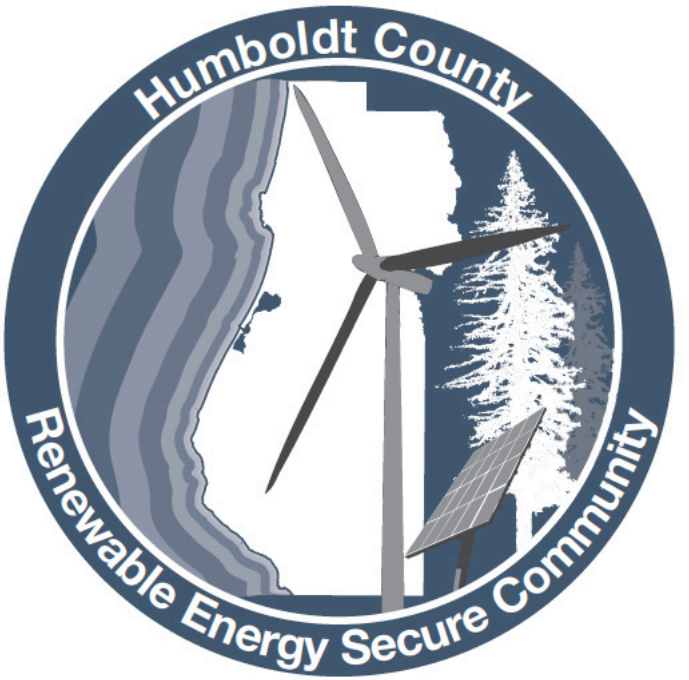
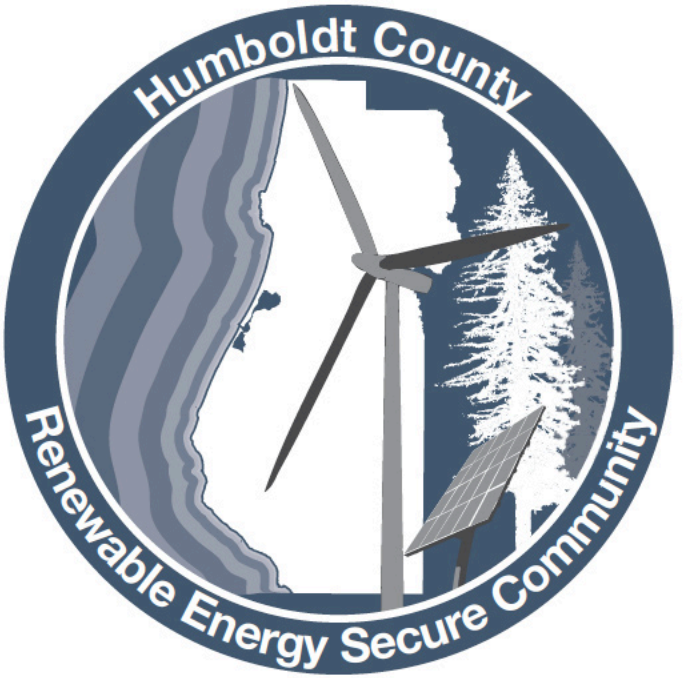

Humboldt County
Renewable Energy Secure Community

Humboldt County's Renewable Energy Futures:

Preliminary Results from a Renewable Energy Secure Communities (RESCO) Study



Peter Alstone and Colin Sheppard

Schatz Energy Research Center

December 2, 2010

Sustainable Futures Speaker Series

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RESCO Goal

Develop a strategic plan for Humboldt County to develop its renewable energy resources to meet 75-100% of local electricity demand and a significant fraction of heating and transportation demand.

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RESCO Participants

- **Redwood Coast Energy Authority** - Lead Agency
- **Schatz Energy Research Center** - Primary Research Team
- **Pacific Gas and Electric Company** - Integration Issues
- **Local Stakeholders** - Input on Strategic Plan

Redwood Coast Energy Authority

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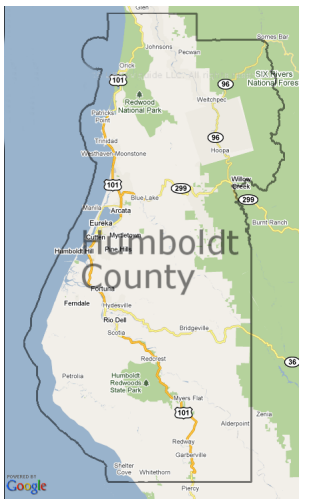
PG&E



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STATE OF CALIFORNIA ENERGY COMMISSION

Humboldt County Renewable Energy Secure Community

Today's Talk:

- Snapshot of Humboldt Co. energy sector and context
- Technical Approach: a year-long hourly energy balance model
- Preliminary results and next steps

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Humboldt County Renewable Energy Secure Community

Humboldt's Energy Demands:

Energy powers our economy and lifestyle

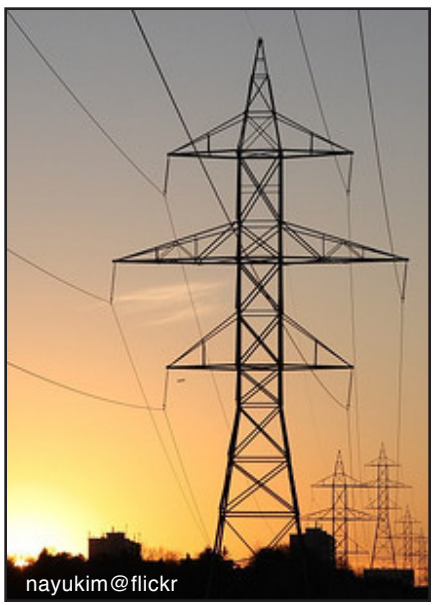
Humboldt's Energy Resources:

Conventional Energy

- **Natural Gas**: pipeline connection with limited production in Eel River Valley; used for electricity, heating, and process needs.

- **Conventional Electricity**: Local Natural Gas powered generation and imported from Western US Grid via interconnection lines.

- **Transportation Fuels:** Gasoline and Diesel barged into the county.



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Renewable Energy Secure Community

Humboldt's Energy Resources:

Biomass as a key resource today and in the future

ASSOCIATED PRESS / BEN MARGOT

Humboldt's Energy Resources:

Emerging Renewables: Wind, Wave, Solar, and Hydro

Humboldt's Energy Demand Trends:

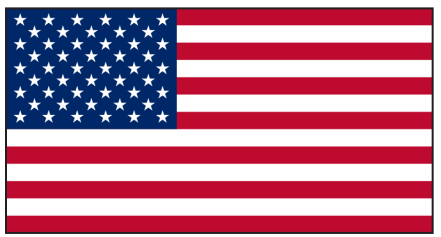
Declining traditional industry, growth in others

Humboldt's Energy Sector:

State, national, & global political context

California on the move:

- AB 32 upheld in recent election – Greenhouse gas (GHG) reduction goal of "1990 levels by 2020."
- Reach 20% of 1990 levels by 2050 (S-3-05)



National action slow but steady:

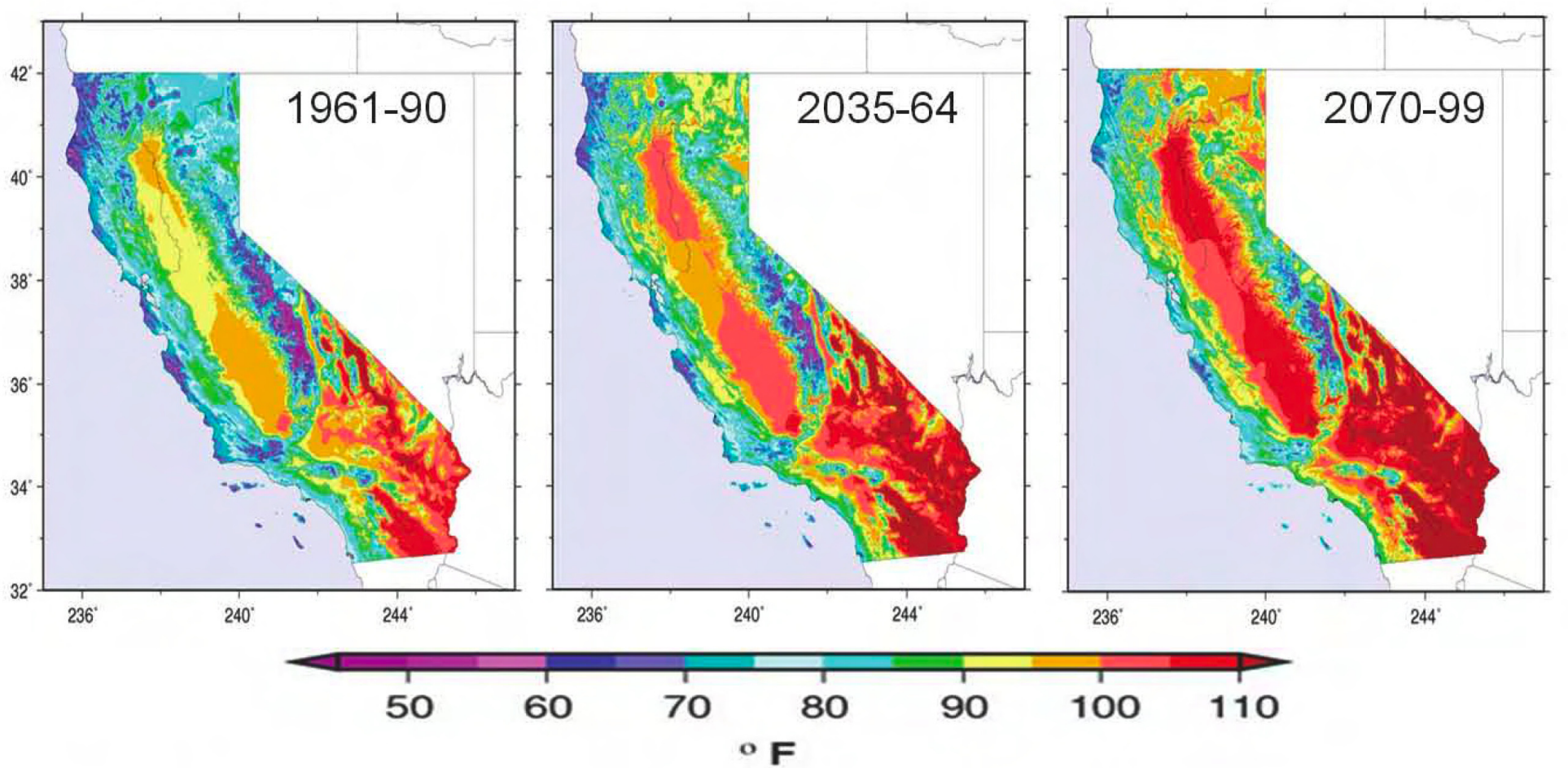
- Political action to address GHG pollution stalled.
- Continuing progress in spite of policy uncertainty.

International trends towards clean energy:

- Emerging consensus on climate change.
- Price of conventional resources climbing as clean energy technology develops and costs fall.

Climate Change Imperative:

Potential 100-year Temperature Rise in California



Source: Dan Cayan et al. 2009.

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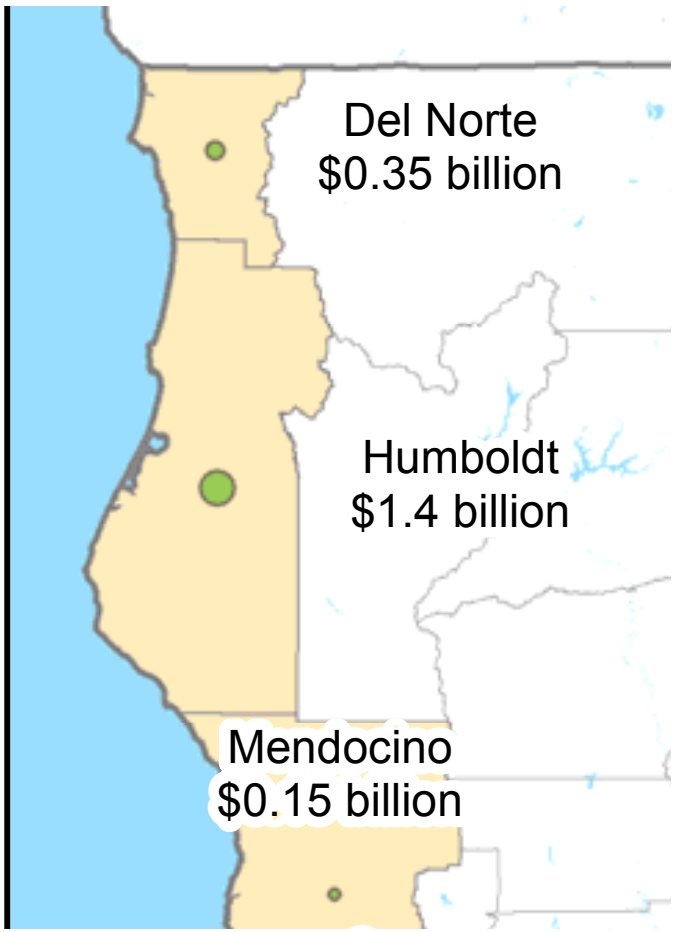
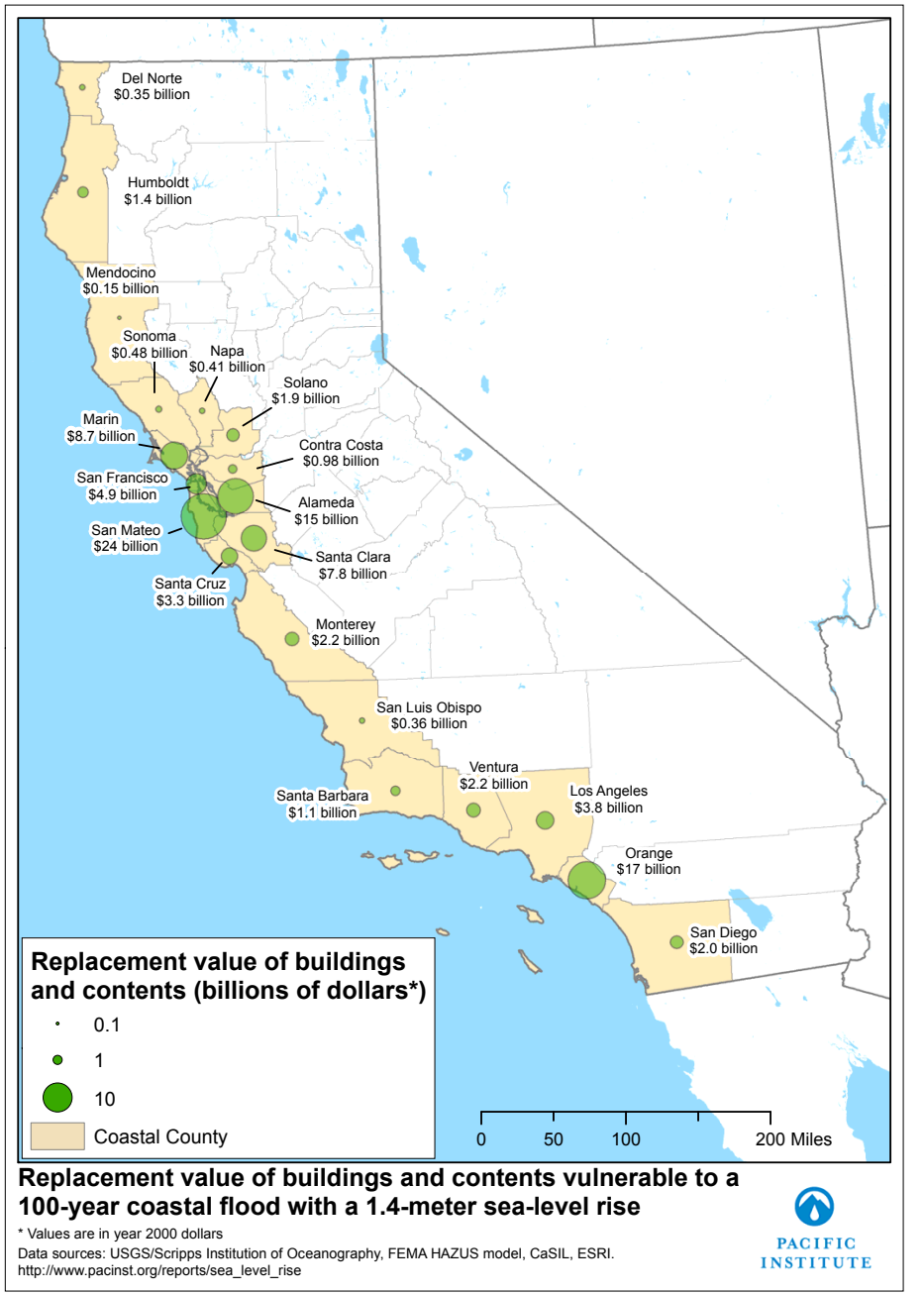
Climate Change Imperative:

Coastal Communities at Risk

Lost property estimates after 100-year flood with 1.4 meter sea level rise.





Replacement value of buildings and contents vulnerable to a 100-year coastal flood with a 1.4-meter sea-level rise

* Values are in year 2000 dollars

Data sources: USGS/Scripps Institution of Oceanography, FEMA HAZUS model, CaSIL, ESRI.
http://www.pacinst.org/reports/sea_level_rise

PACIFIC INSTITUTE

RESCO Technical Approach:

Identify Humboldt County's Clean Energy Futures

- **Investigate energy demand and resources**
- **Develop tools to integrate and analyze findings**
- **Use tools to inform strategic planning process**

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Our modeling challenge:

Create a tool to integrate energy supply and demand information.

Make it detailed, flexible, and well documented enough to be useful for helping to make decisions about policy and investments to achieve RESCO goals.

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Model Framework: Guiding Principles

- **Be data driven** – rely on real world data when it is available. Modeled (synthetic) data is second best.

- **Be results driven** – prioritize effort on elements that are likely to impact the results. Don't sweat the small things.

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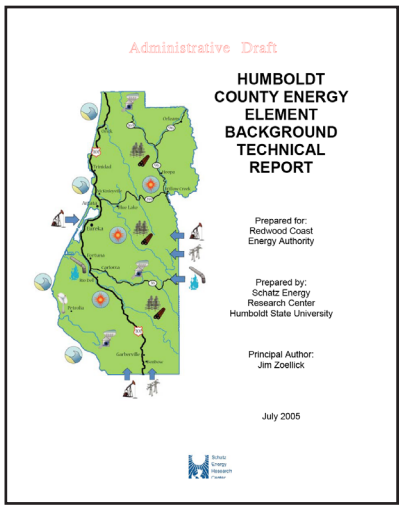
Model Framework: Previous Works

- **Humboldt County Energy Element** - SERC
- **Integrating Humboldt County Energy Systems** (EnergyPLAN software implementation) - Michael Winkler
- **Distributed Renewable Energy…in Humboldt** (HSU Thesis) - Darrell Ross


Administrative Draft

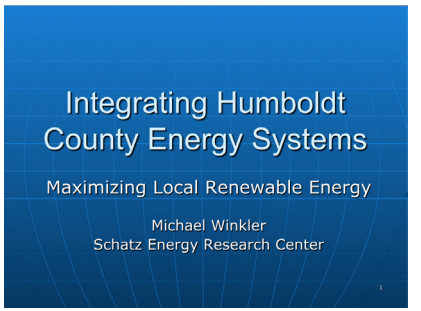
HUMBOLDT COUNTY ENERGY ELEMENT BACKGROUND TECHNICAL REPORT

Prepared for:
Redwood Coast Energy Authority

Prepared by:
Schatz Energy Research Center
Humboldt State University

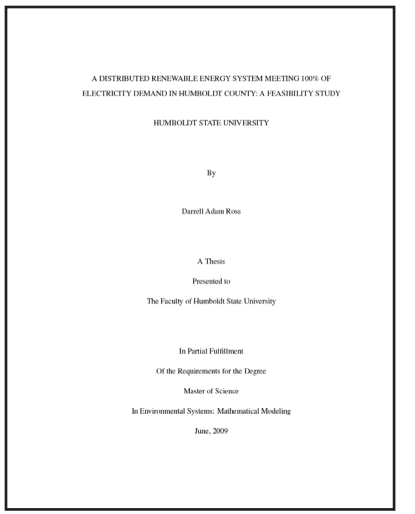
Principal Author:
Jim Zoellick

July 2005


Integrating Humboldt County Energy Systems

Maximizing Local Renewable Energy

Michael Winkler
Schatz Energy Research Center


A DISTRIBUTED RENEWABLE ENERGY SYSTEM MEETING 100% OF ELECTRICITY DEMAND IN HUMBOLDT COUNTY: A FEASIBILITY STUDY

HUMBOLDT STATE UNIVERSITY

By

Darrell Adam Ross

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

In Environmental Systems: Mathematical Modeling

June, 2009

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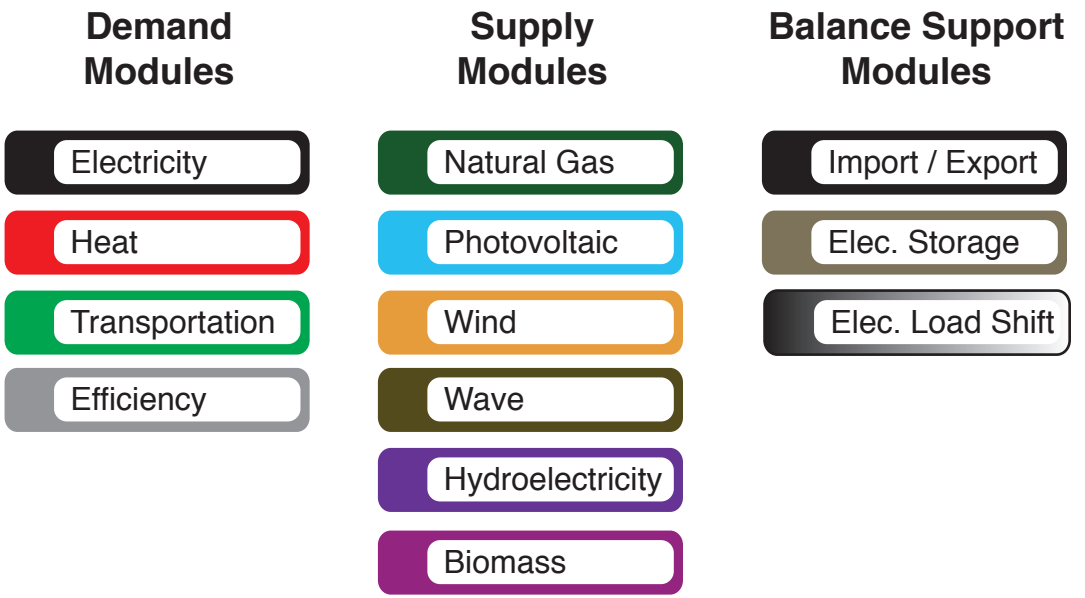
Humboldt County Renewable Energy Secure Community

Model Framework: Tech. & Resource Modules

Establish demand and supply availability based on demographics, resources, and installed technology.



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Model Framework: Energy Balance Algorithm

Meet demands by dispatching Supply and Balance Support technologies according to their availability.

