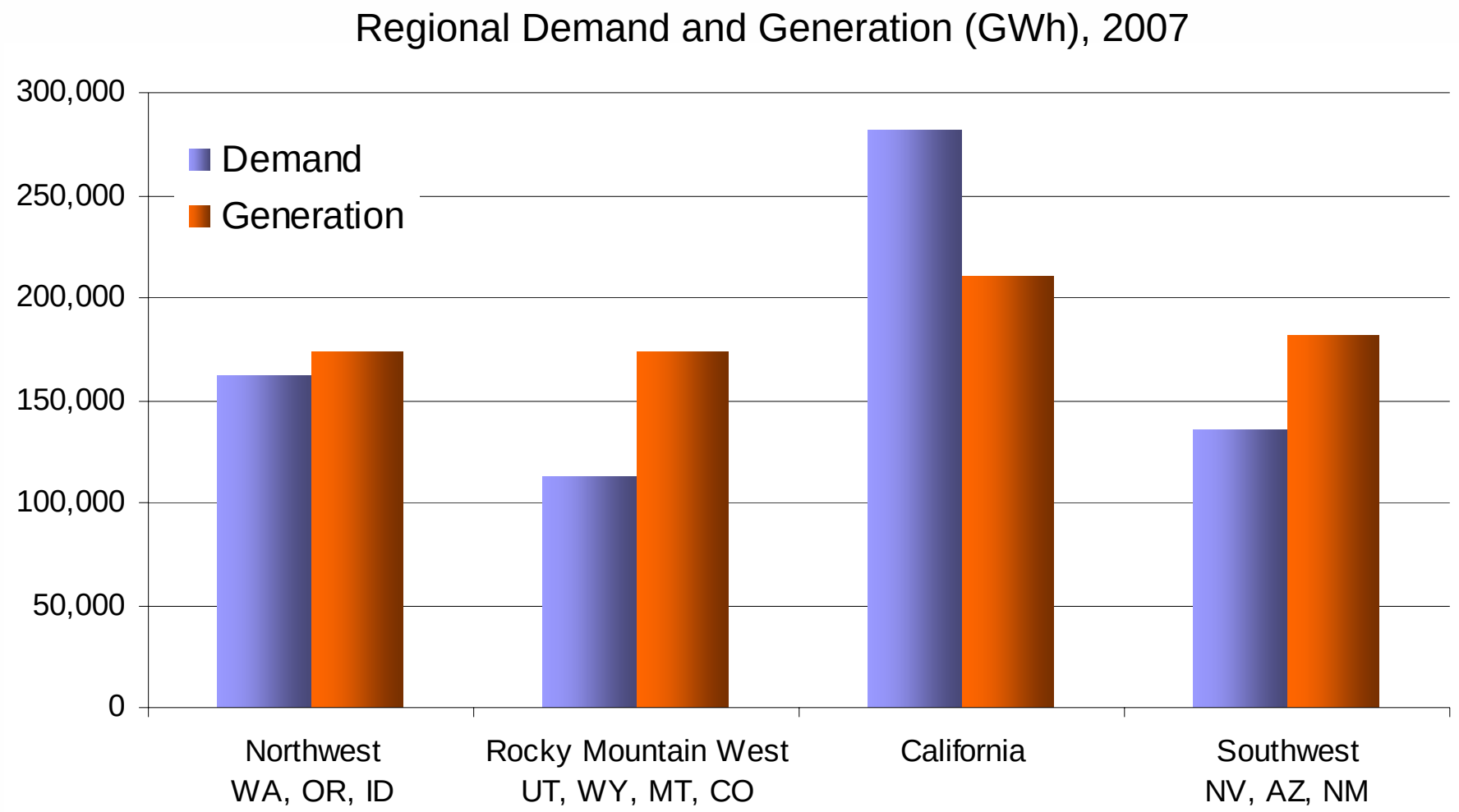


Generation
2007-2008
47,168 GWh



NO_X Emissions
2007-2008
139 million lbs
(70,000 tons)

Displaced Emissions
Exports from region



Emissions and Health

- Emissions of
  - Particulates (primary)
    - Soot, ash, etc…
  - NO_X and SO_2
    - Secondary particulates (sulfates, nitrates)
  - Ozone formation
- Associated with
  - Chronic obstructive pulmonary disease (COPD)
  - Asthma / shortness of breath
  - Bronchitis
  - Minor restricted activity days (MRADs)
  - Increased mortality (elderly and health-compromised populations)

Emissions and Health Approach

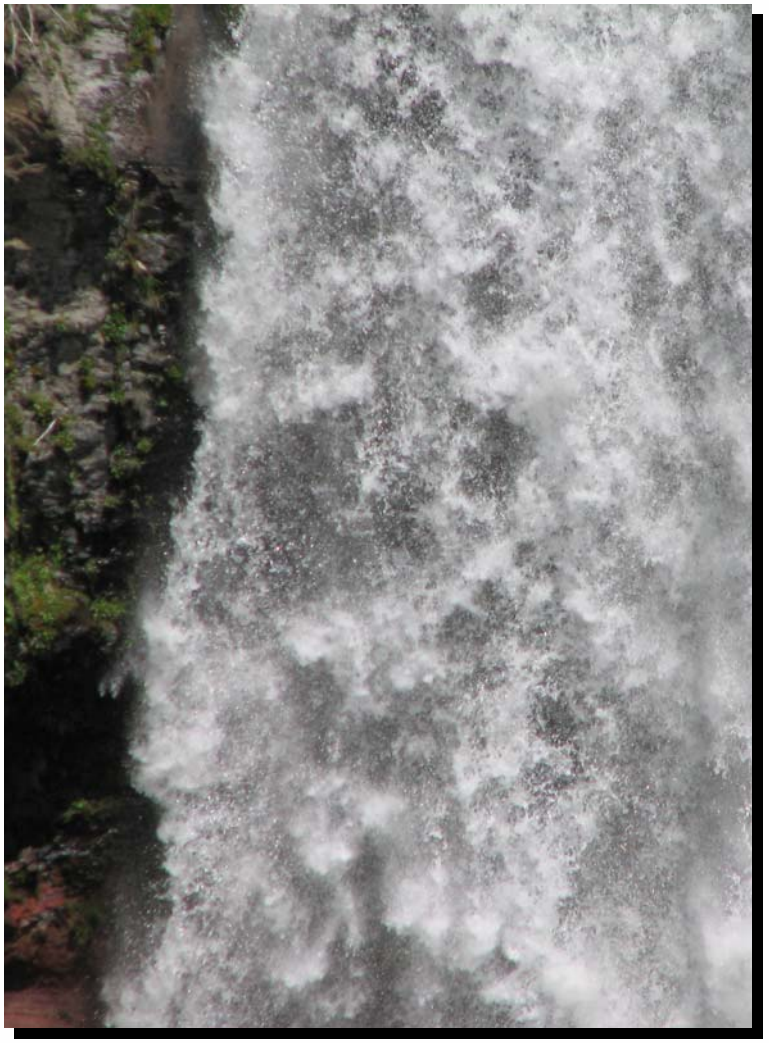
- Emissions by generating unit
  - EPA CAMD / Continuous Emissions Monitoring
  - Dispatch model
- Exposure characterization
  - Source-receptor (S-R) matrix
  - Based on transport model
- Health impact calculation
  - Concentration-response function

Emissions and Health
Value of a Statistical Life and Morbidity

- Value of a Statistical Life
  - Difficult and ambiguous question
  - Assumed EPA-accepted standard - $8,000,000
- Morbidity
  - Cardiovascular and respiratory hospital admissions
  - Asthma-related ER visits
  - Restricted activity days (MRADs)

