SB 350 Study: The Impacts of a Regional ISO-Operated Power Market on California

Analysis and Results

PRESENTED TO

Joint State Agency Workshop on the Proposed Regionalization of the Independent System Operator

Sacramento, California

July 26, 2016

PREPARED BY

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Scope of the SB 350 Study

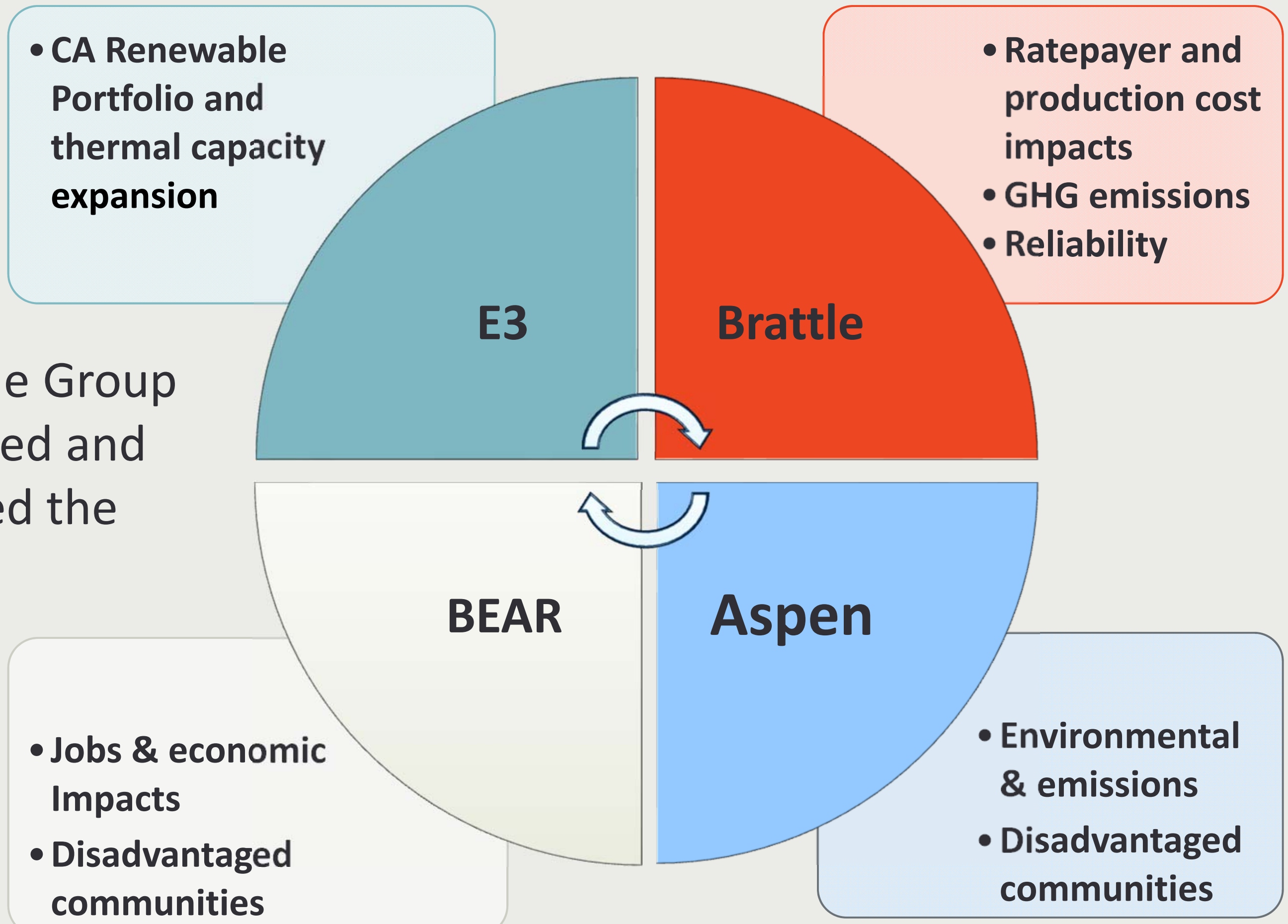
Fulfilling the Legislative Requirement:

- 359.5. (a) It is the intent of the Legislature to provide for the transformation of the Independent System Operator into a regional organization…, and that the transformation should only occur where it is in the best interests of California and its ratepayers.

- The ISO conducted studies of the impacts of a regional market, including:
  1. Overall benefits to **California ratepayers**
  2. Emissions of **greenhouse gases** and **other air pollutants**
  3. Creation or retention of **jobs** and other **benefits to the California economy**
  4. **Environmental** impacts in California and elsewhere
  5. Impacts in **disadvantaged communities**
  6. **Reliability** and **integration of renewable energy** resources

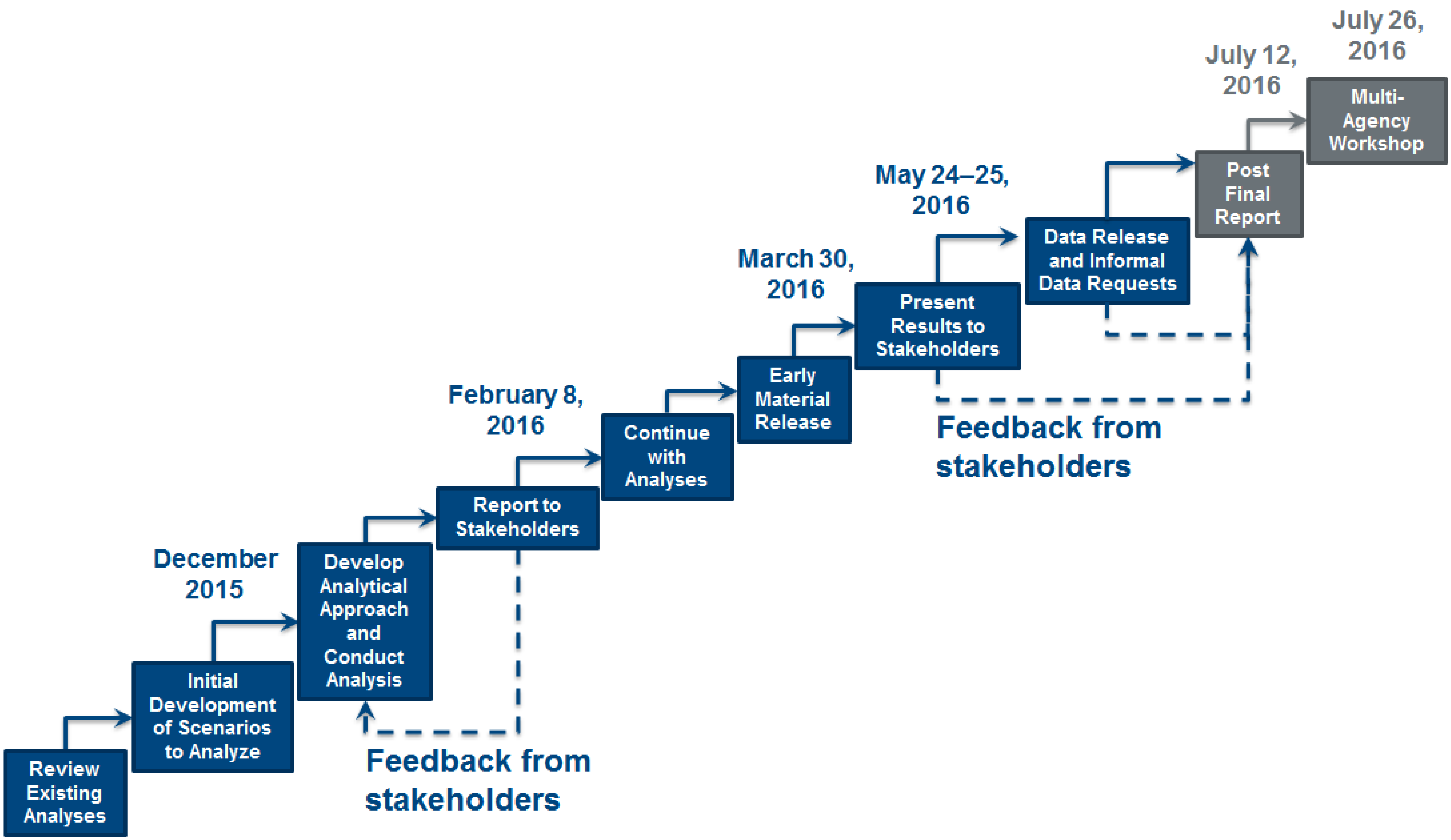
- As required, the modeling results, including all assumptions and inputs underlying the modeling, have been made available for public review.

Roles of Consultants



The Brattle Group coordinated and aggregated the analyses

Study Timeline



Senate Bill 350 Study – Published July 12, 2016

I. Purpose, Approach and Findings of the SB 350 Regional Market Study
II. The Stakeholder Process
III. Description of Scenarios and Sensitivities
IV. Renewable Energy Portfolio Analysis
V. Production Cost Analysis
VI. Load Diversity Analysis
VII. Ratepayer Impact Analysis
VIII. Economic Impact Analysis
IX. Environmental Study
X. Disadvantaged Community Impact Analysis
XI. Renewable Integration and Reliability Impacts
XII. Review of Existing Regional Market Impact Studies

Stakeholder Transparency

As required, the modeling results, including all assumptions and inputs underlying the modeling, have been made available for public review.

March 18, 2016 – Published responses to February 8 stakeholder comments (102 pages)

July 12, 2016 – Published responses to May 24-25 stakeholder comments (151 pages)

Data Releases – June 3 and 10,   2,700 MB of data

http://www.caiso.com/informed/Pages/RegionalEnergyMarket/BenefitsofaRegionalEnergyMarket.aspx

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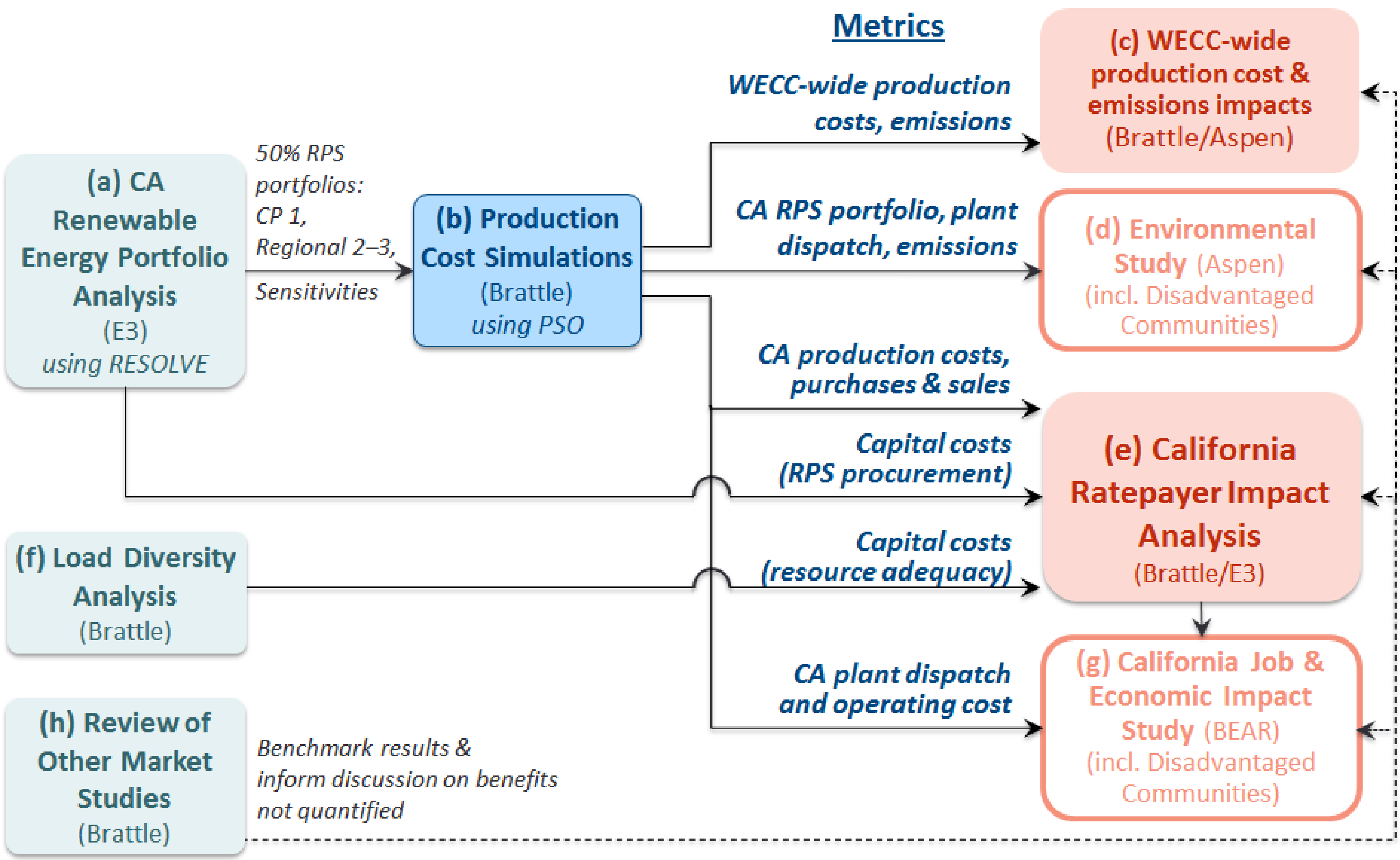
Impacts Evaluated: Scope and Metrics

The study team estimated six impacts, in accordance with SB 350 requirements:

Benefits Considered	Where	Impact Analyzed	Metrics
1. Overall benefits to ratepayers			
a. Operating cost savings	CA, WECC	Production costs and wholesale market prices, grid management costs	Production & Net Purchase Costs (CA); Production Costs (WECC-wide)
b. Capital (investment) cost savings	CA, WECC	Renewable integration, resource adequacy, resource procurement	Net fixed and capital costs
2. GHG and other air pollutants	CA, WECC	Air quality and carbon intensity	Changes in emissions, including in nonattainment areas
3. Jobs and economic impact to CA	CA	Infrastructure investment, responses to changes in retail and operating costs	Employment, Gross State Product, incomes, tax revenues
4. Environmental impacts in CA and elsewhere	CA, WECC	Land use/visual resources, biological/ ecology, water supply	Impacts on environmental resources and sensitive areas
5. Impacts in disadvantaged communities	CA	Environmental and economic	Impacts in specific communities
6. Reliability and integration of renewable energy resources	CA, WECC	Ability to integrate/facilitate diverse renewable resources; regional operations and control	Description of improved system monitoring and ability to integrate diverse resources

SB 350 Analytical Framework

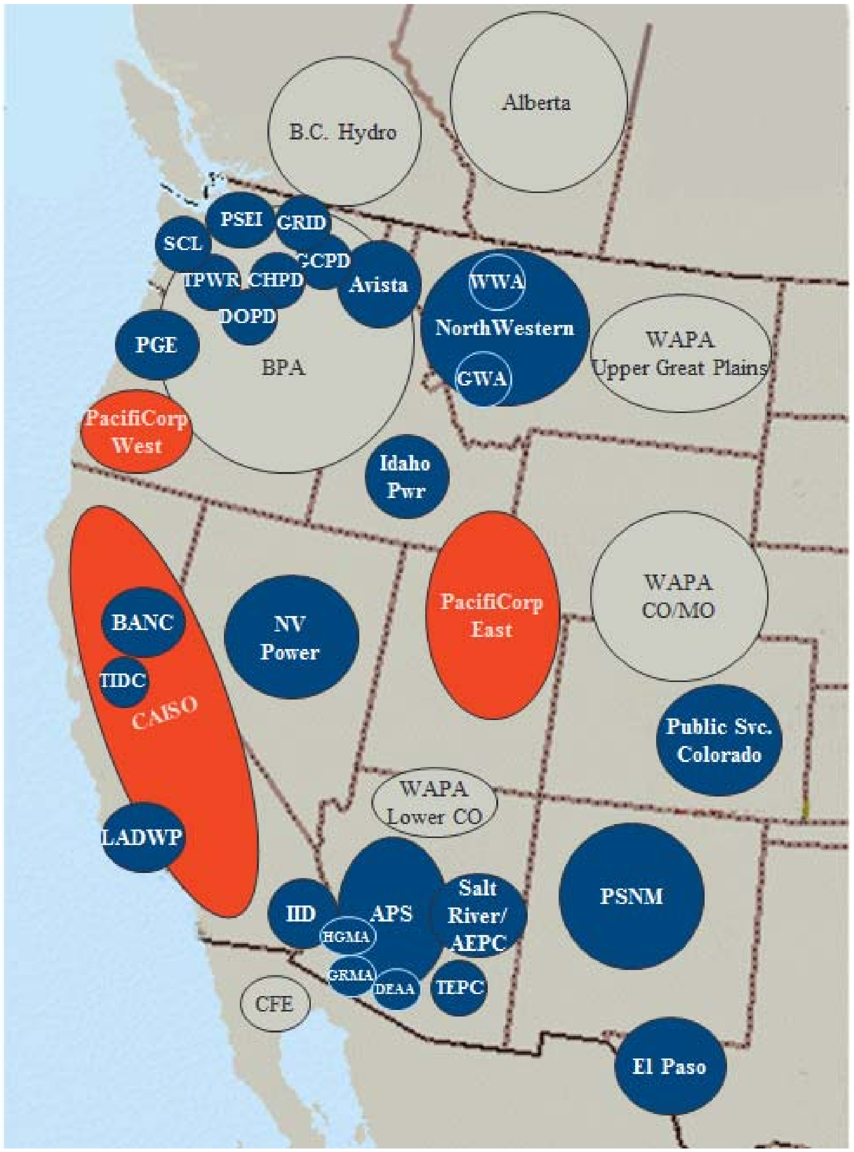


Refinements to Study Approach Based on Stakeholder Input

In response to stakeholder comments, we:

- Refined renewable portfolio optimization (see E3's presentation)
- Revised hypothetical regional footprint for 2020 and 2030 (see next slide)
- Estimated ratepayer impacts for the State of California as a whole
  - Impacts not attributed to specific parties (other than disadvantaged communities)
- Estimated WECC-wide impacts on production costs, emissions, load diversity
- Analyzed various sensitivities (including footprints, bilateral flexibility, WECC carbon pricing, high EE, higher RPS, without renewables beyond RPS)
- Ensured compliance with RPS in U.S. WECC, including Oregon's new 50% by 2040 RPS
- Incorporated additional announced coal retirements, and conventional plant additions from utility integrated resource plans (IRPs)
- Evaluated California and the rest of U.S. WECC's ability to meet CPP's mass-based targets
- Developed future reserve and load following requirement estimates
- Assumed California municipal utilities also reach 50% renewables by 2030
- Updated input assumptions based on CEC's 2015 Integrated Energy Policy Report (IEPR), CPUC's 2016 Long-Term Procurement Plan (LTPP), federal PTC and ITC

2020 and 2030 Hypothetical Regional Footprints



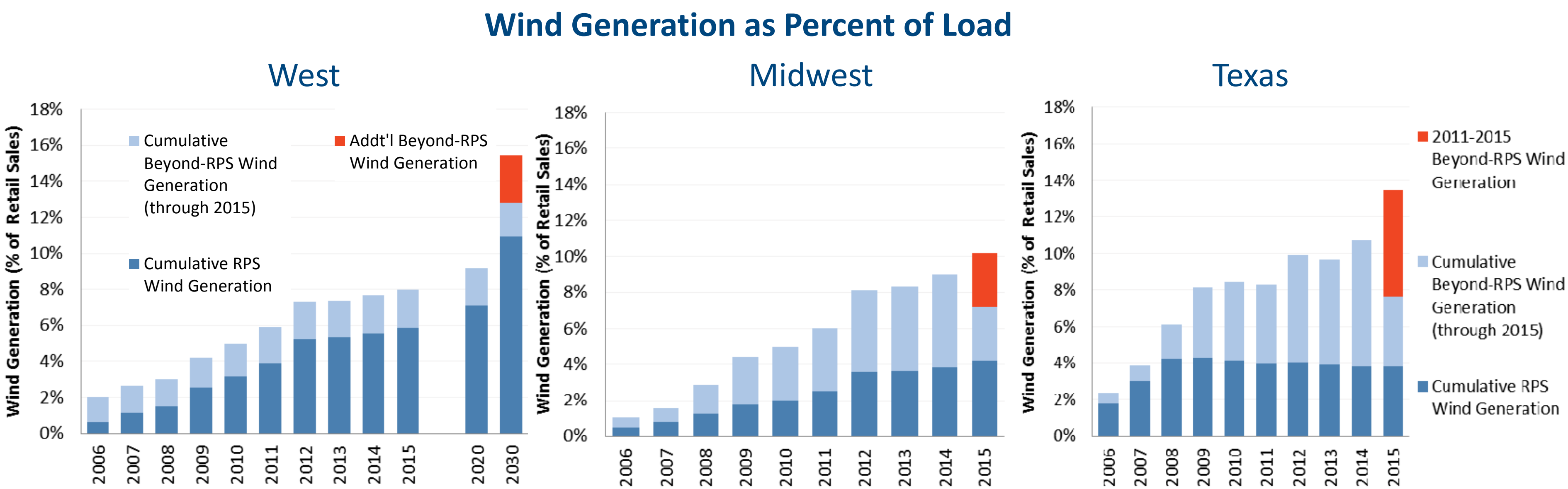
WECC currently consists of 38 individual Balancing Authorities