Demand Modules

- Electricity
- Heat
- Transportation
- Efficiency

Supply Modules

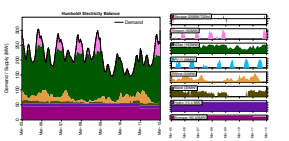
- Natural Gas
- Photovoltaic
- Wind
- Wave
- Hydroelectricity
- Biomass

Balance Support Modules

- Import / Export
- Elec. Storage
- Elec. Load Shift

Energy Balance Algorithm

- Supply Dispatch
- Grid Stability
- Power Reliability



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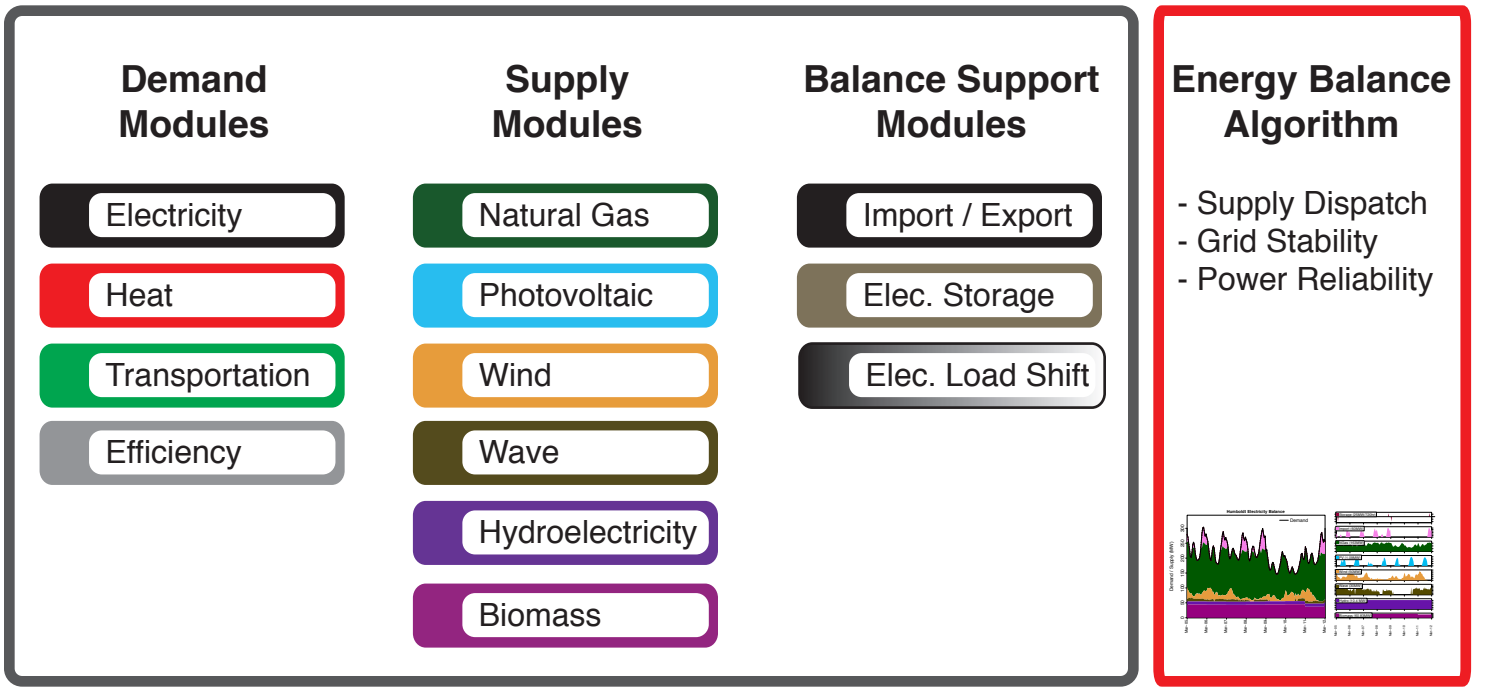
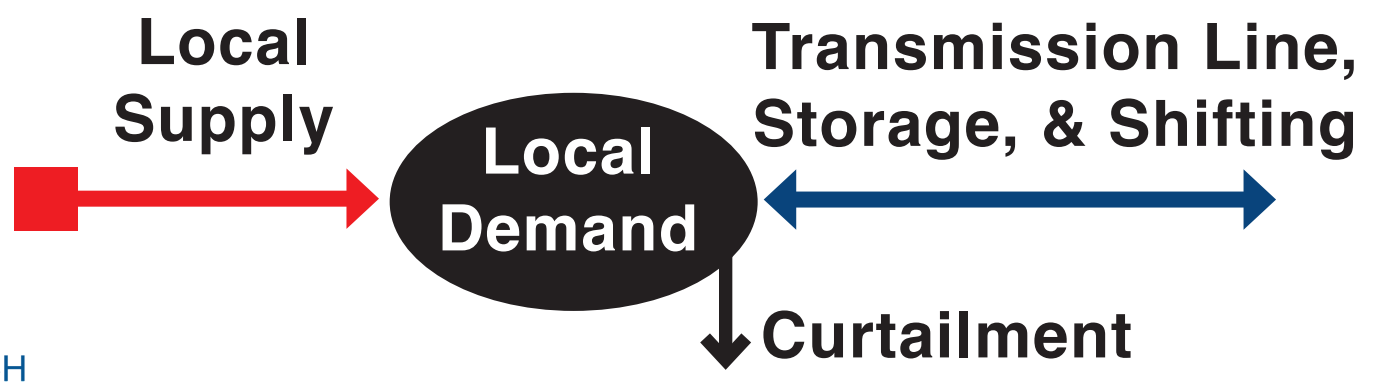
Model Framework: Energy Balance Algorithm

Single node model focused on temporal matching on an hourly basis through a one-year period based on a given scenario.





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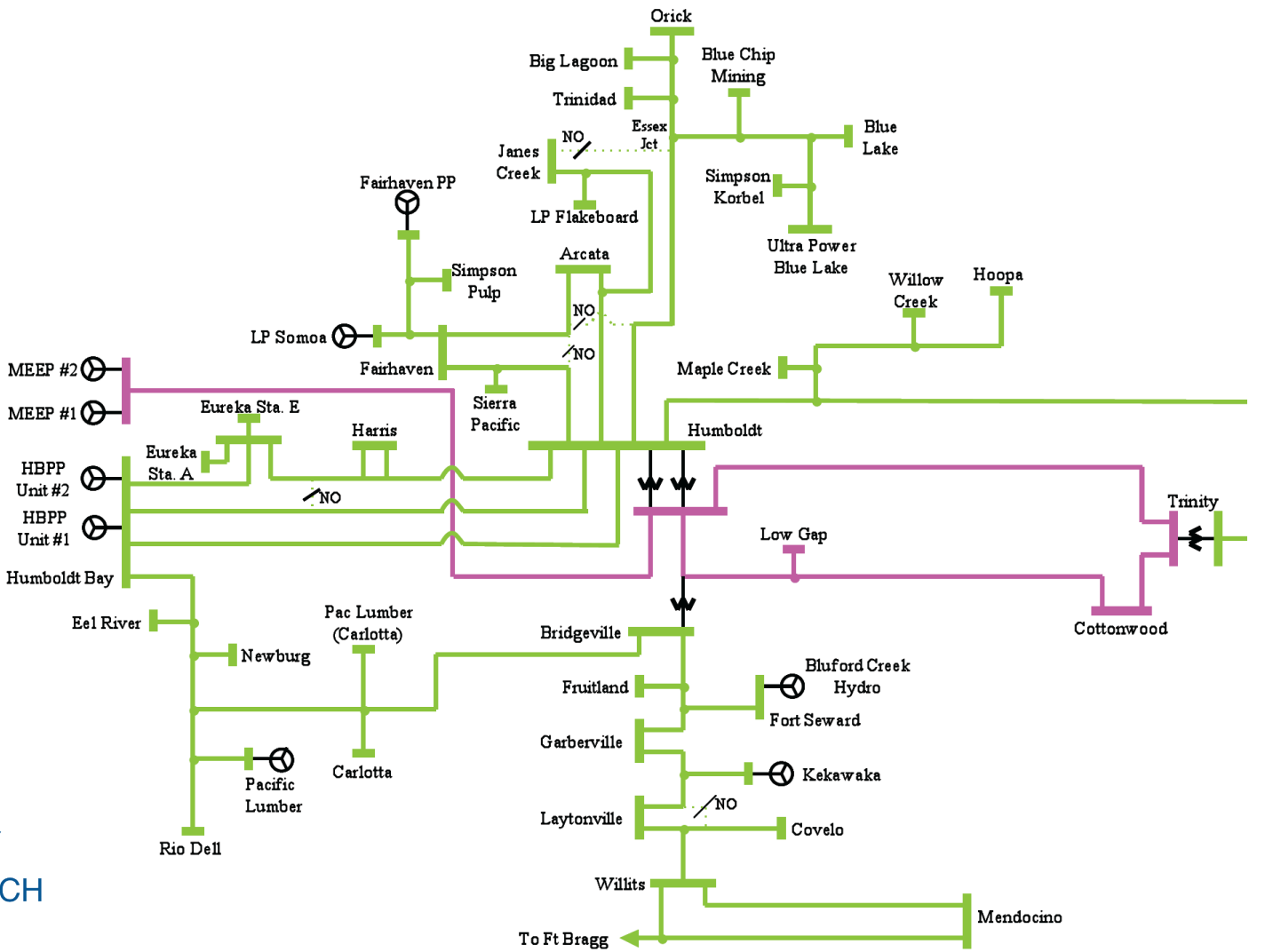
Key Assumption: Single Node Approximation

PG&E's role:

Power Flow & Transient Stability Analysis of Infrastructure



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Model Framework: Post Processing

Calculate key metrics that describe the performance of the scenario.

Demand Modules

- Electricity
- Heat
- Transportation
- Efficiency

Supply Modules

- Natural Gas
- Photovoltaic
- Wind
- Wave
- Hydroelectricity
- Biomass

Balance Support Modules

- Import / Export
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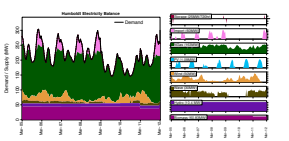
- Elec. Load Shift

Energy Balance Algorithm

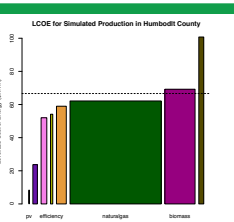
- Supply Dispatch
- Grid Stability
- Power Reliability



Post Processing

Economics:
- Cost of Energy
- Job Creation
- Local Economy

RESCO Goals:
- GHG Emissions
- Fraction Renewables



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Humboldt County Renewable Energy Secure Community

Model Framework: Inputs and Outputs

Key Inputs: Demand levels, installed capacities

Demand Modules

- Electricity
- Heat
- Transportation
- Efficiency

Supply Modules

- Natural Gas
- Photovoltaic
- Wind
- Wave
- Hydroelectricity
- Biomass

Balance Support Modules

- Import / Export
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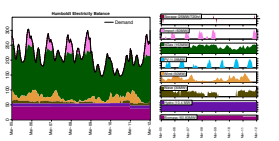
- Elec. Load Shift

Energy Balance Algorithm

- Supply Dispatch
- Grid Stability
- Power Reliability



Post Processing

Economics:
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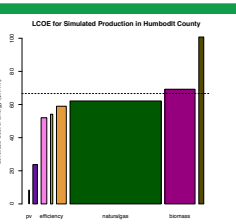

Key Outputs: Cost of Energy, GHG Emissions, Service Quality

Model Details: Demand Modules

Sector	2008 Scale (PJ)	Other Units	Notes
Electricity	3.4	1 TWh	5 years of 15 minute interval data
Heat	5.7	54e6 therms	Building Model + Monthly NG data
Transportation	8.0	66e6 gal. gas	EPRI technology model
Efficiency	-0.007	-2 GWh	Utility Program Scoping Study

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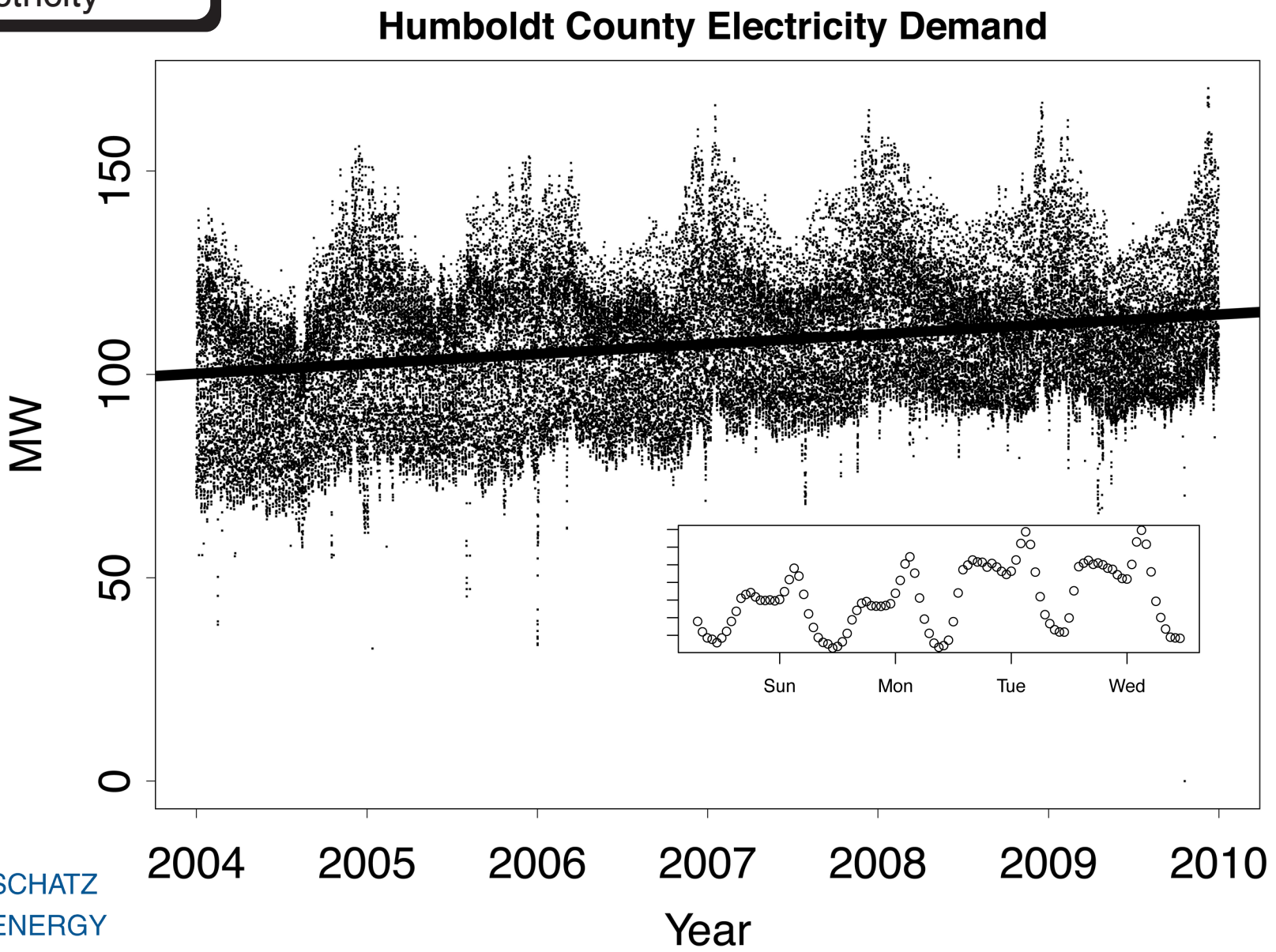
Module Highlight: Electricity Demand

Electricity



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Module Highlight: Demand-side Fuel Switching

Heat

Transportation

Heat pumps and electrified transportation can **build electricity demand** for local renewable generation and replace conventional fuels.

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Model Details: Supply Modules

Technology	Capacity (MW) Baseline	Outlook	Notes
Natural Gas	163	163	PG&E King Salmon Plant
Photovoltaic	~ 1	1-15	Based on NSRDB Data
Wind	~ 0	0-250	NREL model for Bear River Ridge
Wave	0	0-100	NOAA Buoy + Wave Machine Matrix
Hydroelectricity	10.5	10.5-35	Hydrological + Energy Model
Biomass	61	61-250	Scotia, Fairhaven, Blue Lake Plants

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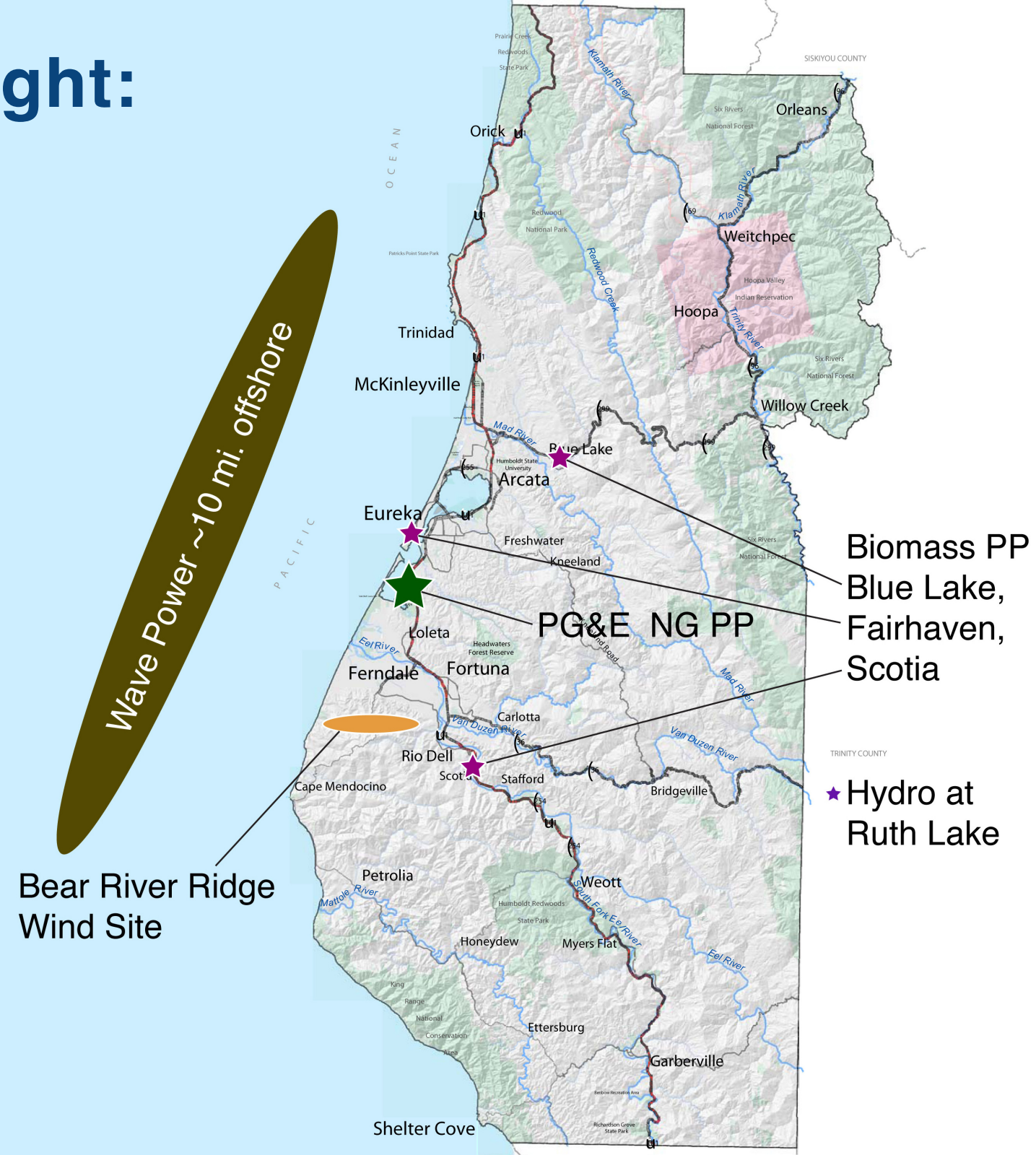
Module Highlight:

Supply Locations

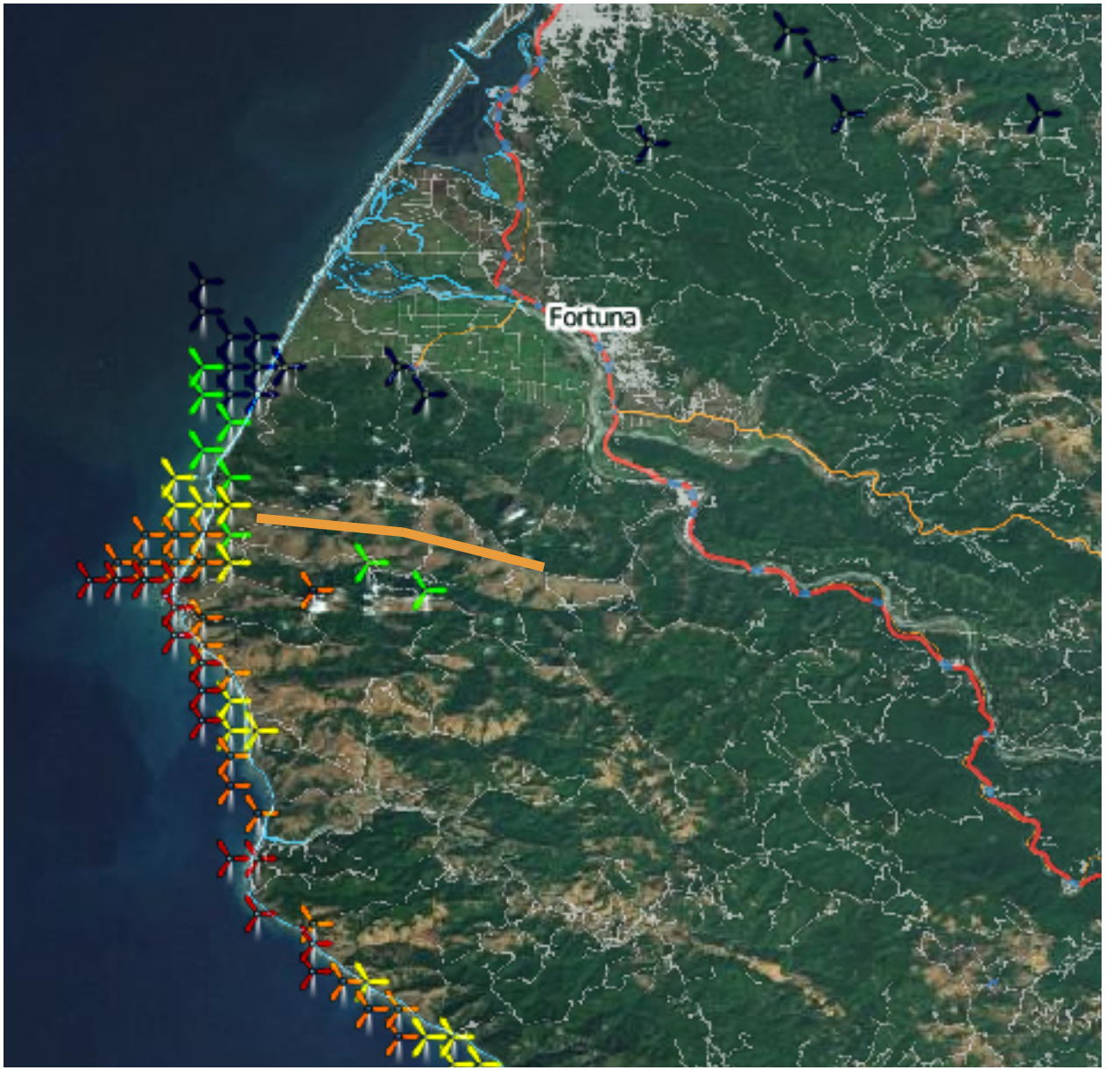


Module Highlight: Bear River Ridge Wind

Wind

Data Source:

Icons show sites with three years of modeled wind farm output from NREL's Western Wind Dataset; it was produced by 3Tier.



Bear River Ridge

Orange line shows potential Shell Wind installation

Model Details: Balance Support Modules

Sector	Capacity (MW) Baseline	Outlook	Notes
Import / Export	60	60-200	Main Lines: 2x 115 kV to Redding
Elec. Storage	0	0-100	Batteries, Pumped Hydro, CAES
Elec. Load Shift	~0	0-24	Demand Response across sectors

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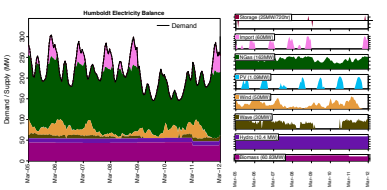
Model Details: Energy Balance Algorithm

- Meet demand
- Use renewables first
- Don’t export power from fossil fuels
- Meet reserve requirements
- Meet stability constraints

Energy Balance Algorithm



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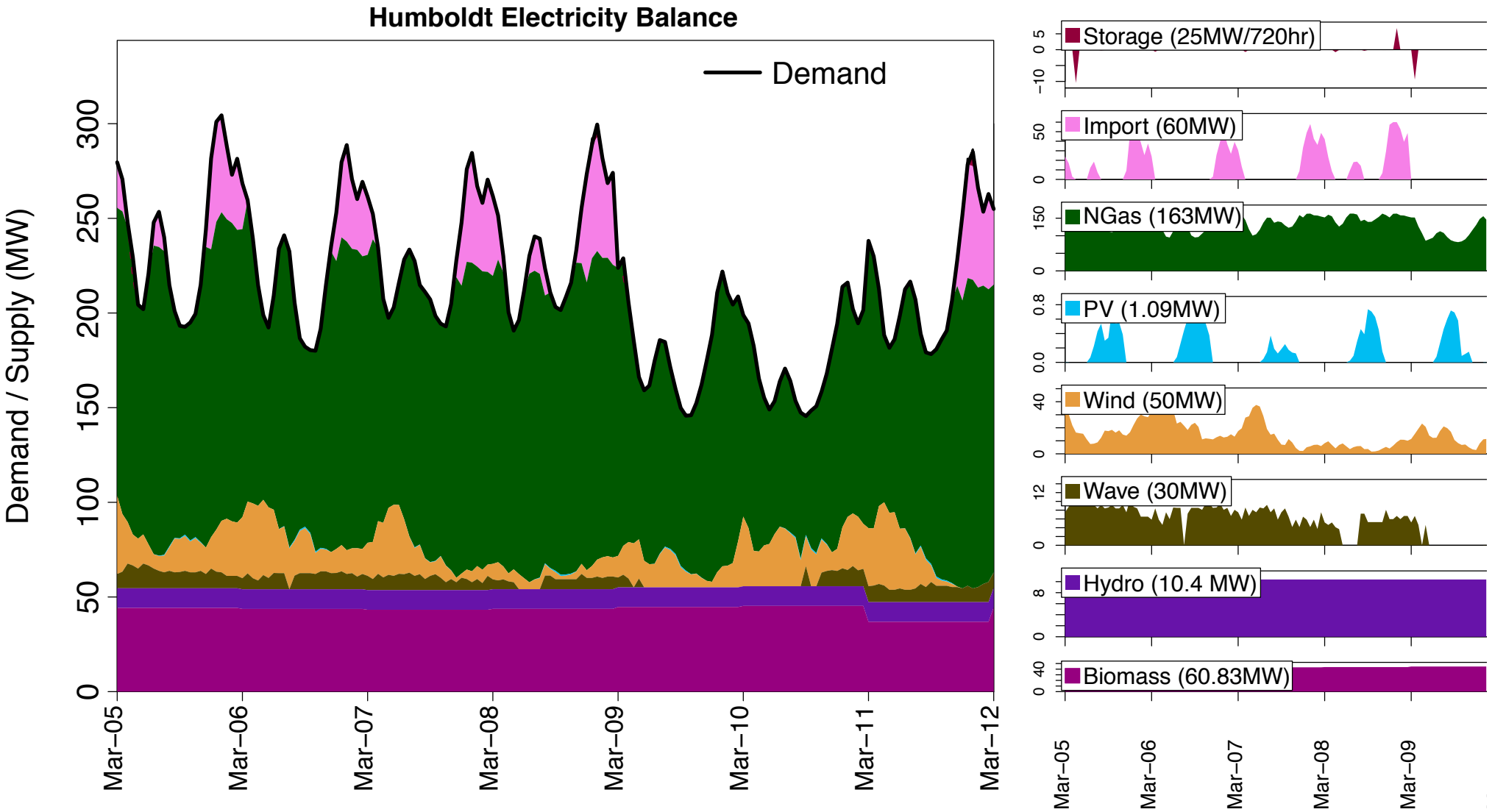
Model Details: Energy Balance Dashboard