Water Consumption

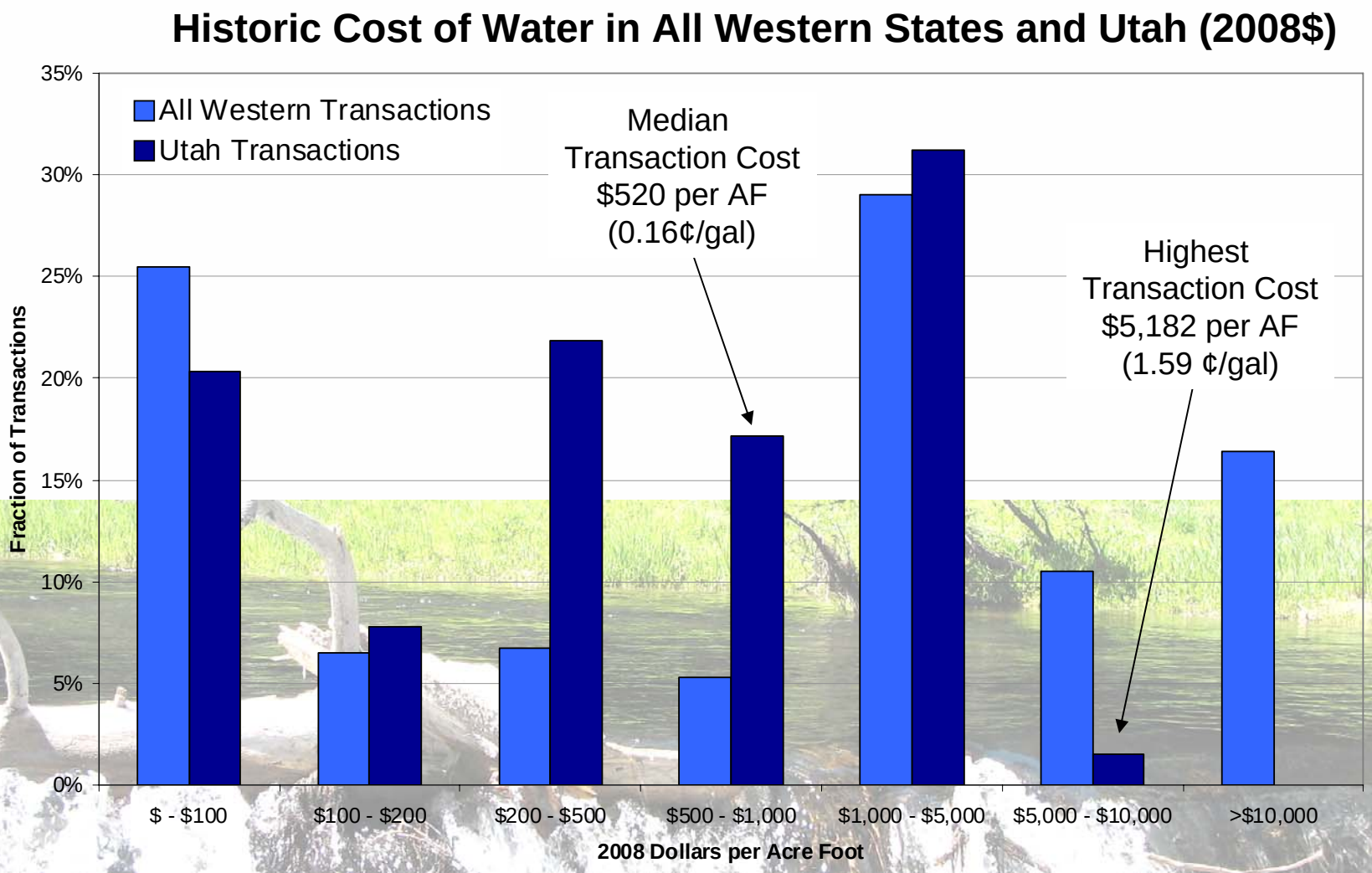
- Water Consumption
  - Thermal power uses water for boilers, cooling, and emission controls
- Social Cost
  - Water is a scarce resource
  - Alternative uses are valuable
  - Generators own current water rights at nominal cost



Water Consumption Approach

- Water consumption by
  - Fossil units
  - Geothermal and CSP
- Value of water
  - Transaction cost, historic
  - Market cost of water today (low)
  - Marginal cost of water in stressed conditions (high)
- Monetary cost of water consumed

Water Consumption
Marginal Price of Water: Historical Water Rights



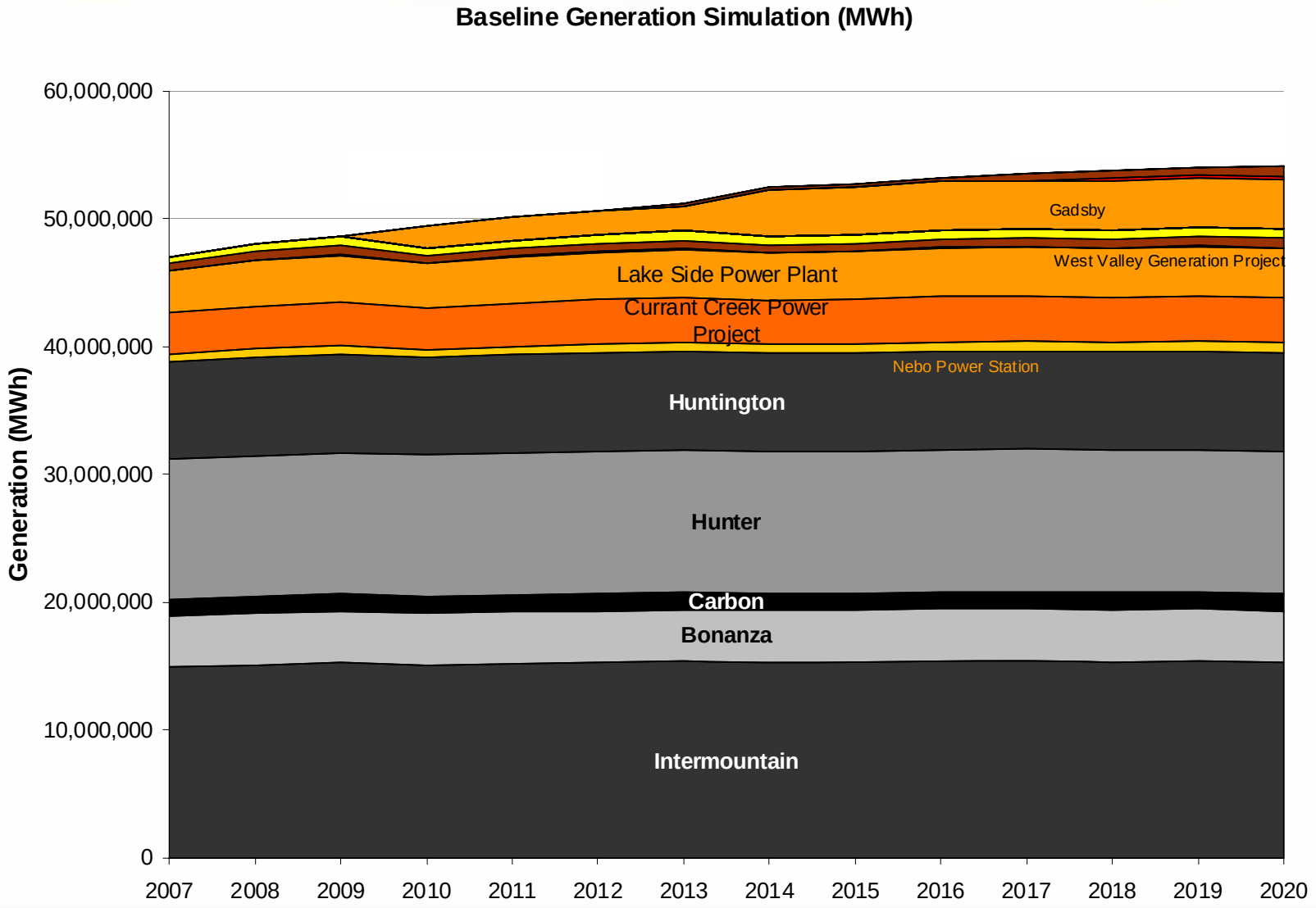
Results
Annual Externalities in Utah (2007-2008)

	Physical Externality		Cost (Million 2008$)	
	Regional	**In Utah**	**Regional**	**In Utah**
Statistical Deaths per Year	202	28	$1,612	$222
Cardiovascular Hospital Admissions per Year	21	1.7	$32	$16
Respiratory Hospital Admissions per Year	154	70		
Emergency Room Visits per Year	175	72		
Water Use (Acre Feet per Year)	73,800		$38 – 469	
		Total	**$1,683 – $2,114**	
Cost per MWh of Fossil Generation			**$36 – 45 / MWh**	