2020 Footprint: Regional ISO to consist of only CAISO and PacifiCorp: denoted as "**CAISO+PAC**"

+ **2030 Footprint** (and 2020 Sensitivity): Expanded Regional ISO to consolidate all balancing areas in the U.S. WECC except the Federal Power Marketing Agencies (U.S. WECC w/o PMAs)

PMAs shown in the graphic as BPA, WAPA Upper Great Plains, WAPA CO/MO, WAPA Lower CO

Renewable Development Beyond RPS



- Renewable development beyond RPS is pronounced in areas where low-cost resources have access to regional operations and markets (in Texas and the Midwest)
  - Between 2011 and 2015 (5 years), these areas added new wind generation to meet 3–6% of retail sales
  - Assuming that regional market in U.S. WECC would attract additional 5,000 MW of beyond-RPS renewables by 2030 is only approximately 2.6% of retail sales compared to ~3% added in the Midwest and ~6% added in Texas between 2011 and 2015

Source of historical data: EIA and LBNL (2016)

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Renewable Portfolios for CAISO SB 350 Study

All-Agency Workshop

July 26, 2016

Sacramento, California

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Overview of the analysis

- **E3 developed optimal resource portfolios to meet a 50% RPS under a Current Practice and two regional market scenarios**
  - E3's RESOLVE model selects portfolio of solar, wind, geothermal, biomass, and small hydro
  - Adds integration solutions such as energy storage and flexible capacity to minimize total cost over the analysis period
- **Resources are added to meet RPS target, overbuilding renewable portfolio if necessary**
  - Renewables are curtailed due to oversupply, if the output cannot be consumed in California or exported to neighboring systems
  - Additional renewable resources are added to portfolio if necessary to replace curtailed output

Study assesses the effect of regional markets on renewable procurement

Two major effects are tested:

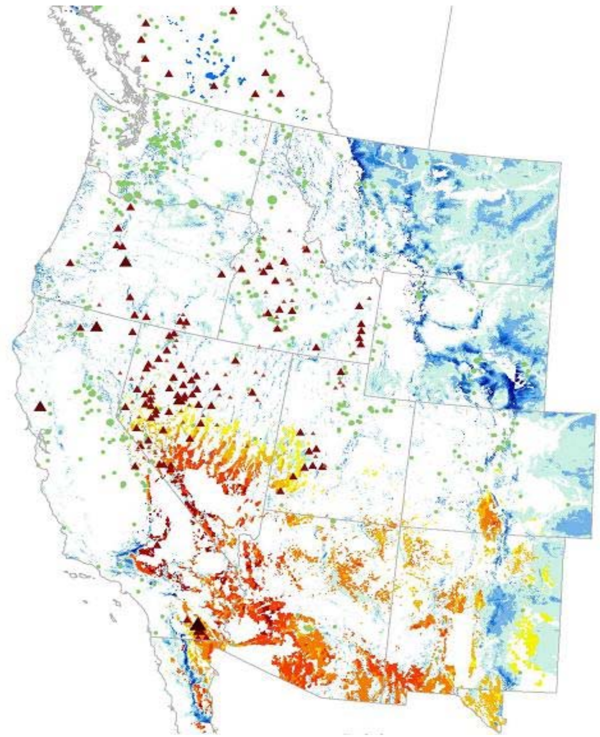
1. Effect of regional operations

- Increased access to latent flexible capacity across a broad, diverse region
- Increased ability to export surplus energy
- Could result in changes to least-cost portfolio

2. Effect of regional transmission tariff

- Reduces wheeling costs across the region
- Provides a mechanism for needed new transmission infrastructure to be studied and approved for inclusion in rates
- Provides access to high-quality wind in the Rockies and solar in the Southwest

Renewable Resource Potential in the West



Source: NREL

Three scenarios studied

1. **Current Practice Scenario**
   - Renewable energy procurement is largely from in-state resources
   - No regional market to help reduce curtailment
2. **"Regional 2": Regional market operations with Current Practice renewable procurement policies**
   - Assumes no increase in availability of out-of-state resources, but transmission wheeling charges are de-pancaked
   - Curtailment of renewables is reduced through better integration
3. **"Regional 3": Regional market and regional renewable energy procurement**
   - Like Scenario 2, but with additional high-quality wind resources made available, requiring new transmission facilitated by the regional entity

Exports of surplus null power vary by scenario

- **Under a 50% RPS, California will have surplus renewable energy during many hours of the year**
- **Trading opportunities are needed that will allow California LSEs to sell the energy while keeping the environmental attributes (REC and carbon attribute)**
  - Under current system of bilateral trading, the ability of other Balancing Authorities to absorb surplus "null" power from California is limited
- **Exports are assumed to vary by scenario:**
  - Current Practice Scenario: 2,000 MW
  - Regional Market Scenarios: 8,000 MW

Out-of-state resource availability varies by scenario

- **Three categories of out of state resources are made available: RECs, Existing Transmission, New Transmission**
  - Selection based on least portfolio cost; not all out-of-state resources are picked
- **Pancaked wheeling and loss charges apply under Current Practice only**
- **Regional transmission organization facilitates new transmission development for highest-quality WY and NM wind in Scenario 3**

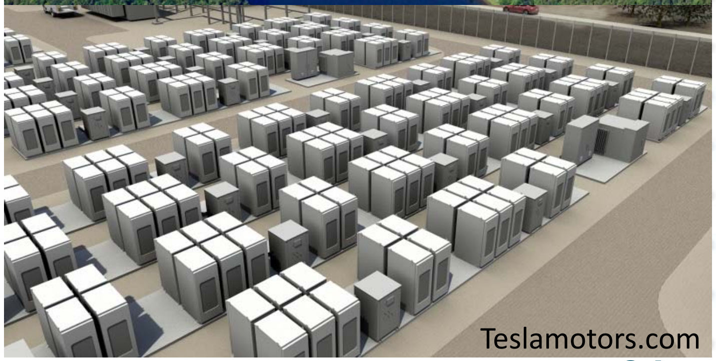
Renewable resource potential (MW) (not all resources are selected)	Current Practice and Regional 2	Regional 3
NW Wind RECs	1,000	1,000
NW Wind, Existing Transmission	1,000	500
WY Wind, Existing Transmission	500	1,000
WY Wind, New Transmission	-	**3,000**
SW Solar RECs	1,000	1,000
SW Solar, Existing Transmission	500	500
NM Wind, Existing Transmission	1,000	1,000
NM Wind, New Transmission	-	**3,000**
Total Out of State Resources for IOUs	*5,000*	*11,000*

Many renewable integration solutions assumed in all scenarios

- Time-of-use rates that encourage daytime use
- 5 million electric vehicles by 2030 with near-universal access to workplace charging
- 500 MW pumped storage manually added
- 500 MW geothermal manually added
- 5,000 MW of out-of-state renewable resources available to be selected on a least-cost basis
- Unlimited storage available to be selected on a least-cost basis
- Renewables provide operating reserves
- Storage and hydro provide operating reserves and frequency response

https://www.linkedin.com

http://renews.biz/67193/vattenfall-pumps-new-life-into-80mw



Teslamotors.com

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PORTFOLIO RESULTS

Portfolios shown are for 2030, incremental to resources needed for 33% RPS in 2020

Portfolios for non-CAISO Balancing Areas

- Hand-picked portfolios representative of plausible renewable procurement activities under each scenario
- Results also included in detailed tables on following pages

> • Portfolios shown are for 2030, incremental from 33% RPS in 2020

MW

Type	Zone	Scenario 1a	Sensitivity 1b	Scenario 2	Scenario 3
Solar PV	In-state	2,375	2,375	2,375	1,304
Wind	NW	447	447	447	318
Wind	UT	604	604	604	420
Wind	NM	-	-	-	462
Wind	WY	-	-	-	495
Total		**3,426**	**3,426**	**3,426**	**2,998**

GWh

Type	Zone	Scenario 1a	Sensitivity 1b	Scenario 2	Scenario 3
Solar PV	In-state	6,592	6,592	6,592	3,616
Wind	NW	1,253	1,253	1,253	891
Wind	UT	1,693	1,693	1,693	1,177
Wind	NM	-	-	-	1,861
Wind	WY	-	-	-	1,993
Total		**9,538**	**9,538**	**9,538**	**9,538**

Incremental Renewable Resource Portfolio Composition

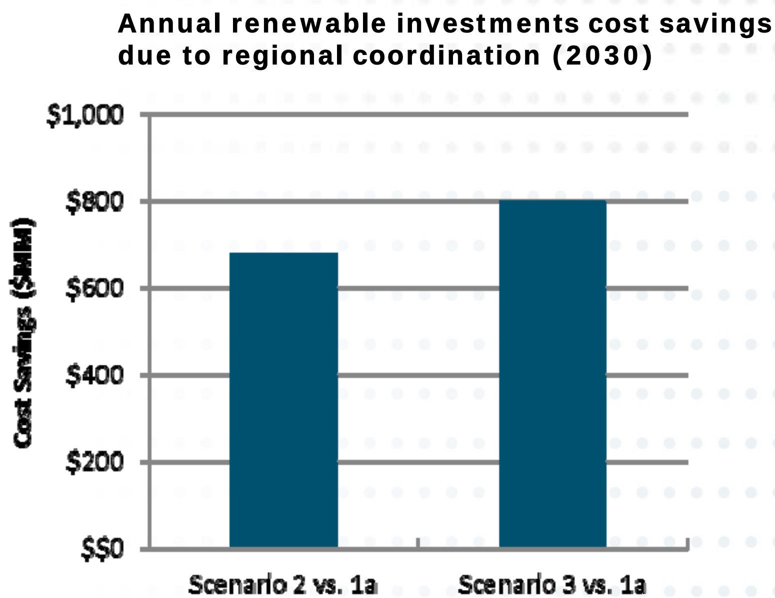
- Model picks a mix of wind and solar resources in all scenarios

	Current Practice	Regional 2	Regional 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	7,601	7,804	3,440
California Wind	3,000	1,900	1,900
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	1,447	562	318
Northwest Wind RECs	1,000	1,000	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	11,101	10,204	5,840
Total Out-of-State Resources	5,551	5,166	7,694
Total Renewable Resources	16,652	15,370	13,534
Energy Storage (MW)	972	500	500

Renewable procurement cost results

+ Annual renewable procurement cost savings in 2030: $680-$799 million

- Fixed costs only; variable cost differences accounted for in PSO analysis
- Modest savings assumed for non-CAISO BAs
- Renewable procurement savings are only one component of ratepayer savings



Renewable Procurement Costs ($MM)	Scenario 1a	Scenario 2	Scenario 3
Fixed Costs - CAISO	$2,578	$1,934	$1,840
Fixed Costs– non-CAISO BAs	$714	$678	$652
Total California Fixed Costs ($MM)	**$3,291**	**$2,612**	**$2,492**
Fixed Costs Relative to Scenario 1a		**-$680**	**-$799**

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SENSITIVITY ANALYSIS

Sensitivity analyses were performed in RESOLVE and capture changes in procurement cost only

Description of sensitivity cases

Eight additional sensitivity cases were run:

A. High coordination under bilateral markets ("Sensitivity 1b")

B. High energy efficiency (doubling of EE by 2030)

C. High flexible load deployment

D. Low portfolio diversity (remove 500 MW each of geothermal and pumped storage)

E. High rooftop PV

F. High out-of-state resource availability

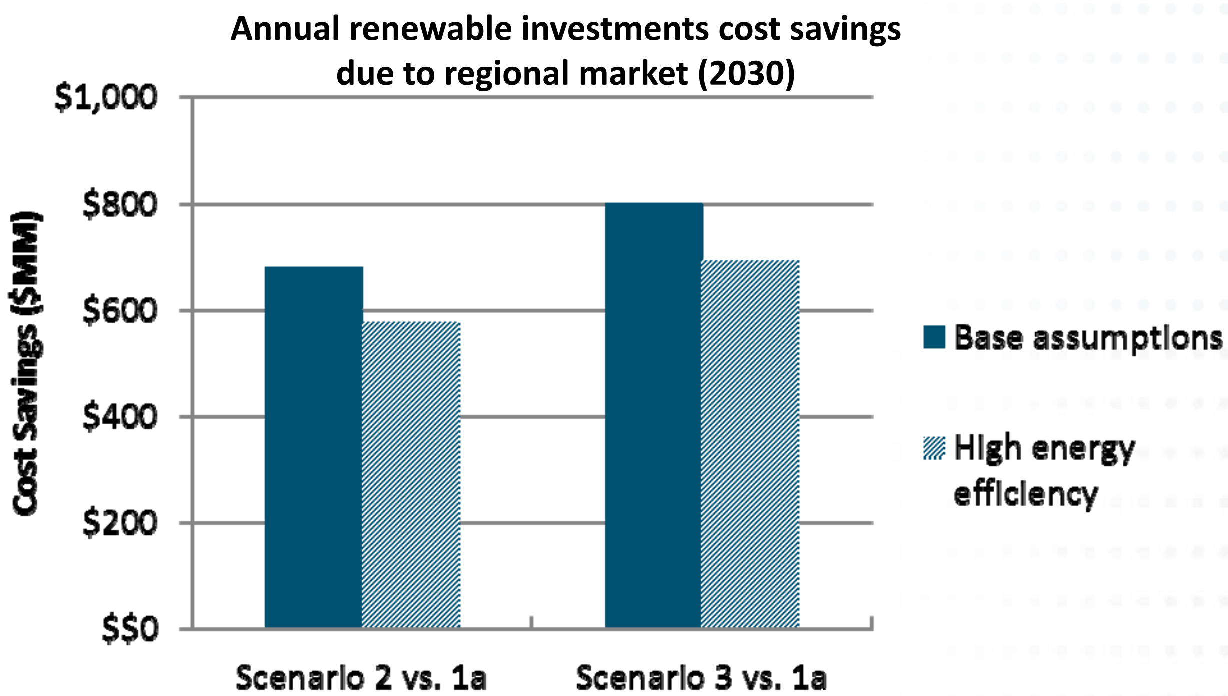
G. Low cost solar

H. 55% RPS

I. 60% RPS

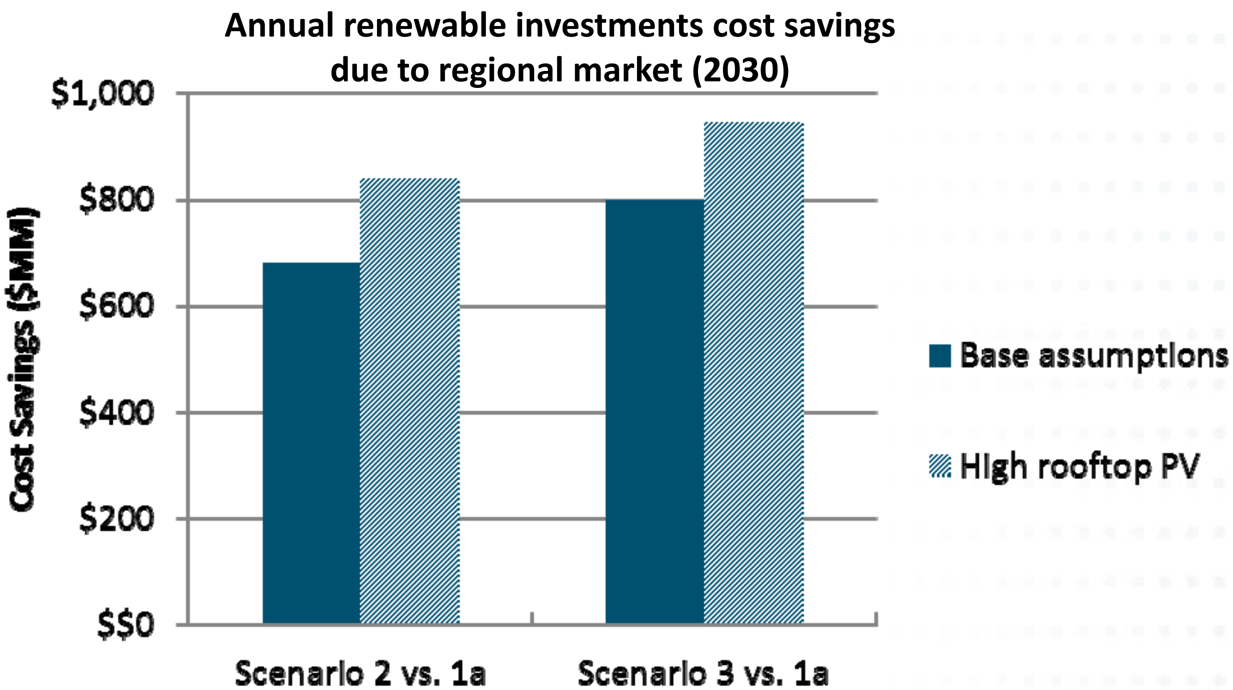
B: High energy efficiency

- **Reduce loads consistent with goal of doubling energy efficiency by 2030**
  - Input data from California energy agencies
- **Lower loads reduce benefits of regional coordination**



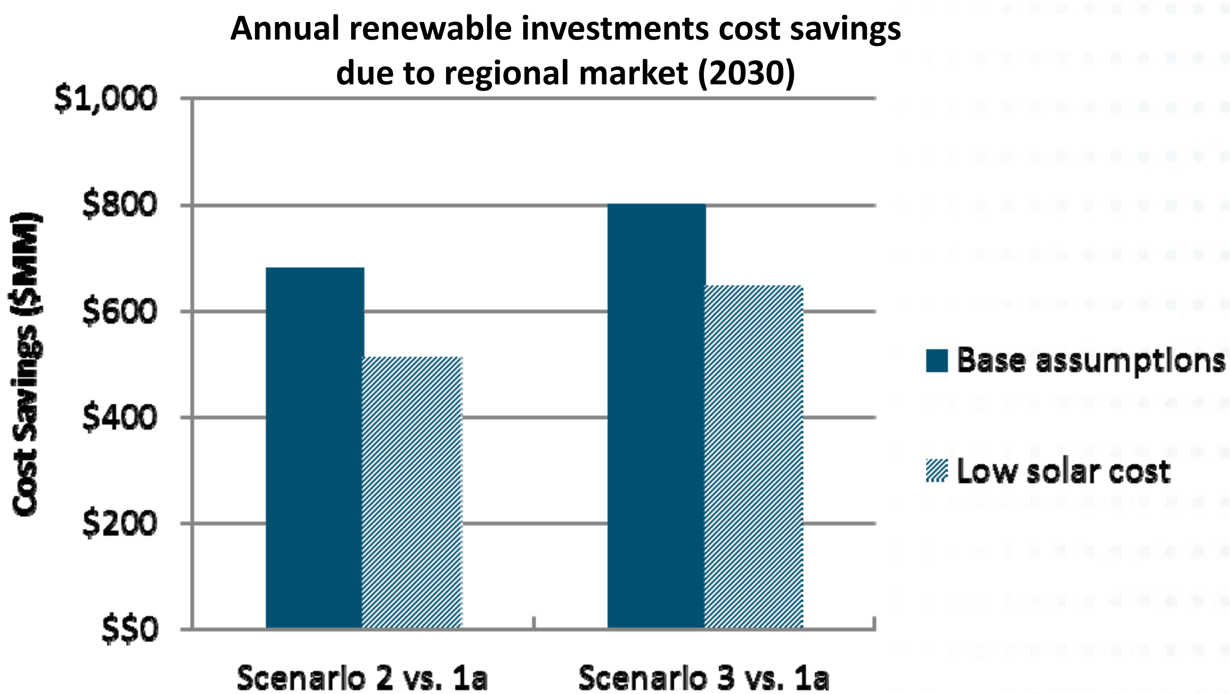
E. High rooftop PV

- Increase CAISO rooftop PV from 16 GW to 21 GW by 2030
- Reduces load and RPS procurement need, but increases solar-driven curtailment
- Benefits are higher than under base assumptions – regional market has a significant benefit in integrating rooftop solar!