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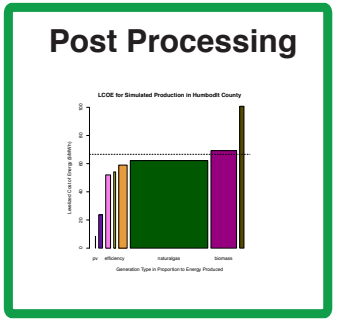
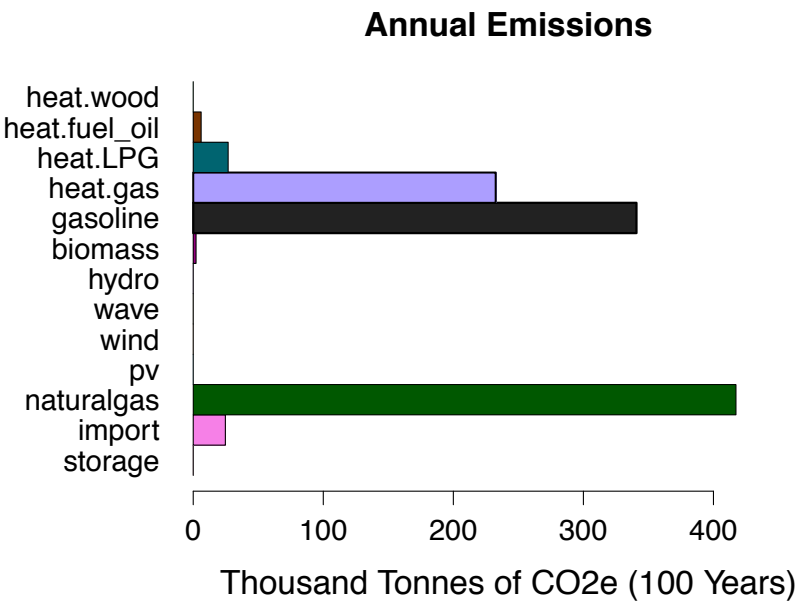
Post processing: GHG Emissions





Includes

- Fossil fuel consumption

Not Included:

- "Embedded" emissions
- GHG sinks (e.g., growing forests)
- Biomass energy emissions

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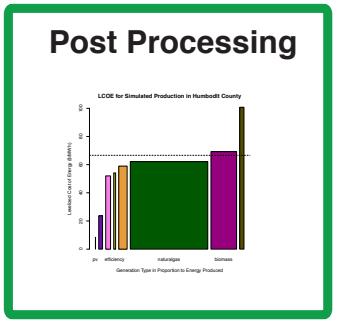
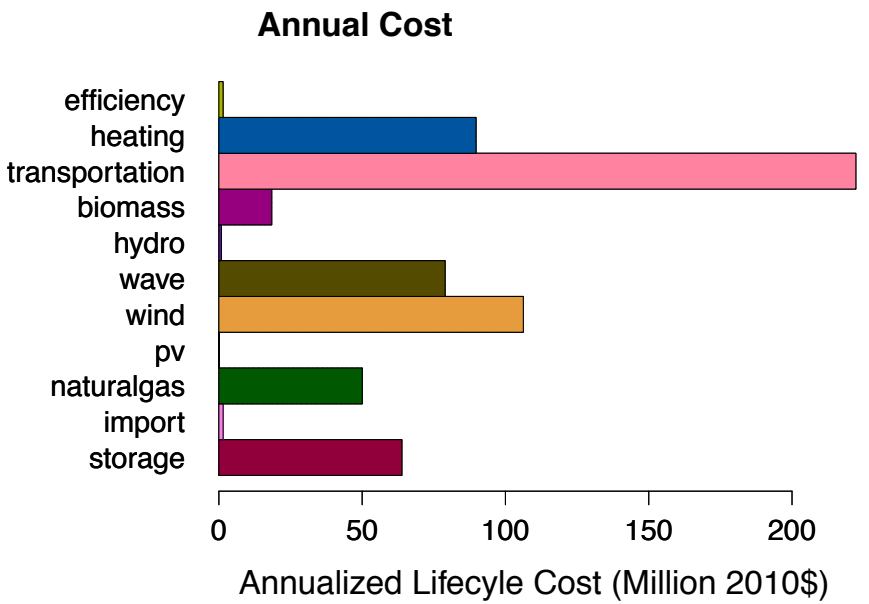
Post processing: Costs





Includes

- "Annualized" Life cycle costs (capital, operations, fuel) for supply
- Vehicles in transportation sector
- Heat pump upgrades
- Efficiency upgrades (program and consumer)

Not Included:

- Grid infrastructure costs
- Appliances
- Project-level specifics

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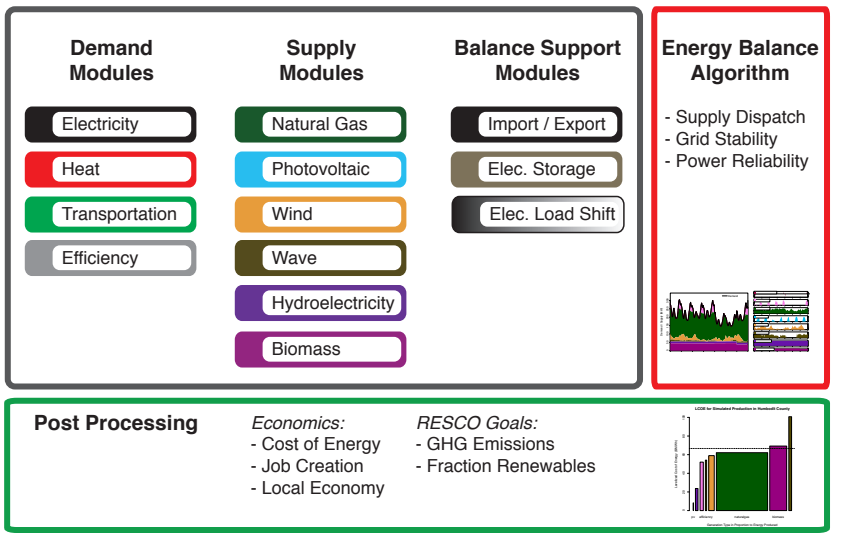
Model Recap:

- **Data Driven:** Based on a fresh look at Humboldt County's energy sector with up-to-date trends in technology
- **Key Inputs:** Magnitudes of demand and installed capacity for each technology
- **Key Outputs:** Costs, GHG emissions, service quality
- **Limitations:** Only as good as assumptions and inputs



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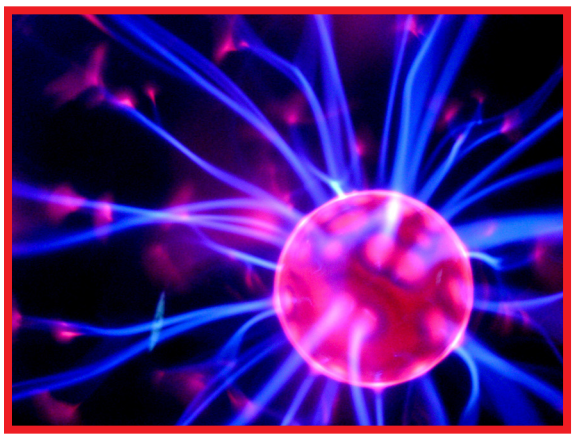
Model Application / Optimization

Inputs

- Photovoltaic
- Wind
- Wave
- Hydroelectricity
- Biomass
- Import / Export
- Elec. Storage
- Elec. Load Shift
- Heat
- Transportation
- Efficiency

Model



Outputs

Demand met?

Emissions

Costs

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Optimization: Objectives / Constraints

Objectives

- Minimize carbon emissions

Constraints

- Meet demand 99.9% of the time
- Maximum annual cost

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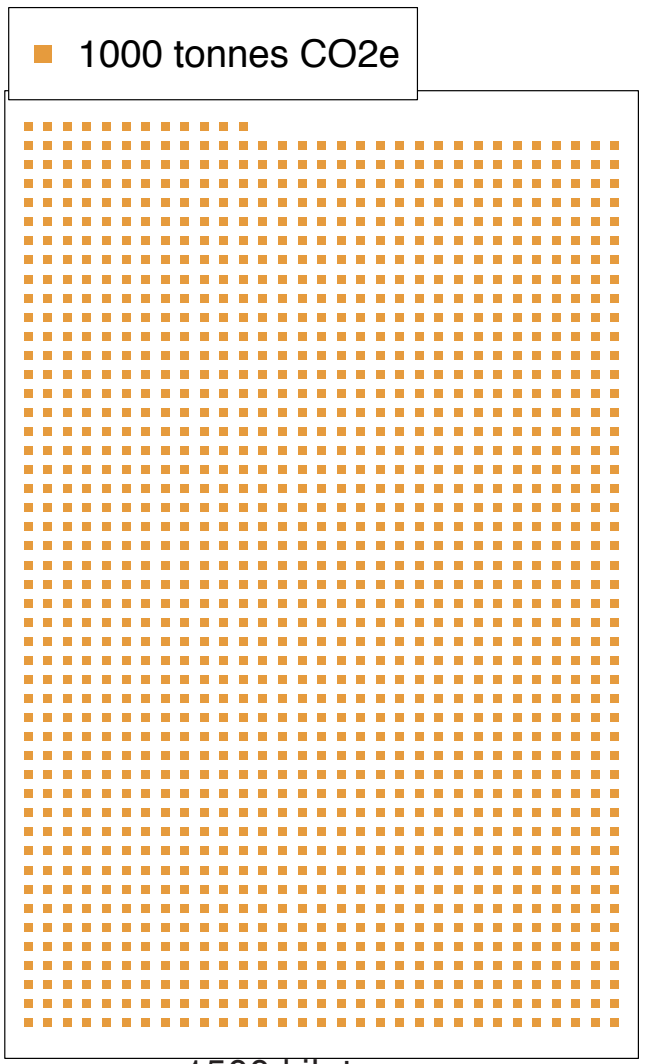
Optimization: Preliminary Results

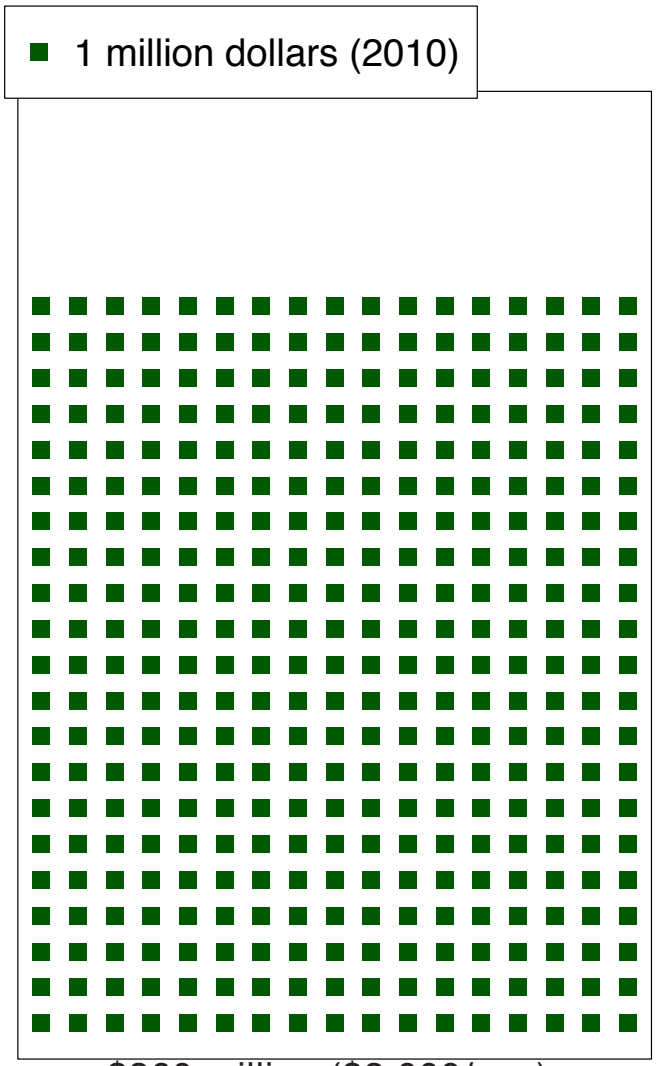
2030 Business as Usual

Emissions



1500 kilotonnes

Cost



$360 million ($3,000/cap)

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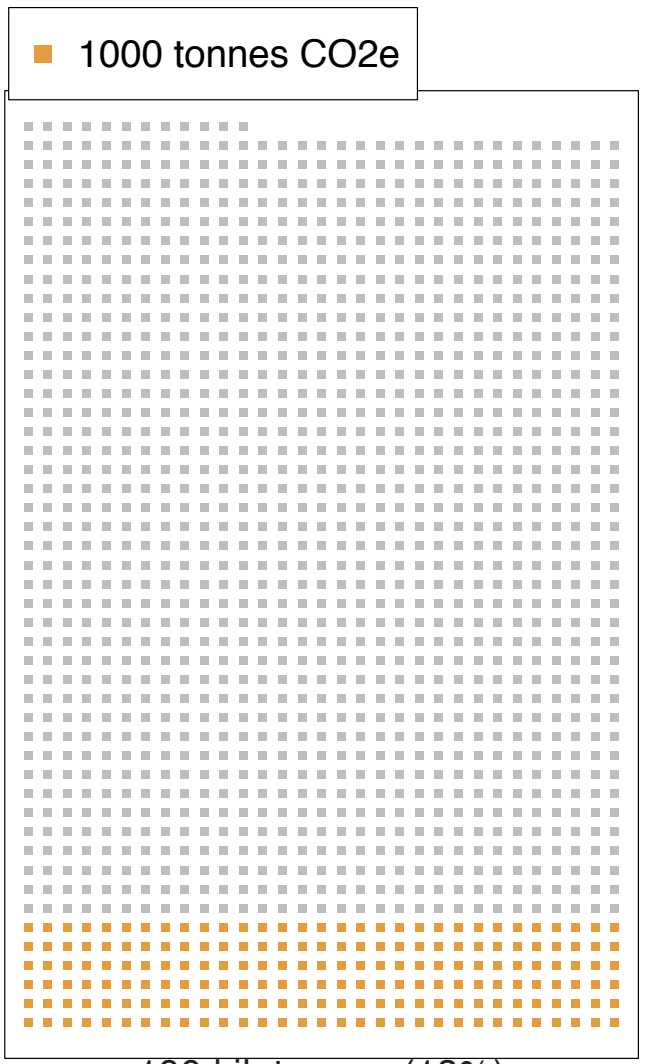
Optimization: Preliminary Results

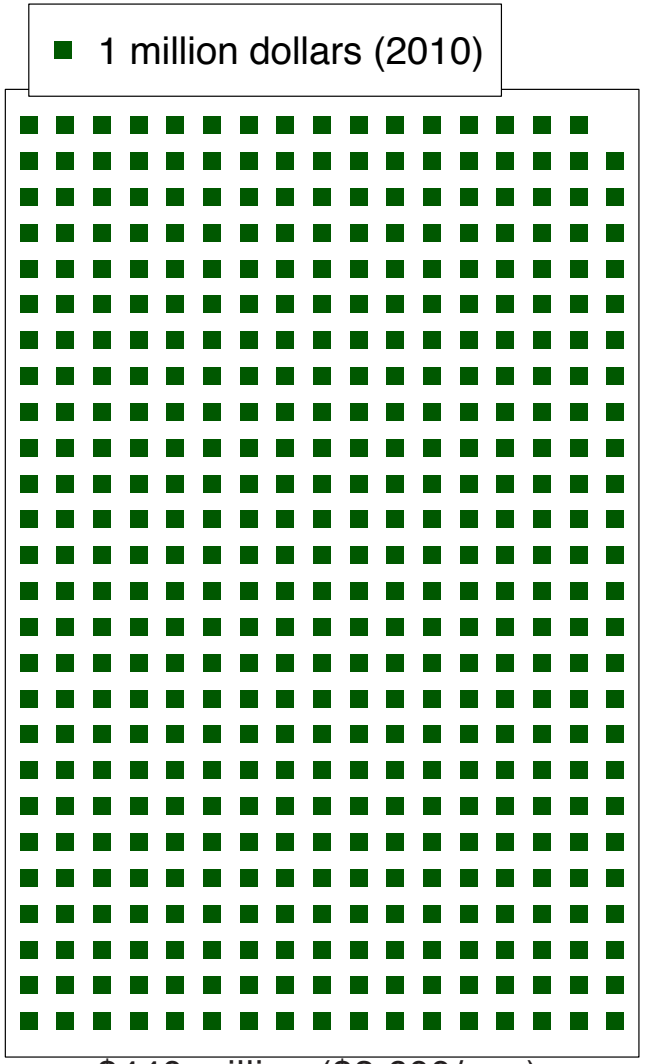
2030 Minimize Carbon, No Cost Constraint

Emissions



190 kilotonnes (13%)

Cost



$440 million ($3,600/cap)

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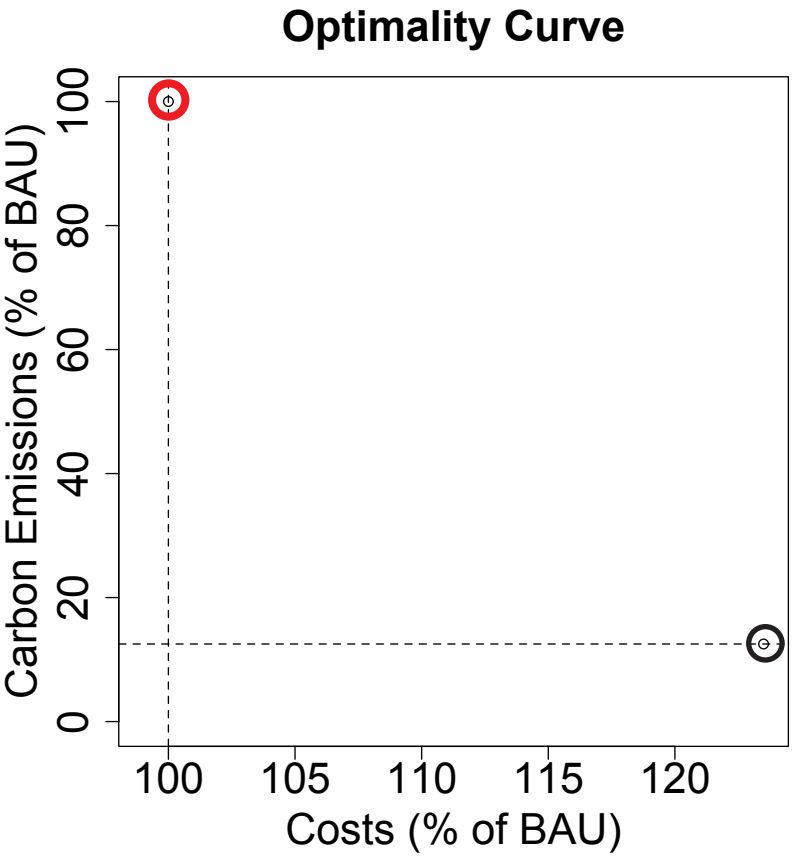
Optimization: Preliminary Results

Minimize Emissions



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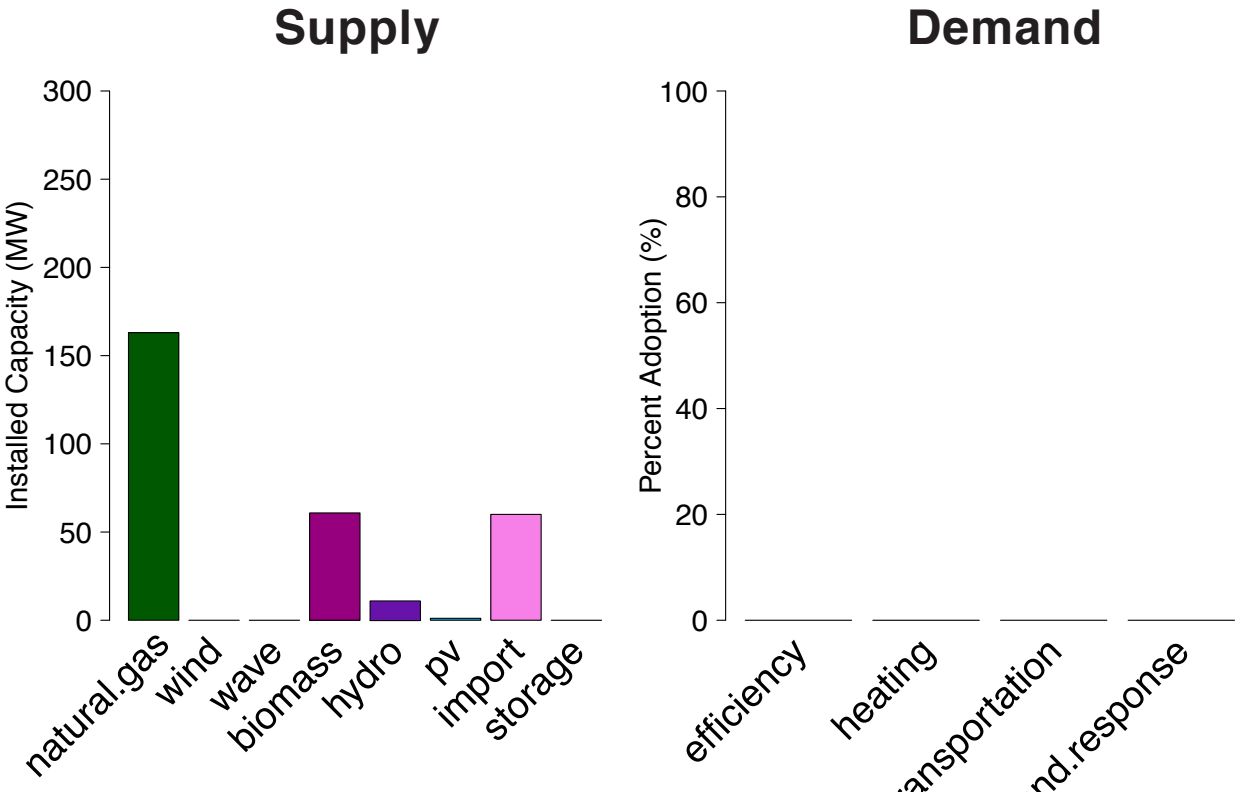

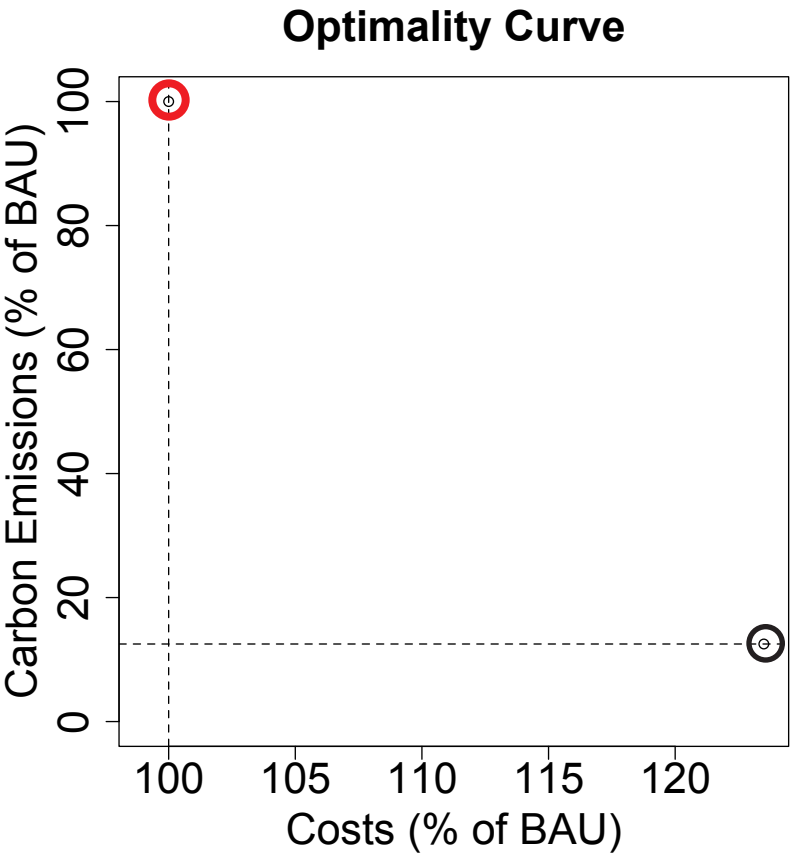

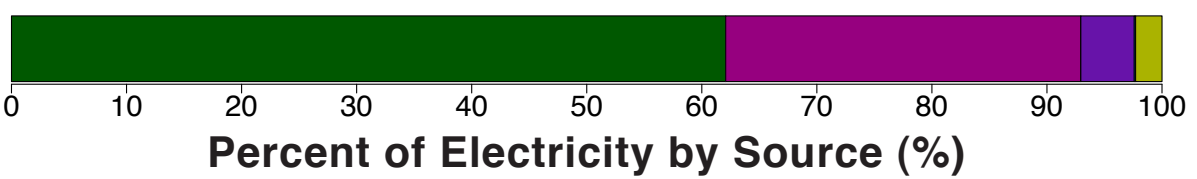

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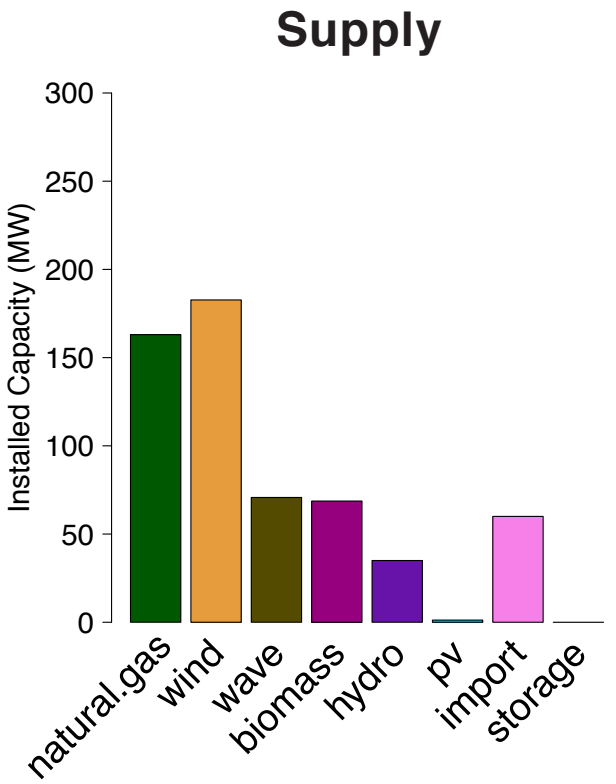