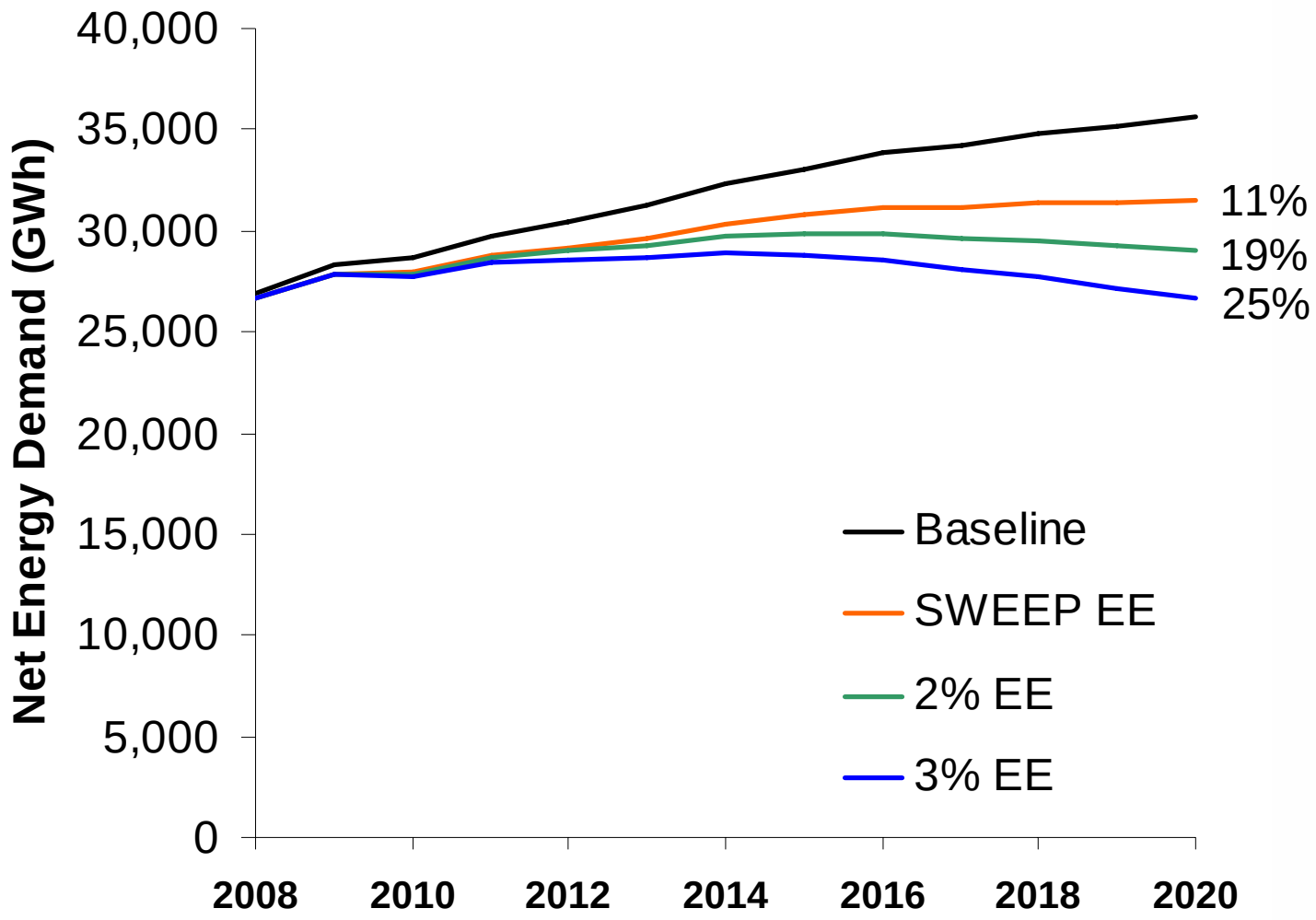
Scenario Analysis
Build-out Assumptions

- Baseline load growth from PacifiCorp (2008)
- No retirements
- All new load met with new gas generation (CC and CT)
  - Run model annually to 2020, add new gas capacity as required
- No changes in water consumption or emissions
- No change in dispatch
- Statistical dispatch model based on hourly generation and emissions (EPA) and demand (PC)

Scenario Analysis
Baseline Scenario Generation (MWh)