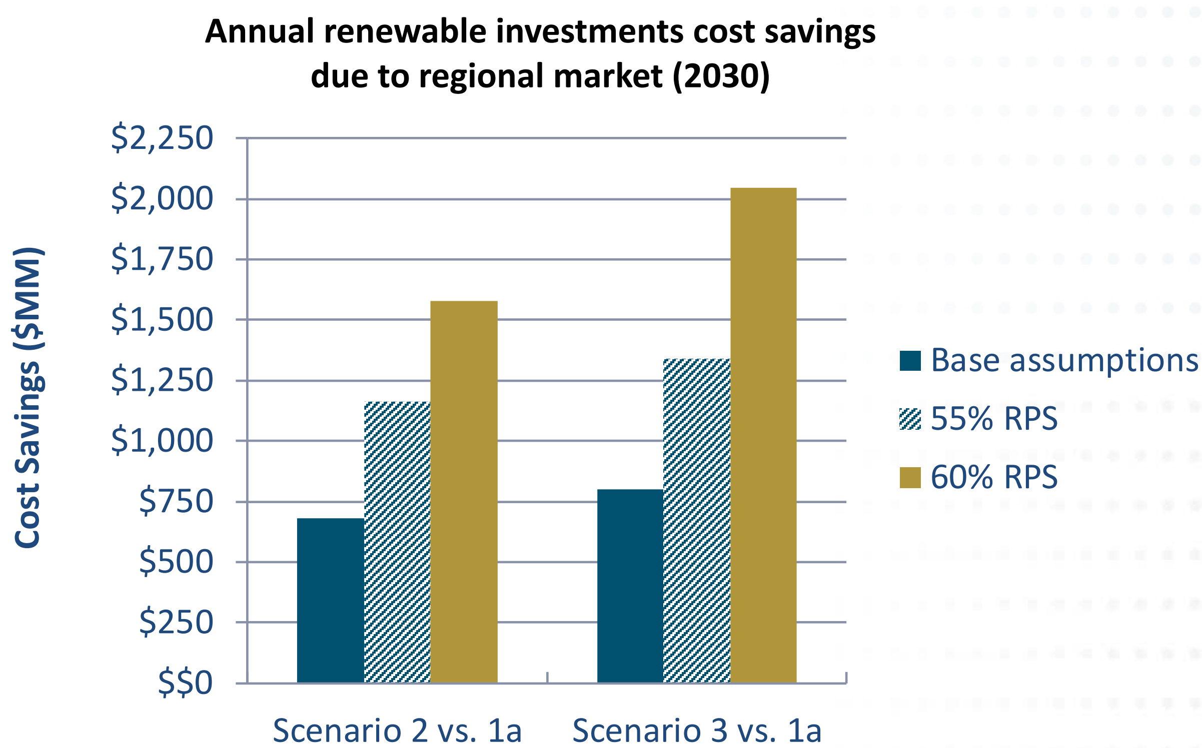
G. Low Cost Solar

- Reduce solar cost to $1/W by 2025
- Benefits are lower because lower cost California solar displaces out-of-state wind in Scenario 1
- Still significant curtailment reduction benefits in Scenario 2, NM and WY wind still selected in Scenario 3



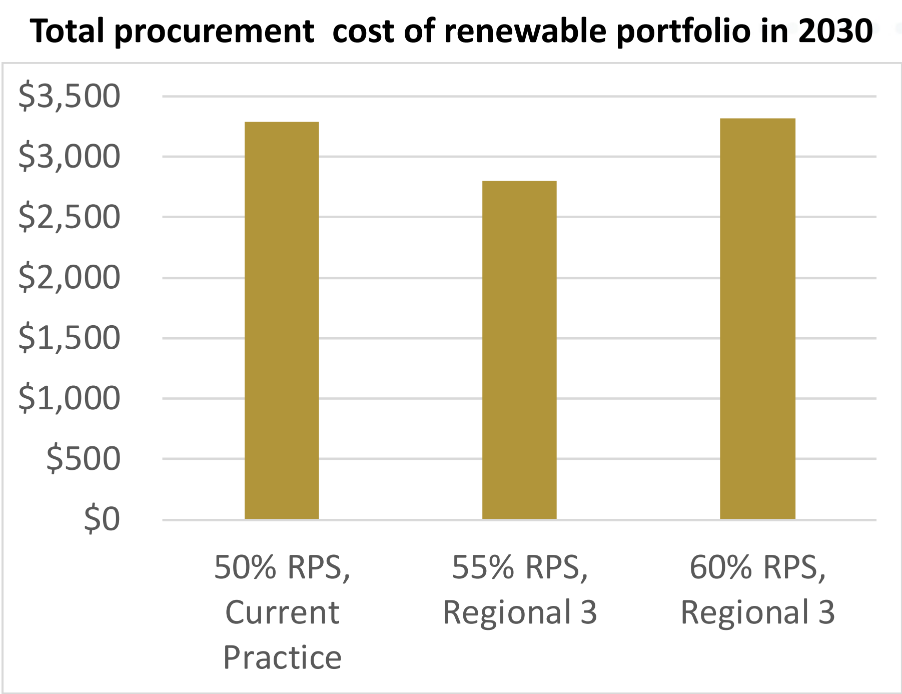
H & I: Higher RPS

- Increase California RPS to 55% and 60% in all scenarios
- Benefits are significantly higher because it is much more costly to meet higher RPS in Current Practice Scenario



H & I: Higher RPS

+ **Cost of meeting a 60% RPS under Regional 3 is similar to cost of meeting 50% RPS under Current Practice**
  - This is before considering fuel cost savings due to more renewables



Summary of results with sensitivity analysis

- **Annual savings from regional integration range from $391 million to $1.004 billion per year under 50% RPS**
  - High flexible loads, high bilateral coordination and lower solar cost reduce savings
  - Reduced portfolio diversity, high rooftop PV, and higher RPS increase savings

Renewable Portfolio cost savings from regional market ($MM)	Scenario 2 vs. 1a	Scenario 3 vs. 1a
Base assumptions	$680	$799
A. High coordination under bilateral markets	$391	$511
B. High energy efficiency	$576	$692
C. High flexible loads	$495	$616
D. Low portfolio diversity	$895	$1,004
E. High rooftop PV	$838	$944
F. High out-of-state resource availability	$578	$661
G. Low cost solar	$510	$647
H. 55% RPS	$1,164	$1,341
I. 60% RPS	$1,578	$2,048

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Production Cost Simulations: Methodology

We conducted nodal market simulations to estimate:

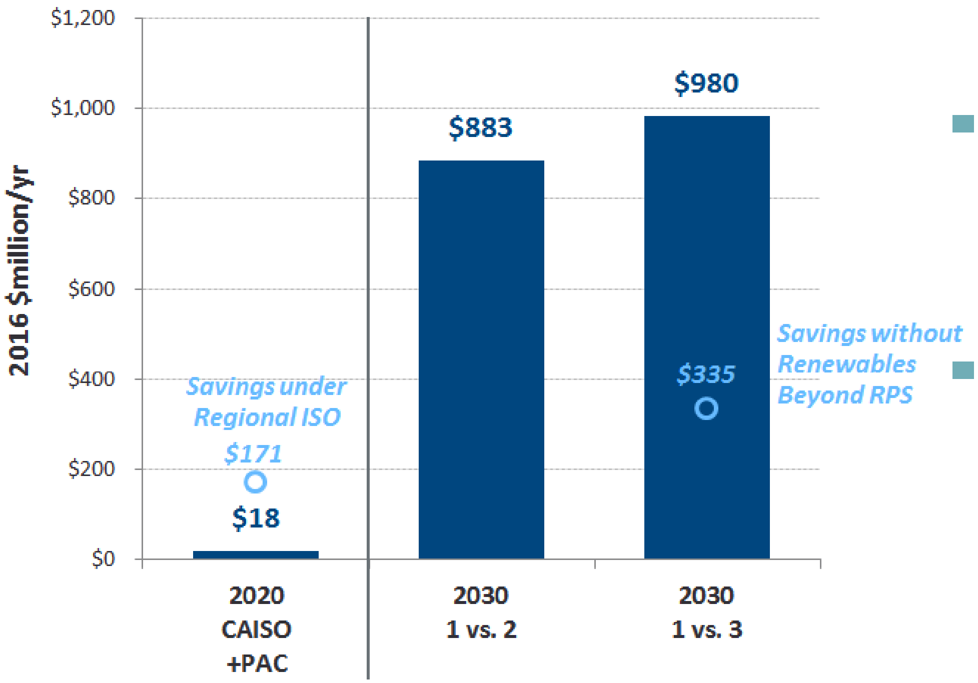
- Production cost impacts associated with de-pancaking transmission charges , joint unit commitment and dispatch used in ratepayer impact analysis and economic impact analysis
- Changes in generation output and emissions of GHG and other air pollutants used in environmental impact analysis

Modeling Framework:

- Simulating WECC with and without regional market for near-term and longer-term
  - 2020 to demonstrate near-term impacts prior to larger regional expansion and ramp-up of California's renewable generation needs
  - 2030 to highlight impacts of an expanded regional market with a higher level of renewable resources procured to meet the 50% RPS in California
- Key results include:
  - Production cost impact for across the WECC
  - GHG emissions, unit starts, and changes in generation output (incl. NOx, SO_2)
  - Impact on California's net production, purchase and sales cost

Results: WECC-Wide Production Costs Savings

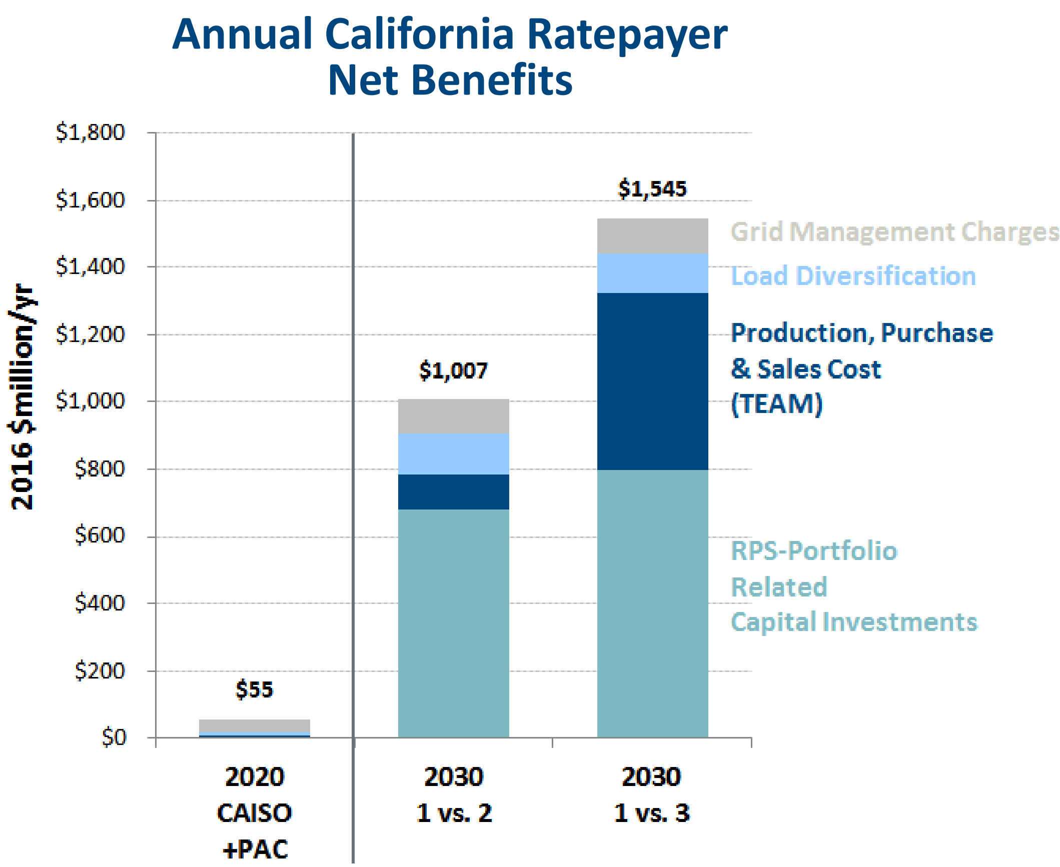
WECC-Wide Annual Production Cost Savings in 2020 and 2030
(excludes emissions-related costs & incremental renewable investment costs)



* Based on fuel, start-up, and variable O&M costs only
Does not include: societal benefits of emission reductions or incremental investment costs associated with the additional renewable resources facilitated by the regional market in 2030 Scenarios 2 and 3.

- Regional production cost savings of $18 million in 2020 is low due to limited scope of regionalization (CAISO+PAC) and conservative modeling assumptions
  - 2020 expanded region (U.S. WECC without PMAs) savings would be $171 million
- 2030 annual production cost savings range from **$883 million to $980 million (4.5–5% of total production costs)** under the regional market (U.S. WECC without PMAs)
- Results depend on:
  - Ability to manage excess generation in a bilateral, non-market environment
  - Extent to which CA renewable procurement is focused on in-state vs. regional resources (Scenario 2 vs. 3)
  - Extent of additional renewables facilitated by market (Scenario 3 without the additional beyond-RPS renewables yield $335 million in annual savings)

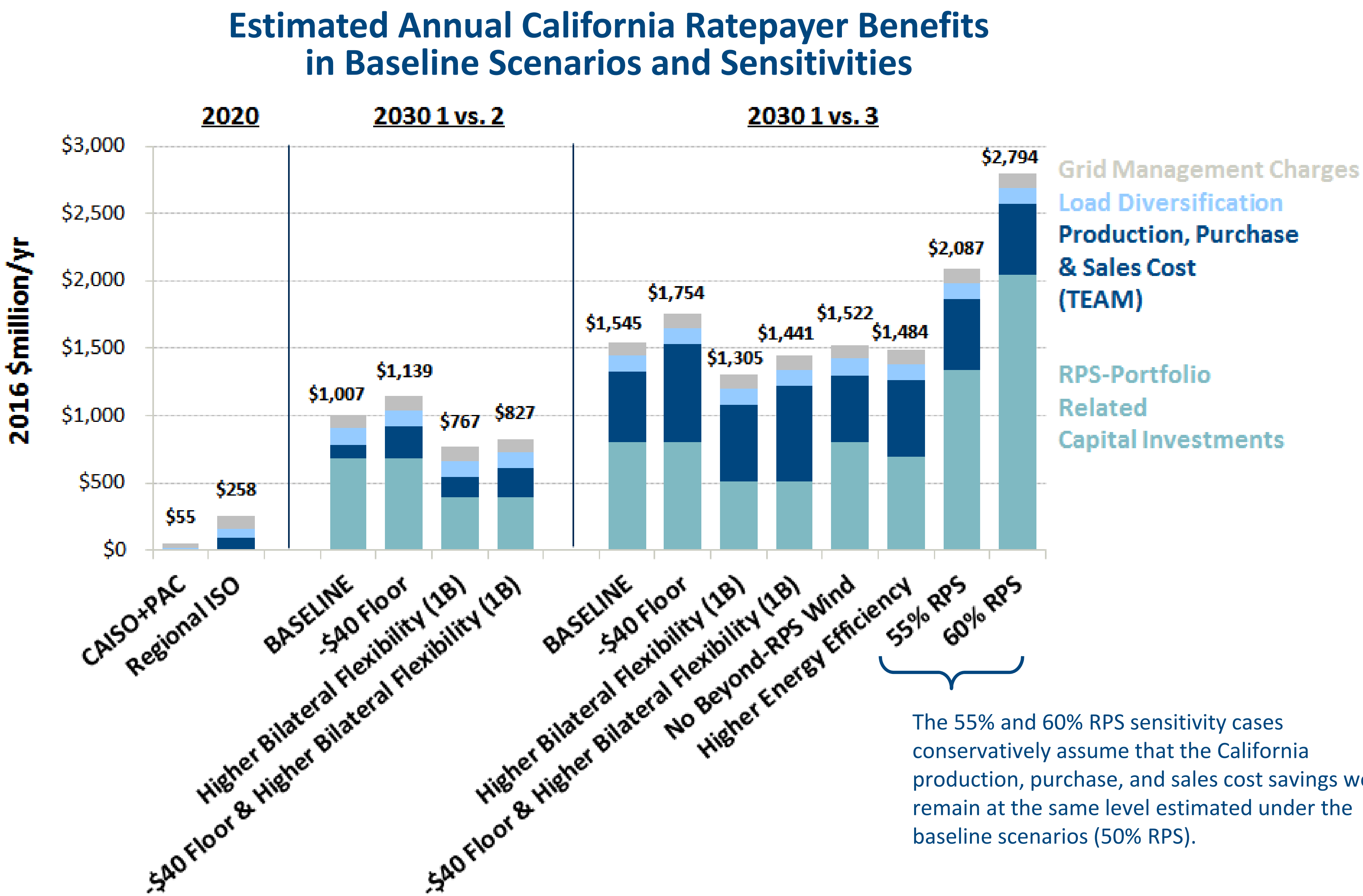
Overall Benefits to California Ratepayers



- California ratepayer impact analysis of an expanded regional market shows estimated savings of:
  - **$55 million/year in 2020** (0.1% of retail rates) based on limited scope of CAISO-PAC region.
    - Would be $258 million/year for expanded regional footprint (WECC without PMAs)
  - **$1 billion to $1.5 billion/year in 2030** (2–3% of retail rates) depending on renewable procurement to meet 50% RPS

Overall benefits likely larger, consistent with findings of other studies
- Estimates based on conservative assumptions
- Value of additional regional market benefits was not quantified

CA Annual Ratepayer Impacts: Baseline and Sensitivities



The 55% and 60% RPS sensitivity cases conservatively assume that the California production, purchase, and sales cost savings would remain at the same level estimated under the baseline scenarios (50% RPS).