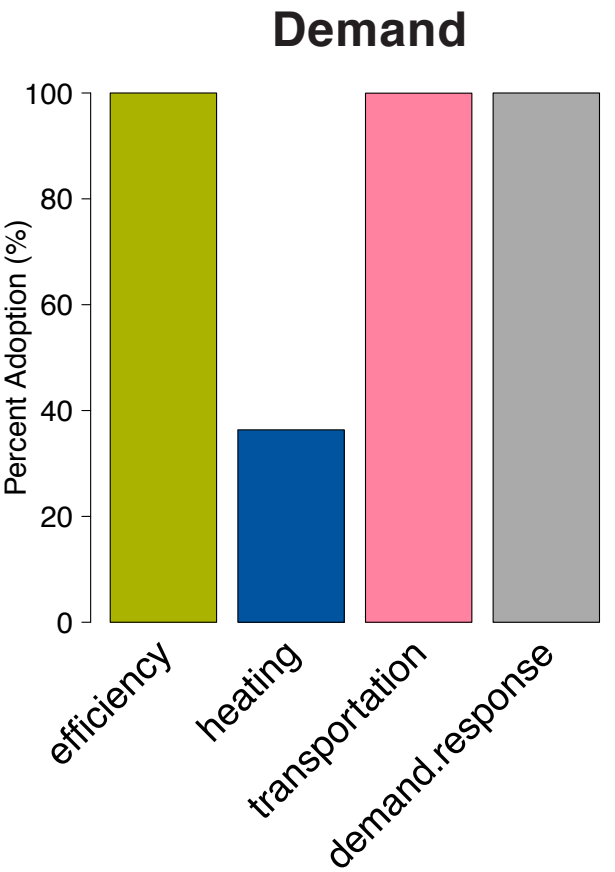

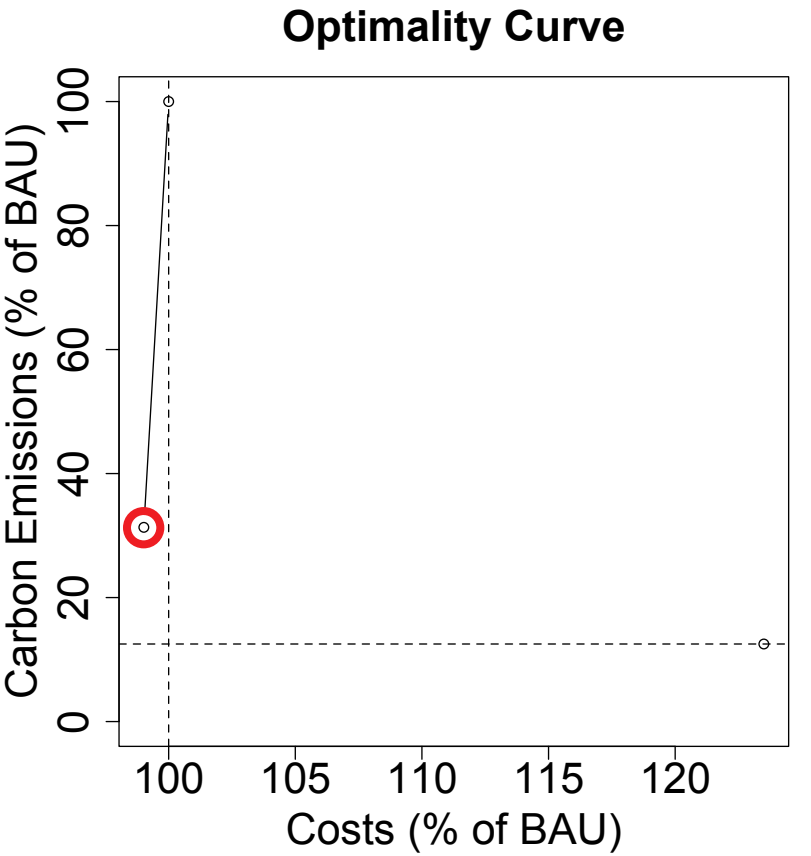

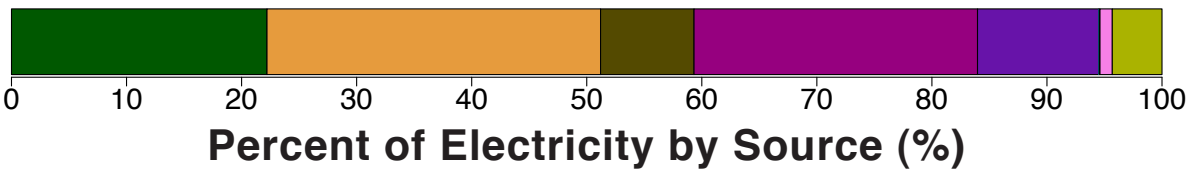

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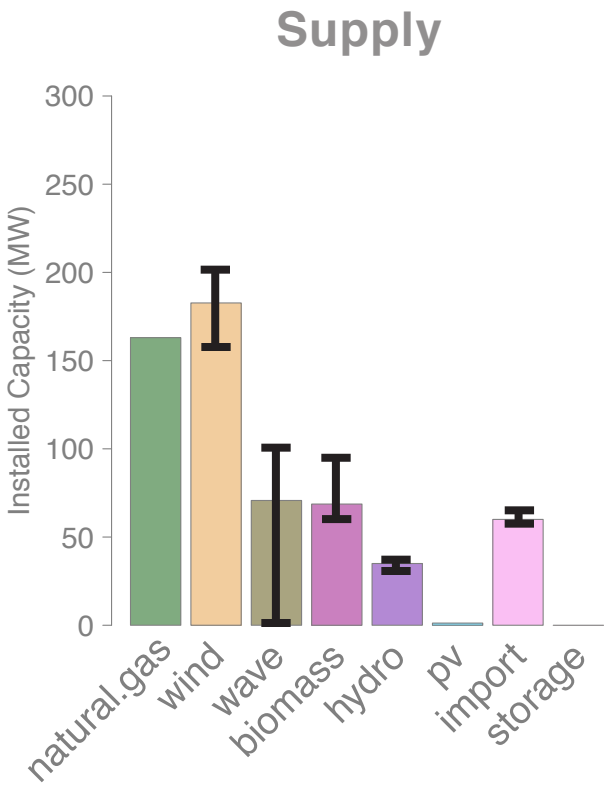

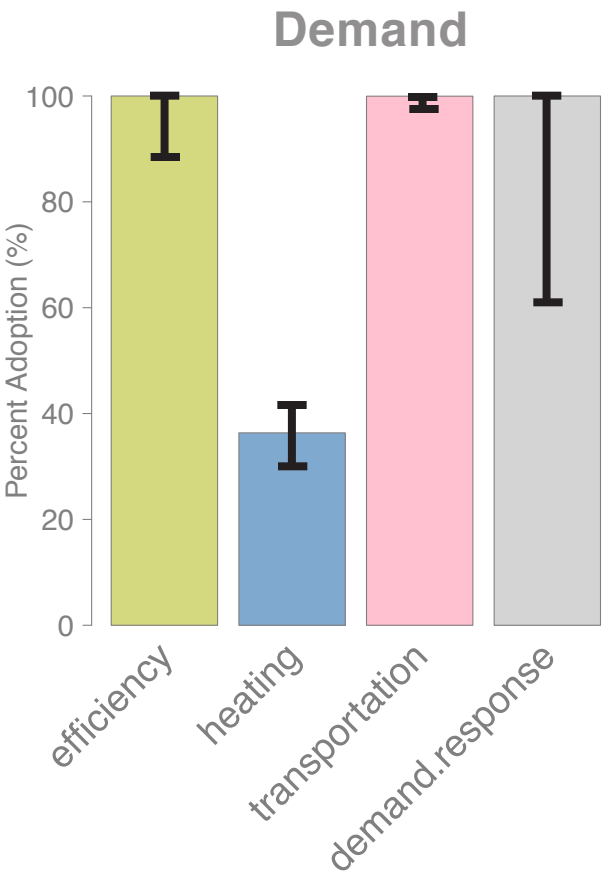

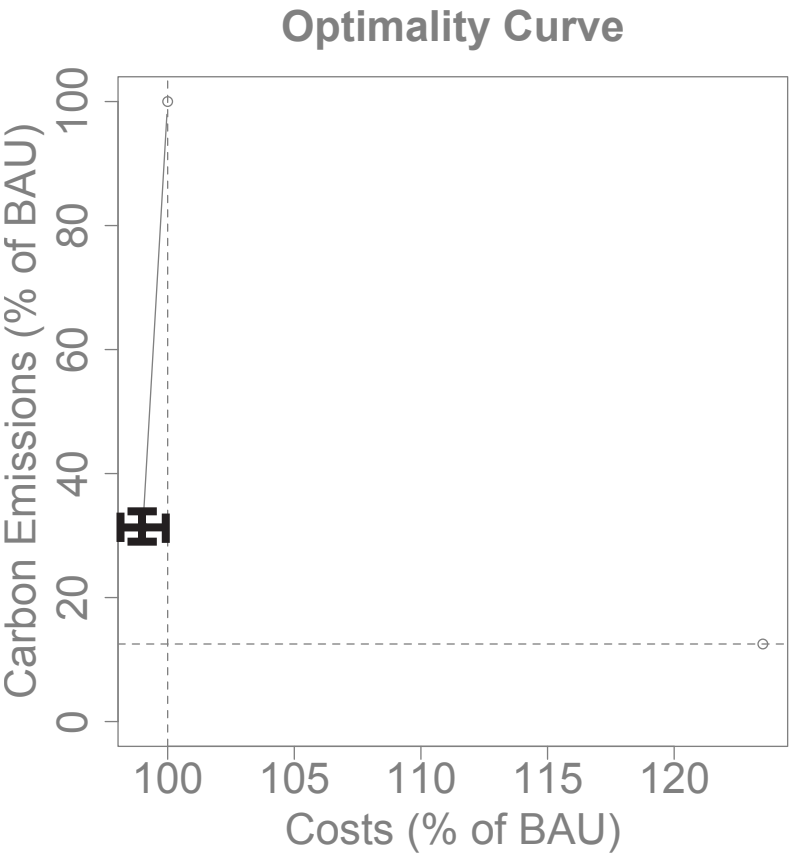

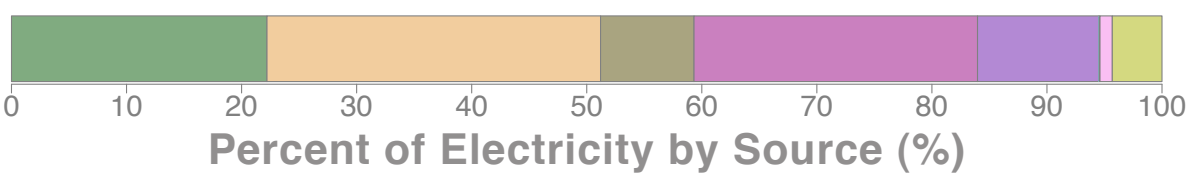

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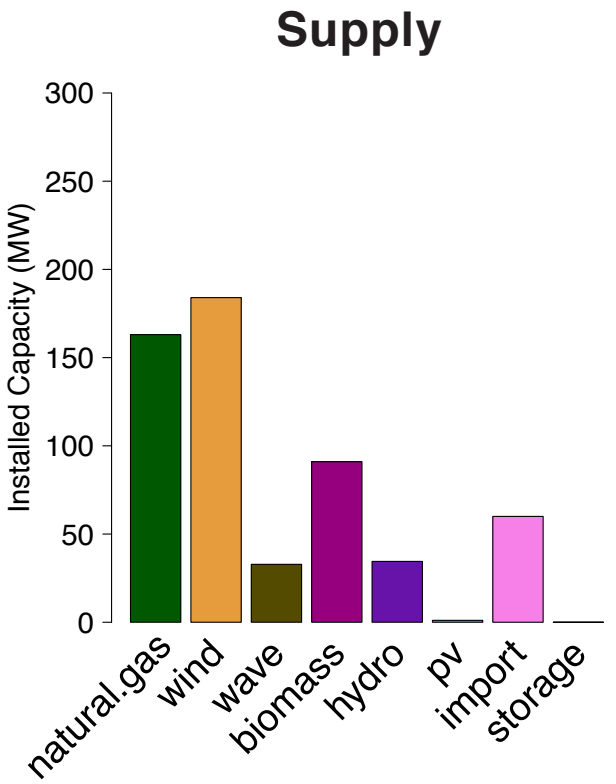

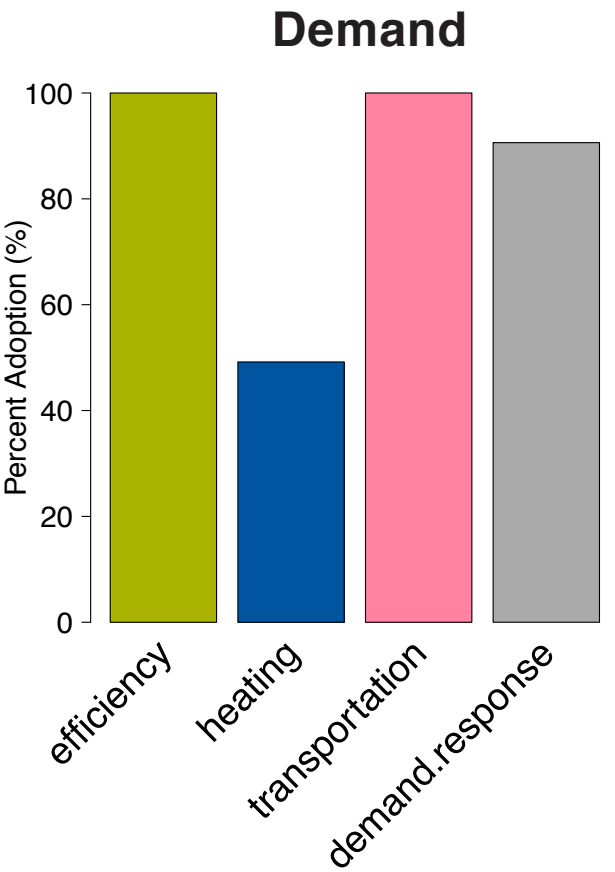

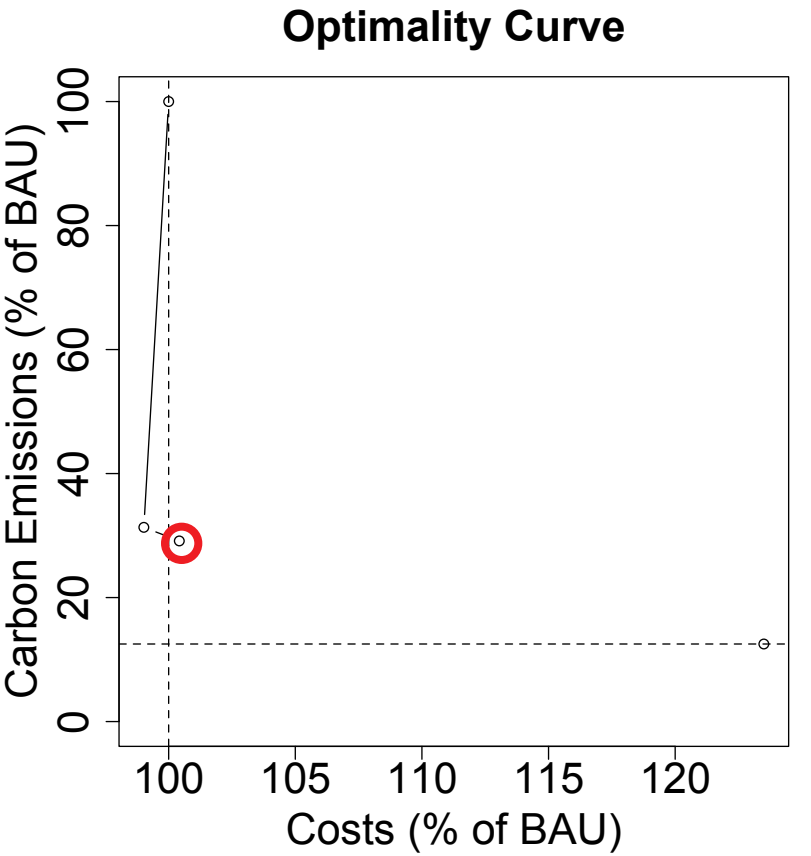

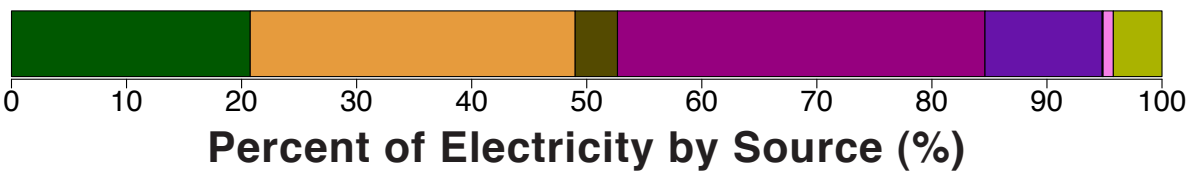

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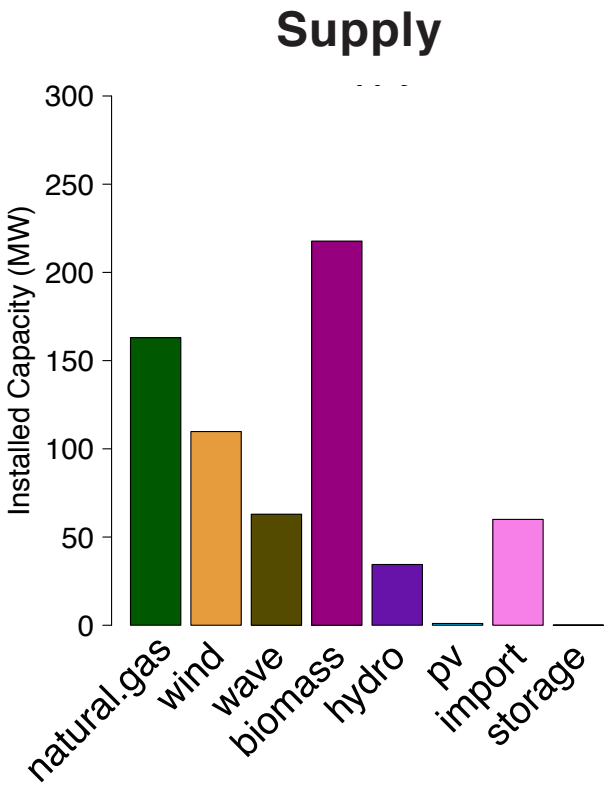

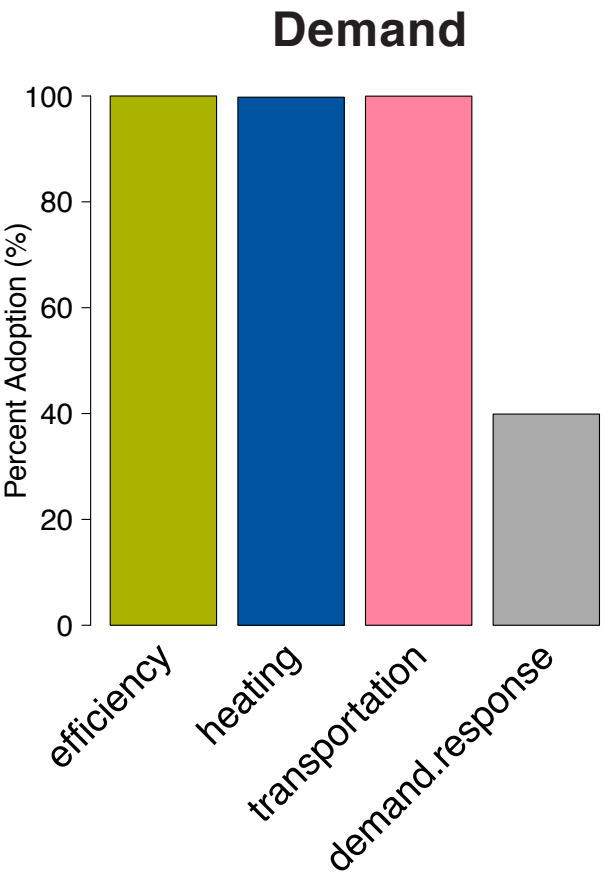

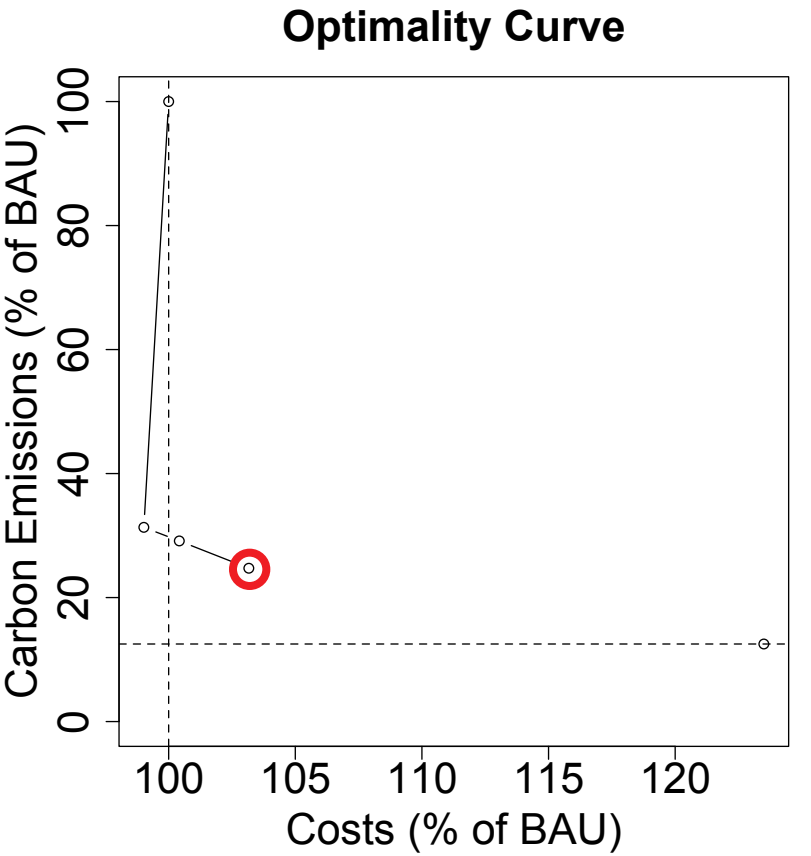

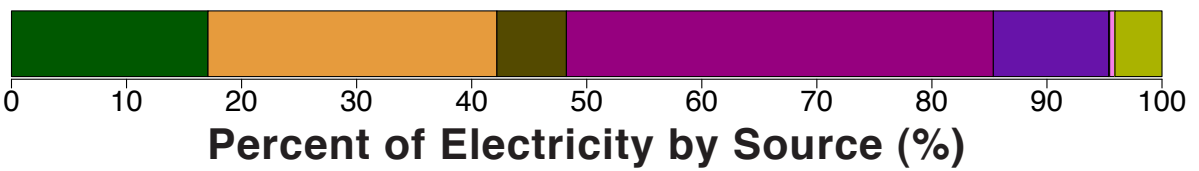

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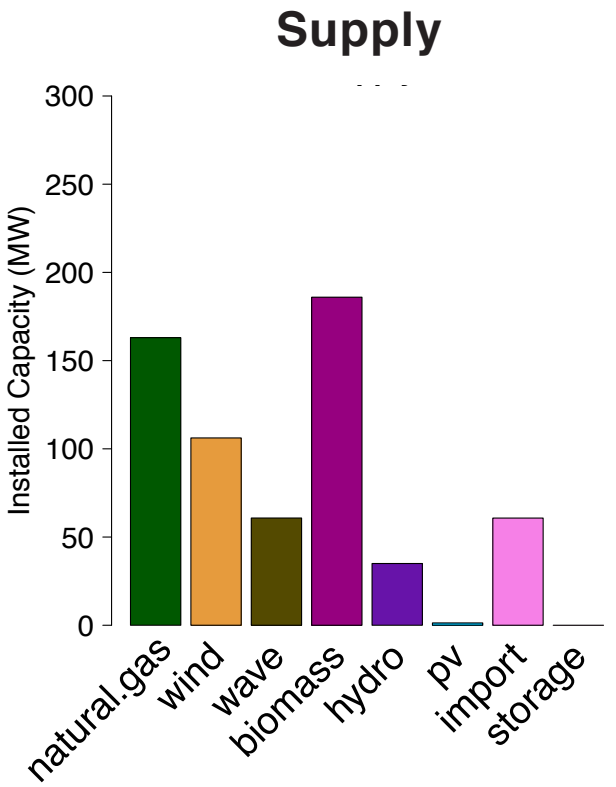