Scenario Analysis
Energy Efficiency



Scenario Analysis
Wind Energy

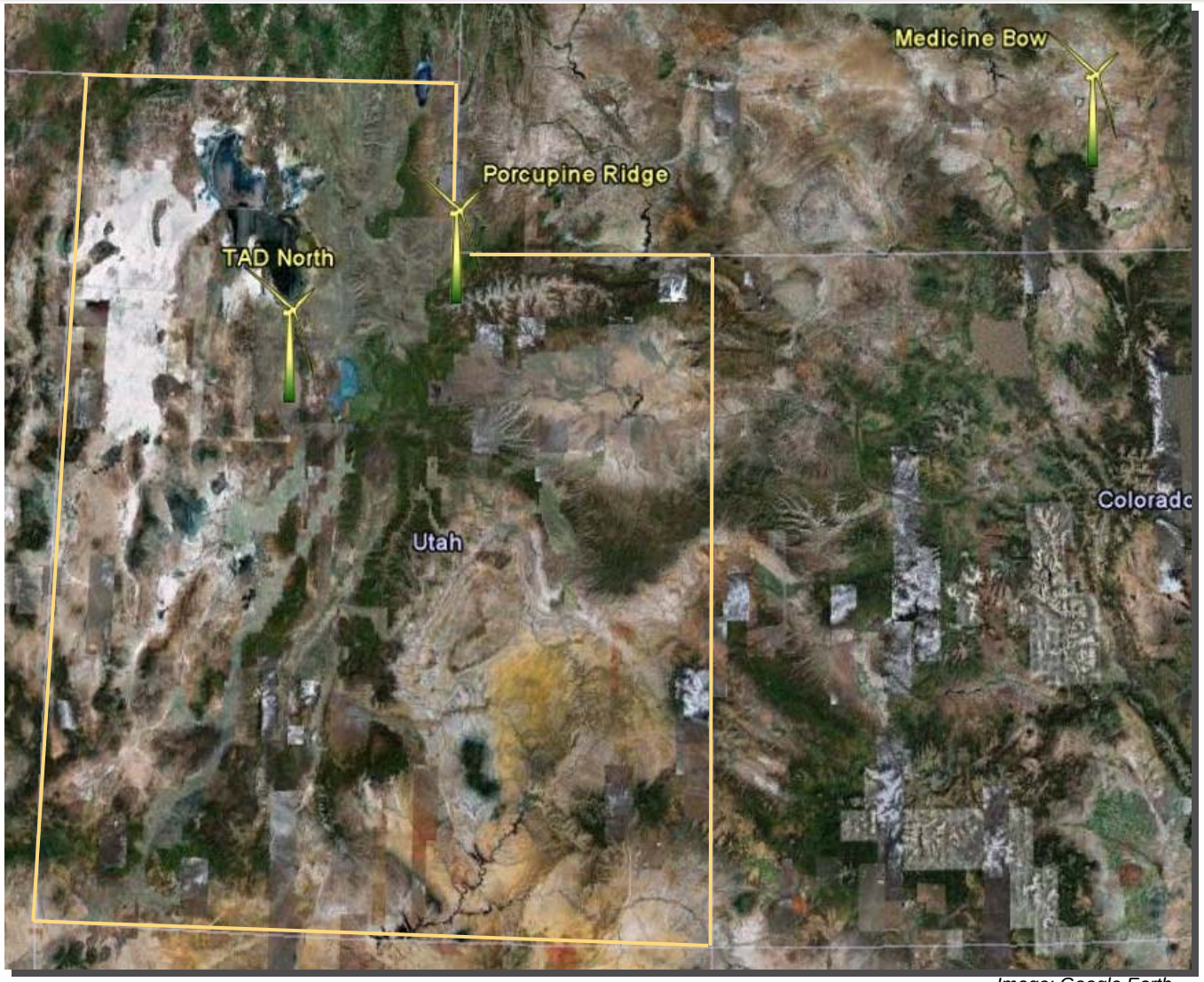


Image: Google Earth

New Resource Scenarios
Solar and Geothermal Energy

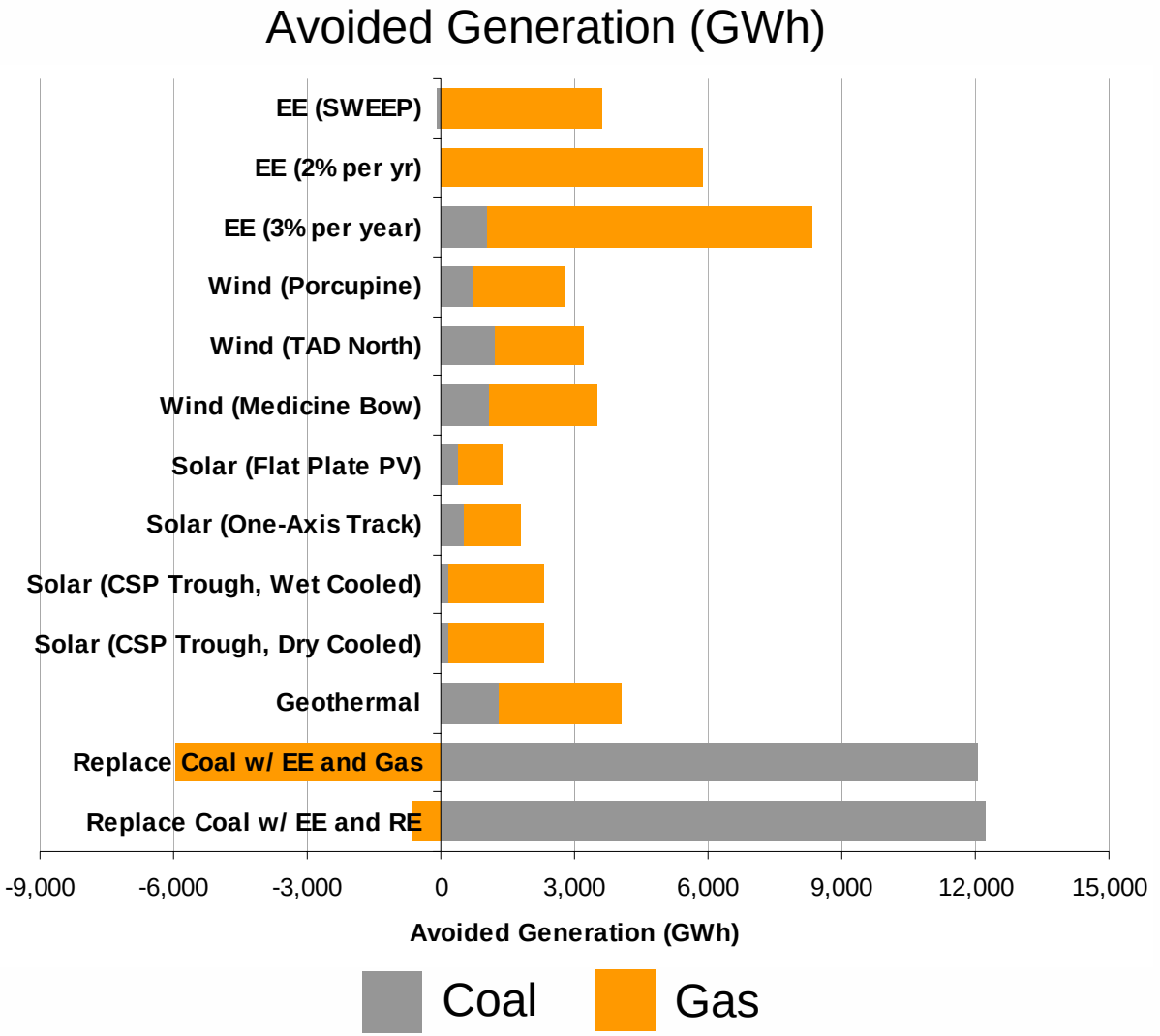
- Solar Photovoltaic
  - Flat Plate
  - Single Axis
- Concentrating Solar Power
  - Trough, wet-cooled
  - Trough, dry-cooled
- Geothermal
  - Wet-cooled binary

New Resource Scenarios
Replacement Scenarios

- Replace
  - Carbon: 2012-2013
  - Huntington: 2014-2016
  - Hunter 1: 2018

- Replace units with energy efficiency and gas
- Replace units with energy efficiency, renewable energy, and gas

Findings
Displaced Generation and Emissions



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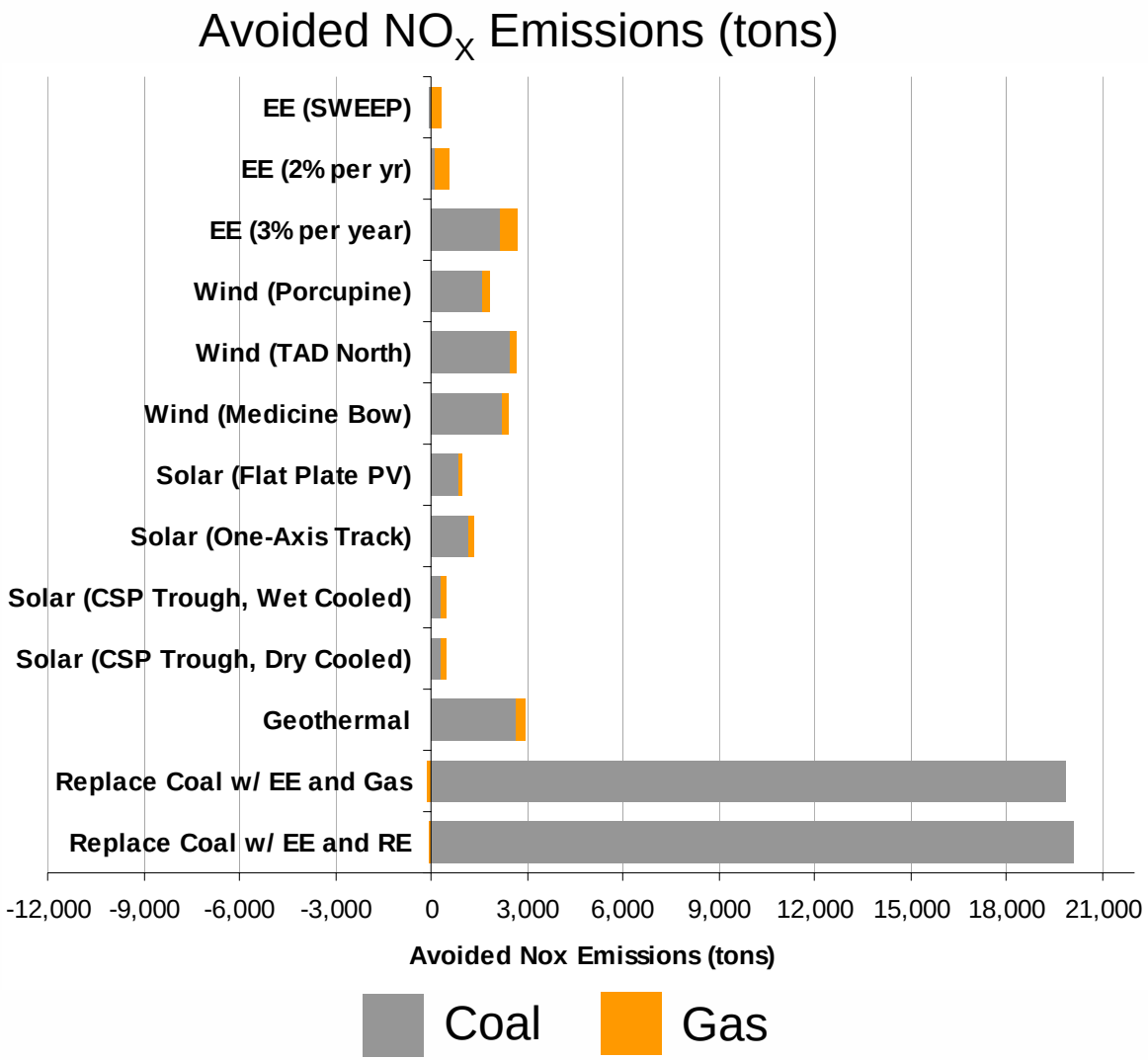
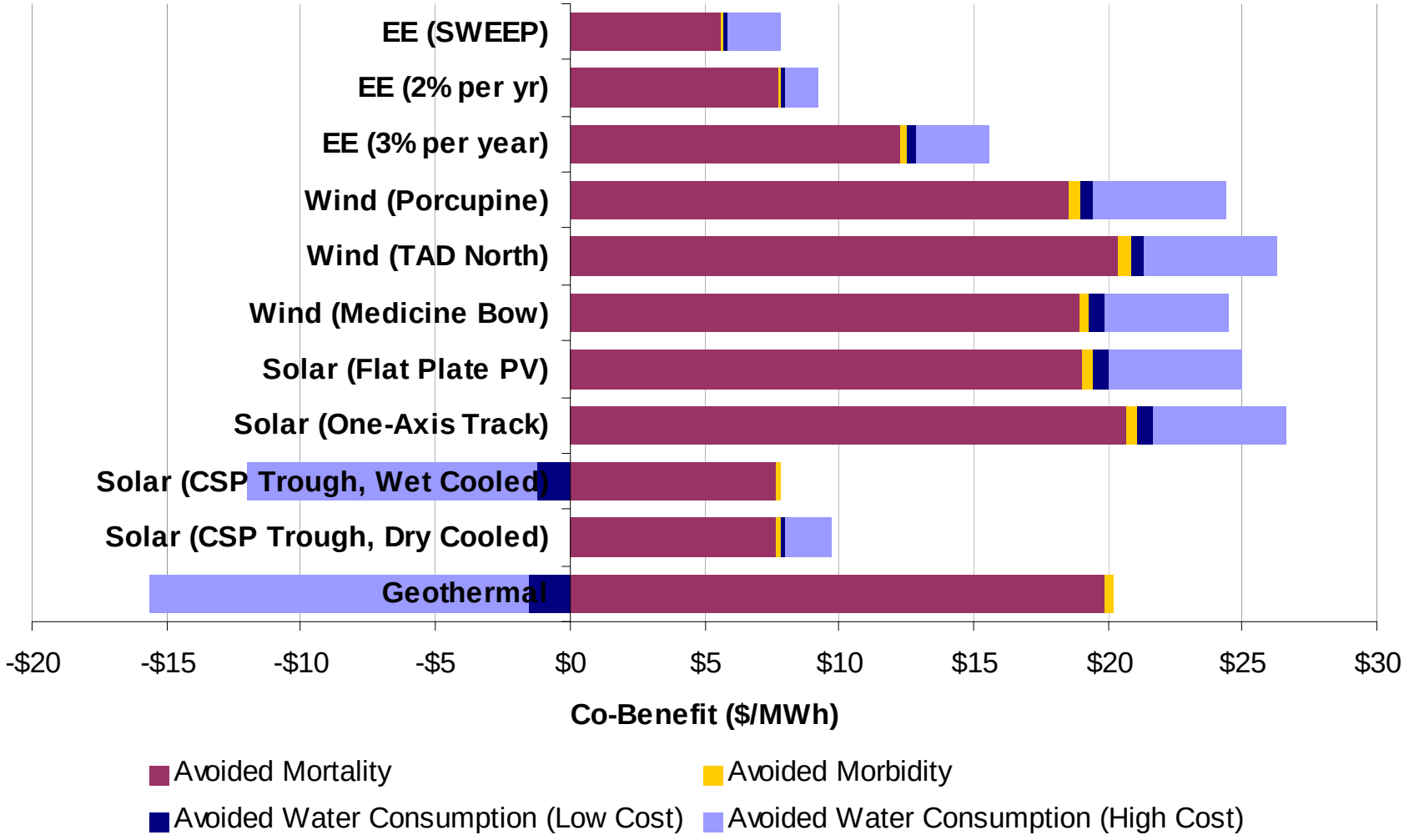