Additional Ratepayer Benefits not Quantified

- **Increased operational reliability** due to expanding ISO operations to a larger regional footprint that improves pricing, congestion management, generation commitment, real-time operations, and system visibility/monitoring
- **Improved use of the physical capabilities of the existing grid** on constrained WECC transmission paths, within the existing WECC balancing areas, and scheduling constraints on CAISO interties
- **Improved regional and inter-regional system planning** to increase efficiency in transmission buildout across the West
- **Improved risk mitigation** from a more diverse resource mix and larger integrated market that can better manage the economic impacts of transmission and major generation outages and better diversify weather, hydro, and renewable generation uncertainties
- **Long-term benefits** from stronger generation efficiency incentives and better long-term investment signals across a larger regional footprint
- Consistent with findings of other regional market studies

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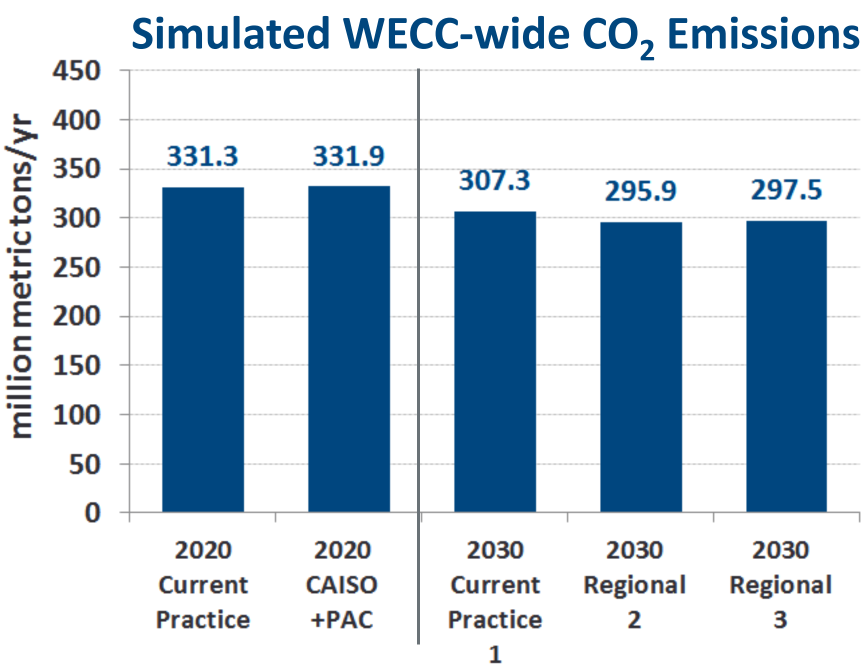
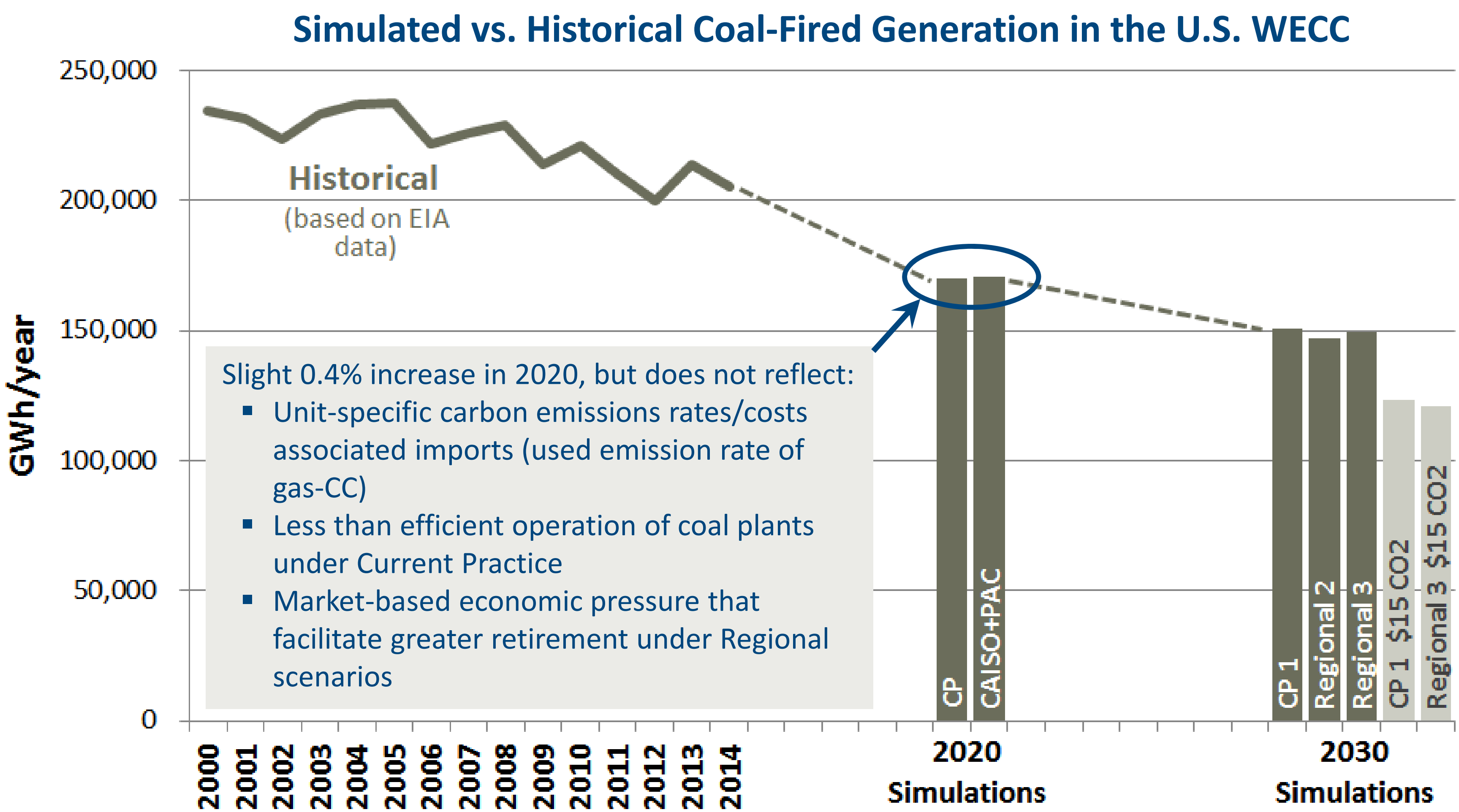
WECC-Wide CO_2 Emissions



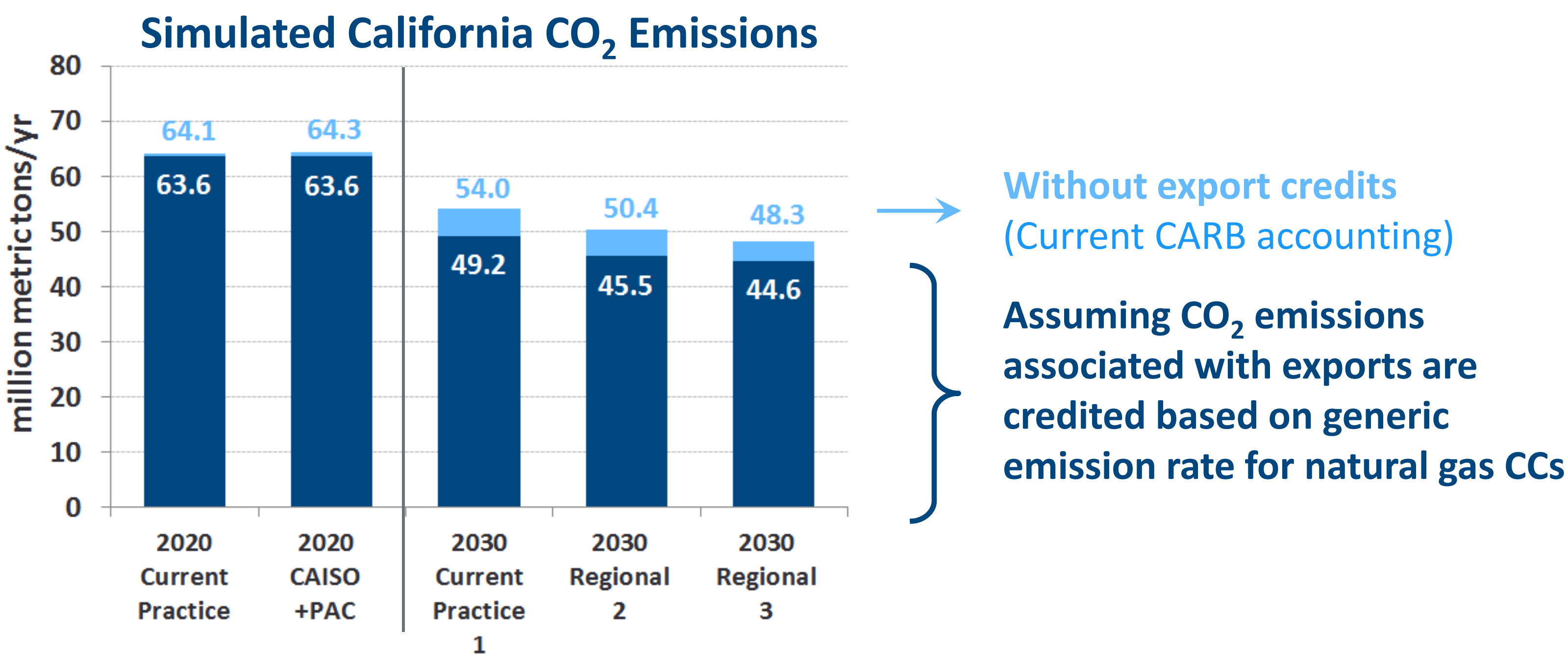
- 2020 simulations of regional market (CAISO+PAC) show almost no change in annual CO_2 emissions relative to Current Practice
  - Slight 0.2% increase is related to 2020 coal dispatch simulation results, which do not reflect unit-specific CA carbon import charges, nor increased market pressures to reduce baseload operations and facilitate retirements

- In 2030 (and despite load growth in rest of WECC), the expanded regional market (U.S. WECC without PMAs) is estimated to **decrease CO_2 emissions levels by about 10–11 million tonnes (3.2–3.7% of total)** depending on the Scenario
  - For load served across WECC, regional market in 2030 is expected to **reduce CO_2 emission intensity by 0.01 tonne/MWh**
- Achieving CPP compliance in non-CA portion of WECC would require additional measures (see $15/tonne carbon pricing sensitivity for rest of WECC)

Impact on Coal Dispatch in WECC



California CO_2 Emissions



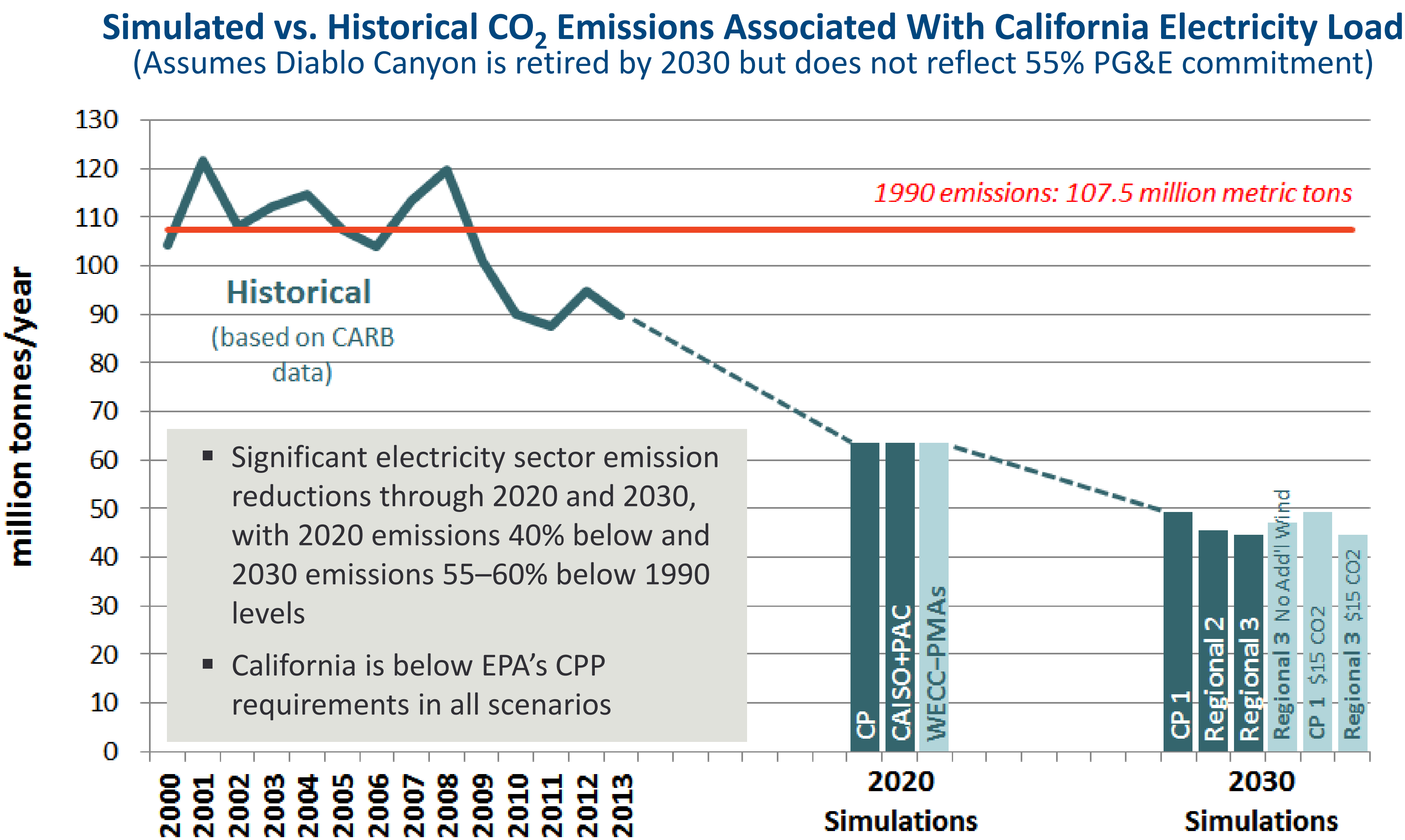
- Regional market reduces CO_2 emissions associated with serving California load
  - 2020: Little/no change compared to Current Practice (but 40% below 1990 levels)
  - 2030: **Decrease of 4–5 million tonnes (8–10% of total CO_2)** compared to Current Practice 1
  - 2030 CA exports of surplus renewable energy displace 4–5 million tonnes of CO_2 in rest of WECC; export credits not currently considered in CARB accounting
- **2030 emissions 55–60% below 1990 levels and below EPA's CPP requirements** for California in all scenarios

Sensitivities on CO_2 Emissions: Summary of Results

Several sensitivities focus on how regional market may affect CO_2 emissions under different assumptions about the future

- **WECC Carbon Pricing:** Using $15/tonne for rest of WECC for both Regional 1 and 3 scenarios as a proxy for CPP compliance revealed that, considering significant future coal plant retirements already announced, even a modest CO_2 price is sufficient to meet or exceed CPP emission targets
- **Regional ISO 1 :** Simulating a regional market with the same renewable portfolio in the Current Practice 1 scenario showed that most of the renewable curtailments experienced in the Current Practice 1 would be avoided, which would reduce annual CO_2 emissions by 2.2 million tonnes in California (4.5%) and 2.9 million tonnes WECC-wide (0.9%)
- **Regional ISO 3 Without Renewables Beyond-RPS:** Simulating the Regional 3 scenario without any assumed facilitation of renewables development beyond-RPS showed that a regional market would only slightly decrease CO_2 emissions WECC wide and those associated with CA loads

Simulated vs. Historical California CO_2 Emissions



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Environmental Study

Review for Joint State Agency Workshop

July 26, 2016

Environmental Study
Drivers of Our Findings

- Regionalization allows renewables to be better integrated and California's investments would be more efficient.
- California could build less renewable generation capacity to meet its 50% RPS.
- Regional operations and markets would give California better access to lower-cost out-of-state resources in wind- or solar-rich areas of the west. California's renewable development footprint could shift out of state.

Approach Overview

Our Environmental Study relies on two inputs:

1) New infrastructure buildout from RESOLVE model results

- MW capacity of generation added by 2030
- Locations identified by CREZ
- Impacts: land use, biological, construction activities

2) Changes in operation of generators in 2020, 2030 from production cost simulation

- Dispatch, MWh, unit starts
- Locations identifiable at unit-level, aggregated by air basin
- Impacts: water, air emissions

Land Use and Acreage Required

Approximate Acres Required for Incremental Buildout by 2030 (acres)

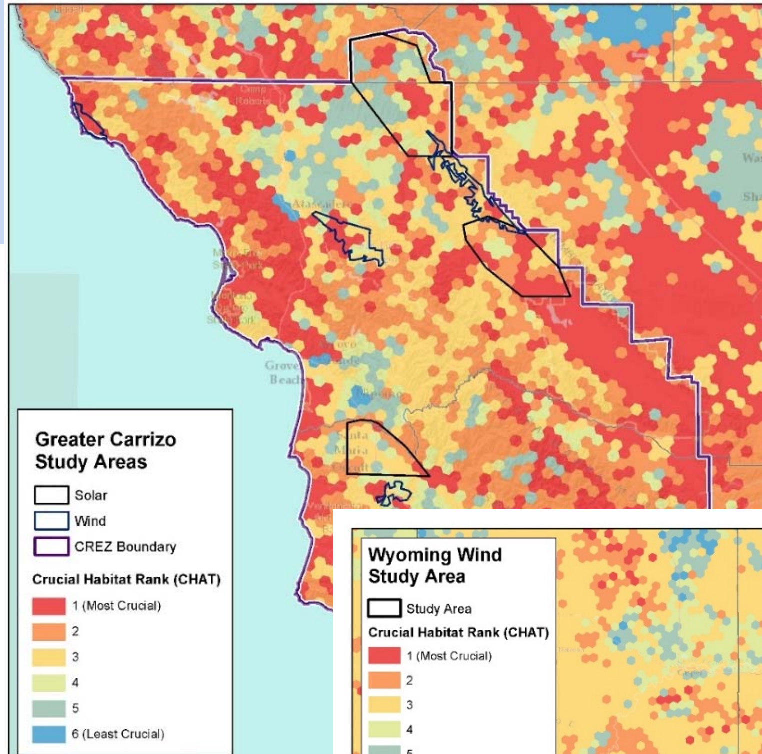
Resource Type	Current Practice Scenario 1	Regional 2	Regional 3	Difference: Regional 2 Relative to Current Practice Scenario 1	Difference: Regional 3 Relative to Current Practice Scenario 1
California Solar	53,200	54,600	24,100	1,400	–29,100
California Wind	120,000	76,000	76,000	–44,000	–44,000
California Geothermal	3,000	3,000	3,000	No change	No change
Out-of-State Solar	7,000	10,500	10,500	3,500	3,500
Out-of-State Wind	182,000	146,600	247,800	–35,400	65,800
Total Acreage in California	**176,200**	**133,600**	**103,100**	**–42,600**	**–73,100**
Total Acreage Out-of-State	**189,000**	**157,100**	**258,300**	**–31,900**	**69,300**
Major Out-of-State Transmission Additions for California RPS?	No	No	Yes	No change	Added
Renewables Beyond RPS, Out of State	No	200,000	200,000	200,000	200,000

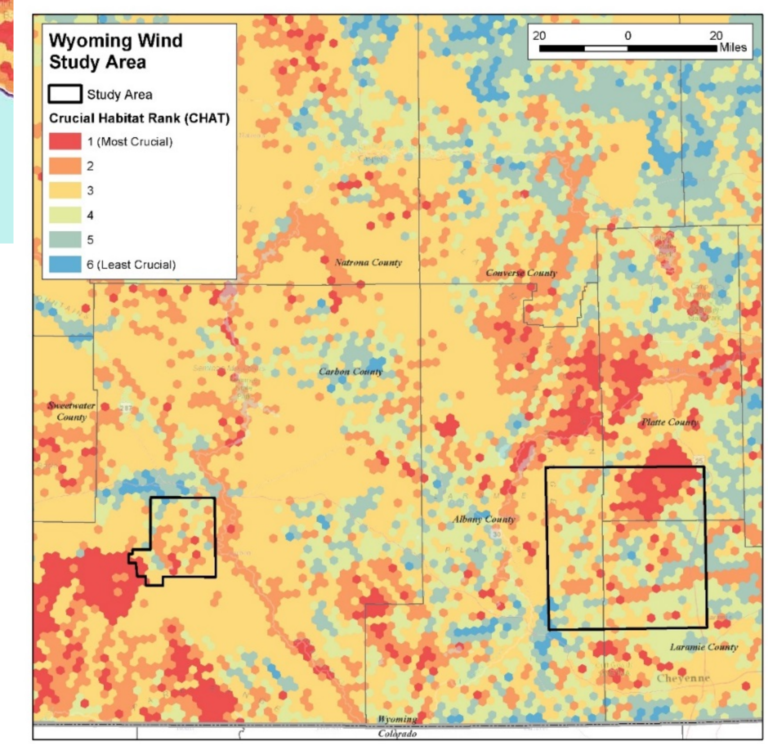
- Both regional scenarios reduce the amount of land in California for wind (-44,000 ac).
- The tradeoff is Out of State: acreage decreases in Regional 2 (-31,900 ac); acreage increases in Regional 3 due to the emphasis on out-of-state wind (+69,300 ac) with additional acreage for transmission to integrate the out-of-state resources.