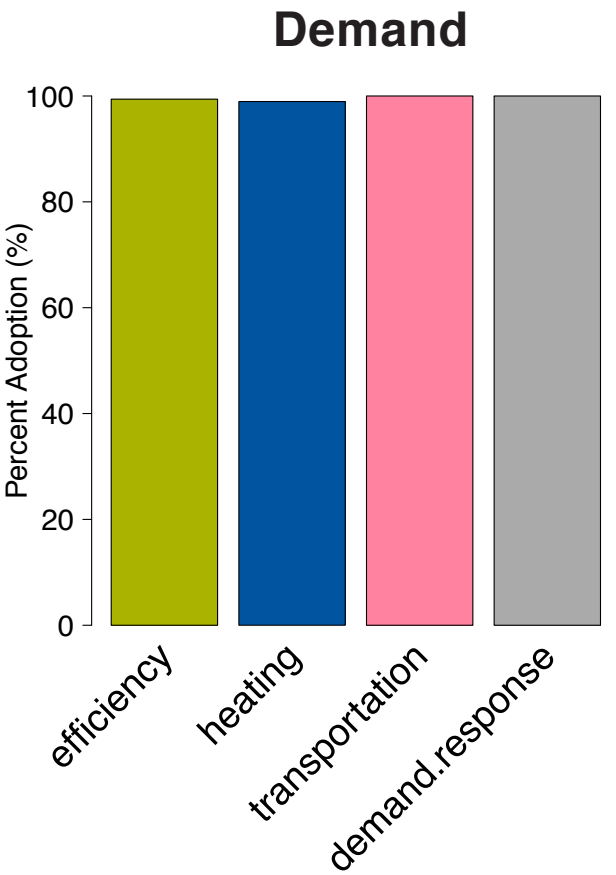

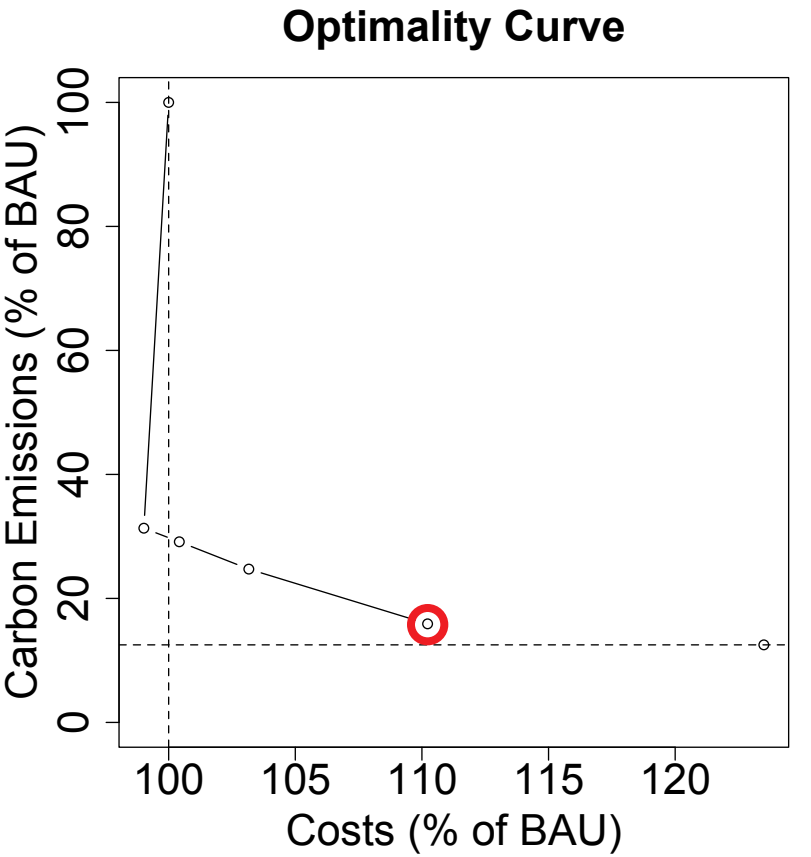

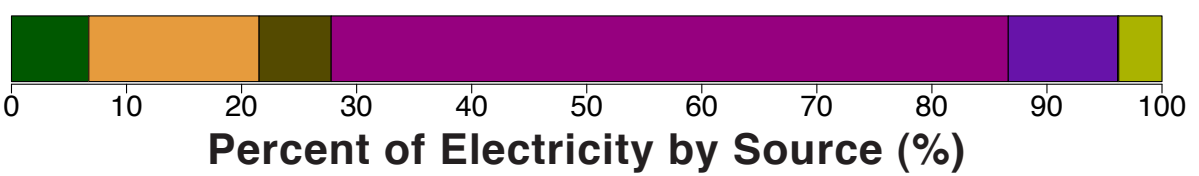

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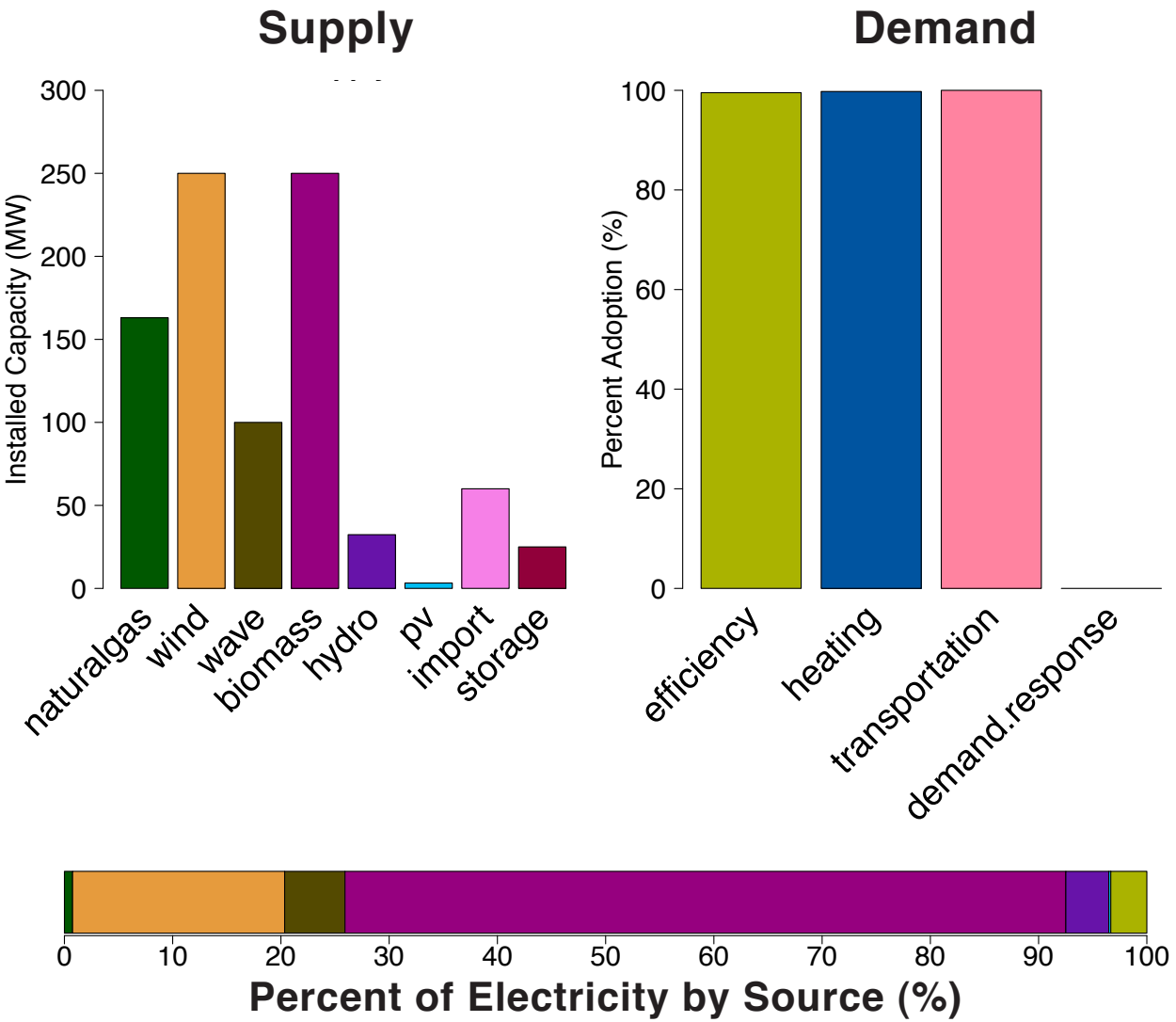

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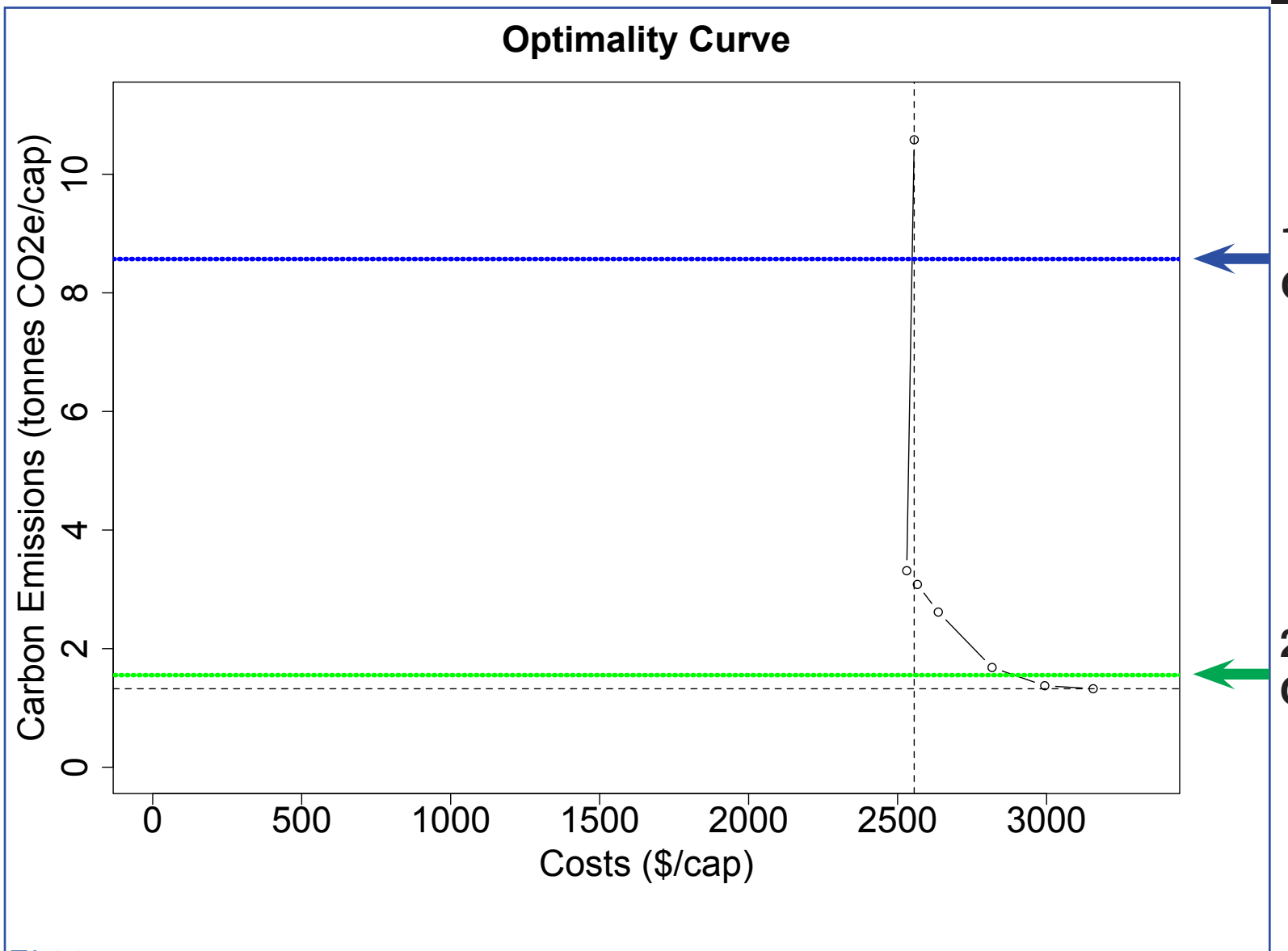

1990 GHG levels

20% of 1990 GHG levels

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Optimization: Objectives / Constraints

Minimize Cost

Objectives

- Minimize cost

Constraints

- Meet demand 99.9% of the time

Impositions

- Carbon has a price (e.g. cap & trade or carbon tax)

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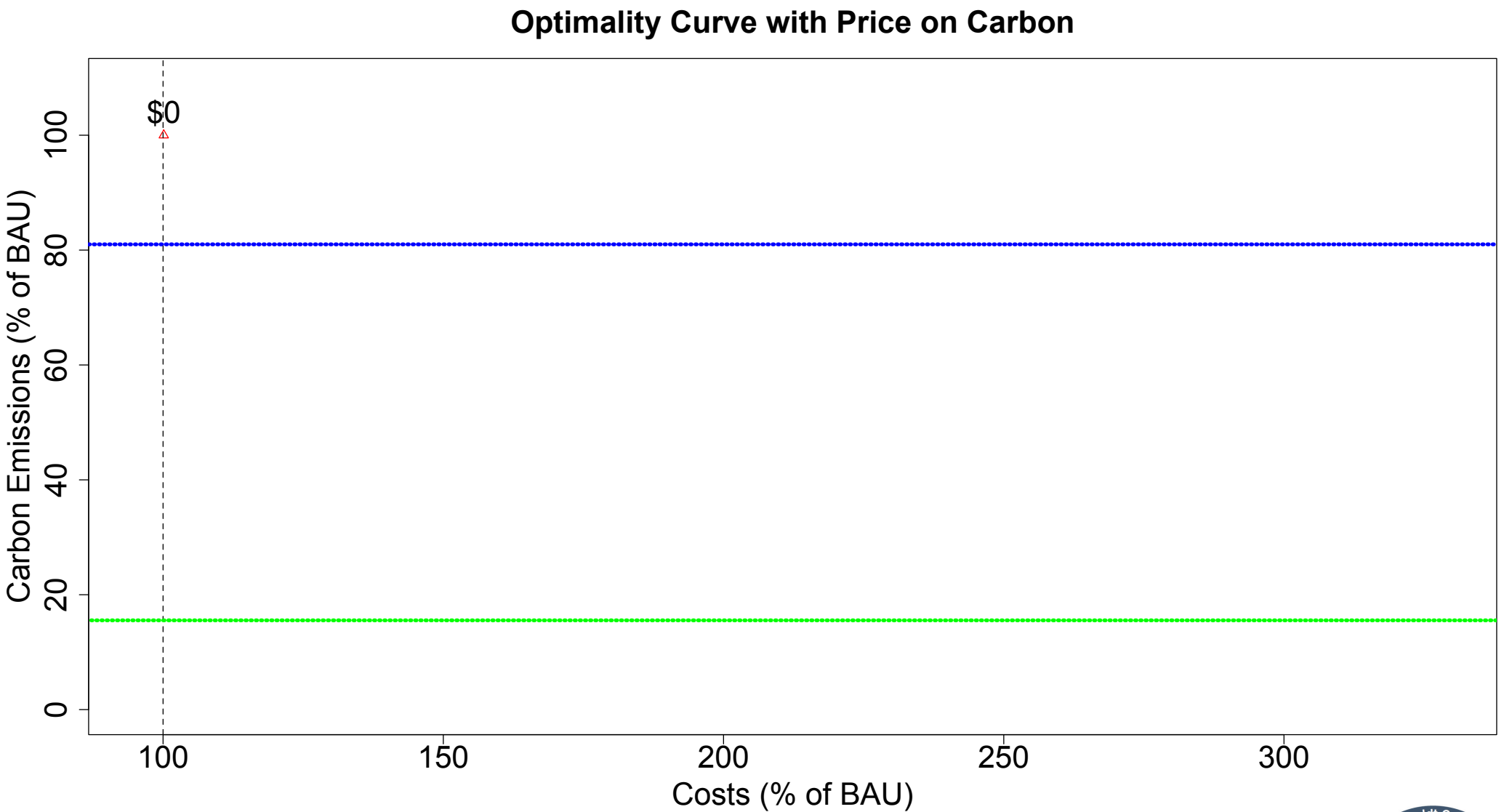
Minimize Cost



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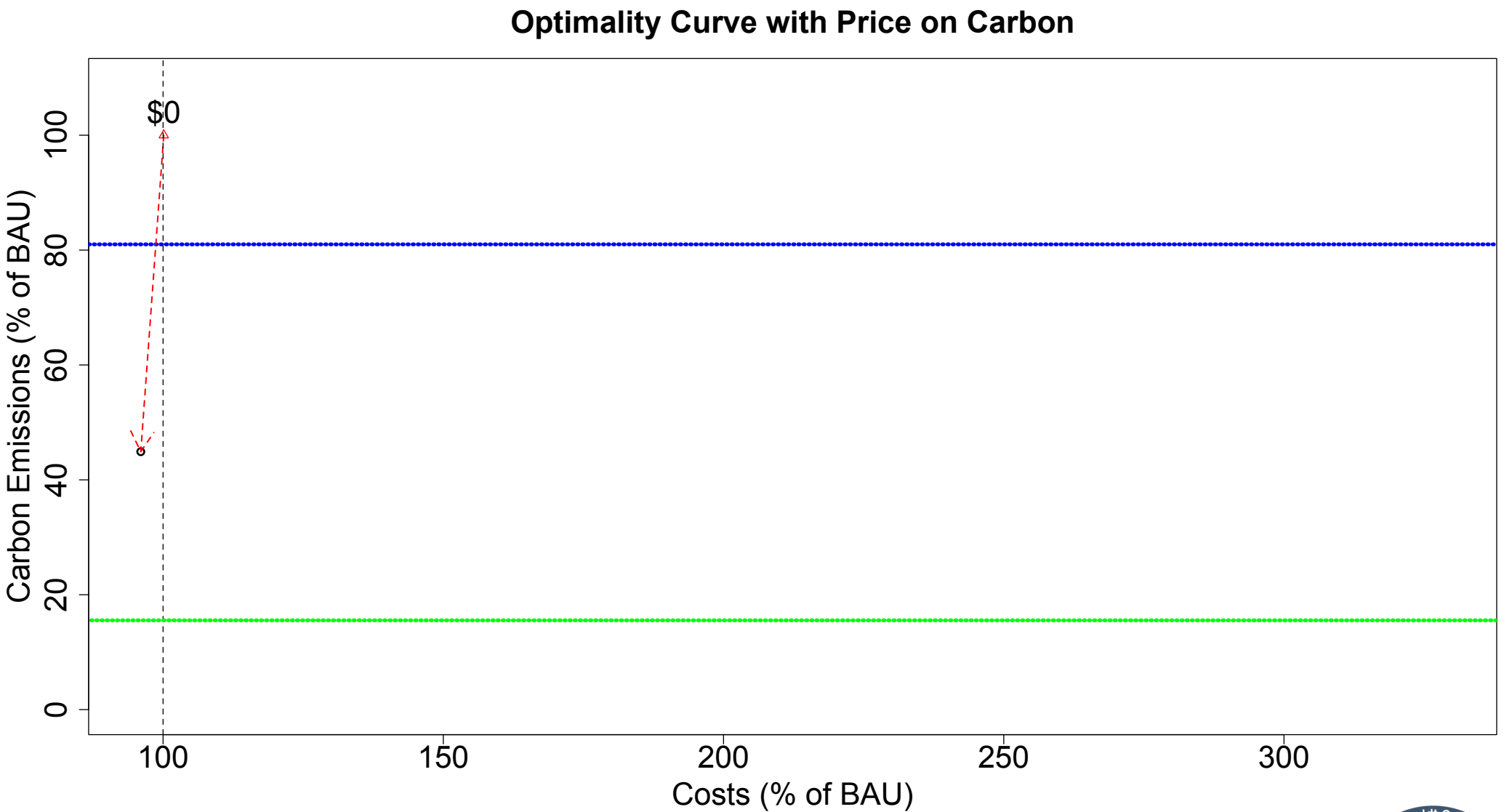

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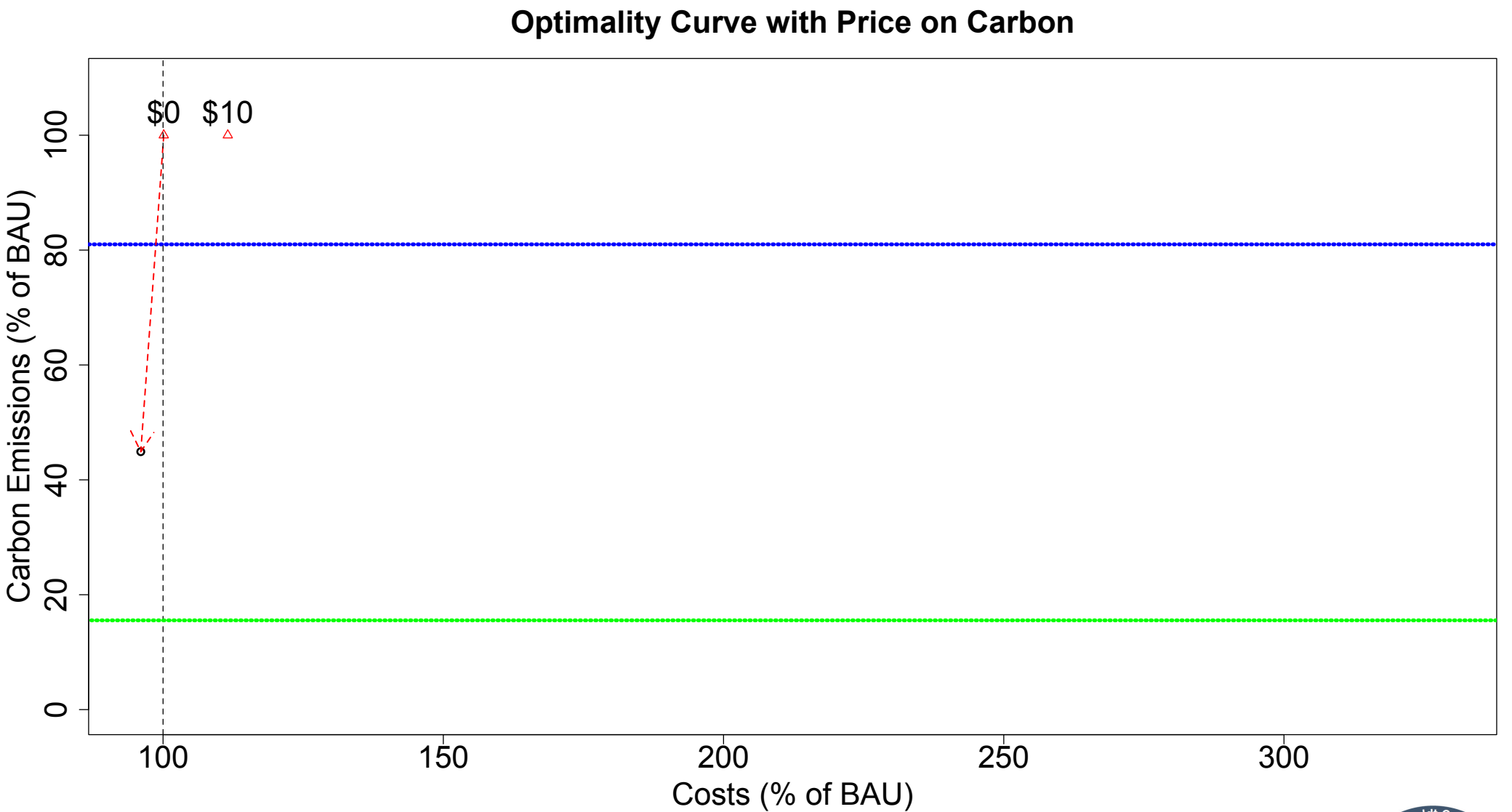

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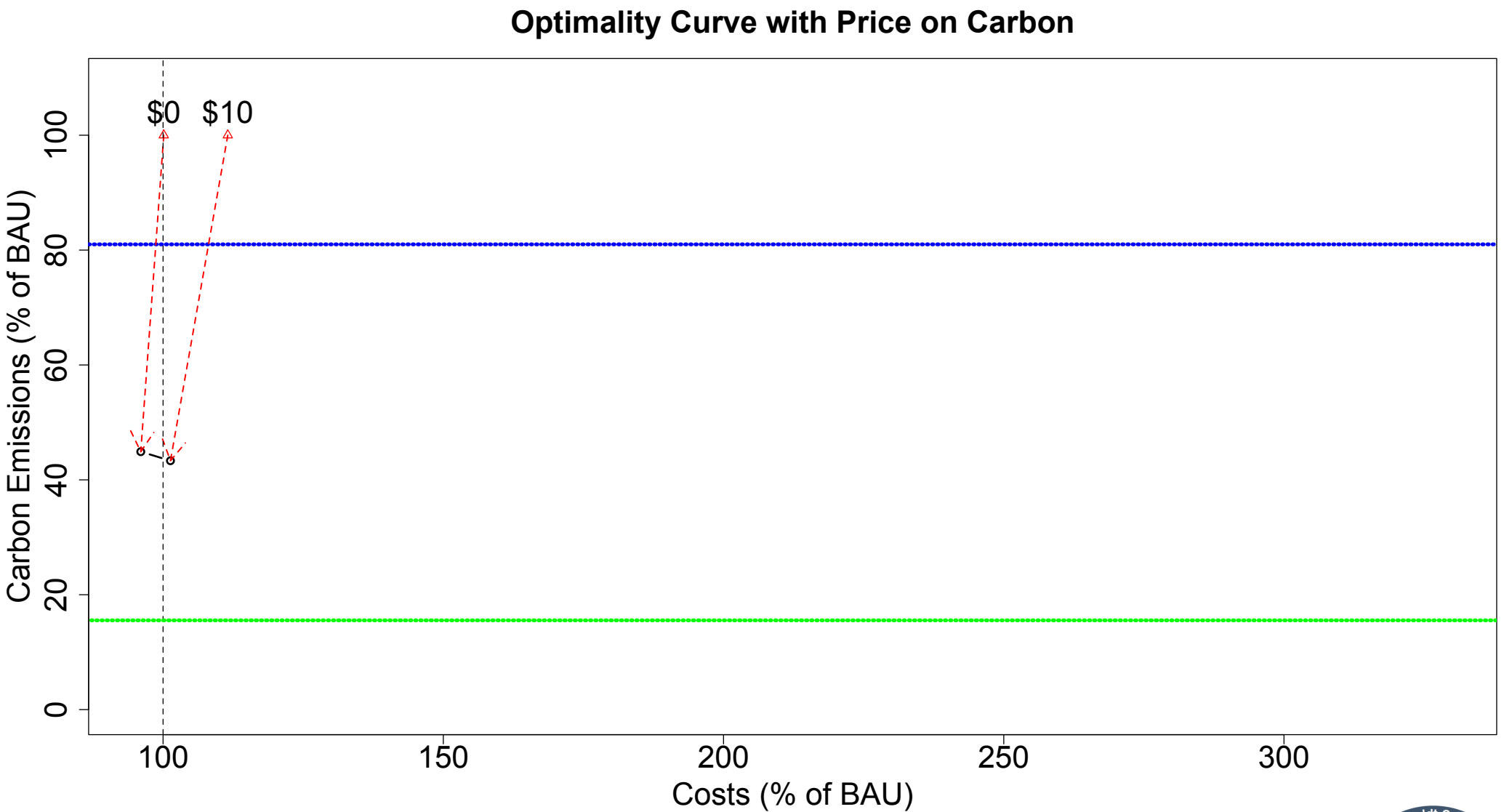