Findings
Monetary Co-Benefits



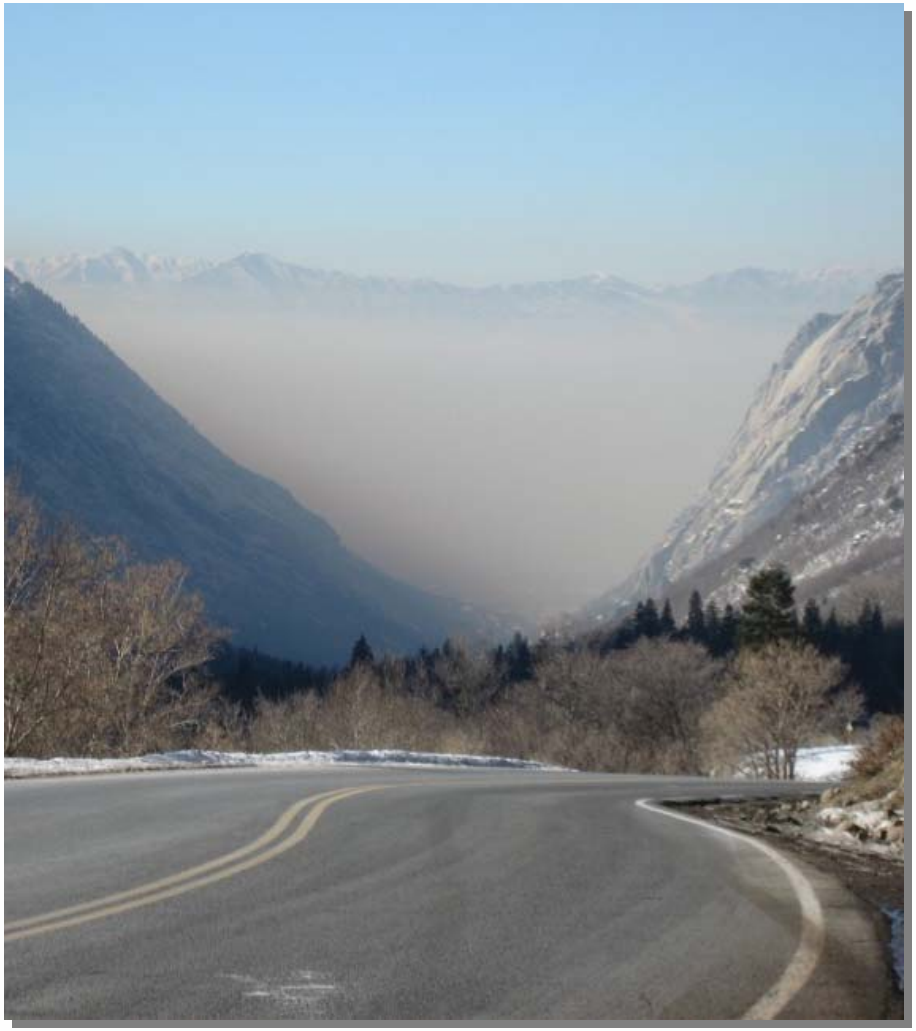
Tier II
Impacts on Natural Gas Prices

- Demand reduction induced price effect (DRIPE)
- Drivers
  - Scale and connectivity of the regional and national natural gas markets
  - Proportion of supply subject to market prices
  - Scarcity of supply
  - Transport constraints
  - High demand

- Natural gas price set regionally
- Utah relatively minor regional consumer
- Change in use in Utah does not have marked impact on NG price

Tier II
Haze and Visibility Impacts

- Regional haze sources
  - Pollution from industrial and energy production
  - Mobile sources
  - Dust
  - Wildfires
  - Sources impacting Utah not defined
- Social cost of haze
  - Visibility
  - Association with poor health quality
  - EPA Clean Air Visibility Rule