Biological Resources

Using the Crucial Habitat Assessment Tool (CHAT)

- We compared study areas against this aggregated measure of crucial habitat and other datasets
- Regional scenarios increase the out-of-state impacts; however, out-of-state areas have less coverage of crucial habitat





Air Emissions:

Regionalization slightly decreases air pollutants from California fleet overall and in California's persistent nonattainment areas

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Environmental Study Key Findings

2020 CAISO + PAC Relative to Current Practice	2030 Regional 2 Relative to Current Practice Scenario 1	2030 Regional 3 Relative to Current Practice Scenario 1
• No incremental buildout causes no change in land use and biological resources • Slight changes in water used for operation of generators and emissions due to dispatch: - decrease in California - increase elsewhere	• Less overall renewable buildout for RPS which reduces the land use and acreage in California (–42,600 acres) and outside California (–31,900 acres) • Fewer impacts due to wind inside California • Facilitates development beyond RPS outside California • Less water used for operation of generators and lower emissions in California • Least water used for operation of generators and lowest emissions outside California	• Least overall renewable buildout for RPS which further reduces the land use and acreage in California (–73,100 acres), while increasing the acreage outside California for wind (+69,300 acres) • Fewer impacts due to wind inside California and fewest impacts from solar inside California • Most avian mortality for wind outside California • Adds impacts of out-of-state transmission for California RPS • Facilitates development beyond RPS outside California • Least water used for operation of generators and lowest emissions in California • Less water used for operation of generators and lower emissions outside California

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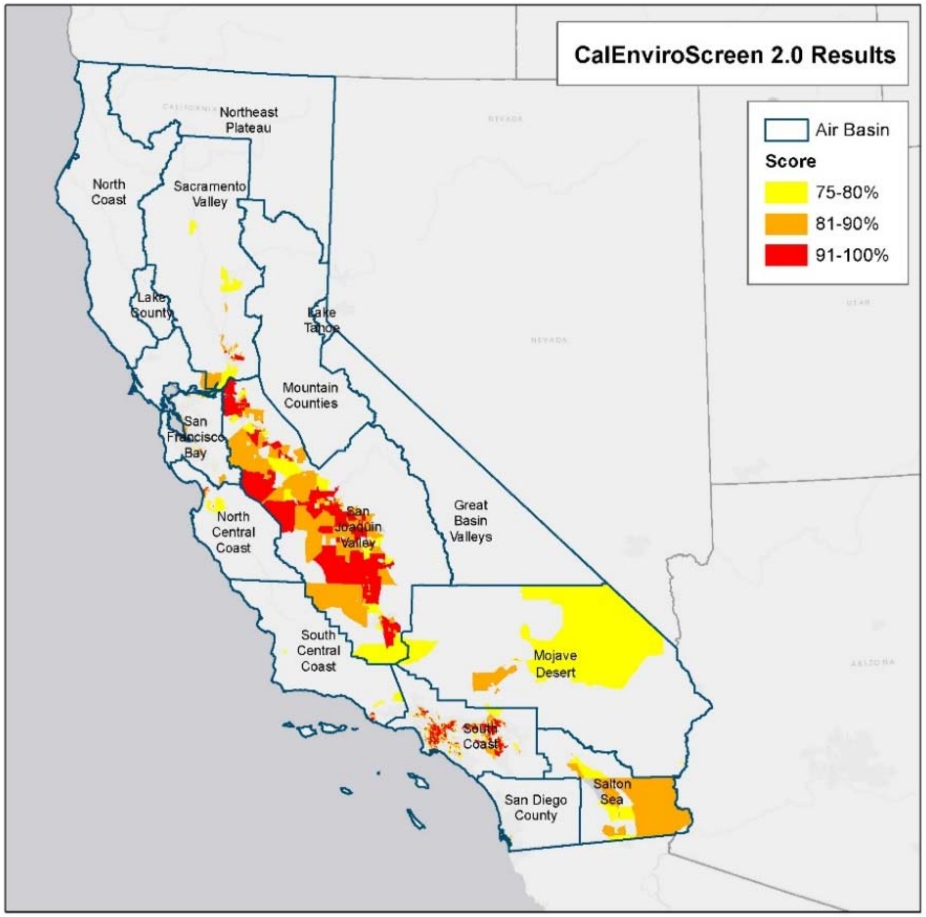
Disadvantaged Communities
Methodology

Screening for Disadvantaged Communities

- Census tract scores from CalEnviroScreen 2.0 results
- 25% highest-scoring census tracts, mapped as disadvantaged communities
- Distributed and mapped within California's Air Basins and Resource Areas of this study



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Screening for Disadvantaged Communities

The following geographical overlay boundaries for the SB 350 study contain the greatest fraction of population within California census tracts that are disadvantaged communities (CalEnviroScreen Score of 7.5-10).

- Locations of greatest concern for potential impacts to disadvantaged communities:
  - Air Basins:
    - San Joaquin Valley
    - South Coast
  - Resource Areas:
    - Westlands
    - Kramer & Inyokern
    - Central Valley North & Los Banos

Disadvantaged Communities Conclusions

Environmental study shows that the regional market:

- Reduces use of natural gas-fired generators, which reduces water use and decreases emissions
- Reduces the community-scale construction- related impacts of the buildout in California
- Examples of NOx emissions from two air basins are presented in the following table:

Air Basin	2020 CAISO + PAC Relative to Current Practice (% NOx)	2030 Regional 2 Relative to Current Practice Scenario 1 (% NOx)	2030 Regional 3 Relative to Current Practice Scenario 1 (% NOx)
San Joaquin Valley	–0.5%	–3.3%	–5.8%
South Coast	–1.4%	–9.2%	–12.8%
Difference Statewide NOx **(California natural gas fleet)**	**–1.2%**	**–6.5%**	**–10.2%**

Content

Income and Job Dynamics

Three main economic drivers in the SB350/CAISO RPS scenarios:

1. Power capacity investment
2. Infrastructure investment
3. Income/expenditure effects of electricity rate reductions

Estimating Impacts

- Direct Effects: Increased economic activity in response to direct spending (investment or consumption).
- Indirect effects: Economic activity in enterprises linked by supply chains to directly affected sectors (e.g., suppliers of input components and raw materials).
- Induced effects: Demand from rising household income (e.g. spending by employees of directly and indirectly affected firms).

Macroeconomic Impacts

Percent change from Reference* in 2030

	Full Capacity Buildout	Buildout with Partial Trade	Buildout with Regionalism
	Current Practice	Regional 2	Regional 3
Gross State Product ($B)	0.32%	0.37%	0.35%
Real Output	0.35%	0.40%	0.39%
Employment (,000)	0.29%	0.35%	0.32%
Real Income	0.48%	0.53%	0.61%
State Revenue	0.21%	0.33%	0.34%

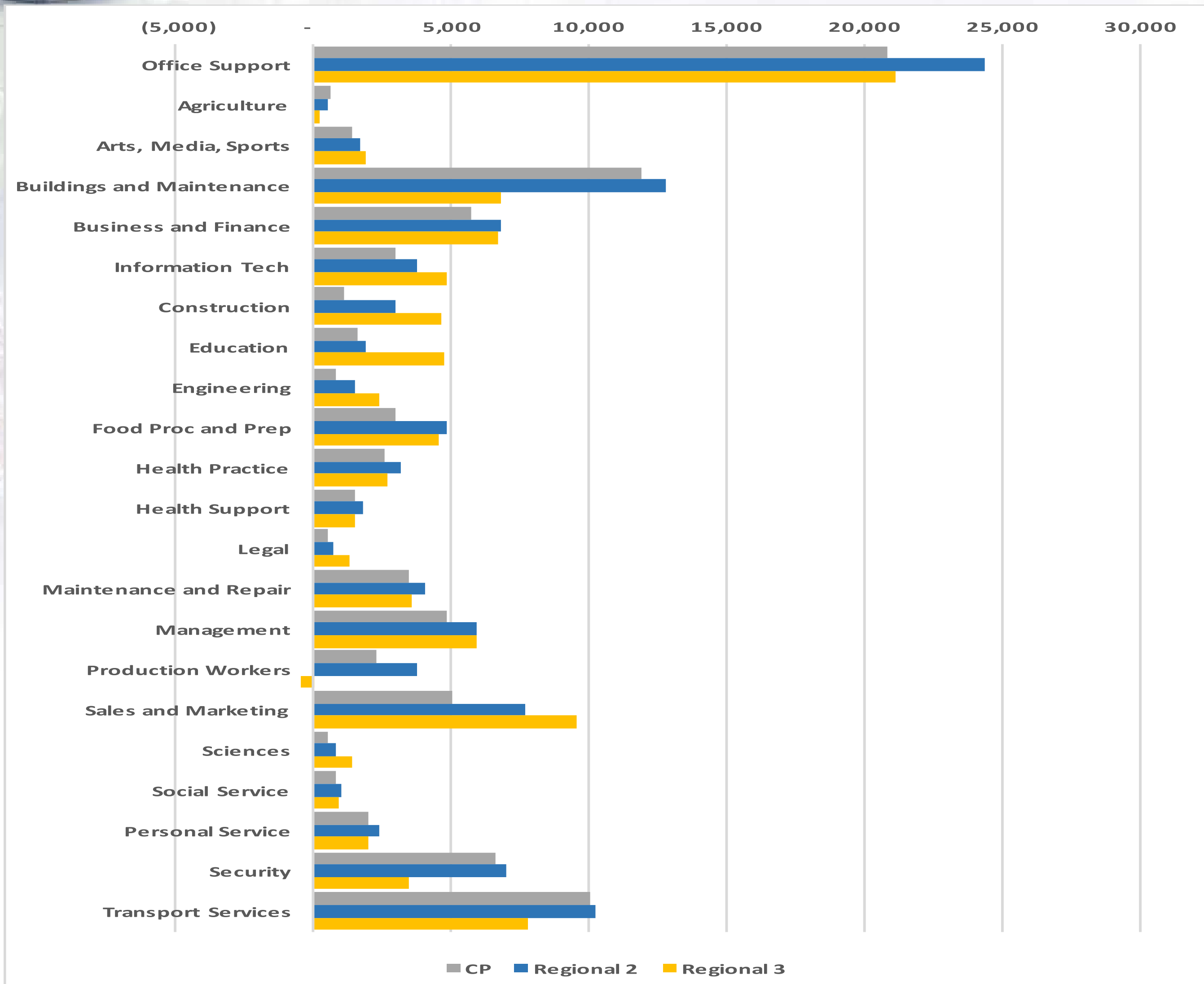
*Differences are estimated with respect to a reference scenario assuming no additional RPS investment ("Build-out") from 2020.

Difference from Reference in 2030

(2015 $ Billions unless noted)

	Full Capacity Buildout	Buildout with Partial Trade	Buildout with Regionalism
	Current Practice	Regional 2	Regional 3
Gross State Product ($B)	11.298	12.987	12.467
Real Output	18.289	21.027	20.564
Employment (,000)	90.330	109.678	100.247
Real Income	26.853	30.970	34.747
State Revenue	6.082	6.669	7.663

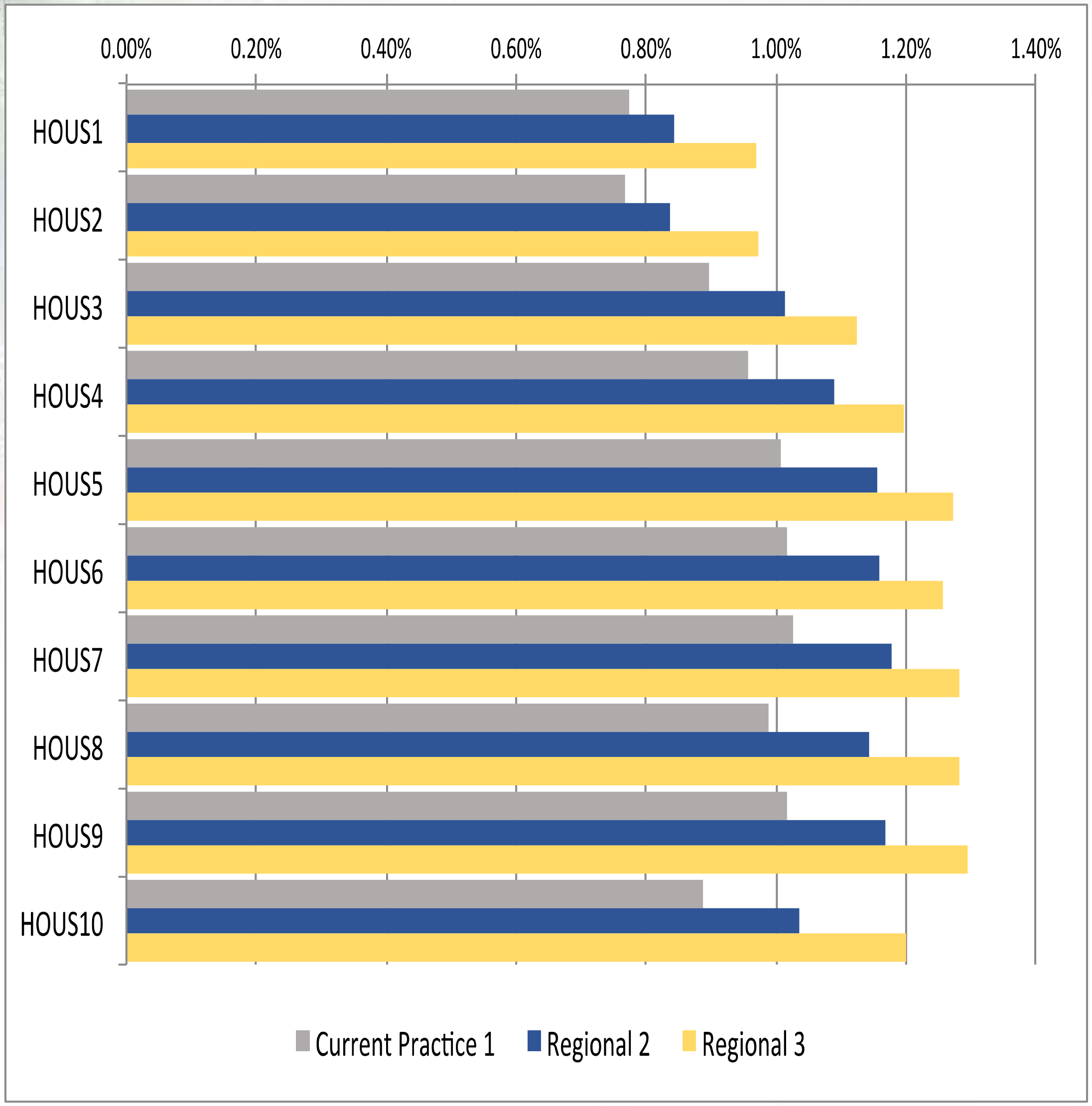
Employment Impacts by Occupation
(FTE Difference from Reference in 2030)



- All scenarios stimulate job creation in California.
- Power sector investments create both temporary and long term jobs.
- More affordable energy creates more diverse, longer term jobs.
- Combining the power sector and power source diversification yields the most FTE jobs.

Household Real Income Impact by Decile

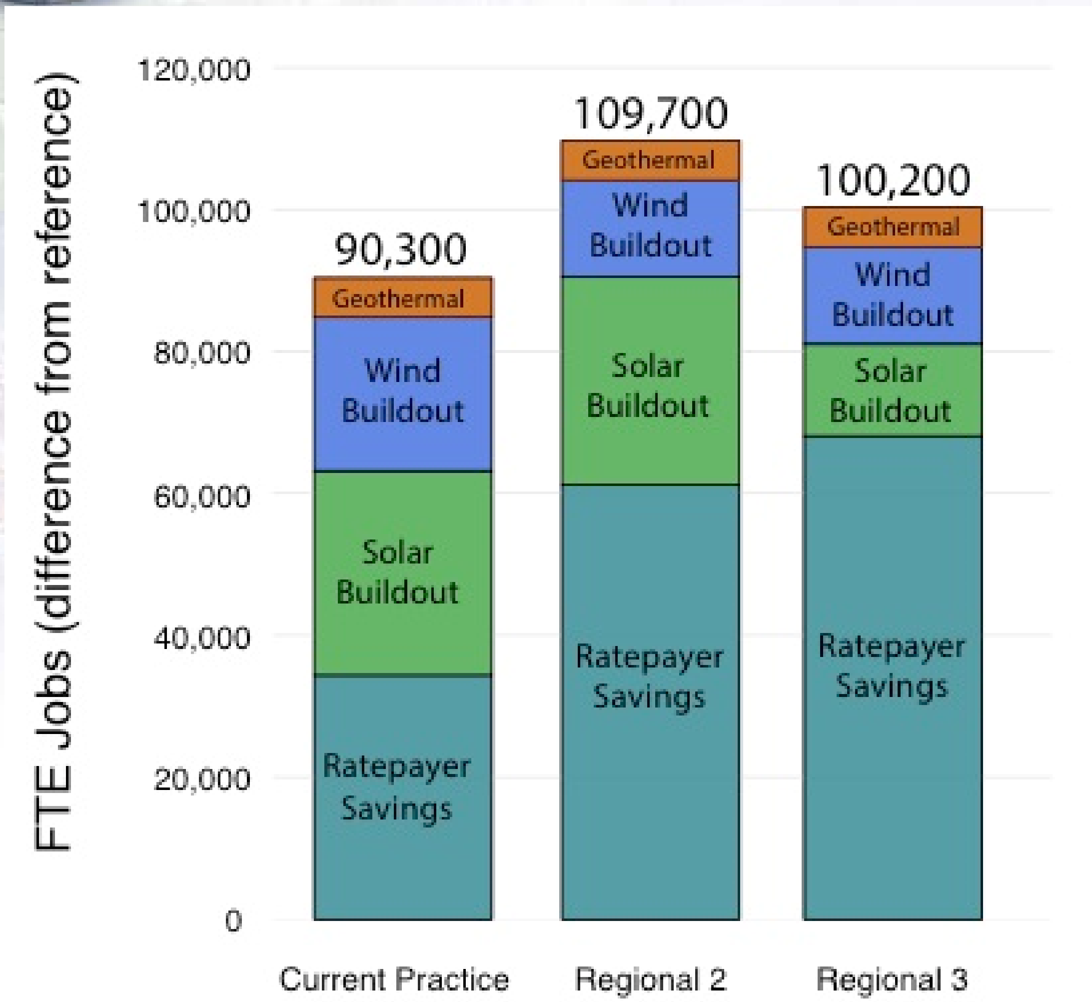
(percent change from Reference in 2030)



- Household income rises for every scenario and every decile group.

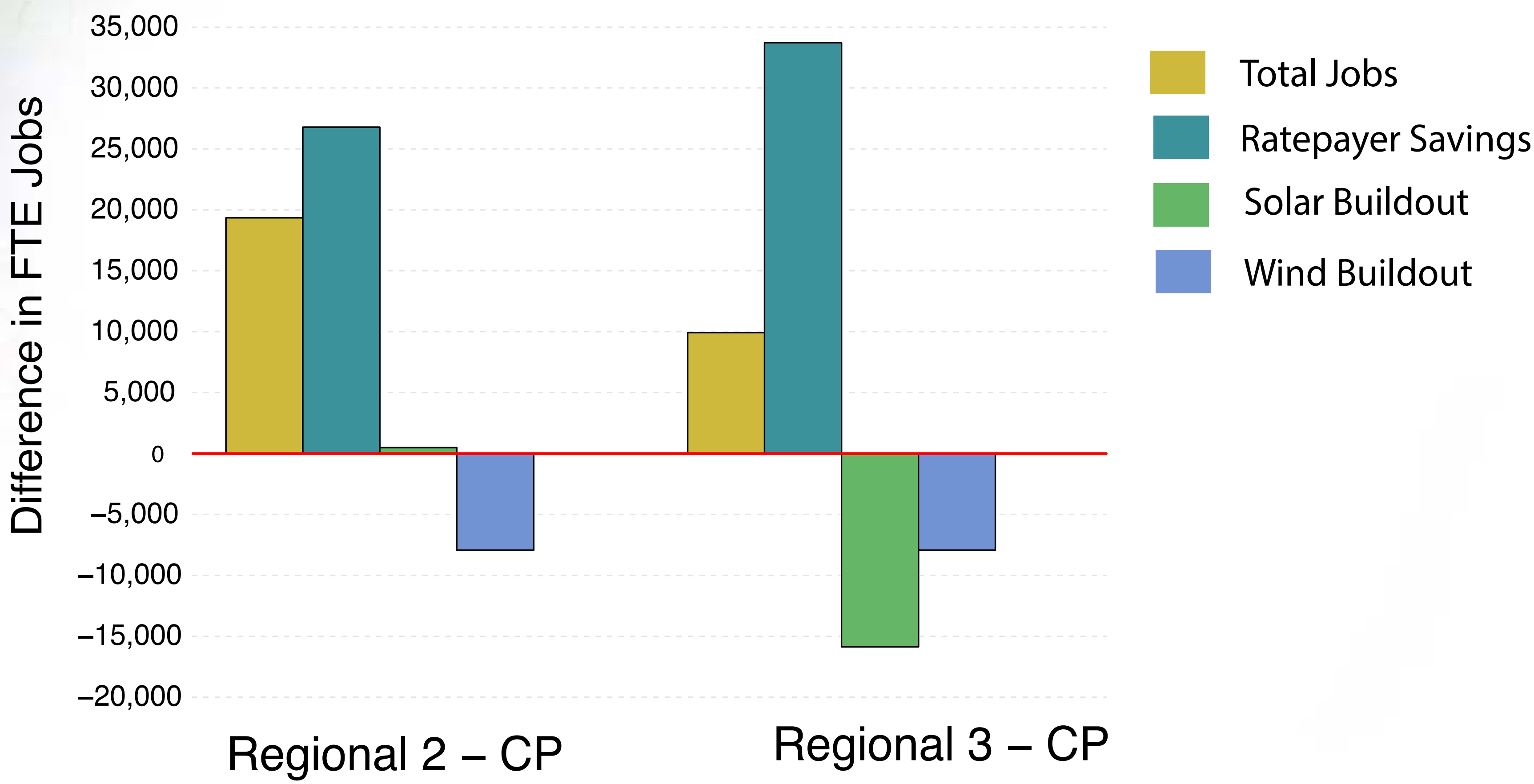
- Households benefit most from more affordable energy.