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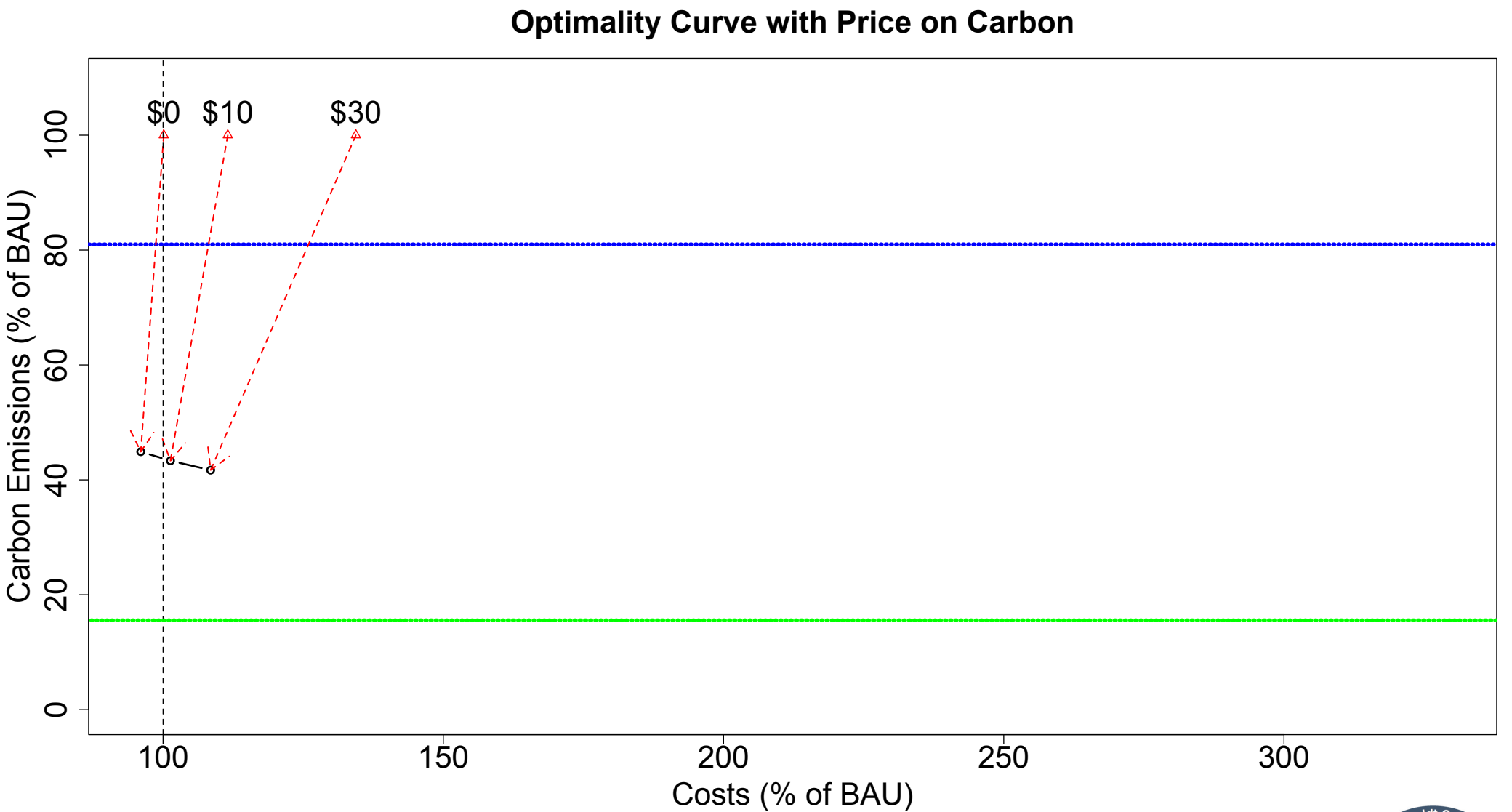

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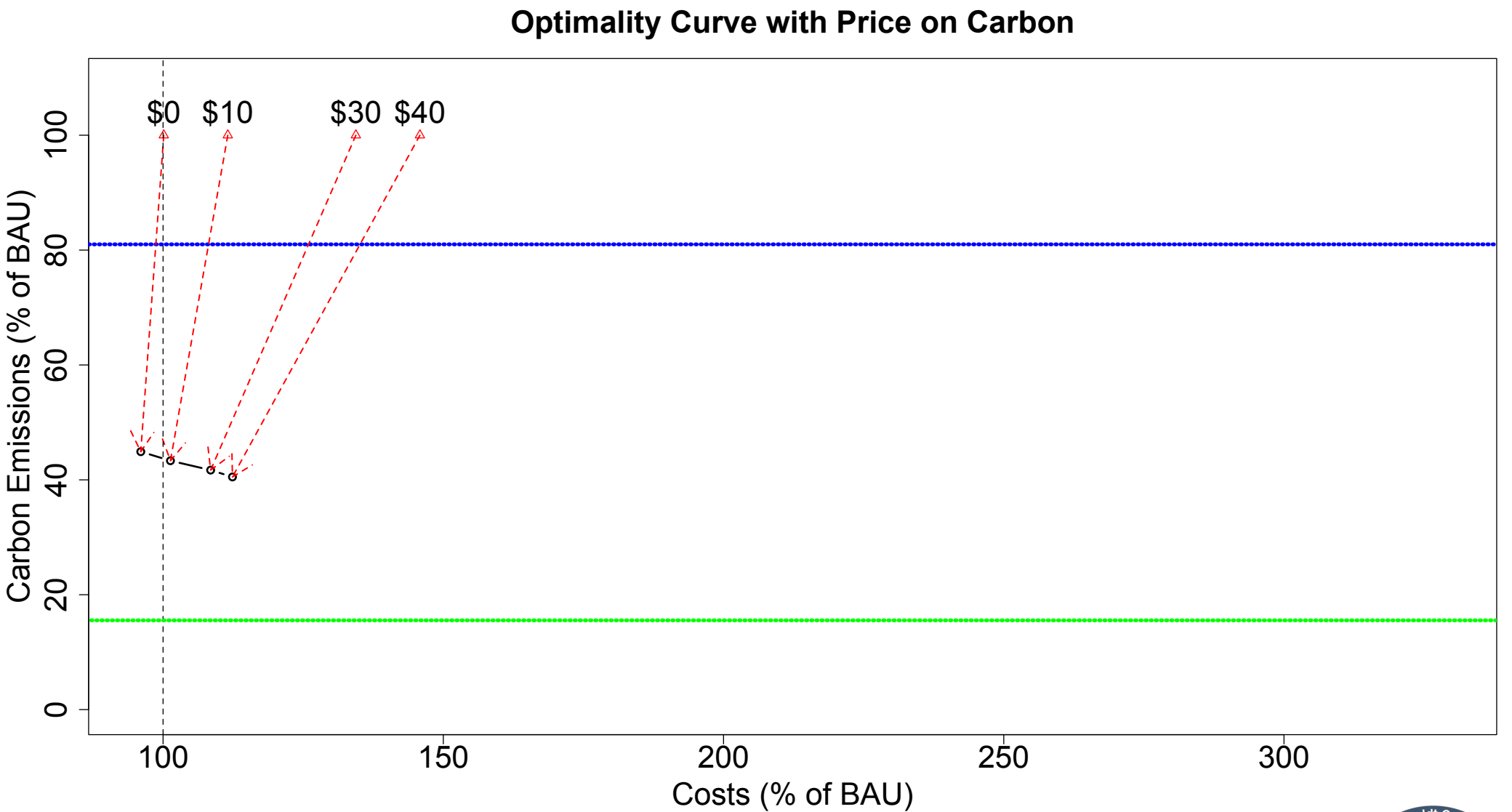

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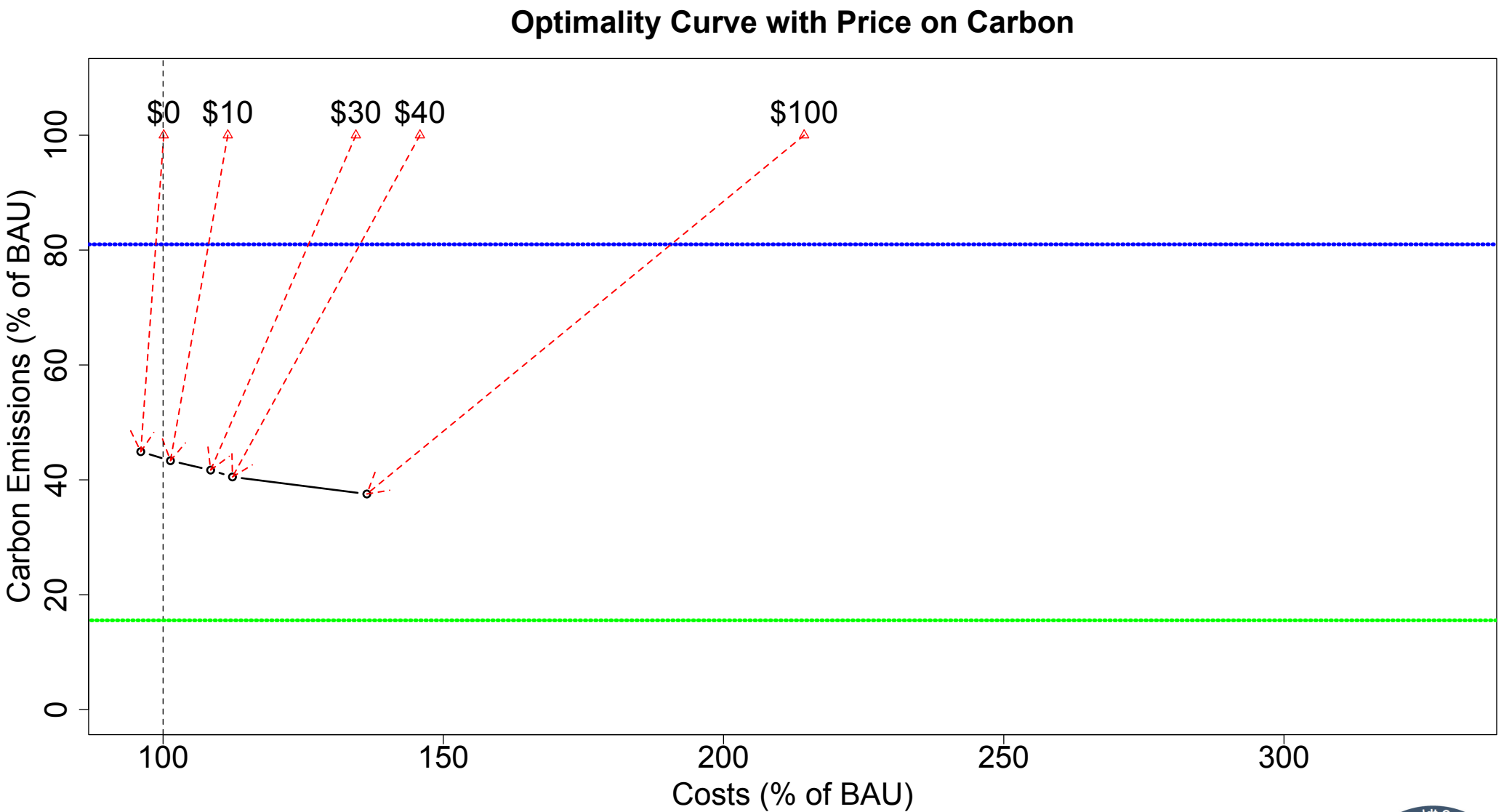

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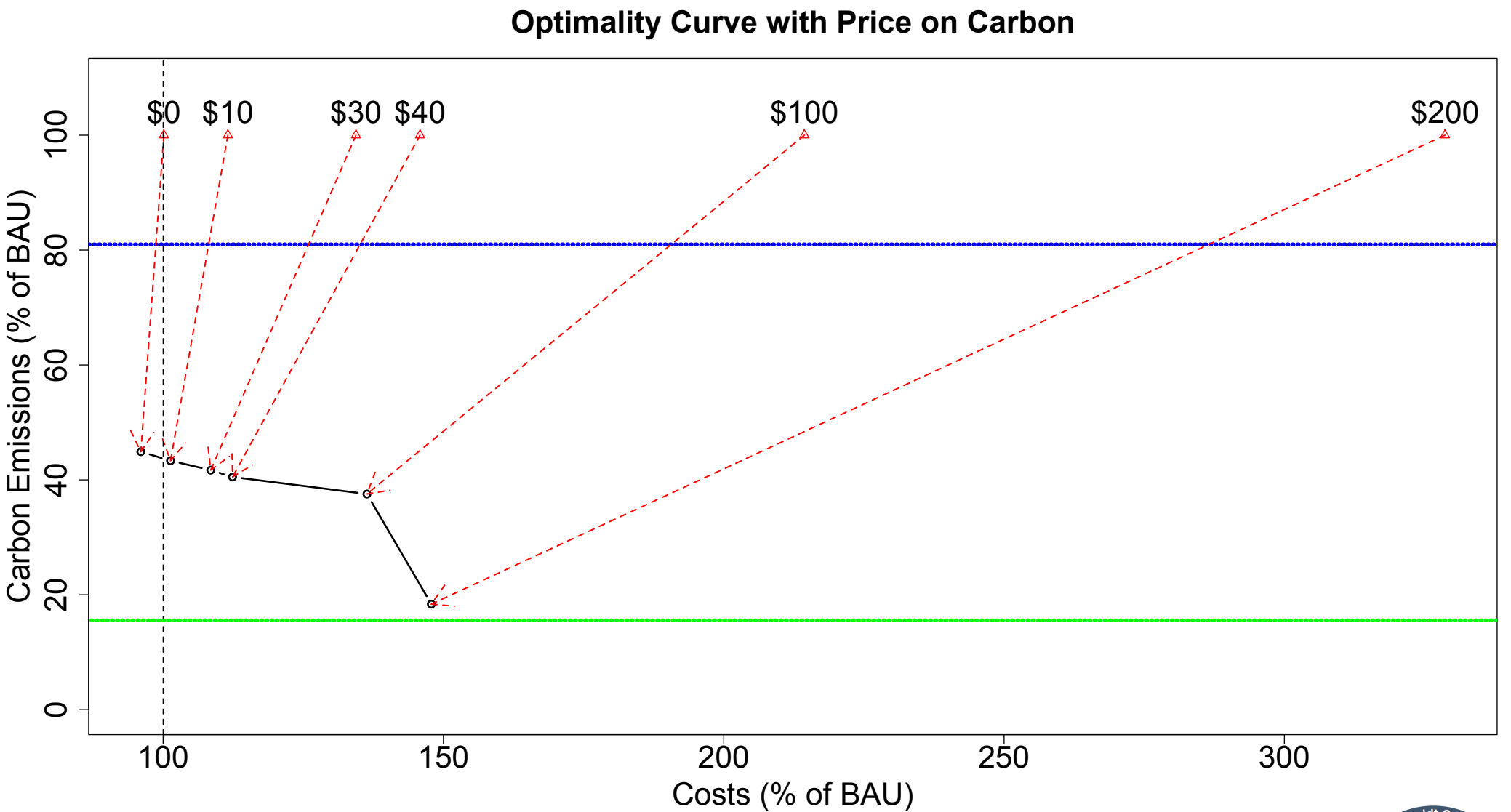

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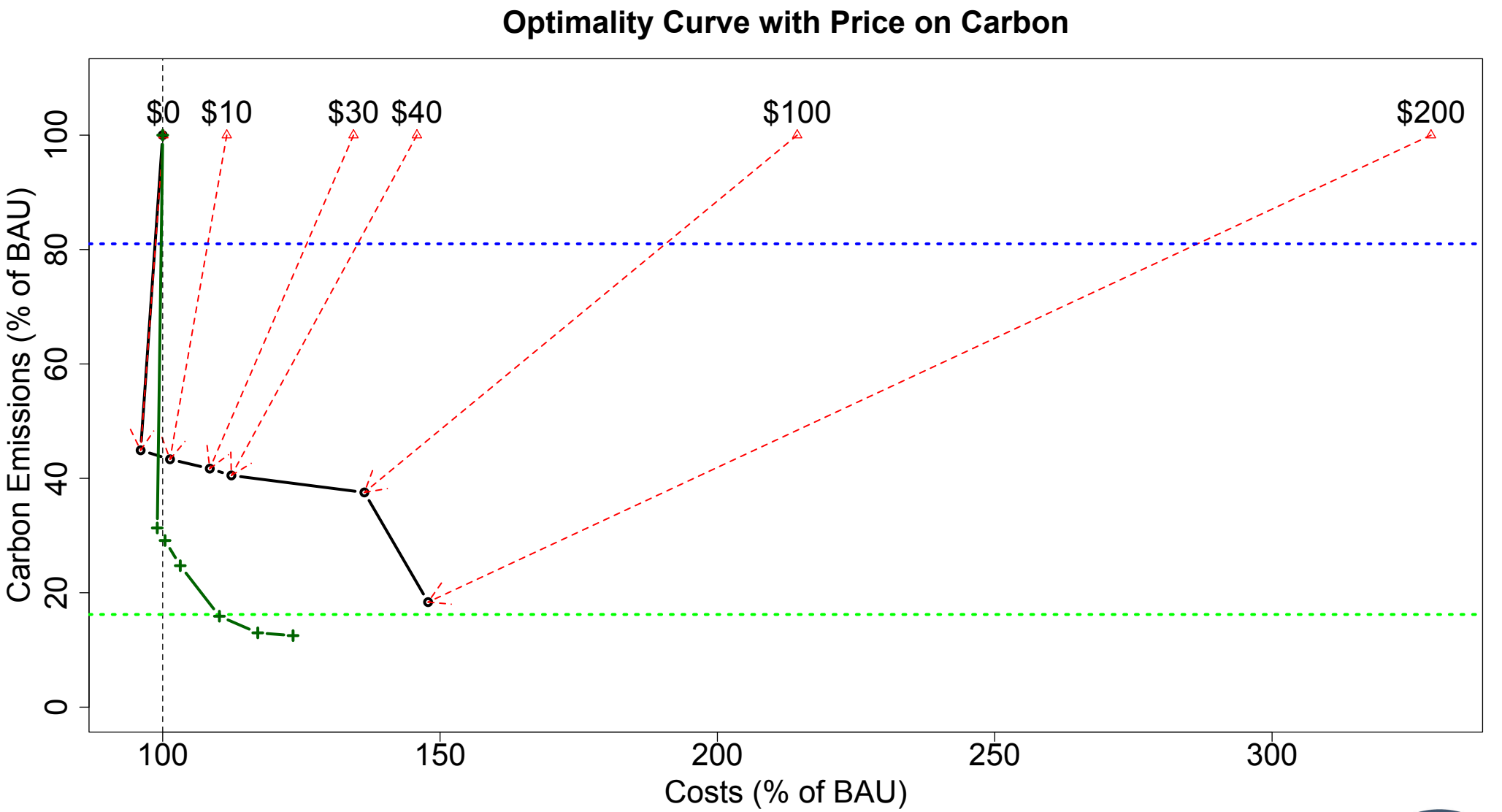

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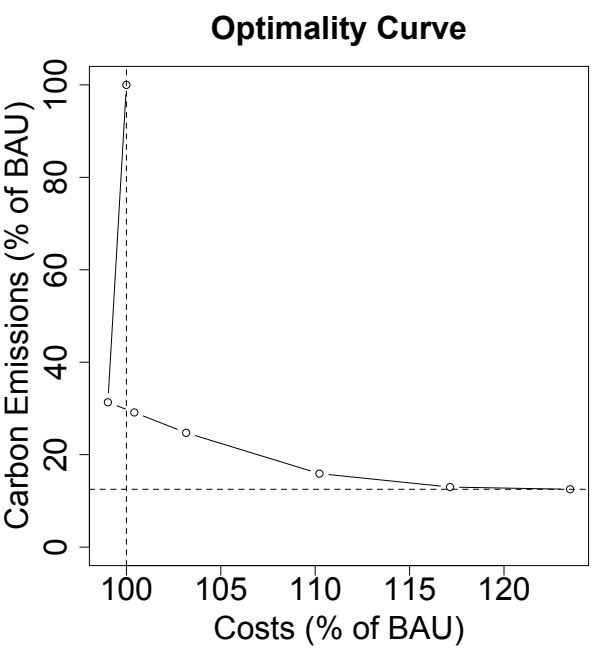
Barriers

- Aggregate costs vs. costs to individual entities.
- Upfront investment vs. lifecycle cost.
- Ownership, development, and environmental issues.
- Other unkown barriers.....



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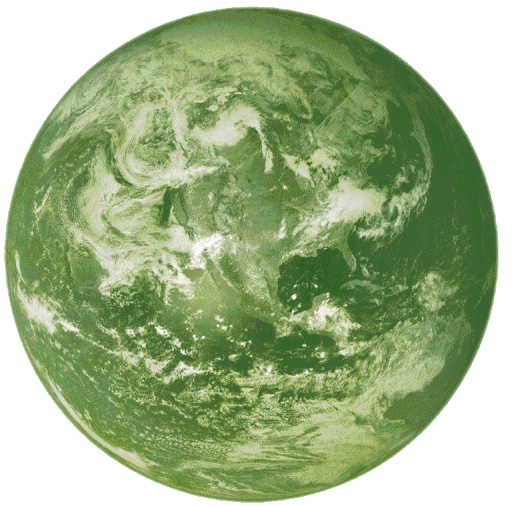
What can we do?

- Conserve energy and upgrade to efficient technologies.
- Consider EV/PHEV's and heat pumps.
- Support local, state, and national initiatives toward a low carbon future.



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Other Project Activities

- Assess Resource and Technology Options
- Examine Development Structure, Financing and Ownership Options
- Conduct Economic Analysis (**presentation next semester**)
- Examine Regulatory and Political Issues
- Conduct Stakeholder Analysis
- Develop Strategic Plan and Identify Next Steps

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Project Participants: Invaluable Contributors

Redwood Coast Energy Authority

- David Boyd, Dana Boudreau, Matthew Marshall, the Board

Schatz Energy Research Center

- Jim Zoellick (project manager), Charles Chamberlin, Steven Hackett, Peter Lehman, Luke Scheidler, Ruben Garcia, Adam Schumaker, Andrea Alstone, Thomas Quetchenbach

PG&E

- David Rubin, Alison Talbott, Ian Caliendo

Others

- Bob Marino (Fairhaven power plant), California Energy Commission (RESCO program), Headwaters Fund

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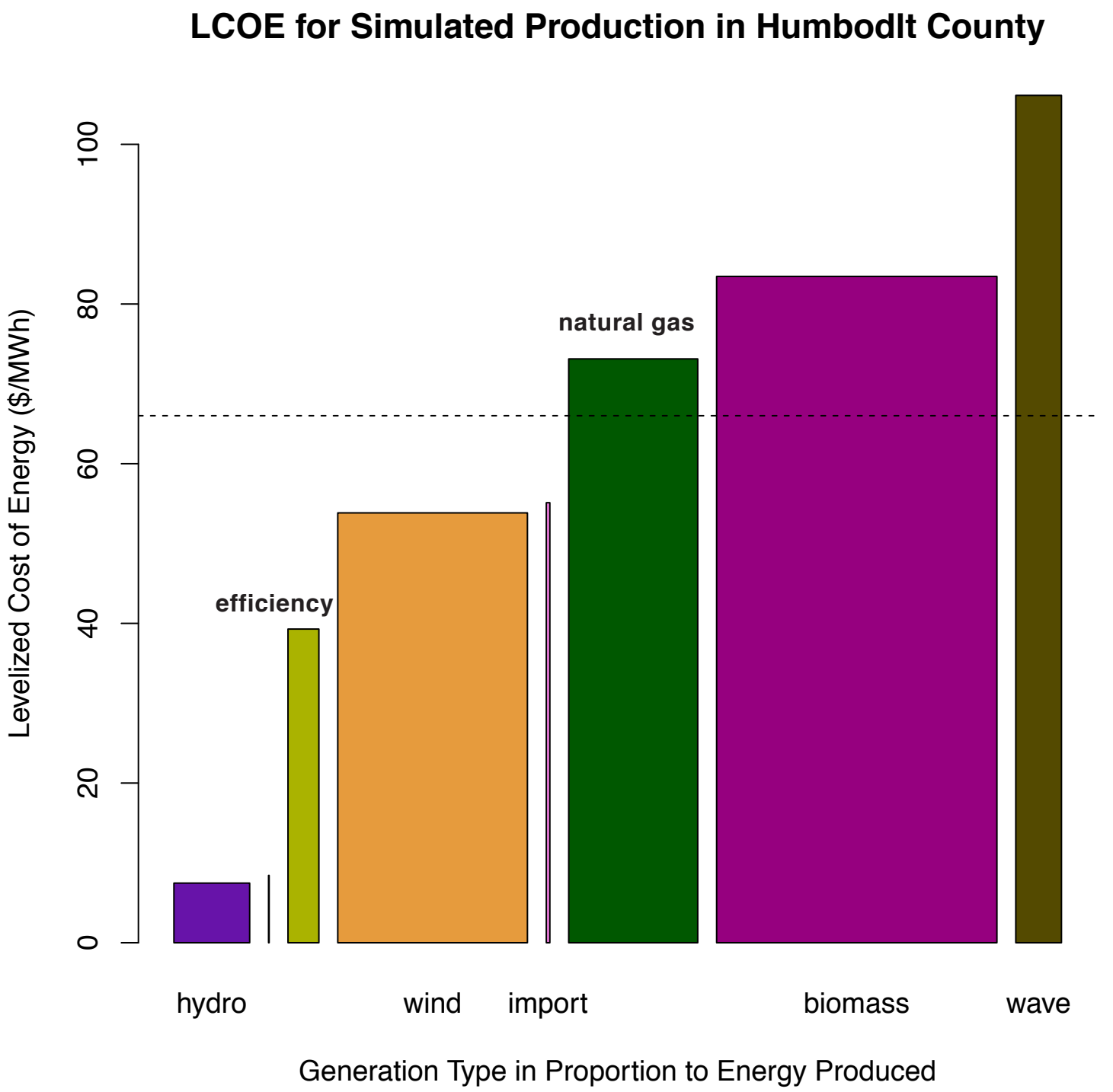
Thanks!