January 26, 2007: Little Cottonwood Canyon - NESCAUM

Findings

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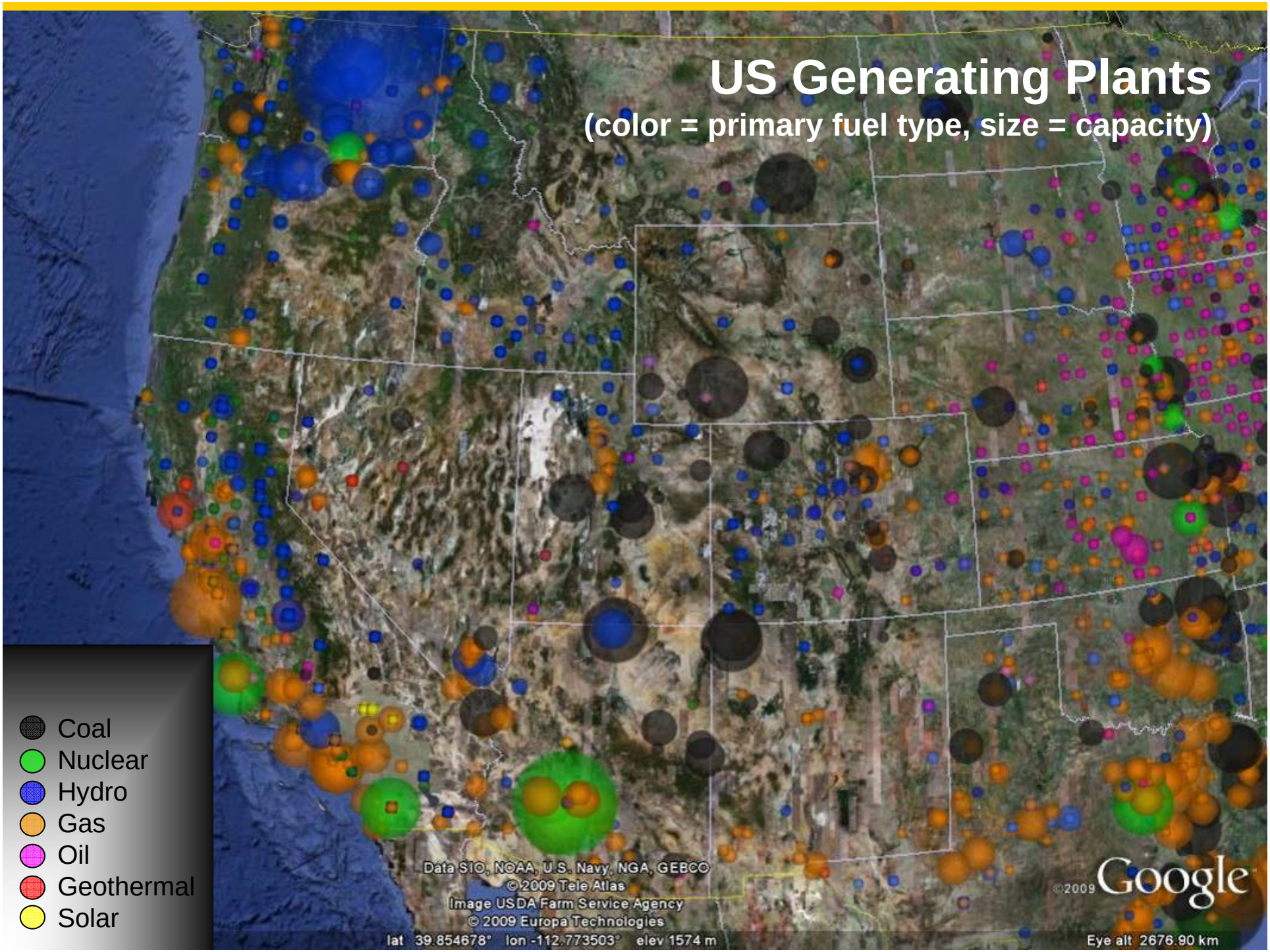
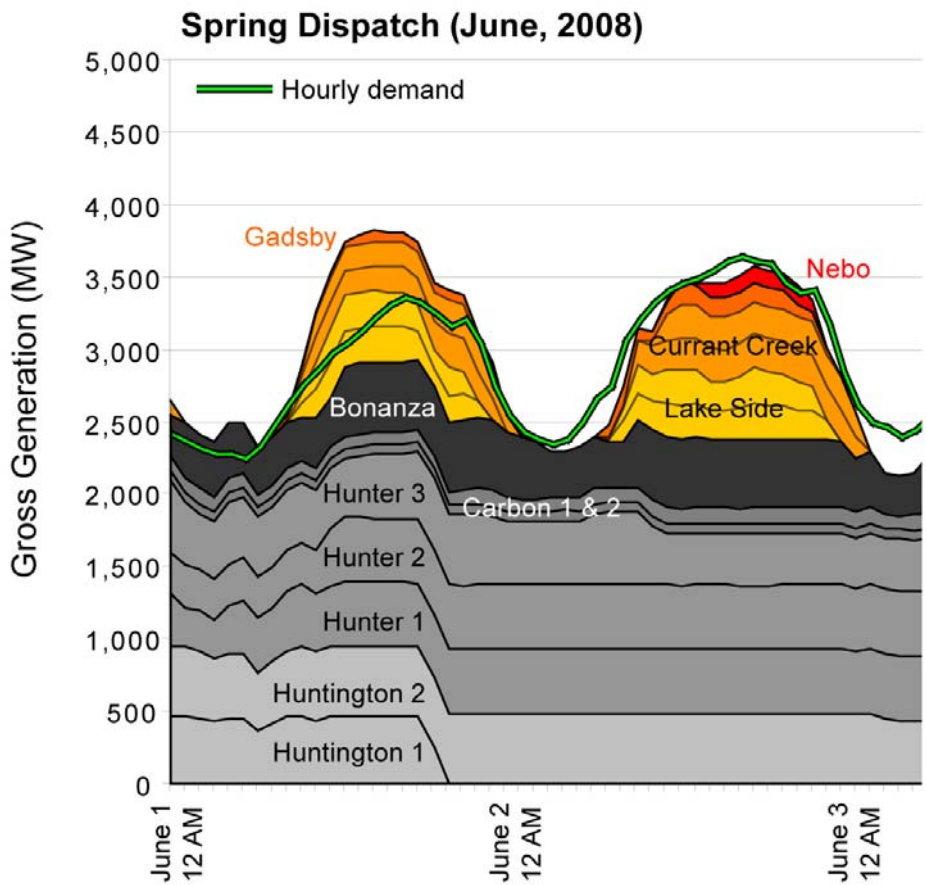
Policy Applications

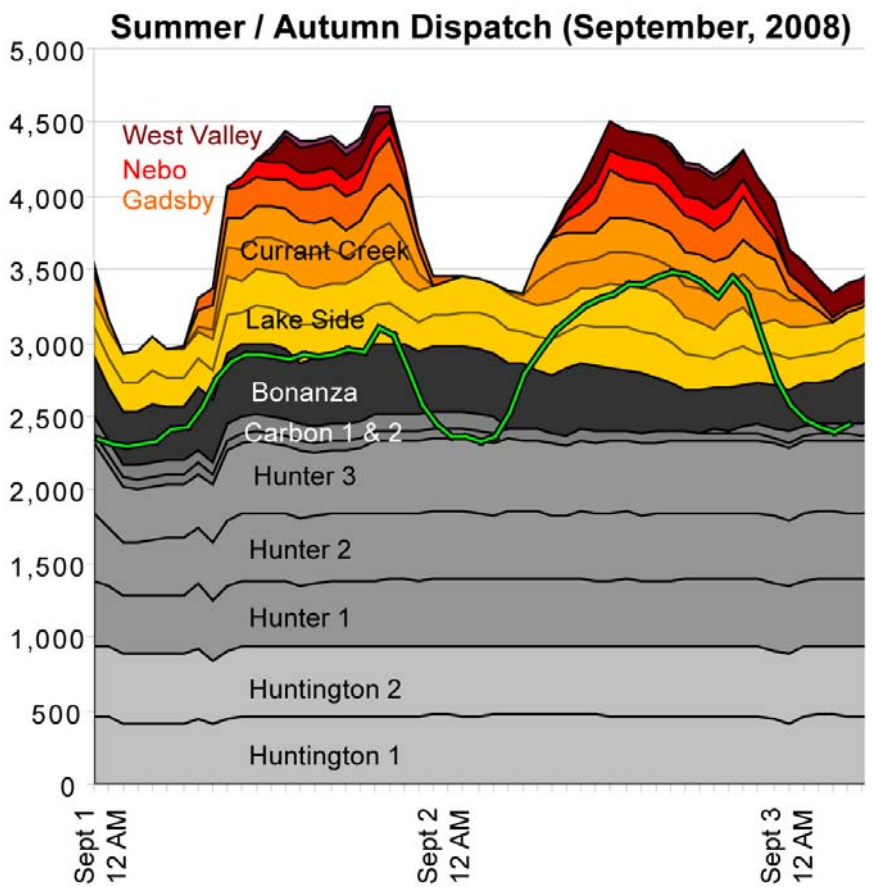
- Integrated Resource Plan (IRP)
- State Implementation Plan (SIP)
- Costs and benefits of RE and EE standards and programs
- Resource acquisition approvals
- Regional air quality, water, and GHG planning