Statewide Jobs Created by 2030, by Scenario



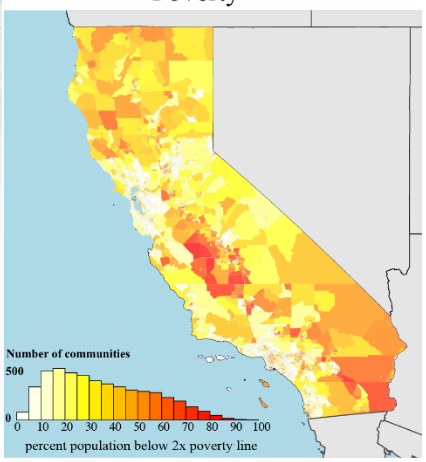
- Direct jobs include both shorter term construction jobs and longer term operations jobs
- Job estimates calculated using data from:
  - Solar – Phillips (2014)
  - Wind and Geothermal – Kammen & El Alami (2015)

Difference in Statewide Jobs Created, by source of stimulus, 2030



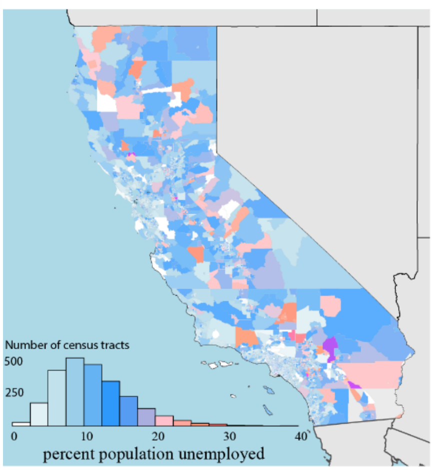
Identifying Disadvantaged Communities (DCs) with CalEnviroScreen 2.0

Poverty



+

Unemployment



+ Environmental factors

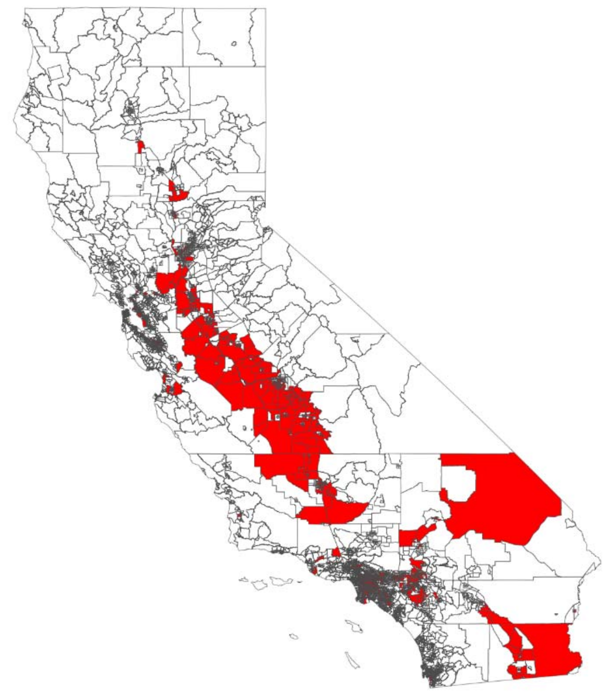
+ Health factors

+ Other socioeconomic factors

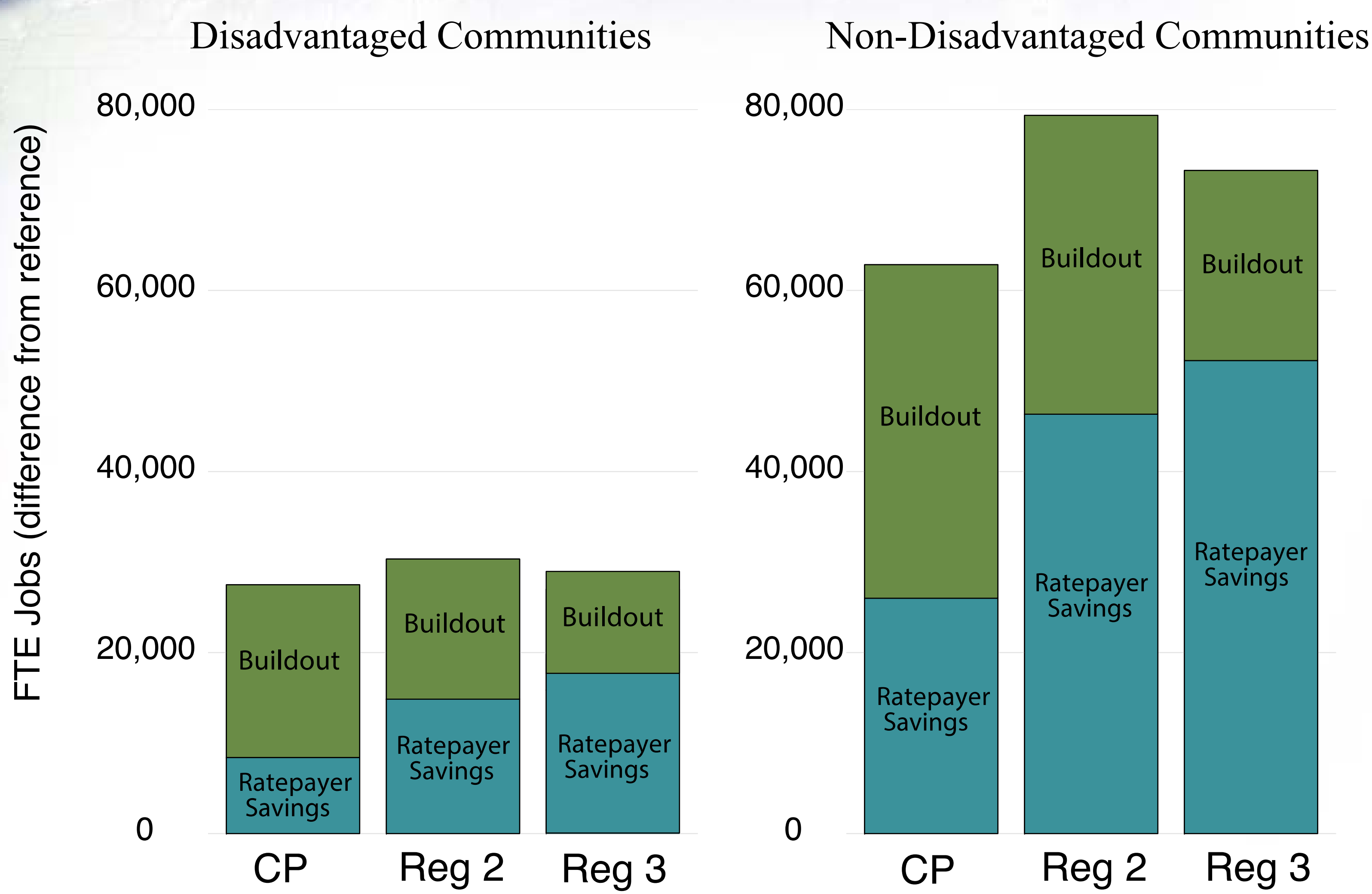
➔

CES Score

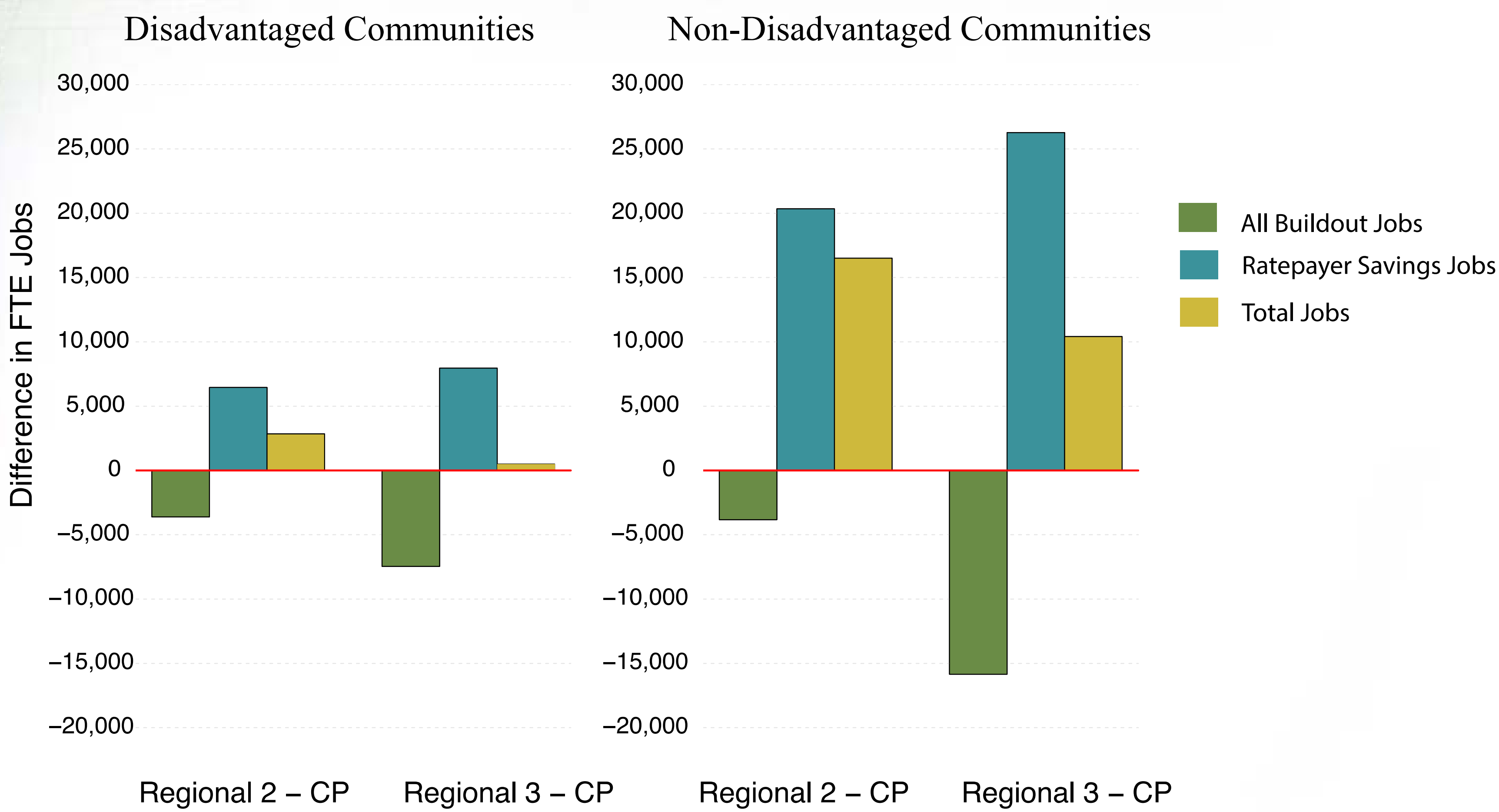
Top 25 percentile of CES Scores Designated as disadvantaged communities



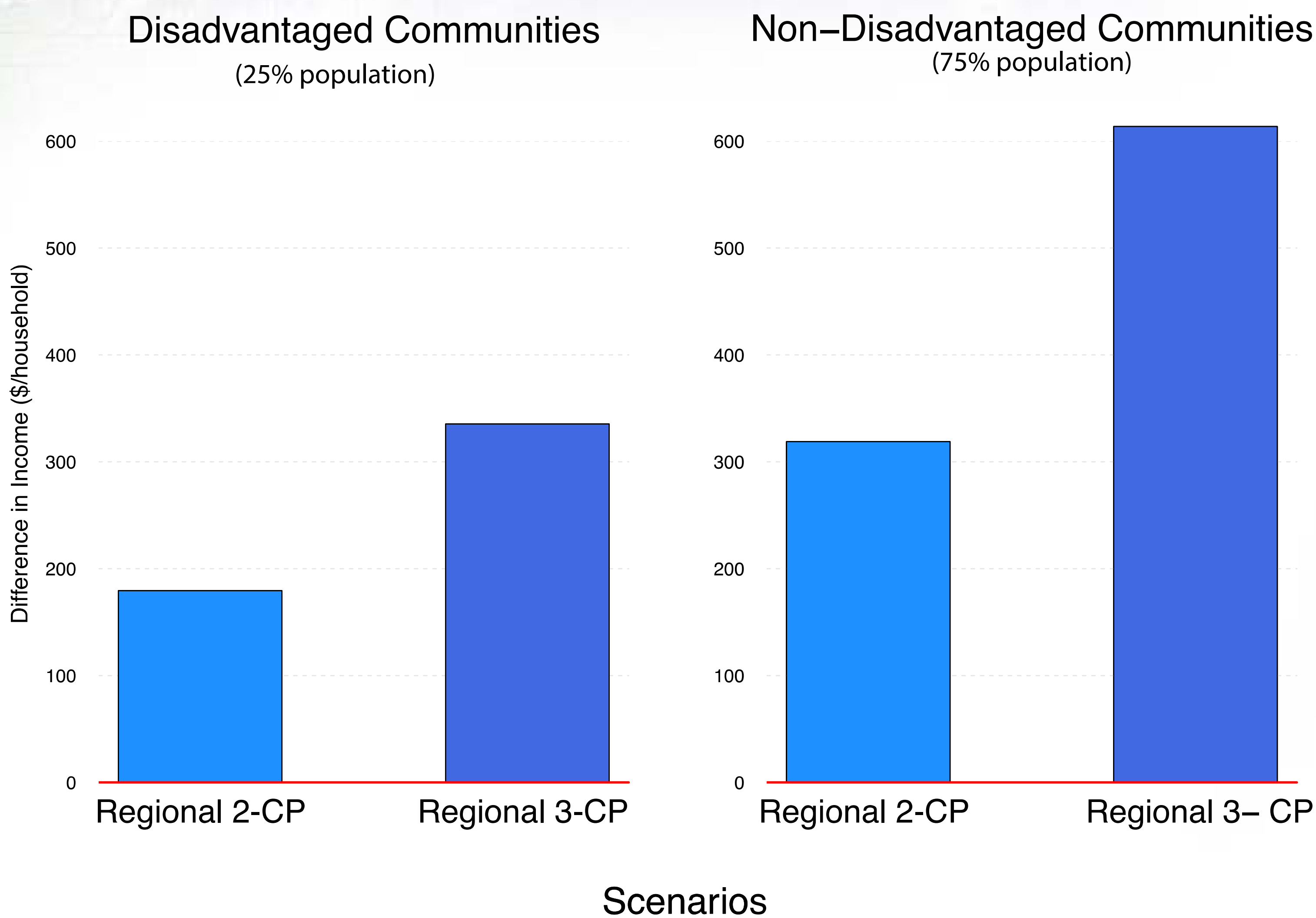
Job Creation Across Scenarios in DCs vs Non-DCs



Difference in Job Creation Across Scenarios in DCs versus Non-DCs

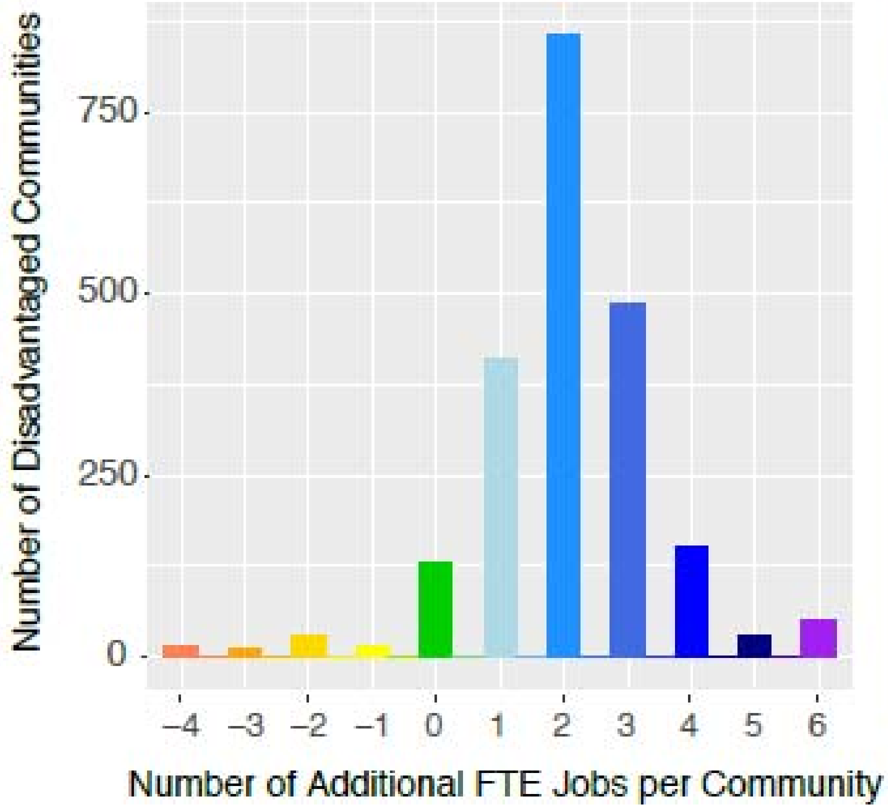


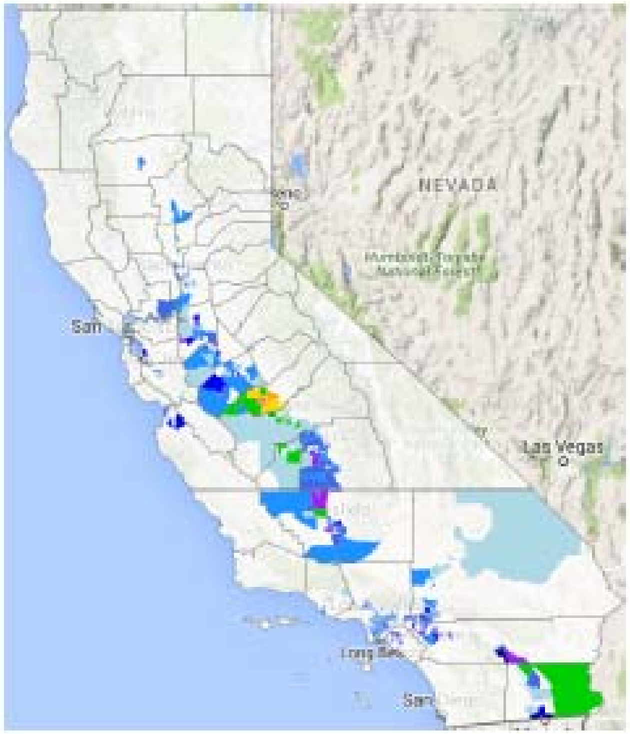
Difference in Real Income Across Scenarios in DCs versus Non-DCs