LCOE for Simulated Production in Humbodlt County
Levelized Cost of Energy ($/MWh)
0
20
40
60
80
100
efficiency
natural gas
hydro
wind
import
biomass
wave
Generation Type in Proportion to Energy Produced

Demand: Electricity

photo: http://www.innsnorthamerica.com/

Includes demands from non-heating electric end-uses in the Residential, Commercial, Industrial Sectors

Key Inputs:

- 15-minute interval data from PG&E for County-wide demand
- Expected growth in population and electric intensity

Current Peak:
170 MW

Current Total:
1 TWh

2030 Peak:
180-300 MW

2030 Total:
1-2 TWh

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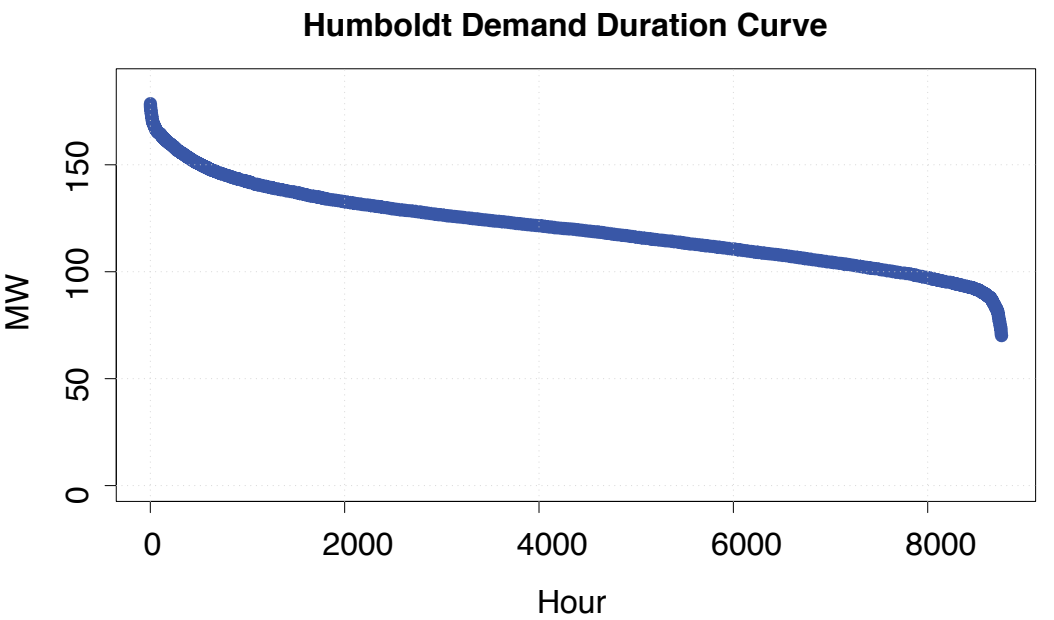
Demand: Electricity

Raw data is de-trended; weeks are chosen randomly from available years to create a full year of demand.



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Demand: Heat

Includes demands from heat end-uses in the Residential, Commercial, Industrial Sectors for space heating and water heating.

Key Inputs:

- Mix of heating technology and market shares (efficiency and fuel type) by building sector.
- Heating service demand curve from DOE2 building energy model, census data, etc.
- Key inputs from Census, RECS, CBECS

Current Use:

5.3 PJ of fuel
~0.4 PJ electricity

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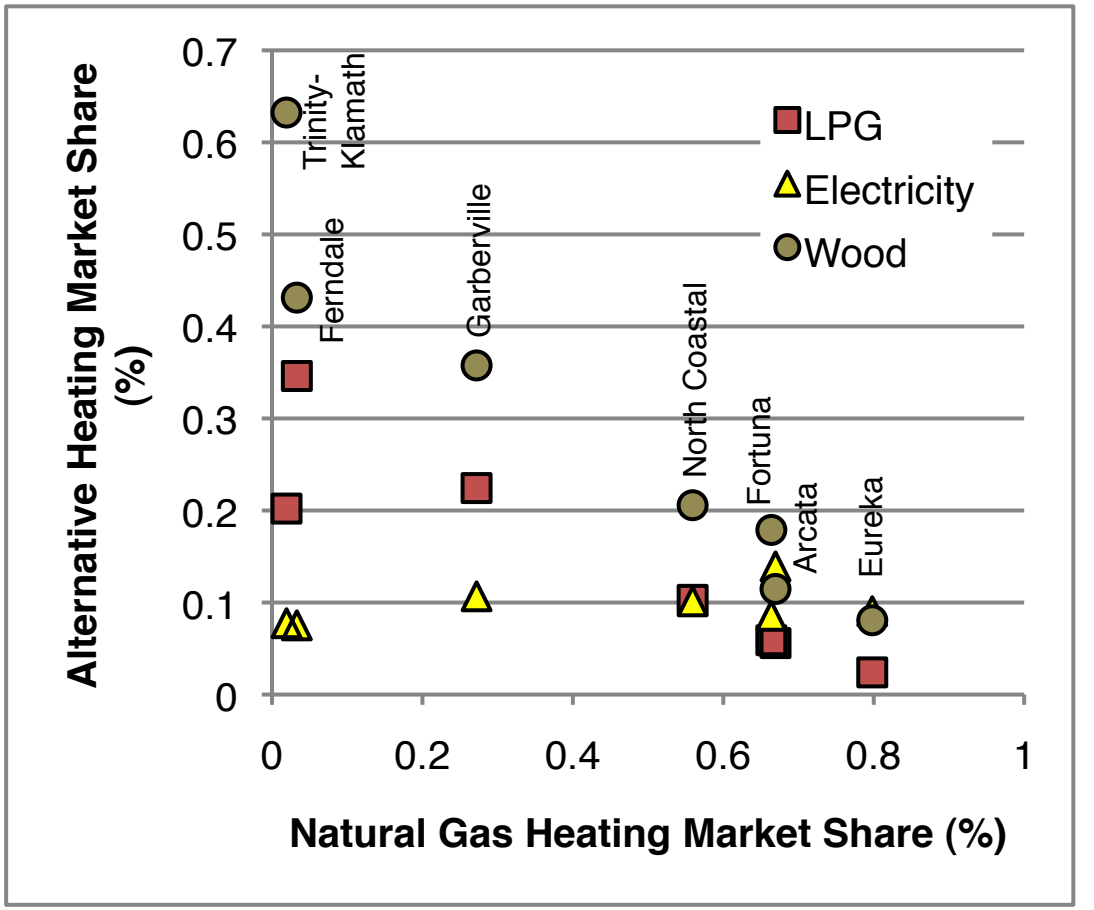
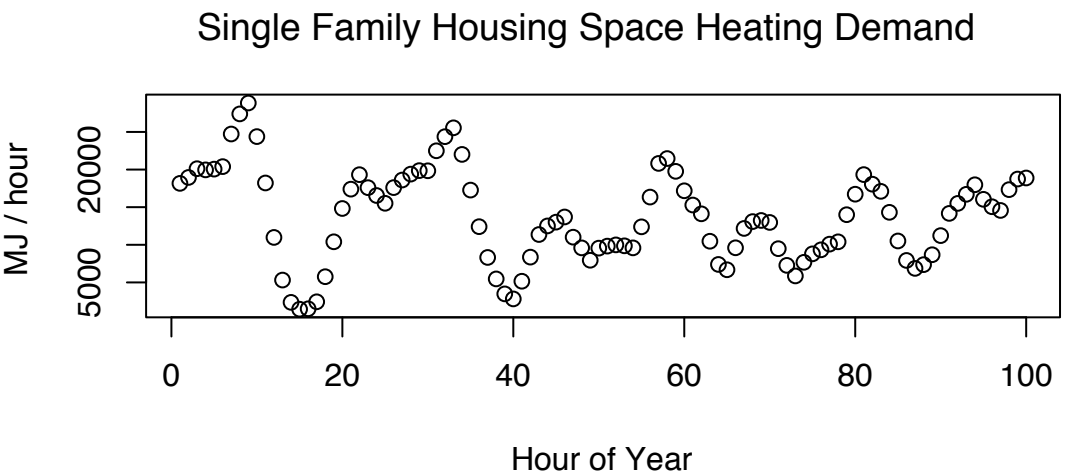
Demand: Heat





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Demand: Transportation

Based on estimates of technology learning curves from EPRI and NREL charging model.

Key Inputs:

- Fraction of fleet conversion from conventional to EV
- Charging strategies (determines distribution of electricity demand)

Current Use:

66 million gallons of gasoline / year

2030 potential:

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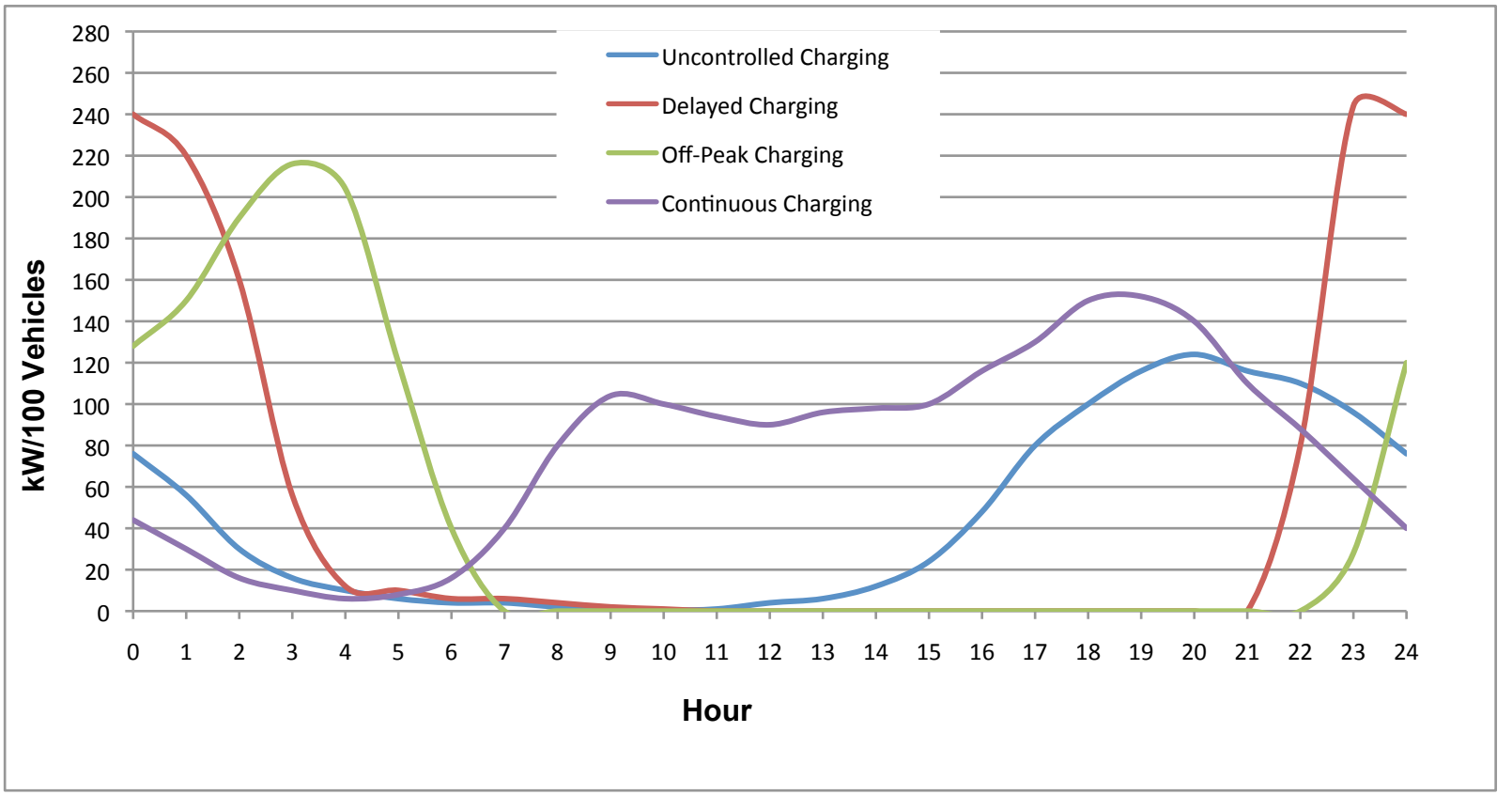
Demand: Transportation



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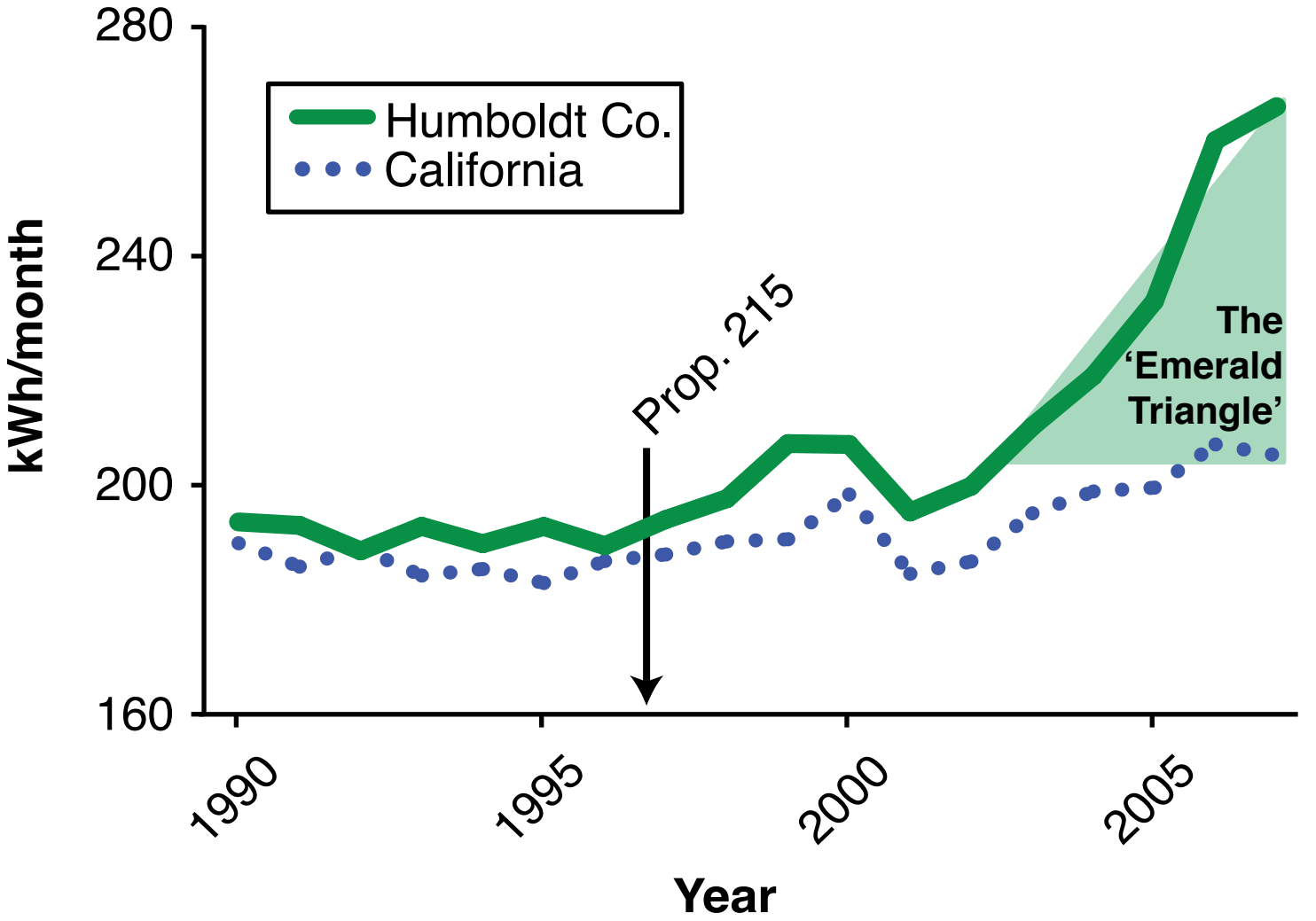
Residential Electricity Consumption per Capita



Data Sources: California Energy Commission, U.S. Census

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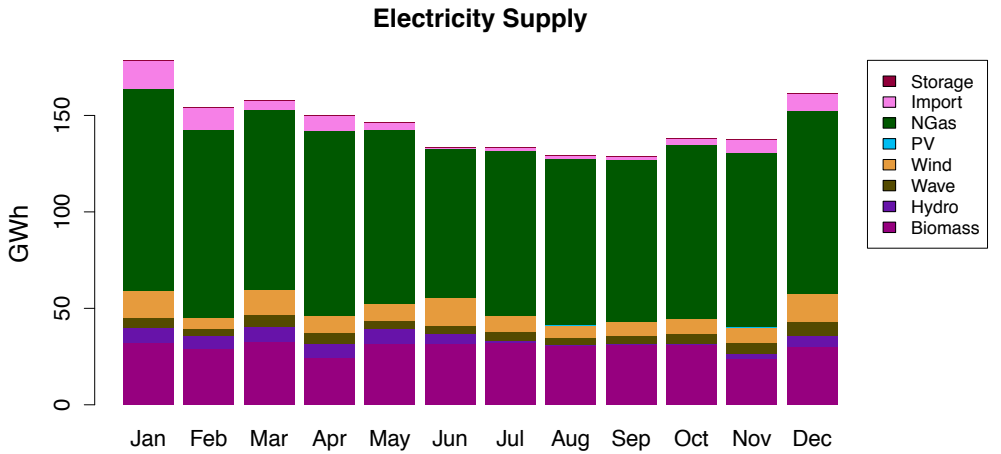
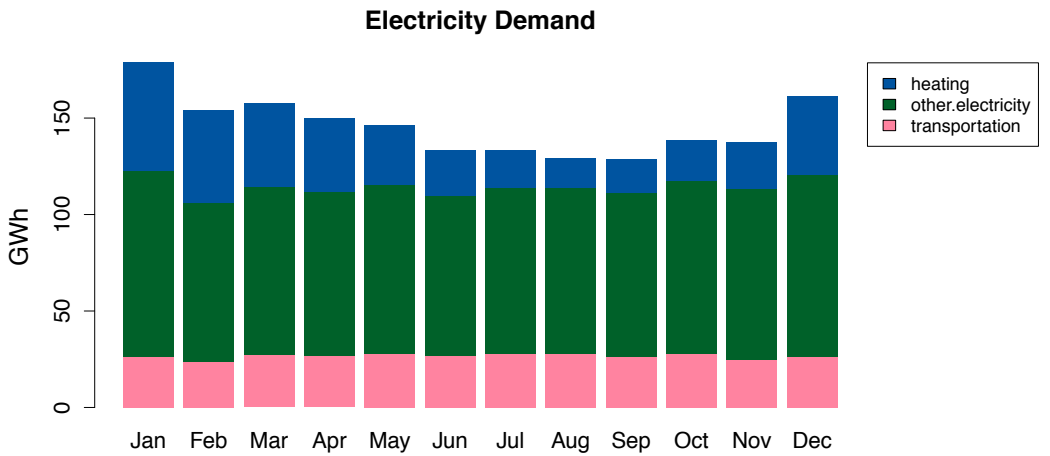
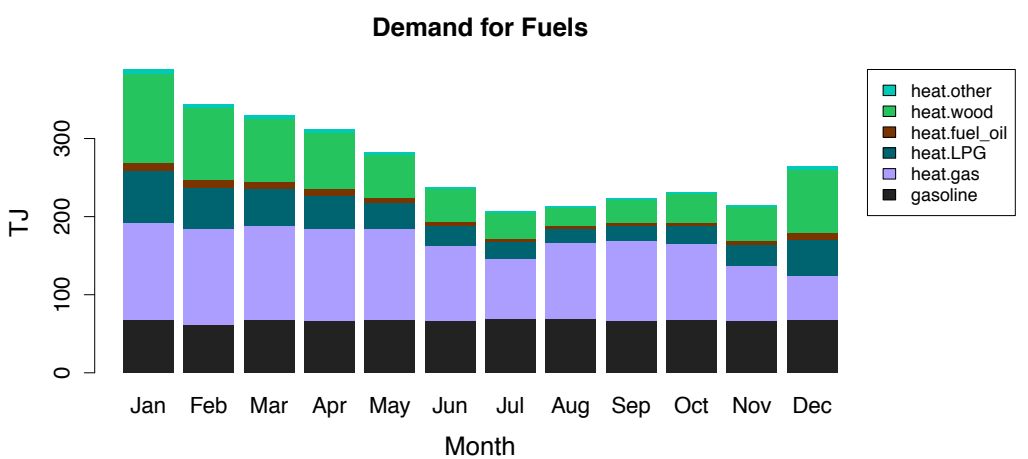
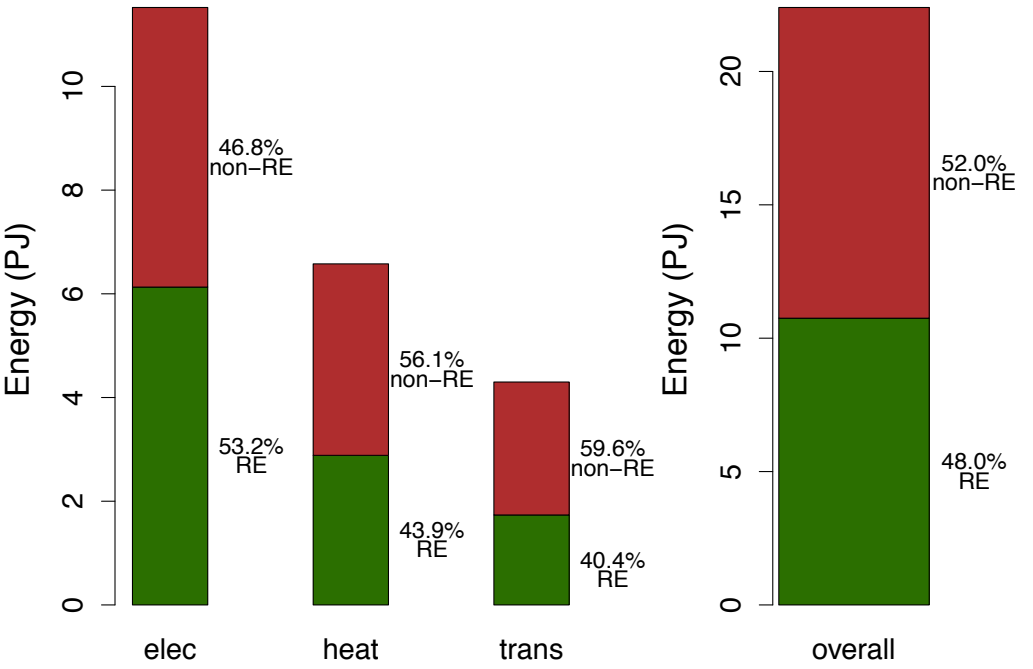
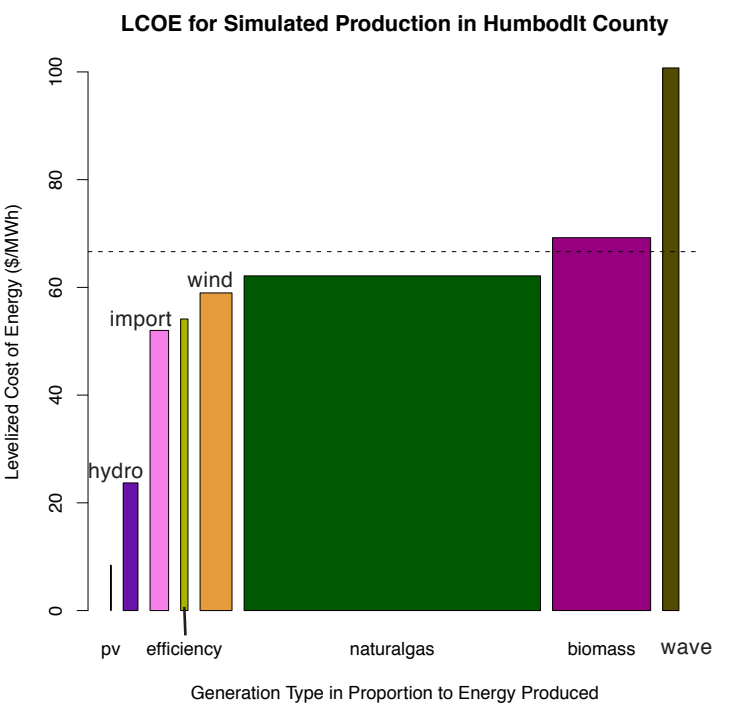
Post processing: Scenario Summary











Supply: Natural Gas

Model based on new Humboldt Bay Repower, 10 x 16MW Internal Combustion Engines. Assumed to always be available and have load following capability.