Questions and Answers


US Generating Plants
(color = primary fuel type, size = capacity)
Coal
Nuclear
Hydro
Gas
Oil
Geothermal
Solar
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2009 Tele Atlas
Image USDA Farm Service Agency
© 2009 Europa Technologies
lat 39.854678° lon -112.773503° elev 1574 m
©2009 Google
Eye alt 2676.90 km

Displaced Emissions
Seasonal Dynamics

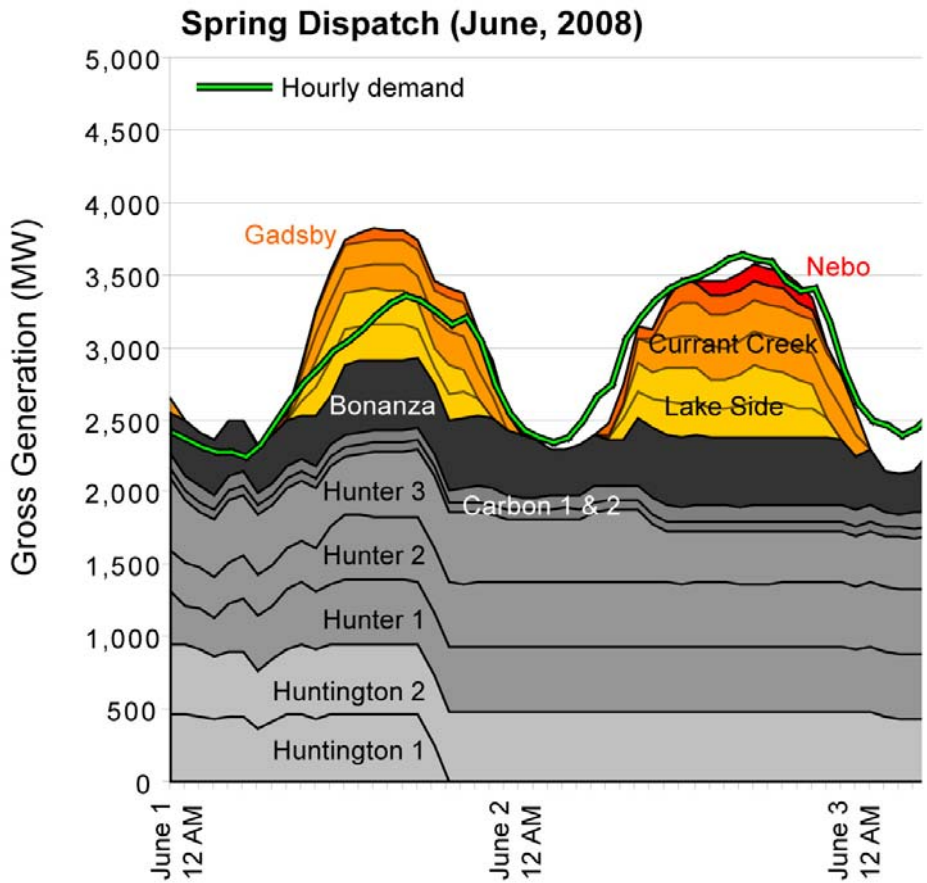




Excludes Intermountain for clarity

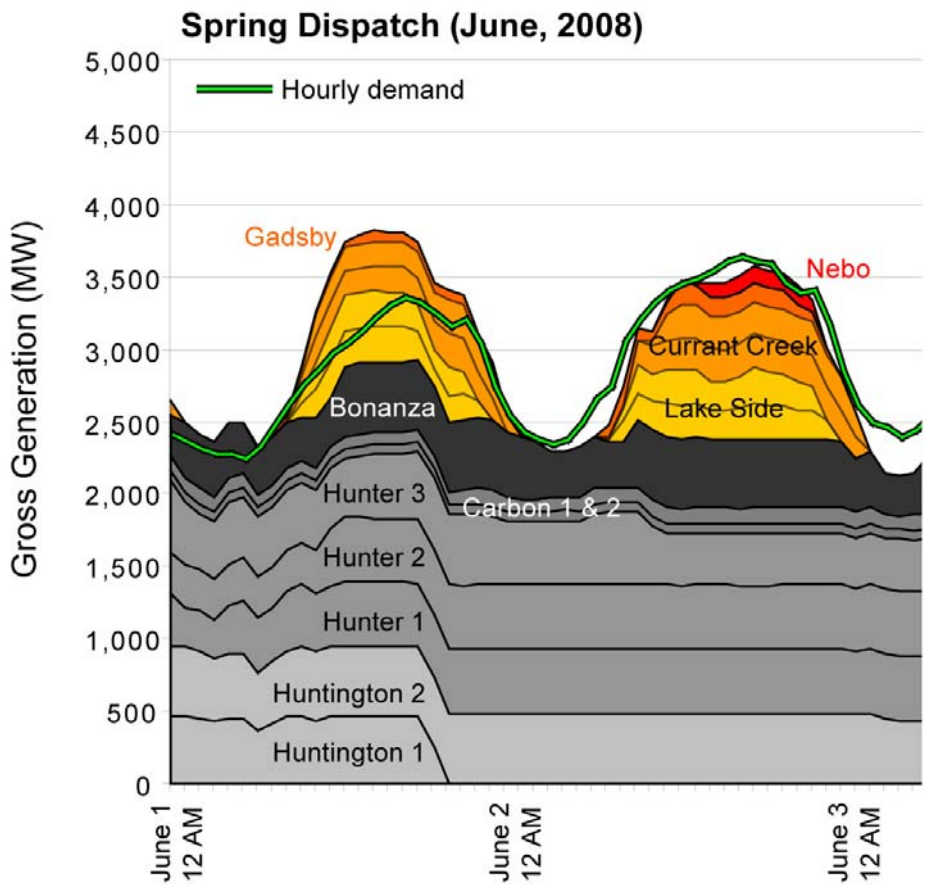
Displaced Emissions
Statistical Dispatch Model (a)

- Data
  - Generation data from EPA Clean Air Markets Division (CAMD)
    - Fossil generation
    - Emissions of NOx, SO2, and CO2
  - Load data from PacifiCorp
- System
  - Break year into hydro and demand periods
  - Break load duration curve into 40 segments (101-123 hrs each)
  - Determine which generators operate in each load segment
  - Determine probable generation output for each generator



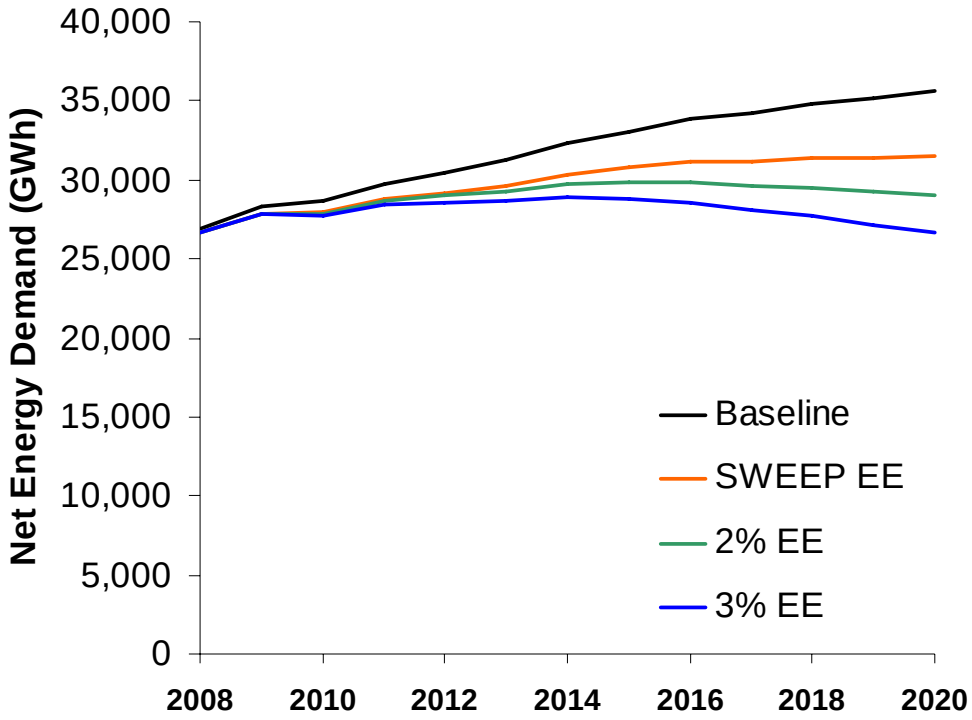
Displaced Emissions
Statistical Dispatch Model (b)