DC Difference in FTE Jobs

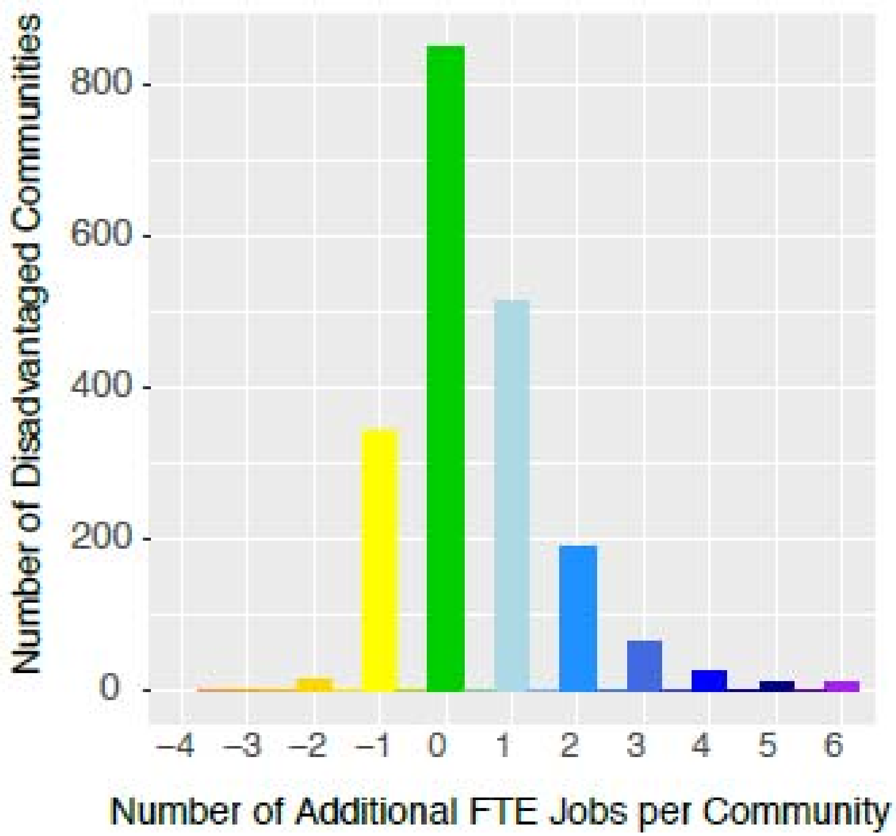
Regional 2 – Current Practice

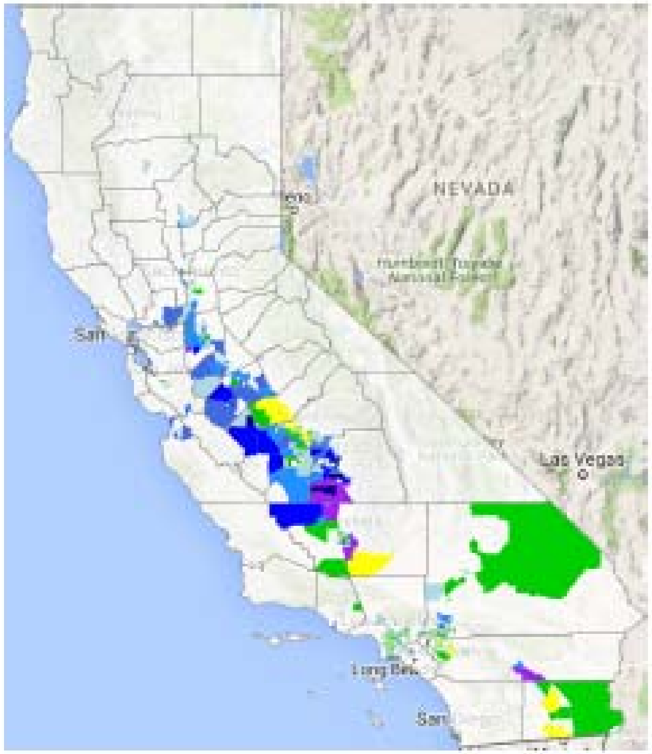




DC Difference in FTE Jobs

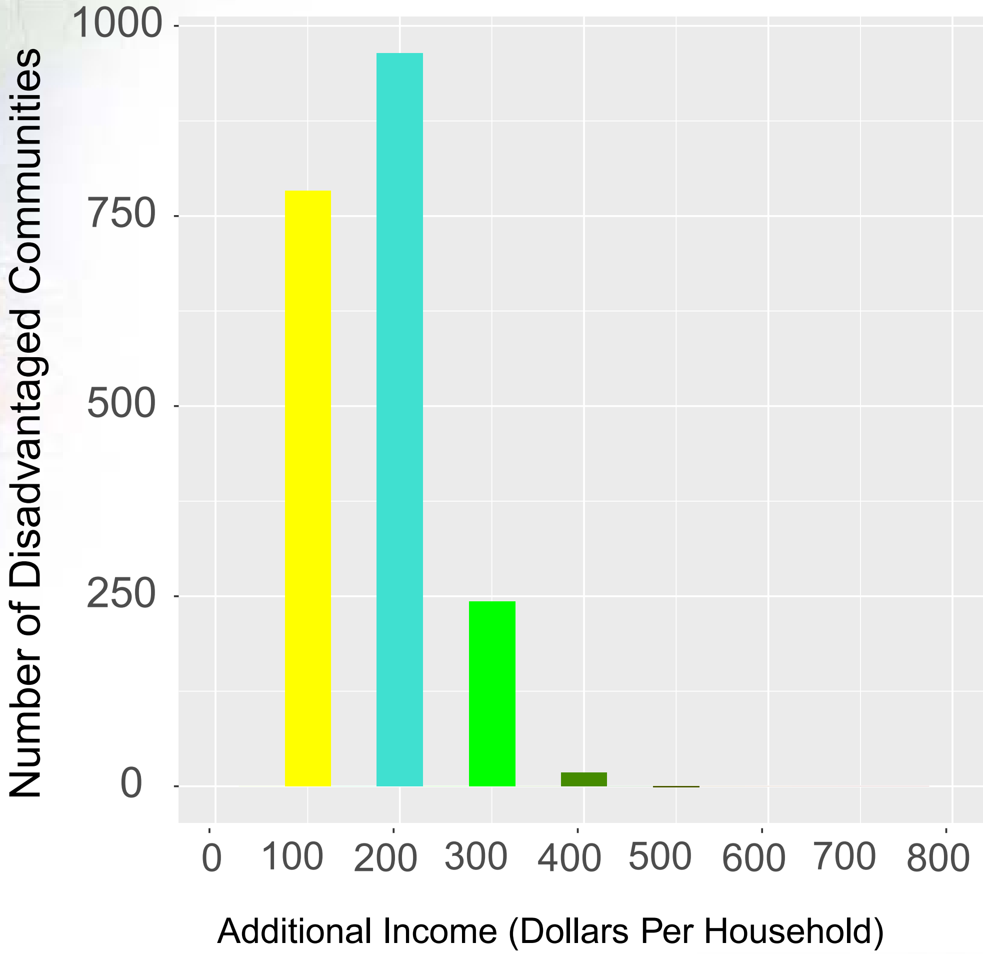
Regional 3 – Current Practice

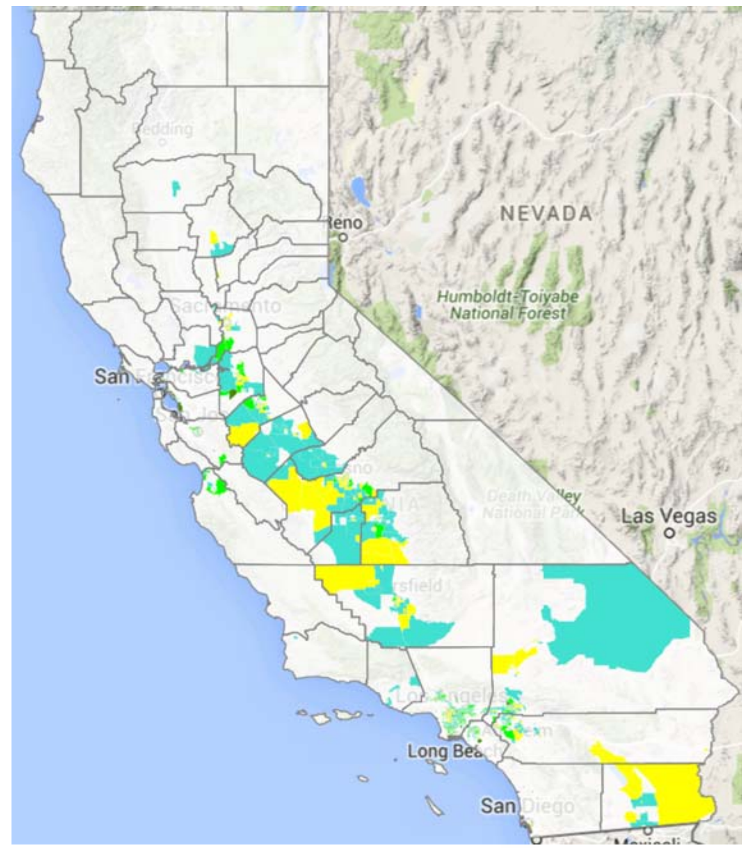




DC Differences in Real Income ($/hh)

Regional 2 – Current Practice





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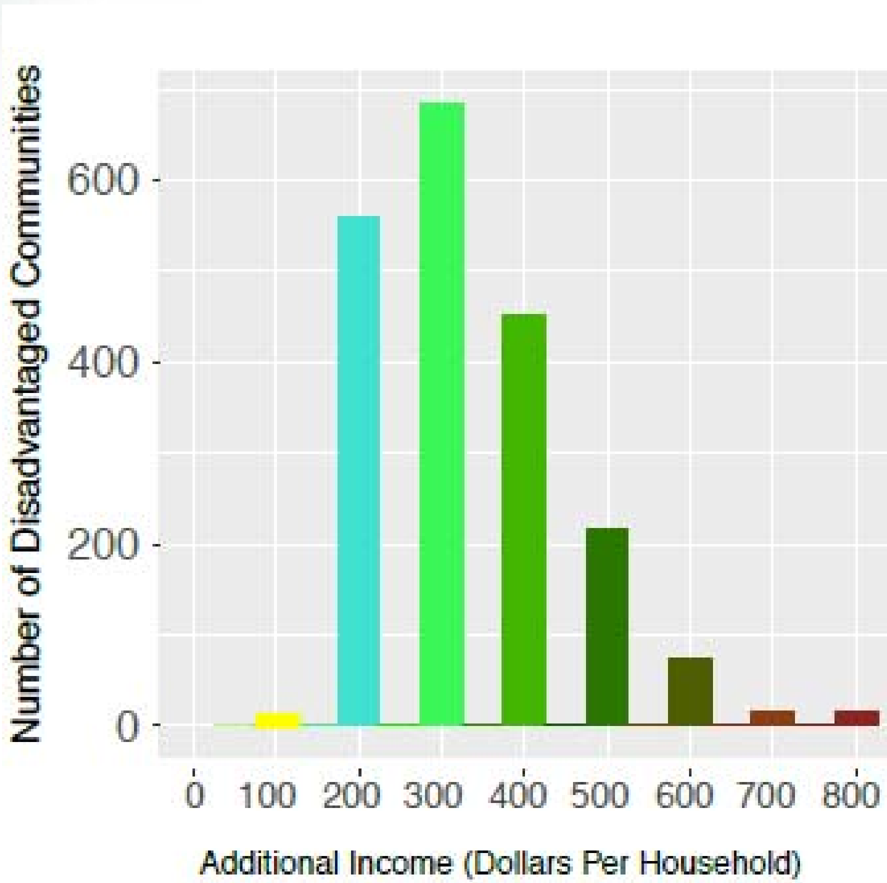
DC Differences in Real Income ($/hh)

Regional 3 – Current Practice



Conclusions

- All three RPS scenarios offer stimulus to the California economy.
- The regionalization scenarios (Regional 2 and Regional 3)
  - Create more numerous and diverse jobs due to greater rate-payer savings
  - Deliver the most geographically extensive and economically inclusive benefits to California households and enterprises.

Content

Reliability Impacts Quantified

Our quantitative analyses focus on maintaining the same level of reliability in a more cost-effective way

- The estimated ratepayer impacts include only the following cost savings associated with meeting applicable planning and operational reliability standards :
  - Lower generation investment costs from load diversity based on estimated market price for capacity
    - Does not include the additional reliability value of higher effective reserve margins
  - Production cost savings associated with:
    - Lower operating, regulation, and load-following reserve requirements
    - Reduced cost of providing these operating reserves due to reserve sharing and net load diversity
- Did not analyze the value of achieving more reliable region-wide system operations (see next slides)

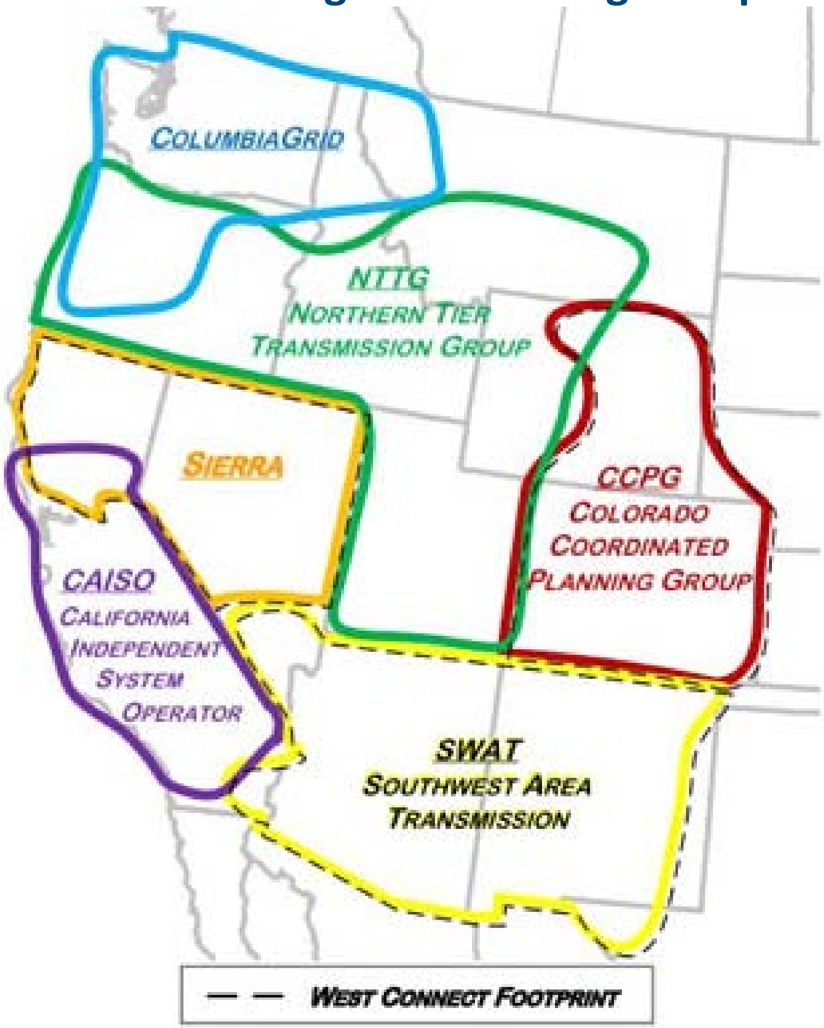
Reliability Benefits of Regional System Operations

- Improved **real-time awareness** of system conditions
- More timely, more efficient, and lower-cost **congestion management** and adjustments for **unscheduled flows**
- Regionally-optimized, multi-stage **unit commitment**
- **Enhanced systems and software** for monitoring system stability and security; enhanced system backup
- Coordinated **operator training** that exceeds NERC requirements
- Frequent review of **operator performance and procedures**
- Consolidated **standards development and NERC standards compliance**
- More unified **regional system planning**, supported by FERC Order 1000
- Broader **fuel diversity** to more effectively respond to changes in fuel availability or costs and hydro/wind/solar conditions
- Better **price signals for investment** in new resources of the right type and in the right place

(See Volume XI or the report for more detail)

Transmission Planning: Current Practice

Western Sub-Regional Planning Groups



Benefit of more unified region-wide transmission planning

- Single planning process and criteria will apply to the larger regional footprint
- Fewer planning coordination challenges related to "market seams" between small, individual planning areas
- Enhanced focus on valuable economic and public policy projects to reduce overall costs
- Facilitate region-wide access to and integration of renewable resources
- Simplified generator interconnection and repowering due to fewer affected systems
- Streamlined cost allocation processes

Source: http://www.westerngrid.net/western-sub-regional-planning/

Content

Conclusions

The ISO conducted studies of the impacts of a regional market, finding:

- ✓ 1. Overall benefits to **California ratepayers**
- ✓ 2. Lower emissions of **greenhouse gases** and **other air pollutants**
- ✓ 3. Creation or retention of **jobs** and other **benefits to the California economy**
- ✓ 4. Reduced **Environmental** impacts in California and elsewhere
- ✓ 5. Reduced impacts in **disadvantaged communities**
- ✓ 6. Improved **Reliability** and **integration of renewable energy** resources

Analyses were undertaken with substantial stakeholder review and input. As required, the modeling results, including all assumptions and inputs underlying the modeling, have been made available for public review.

Content

Appendices

Appendix A: Analytical Framework and Simulation Results

Appendix B: Portfolio and Resource Cost Assumptions

Appendix C: Load Diversity Benefits

Appendix D: GHG Emissions

Appendix E: Renewable Generation Development Stimulated by Regional Markets

Appendix F: Reliability Impacts

Appendix G: Review of Other Market Integration Studies

Appendix H: Environmental Study Details

Appendix I: Economic Assessment

Appendix A

Analytical Framework and Simulation Results

Estimating Ratepayer Impacts of a Regional Market

Cost Savings / Source of Benefits	Captured by Expanding CAISO into a Regional RTO?	Modeling Approach to Quantify Benefit
Operating Cost Savings		
De-Pancaking – Partial	EIM	[already captured by EIM]
De-Pancaking – Full	✓	Production Cost Model
RT Imbalance Market – Partial	EIM	[already captured by EIM]
RT Imbalance Market – Full	✓	Other studies/qualitatively
DA Market and Unit Commitment	✓	Production Cost Model
Integrated Ancillary Services Market	✓	Production Cost Model
Investment Cost Savings		
Regional Resource Adequacy	✓	Load Diversity Estimation
Flexible Resource Procurement	✓	Other studies/qualitatively
Reduced Renewables Overbuild	✓	RESOLVE Model
Lower-Cost Renewable Resources	✓	RESOLVE Model

Renewable Portfolios and Scenarios Analyzed

	2020 Current Practice	2020 Regional ISO CAISO+PAC	2030 Current Practice		2030 Expanded Regional ISO U.S. WECC Minus PMAs	
Renewable Portfolio	Already contracted	Already contracted	**1A**	**1B Sensitivity**	**2**	**3**
CAISO Export Limits	0 MW net export limit	776 MW between CAISO & PAC	2,000 MW bilat. export trading limit	8,000 MW bilat. export trading limit	8,000 MW physical net export limit	8,000 MW physical net export limit
Focus of Analysis	Impact of limited near-term regional market with CAISO+PAC only		Impact of bilateral ability to re-export all existing imports (3,000–4,000 MW) plus an add'l. 2,000–8,000 MW		Impact of regional market under current renewable procurement practices	Impact of greater regional renewable procurement

Production Cost Simulations: Methodology

Day-Ahead Unit Commitment → **Day-Ahead Market Dispatch** → **Intra-Day Adjustments** → **Real-Time Market Dispatch**

Day-Ahead Unit Commitment
- De-pancaked transmission & scheduling charges
- Full grid utilization
- Reduced operating reserves
- Regionally optimized unit commitment
- Reduced additional commitment hurdle

Day-Ahead Market Dispatch
- De-pancaked transmission & scheduling charges
- Full grid utilization
- Reduced operating reserves
- Regionally optimized unit dispatch
- Avoided bilateral transaction cost

Intra-Day Adjustments
- De-pancaked transmission & scheduling charges
- Full grid utilization
- Reduced operating reserves
- Adjusted unit commitment and real-time bids
- Avoided bilateral transaction cost

Real-Time Market Dispatch
- De-pancaked transmission & scheduling charges
- Full grid utilization
- Reduced operating reserves
- Regionally optimized unit dispatch
- Reduced A/S needs
- Resolved uncertainties

Scope of Production Cost Simulations
(without forecast errors, renewable uncertainty, real-time outages, etc.)