Key Inputs:

- Priority
- Minimum turn down factor
- Stability share
- Reserve capability
- Heat rate

Current Capacity:
163 MW

2030 Potential:
163 MW

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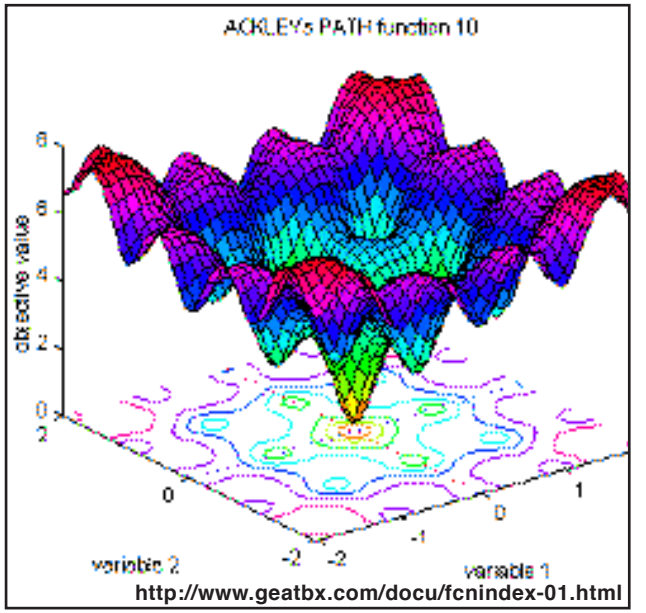
Optimization: Differential Evolution



DE is a variant on genetic algorithms

- Global optimization: robust when function has local minima or correlated independent variables
- For sufficiently complicated objectives, much more efficient than particle swarm or conventional G.A.

Key Inputs:

- Objective function (in form of minimization)
- Constraints (implemented as infinite penalty on the objective)
- Decision variables

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Supply: Biomass

Existing Plants in Scotia, Fairhaven, Blue Lake. Stochastic time series model which accounts for un/scheduled maintenance and observed fluctuations in daily output.

Key Inputs:

- Capacity
- Capacity factors

Current Capacity:
61 MW

2030 Potential:
61-250 MW

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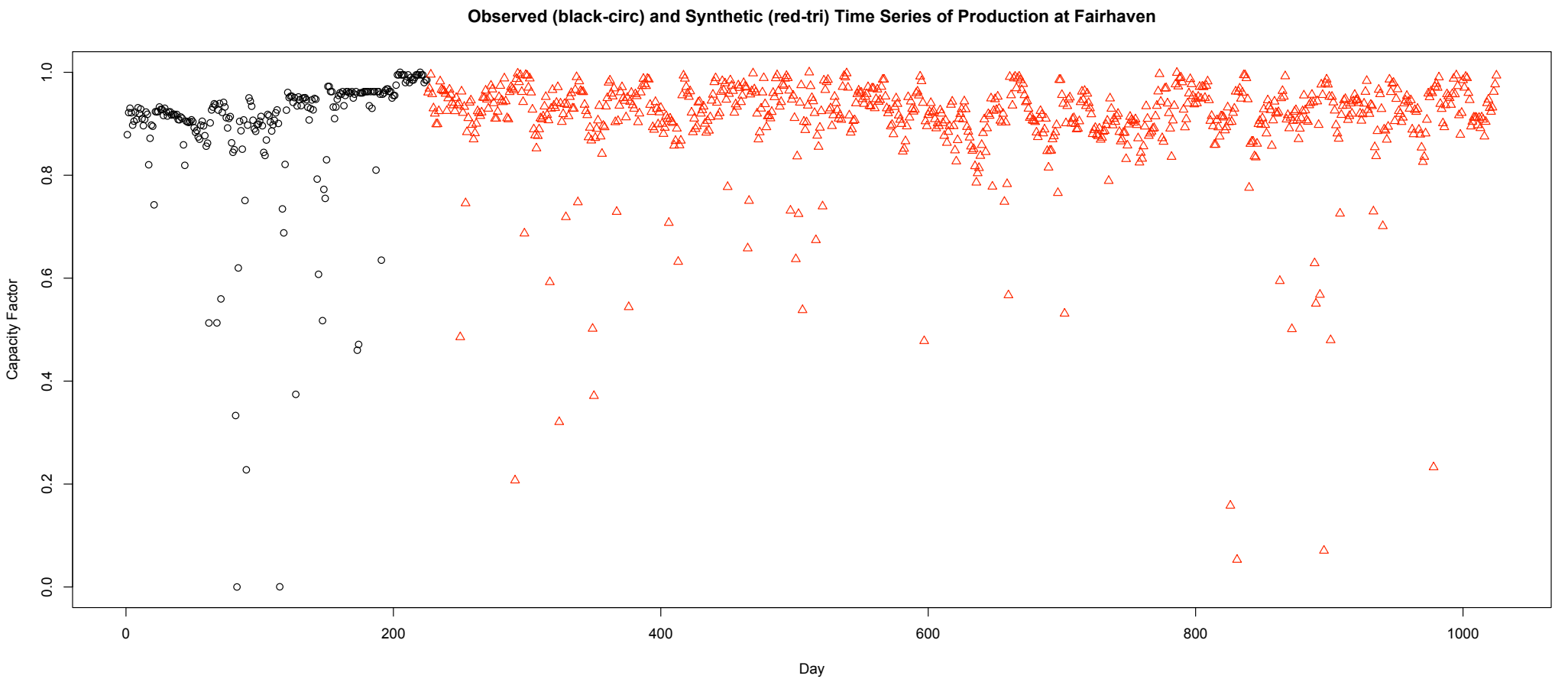
Supply: Biomass

Time series model - Separated Normal Operation (CF ≥ 80%) from Unscheduled outages (CF < 80%) and from Scheduled outages



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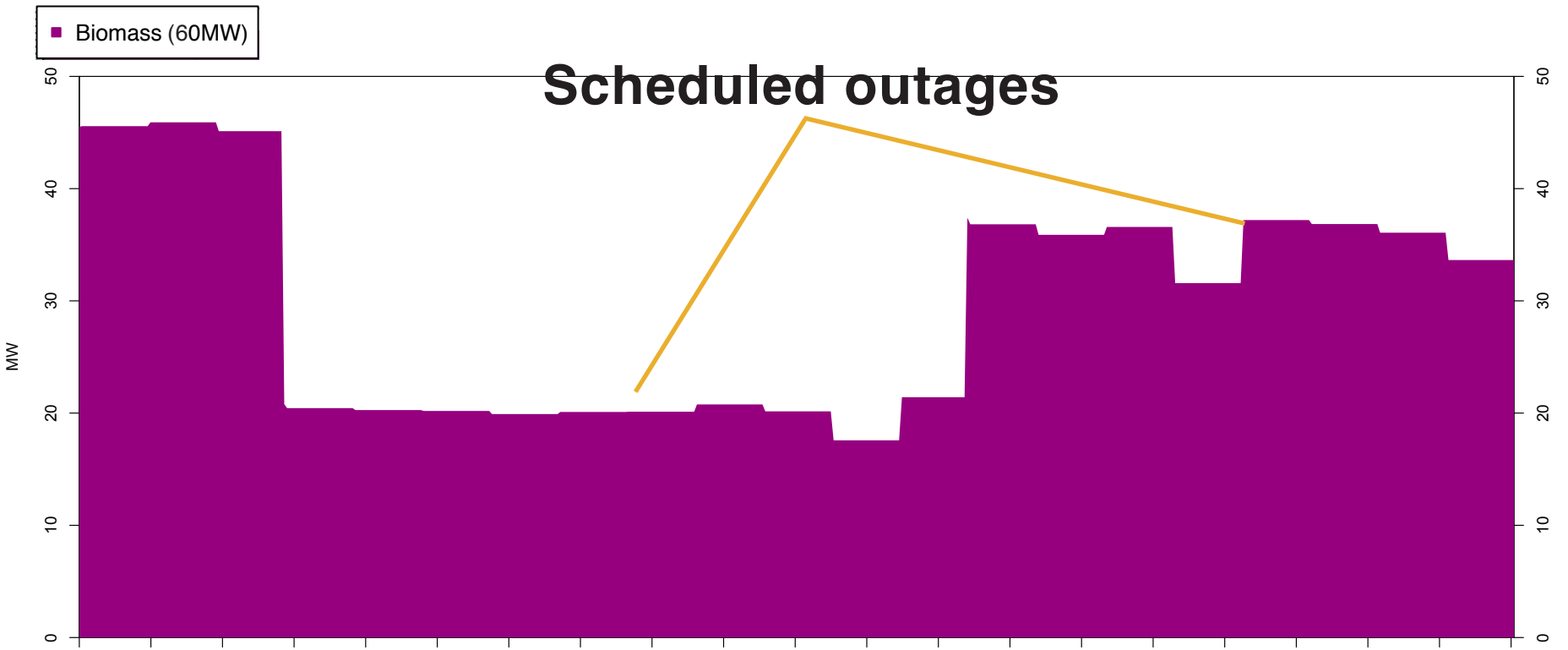
Supply: Biomass

Scheduled outages occur at Fairhaven for ~1 week just before and just after the summer season when prices increase.



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Supply: Hydropower

Sum of three time series models:

- Matthews Dam ~1.3MW
- Run of the river installations ~7.5MW
- Run of the river with peaking ~ 1.7MW

Key Inputs:

- Capacity
- Precipitation year

Current Capacity:
10.5 MW

2030 Potential:
10.5-35 MW

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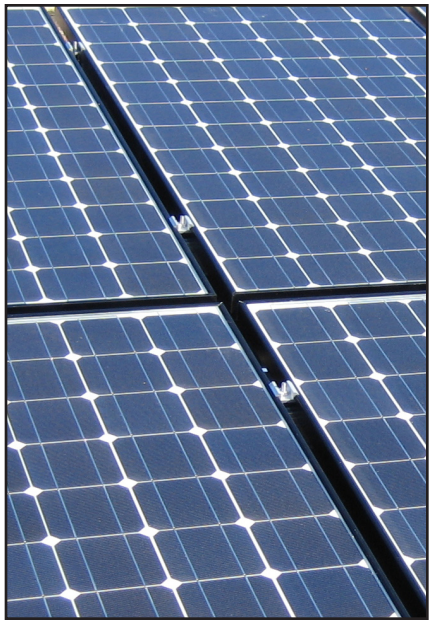
Supply: Photovoltaic



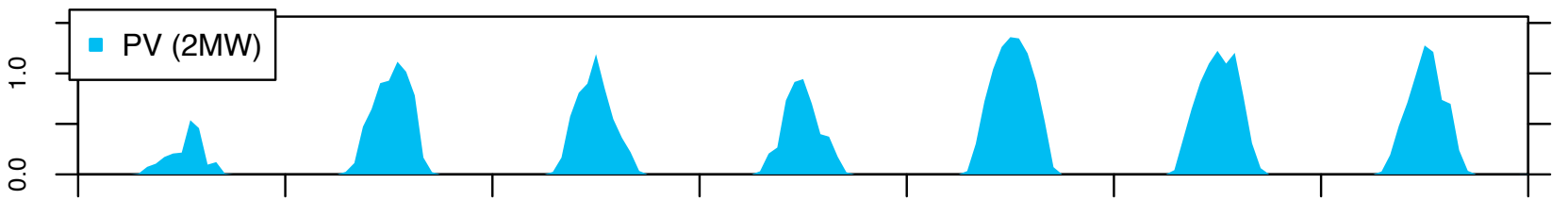
Model based on data from National Solar Radiation Database.

Key Inputs:

- Capacity
- Solar year
- Derate factor

Current Capacity:
1 MW

2030 Potential:
1-15 MW



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Supply: Wind

Based on modeled data from 3Tier by way of NREL.

Key Inputs:

- Hourly wind farm production estimates from NREL Western Wind Data Set.
- Source year (2005-2007), source location (Bear River Ridge, Offshore, etc.)

Current Capacity:
0 MW

2030 Potential:
0-300 MW

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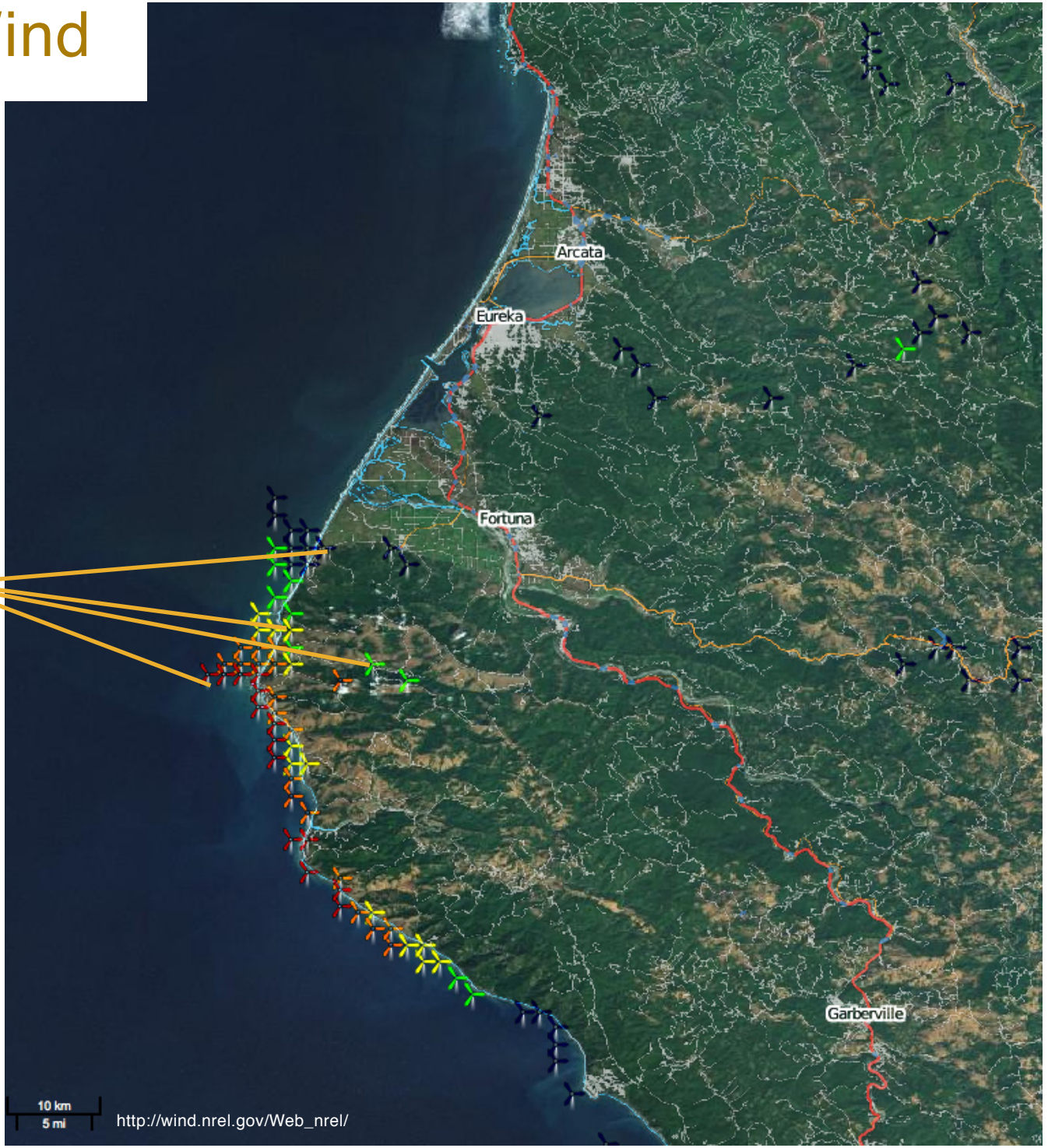
Supply: Wind

Selected Locations



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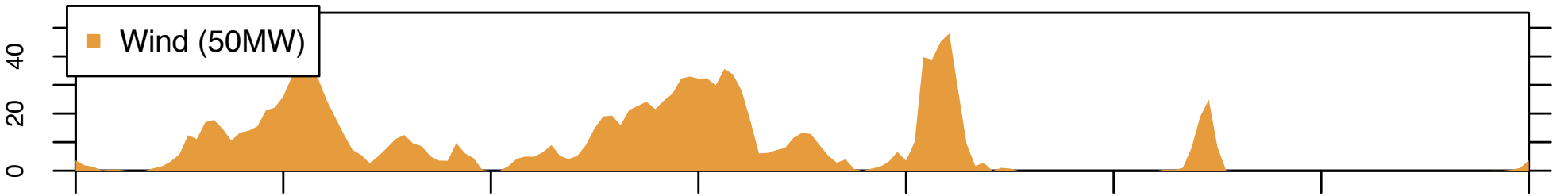
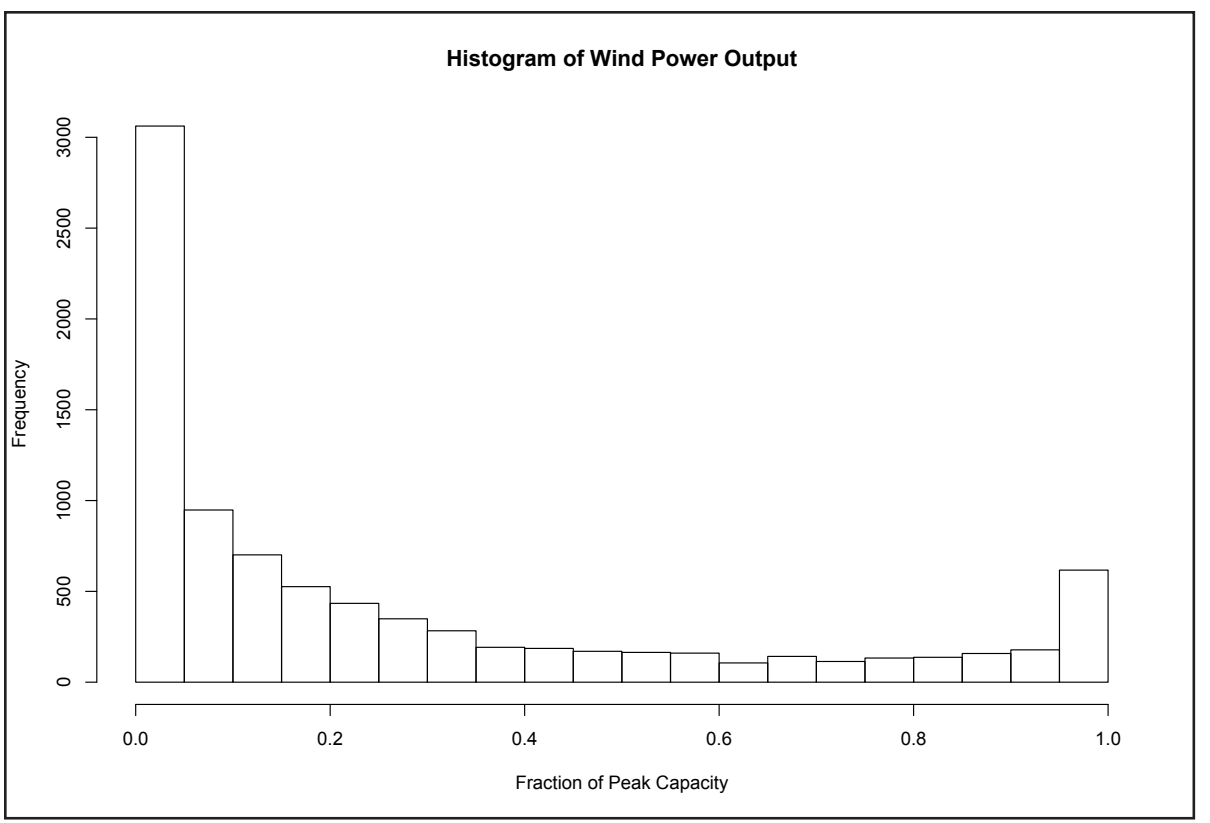
Supply: Wind





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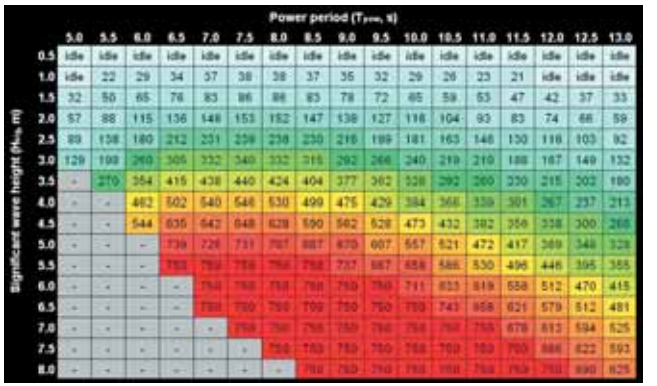
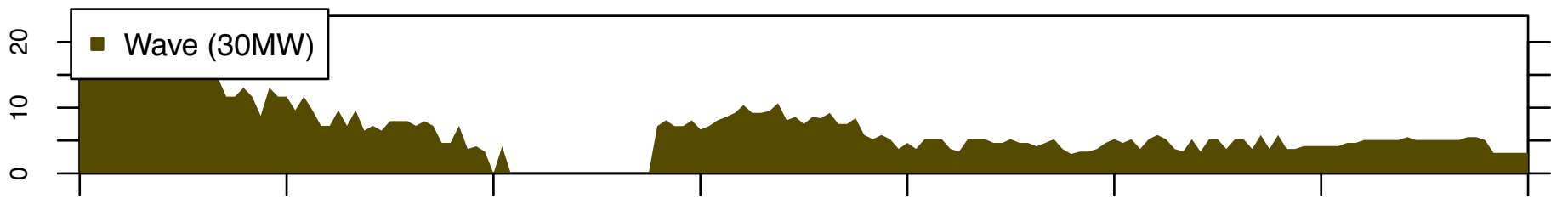
Supply: Wave

Data from NOAA Buoy 46022, power estimates based on Pelamis power matrix.

Key Inputs:

- Capacity
- Wave year





Current Capacity:
0 MW

2030 Potential:
0-100 MW

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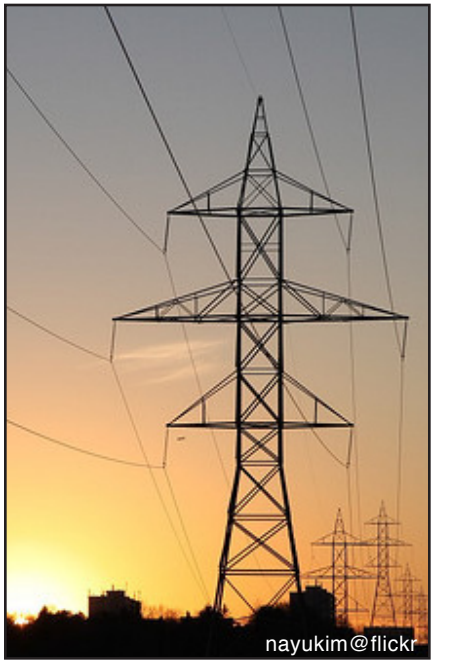
Supply/Demand: Import/Export

There are four circuits connecting Humboldt to rest of California: 2 x 115kV and 2 x 65kV lines

We assume that we can fully utilize transmission in either direction at any time.

Key Inputs:

- Capacity



Current Capacity:
60 MW

2030 Potential:
60-200 MW

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Supply/Demand: Storage

Considered three technologies:

- **NaS Battery**
- **Pumped Hydro (PH)**
- **Compressed Air Energy Storage (CAES)**

Key Inputs:

- Power capacity / Storage capacity
- Efficiency / Stored energy decay rate
- Operational strategy

Current Capacity:
0 MW

2030 Potential:
0-100 MW

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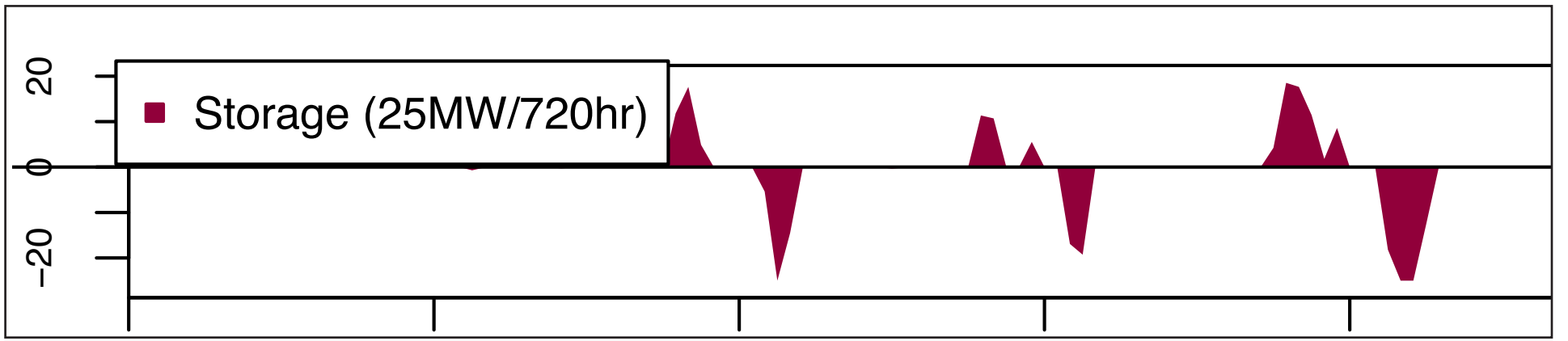
Supply/Demand: Storage

Strategy is to prevent “spillage” and blackouts.



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Dispatch: Reserve

- In any hour, a certain amount of generation capacity must be held in reserve to accommodate unexpected deviations in supply or demand.
- We used the “three sigma” rule on a persistence forecast as our estimate of the requirement.
- Mean requirement in 2030 with no wind/wave: 6.8%
- Mean requirement in 2030 with wind/wave: 19.0%

Key Inputs:

- Demand distribution
- Wind/Wave distributions

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