- Forward estimate of generation and emissions from load-based statistics
- New EE and RE shifts load, changes cohort of plants which respond to load
- Demand changes
  - Insensitive baseload generators
  - Sensitive peaking generators



Scenario Analysis
Energy Efficiency

- SWEEP EE
  - 1% by 2011
  - 120 MW of peak reduction in 2020
- Moderate EE
  - 2% by 2015
  - 260 MW peak reduction in 2020
- Aggressive EE
  - 3% by 2016
  - 260 MW peak reduction in 2020

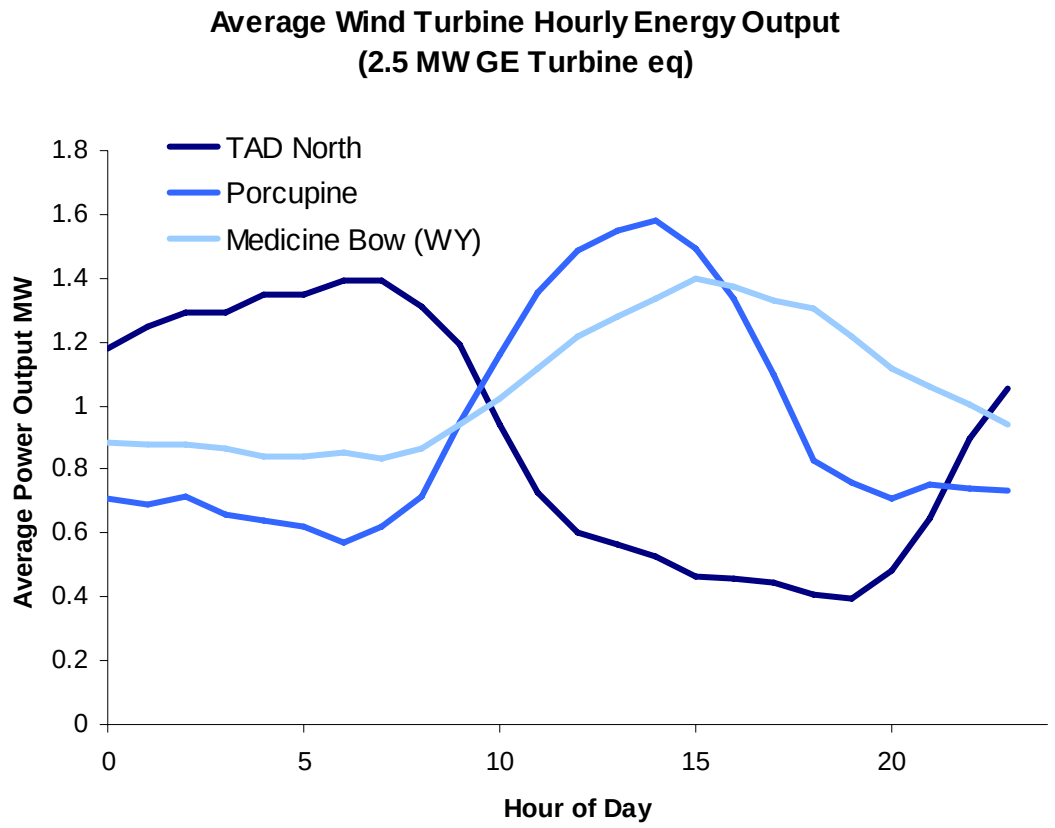


Scenario Analysis
Wind Energy

Image: Google Earth

- Three sites:
  - TAD North
  - Porcupine Ridge
  - Medicine Bow, WY
- Hourly data
  - Full year between 2005 and 2008
  - Scaled to 80m hub heights
  - Eq. to 2.5 MW turbine
- 880 MW of nameplate capacity by 2020

Scenario Analysis
Wind Energy



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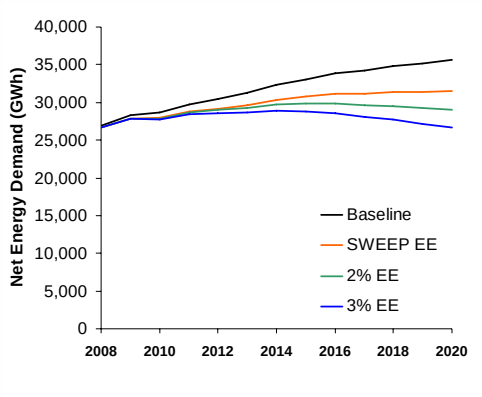
- 880 MW of nameplate capacity by 2020

New Resource Scenarios
Solar and Geothermal Energy

- Solar
  - Solar PV: flat plate and single-axis tracking
    - 25 gal / MWh est. for washing surface
  - Concentrating Solar Thermal (CSP)
    - 6 hr storage
    - Wet cooled: ~840 gal / MWh for cooling
    - Dry cooled: ~80 gal / MWh
  - Iron County location
  - 880 MW by 2020
- Geothermal
  - Assume low-temperature binary plants
  - Wet-cooled 1,400 gal / MWh
  - For model, 100% capacity factor
  - 440 MW by 2020

New Resource Scenarios
Replacement Scenarios

- Replace
  - Carbon: 2012-2013
  - Huntington: 2014-2016
  - Hunter 1: 2018



- Replace units with energy efficiency and gas
- Replace units with energy efficiency, renewable energy, and gas
  - Increase EE by 2% / yr
  - By 2020
    - 660 MW wind from WY
    - 385 MW wind from TAD
    - 330 MW dry-cooled CSP
  - Increase gas capacity as required

Findings
Monetary Co-Benefits

2020-2021	Health Co-Benefits, 2008$ per MWh **All** (in Utah)				Avoided Cost of Water (Low - High)	Total Co-Benefit (Low - High)
	Mortality		**Morbidity**			
				Efficiency Scenarios		
EE (SWEEP)	**$5.6**	($1.5)	**$0.1**	$0.0	**$0.2 - $2.1**	**$5.9 - $7.8**
EE (2% per yr)	**$7.8**	($1.7)	**$0.1**	$0.0	**$0.1 - $1.4**	**$8.0 - $9.3**
EE (3% per year)	**$12.3**	($2.8)	**$0.2**	$0.1	**$0.3 - $3.1**	**$12.8 - $15.6**
				Renewable Scenarios		
Wind (Porcupine)	**$18.6**	($4.5)	**$0.4**	$0.2	**$0.5 - $5.5**	**$19.5 - $24.4**
Wind (TAD North)	**$20.4**	($4.5)	**$0.5**	$0.2	**$0.6 - $5.5**	**$21.4 - $26.3**
Wind (Medicine Bow)	**$18.9**	($4.4)	**$0.4**	$0.2	**$0.5 - $5.2**	**$19.8 - $24.5**
Solar (Flat Plate PV)	**$19.0**	($4.9)	**$0.4**	$0.2	**$0.6 - $5.5**	**$20.0 - $25.0**
Solar (One-Axis Track)	**$20.7**	($5.0)	**$0.4**	$0.2	**$0.5 - $5.5**	**$21.7 - $26.6**
Solar (CSP Trough, Wet Cooled)	**$7.7**	($2.6)	**$0.1**	$0.1	**-$12.0 - -$1.2**	**-$4.2 - $6.6**
Solar (CSP Trough, Dry Cooled)	**$7.7**	($2.6)	**$0.1**	$0.1	**$0.2 - $2.0**	**$8.0 - $9.8**
Geothermal	**$19.8**	($4.6)	**$0.4**	$0.2	**-$15.6 - -$1.6**	**$4.6 - $18.7**
				Replacement Scenarios*		
Replace Coal w/ EE and Gas	**$67.26**	($7.4)	**$1.00**	($0.5)	**$0.9 - $8.7**	**$69.1 - $76.9**
Replace Coal w/ EE and RE	**$68.94**	($7.8)	**$1.00**	($0.5)	**$0.9 - $9.0**	**$70.8 - $78.9**