EIM

Modeling Assumptions: 2020 Scenarios

- Started with CAISO's 2020 Gridview model used in 2015/16 Transmission Planning Process (TPP)
- Updated key assumptions based on CEC's 2015 IEPR data
  - California loads, distributed solar, natural gas prices, and GHG prices
- Wheeling and hurdle rates reflect economic barriers between Balancing Authorities
- Refined representation of future WECC transmission projects
- Refined modeling of pumped storage hydro, and gas CC–CT unit commitment

Inputs	2020 Current Practice (CAISO)	2020 CAISO+PAC Regional Market
Renewable portfolio	CAISO's Gridview model	*Same as CP*
Transmission	CAISO's Gridview model (removed post-2020 projects)	*Same as CP*
Load	2015 IEPR	*Same as CP*
Gas price	2015 IEPR	*Same as CP*
GHG price	2015 IEPR $25/tonne in CA, $0 outside of CA	*Same as CP*
Reserve requirements	Updated frequency response, LF, and regulation	Allow sharing in CAISO+PAC
CAISO net export limit	0 MW	776 MW (based on ISO-PAC contract path)
Hurdle rate	Wheeling based on recent tariff (off-peak); + admin. charges & friction	*Same as CP*
Contract path	CAISO-PAC with wheeling based on recent tariff (off-peak); $1/MWh admin charges & $1/MWh trading margin $4/MWh for unit commitment	CAISO-PAC and PACE-PACW paths not subject to any hurdle rates

Modeling Assumptions: 2030 Scenarios

- Growth in loads, distributed solar, natural gas, and GHG prices based on CEC and WECC data
- Conventional generation additions and retirements, and new regional transmission based on TEPPC 2024 Common Case
  - Additional coal retirements and natural gas additions based on company announcements and IRP plans
- Renewable generation additions to meet current 2030 RPS needs plus added low-cost WY and NM wind (beyond RPS) facilitated by regional market
- Assumed no carbon price for outside of California in base-case scenarios, but separately analyzed a sensitivity with a \$15/tonne CO_2 price in rest of U.S. WECC (outside of CA)

Inputs	2030 Current Practice (CAISO)	2030 Regional ISO (US WECC–PMAs)
Renewable portfolio	Portfolios for Scenarios 1A and 1A from E3	Portfolios for Scen. 2 and 3 from E3 plus renewables facilitated beyond RPS
Transmission	CAISO's Gridview model (removed Gateway D & F)	CAISO's Gridview model (added WY & NM transmission in Scenario 3)
Load	2015 IEPR, WECC Load & Resources forecast	*Same as CP*
Gas price	2015 IEPR	*Same as CP*
GHG price	2015 IEPR \$46/tonne in CA, \$0 outside of CA	*Same as CP*
Reserve requirements	Updated frequency response, load-following, and regulation	Reduced requirements and allowed sharing in WECC minus PMAs
CAISO net export limit	2,000 MW (1a) 8,000 MW (1b)	8,000 MW
Hurdle rate	Wheeling based on recent tariff (off-peak); \$1/MWh admin charges & \$1/MWh trading margin \$4/MWh for unit-commitment	Removed hurdles within regional footprint

Simulation Assumptions:
Incremental Generation Retirements and Additions

Generation retirements and additions in the Rest of U.S. WECC beyond the TEPPC 2024 Common Case assumptions (as reflected in CAISO Gridview Model) further include:

- Coal plant retirements and natural gas plant additions based on utility integrated resource plans (IRPs)
- RPS-related renewable generation additions in the rest of U.S. WECC, based on: (a) utility IRPs, and (b) additional renewables needed to meet 2030 requirements of current RPS standards in rest of U.S. WECC
- Renewable additions facilitated by regional market beyond RPS requirements, based on analysis of non-RPS additions in ERCOT, SPP, and MISO (see main slides and **Appendix B**)

Incremental Generation Updates to TEPPC 2024 Common Case for Rest of U.S. WECC

	Coal (MW)	Gas (MW)	Renewables RPS (MW)	Renewables non-RPS (MW)
Northwest	(3,469)	5,249	1,250	0
Southwest	(923)	4,306	1,500	2,000
Rocky Mt	262	0	500	3,000
Total	**(4,130)**	**9,555**	**3,250**	**5,000**

Notes:

[1] Updates to coal and gas generation capacity reflect additional retirements and additions based on utility IRPs. The increase of 262 MW coal capacity in Rocky Mountain reflects the change of retirement date for Hayden 2 unit to after 2030.

[2] Approximately 6,250 MW of the increase in gas capacity is from CC units and the remaining 3,300 MW is from peakers (mostly CT units).

[3] Renewable additions for RPS are estimated based on the incremental amount needed to meet RPS in rest of WECC. The values do not include the renewables added to meet California's RPS.

[4] The non-RPS renewable additions facilitated by the regional market are included only in scenarios 2–3.

Not Quantified: Improved Utilization of Existing Grid

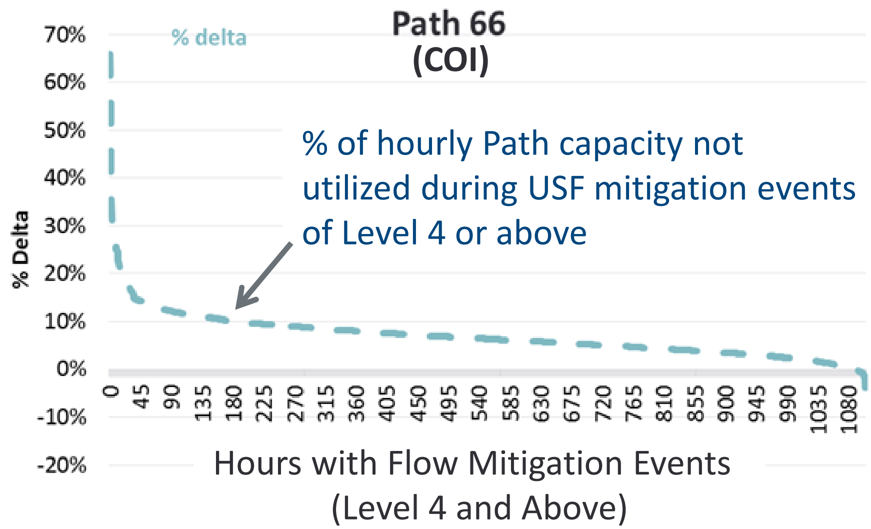
The simulations over-optimize the utilization of the existing grid under current practices, thus understating regional market benefits

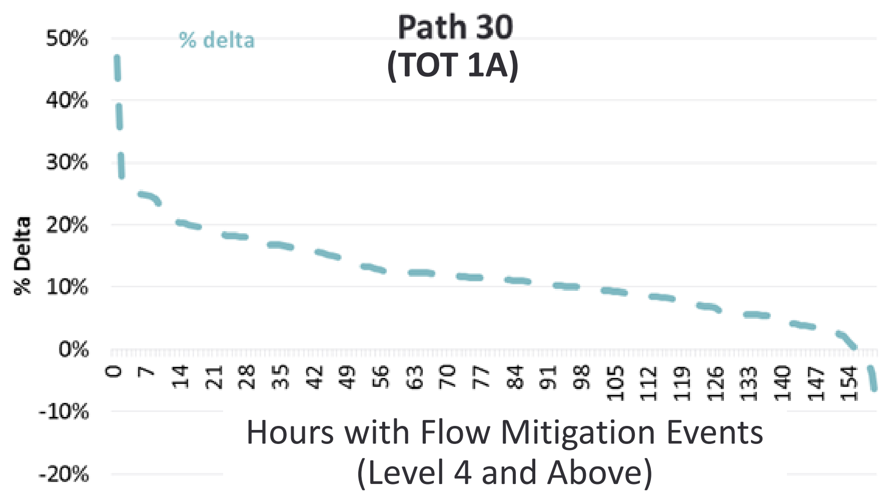
- Simulations "optimize away" many of the congestion-related challenges encountered under the current bilateral market model. For example:
  - Congestion on the California-Oregon border (COI and NOB) have ranged from $60–150 million/year for 2012–14; yet there is almost no congestion in our simulated "Current Practices" (consistent with less than $1 million congestion in the CAISO 2020 and 2025 simulations used for transmission planning studies)
  - BPA announced an RFP to "relieve a major summertime bottleneck in the Northwest" on Path 71; yet there is no congestion on that path in the simulations
  - Flow data shows the existing grid capability is not fully utilized (see end of Appendix A)
- Simulations conservatively assume perfectly optimized, security-constrained unit commitment and dispatch both (a) within each WECC Balancing Area and (b) perfectly optimized coordination across BAs (subject only to the hurdle rates).
  - These two points do not reflect reality
  - Wolak (2011) found that even moving from a zonal market design (previous CAISO market design) to a security-constrained nodal market design offers benefits approximately equal to 2.1% of production cost savings, offering additional annual benefits of $200 million/year to rest of region (see Appendix D)

Production Cost Benefits Not Quantified:
Improved Utilization of the Existing Grid

Bilateral market and the associated contract path transmission service are not able to fully utilize the physical capabilities of the existing grid, compared to ISO-operated markets.

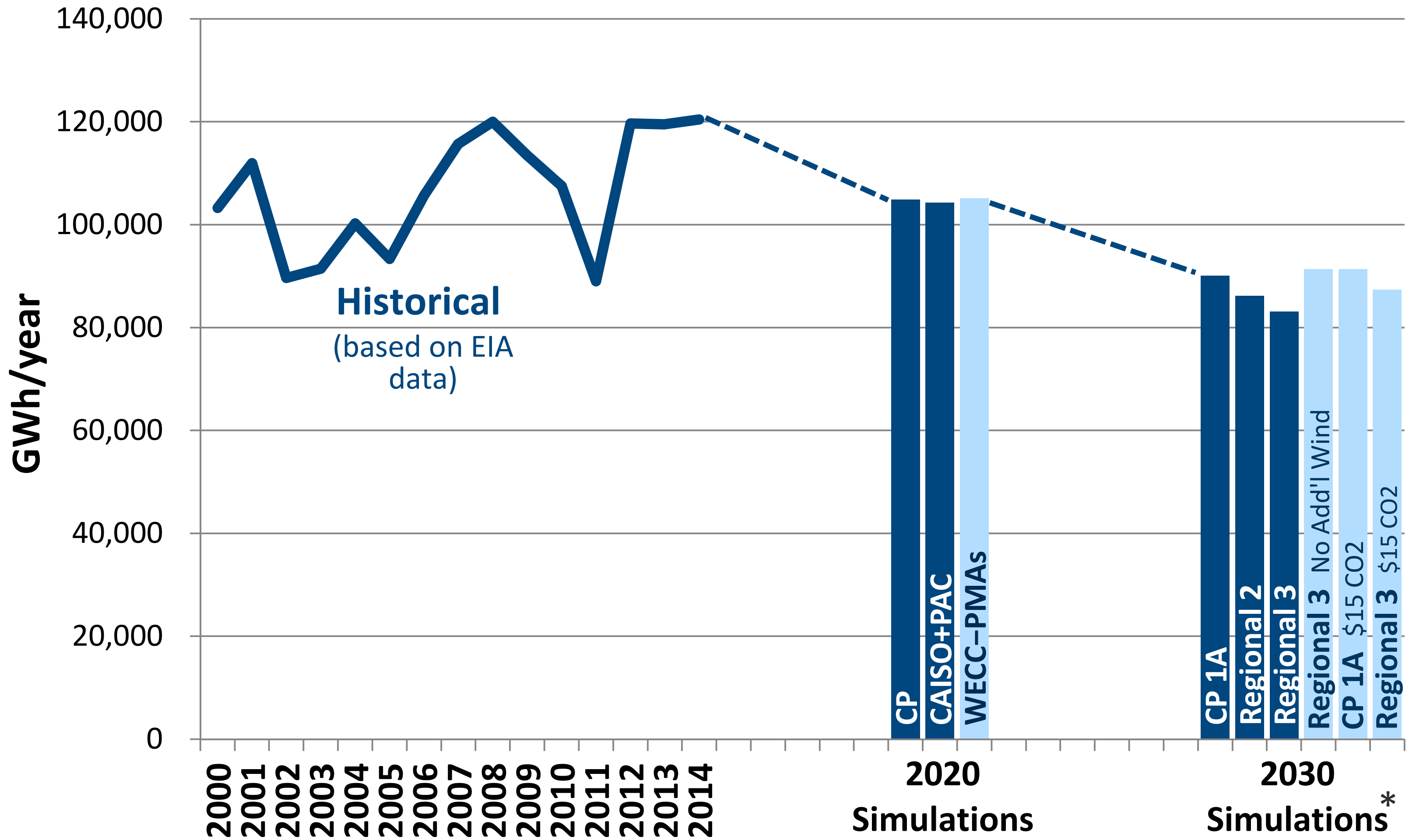
- A 2003 MISO study showed that its bilateral Day-1 market did not utilize between 7.7% to 16.4% of the existing grid capacity during congestion management events (compared to the flows that could have been accommodated in its regional Day-2 with regional security-constrained economic dispatch)
- Analysis of 2012 WECC path-flow data (most recent year available), showing **5–25% of grid capacity remains unutilized** during unscheduled flow (USF) mitigation
- **Not reflected in simulations**; will only be partly addressed by EIM





Simulation Results:

Simulated vs. Historical Gas Generation in California



* 2030 values reflect increased natural gas use associated with assumed retirement of Diablo Canyon nuclear plant

Impact of Generation Unit Starts on Costs and Emissions

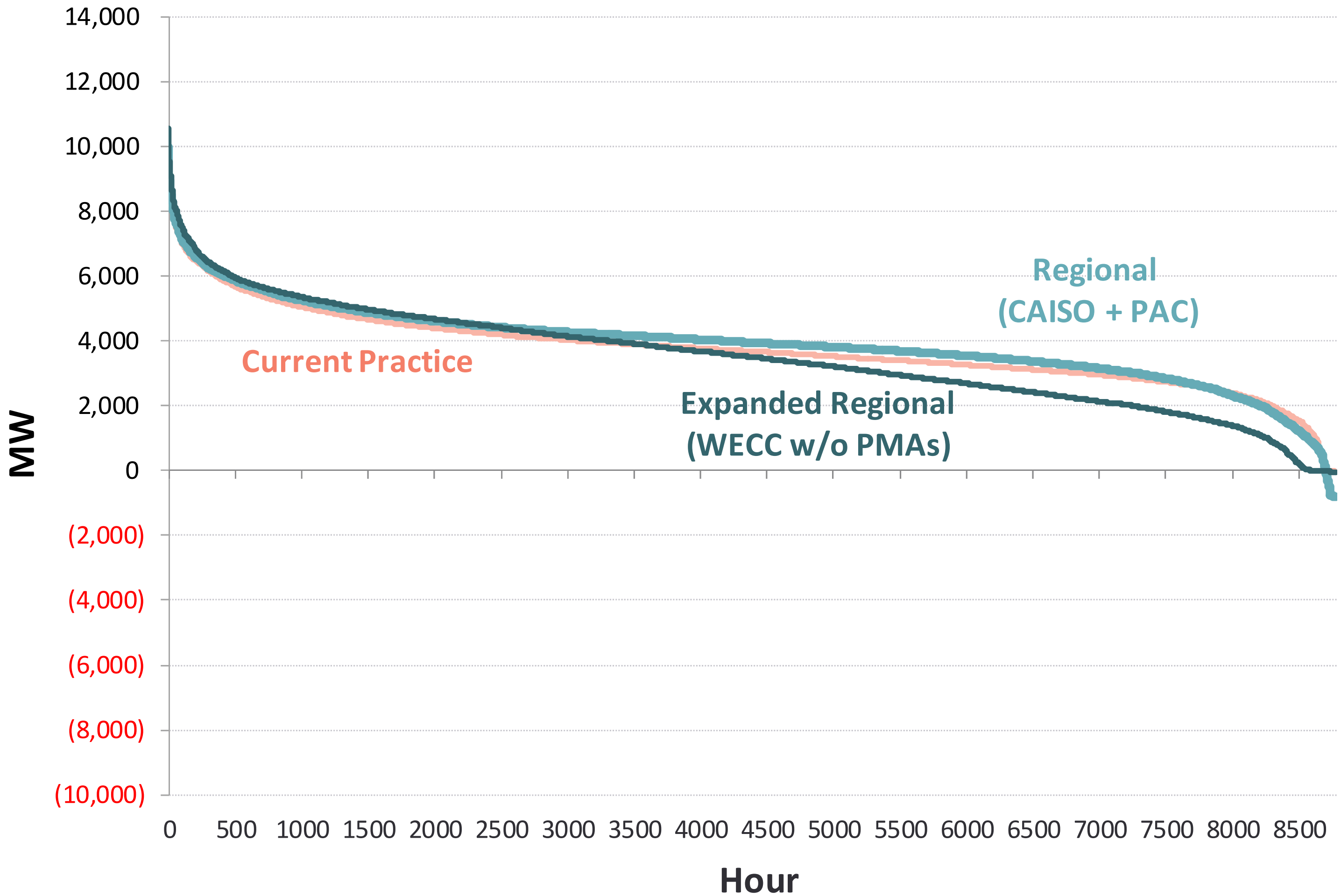
- A regional market **reduces the number of unit starts**
- **Production cost and emissions also decrease** with the number of times generators shut down and start up.
- Regional market scenarios reduce cycling of the California natural gas generators significantly compared to Current Practice scenarios to less challenging over-generation conditions
  - Thus, less startup costs (as reflected in production cost savings) and emissions
  - Starting a combined cycle unit emits as much NO_x as approximately 7 hours or full-load, steady state operation

Number of Starts in 2030
California State Natural Gas-Fired Generators

Unit Type	Avg. MW Started	Number of Starts		
		2030 Current Practice 1A	2030 Regional ISO Exp. 3	3 minus 1A
CC-Industrial	429	5,404	3,460	(1,944)
CT-Aero	41	5,033	3,148	(1,885)
ICE	8	11,477	10,896	(581)
CC-Single Shaft	281	1,767	1,318	(449)
CC-Aero	172	1,018	744	(274)
ST	45	232	108	(124)
CT-Industrial	93	347	355	8

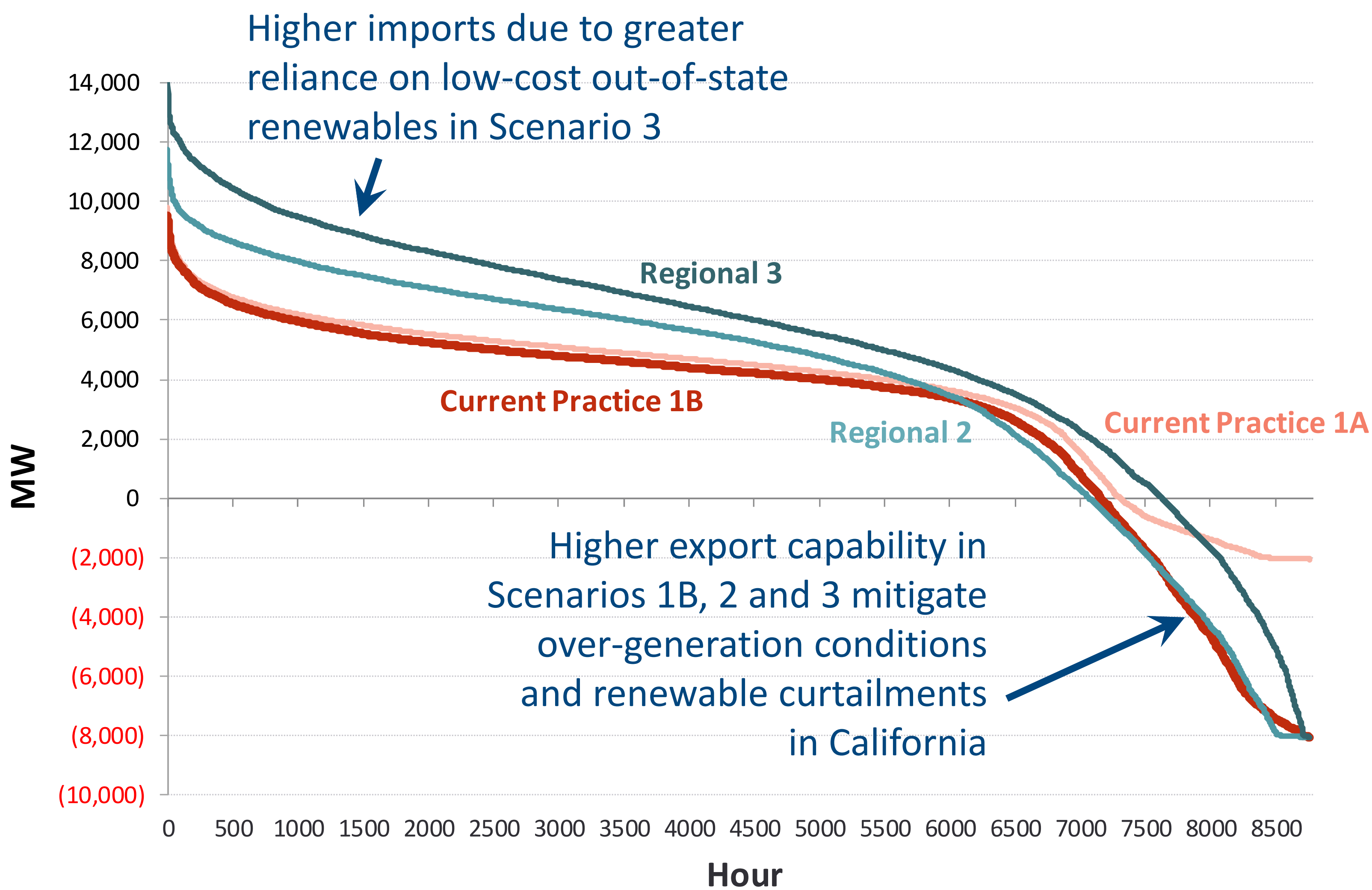
Simulation Results:

2020 CAISO Net Import Duration Curves



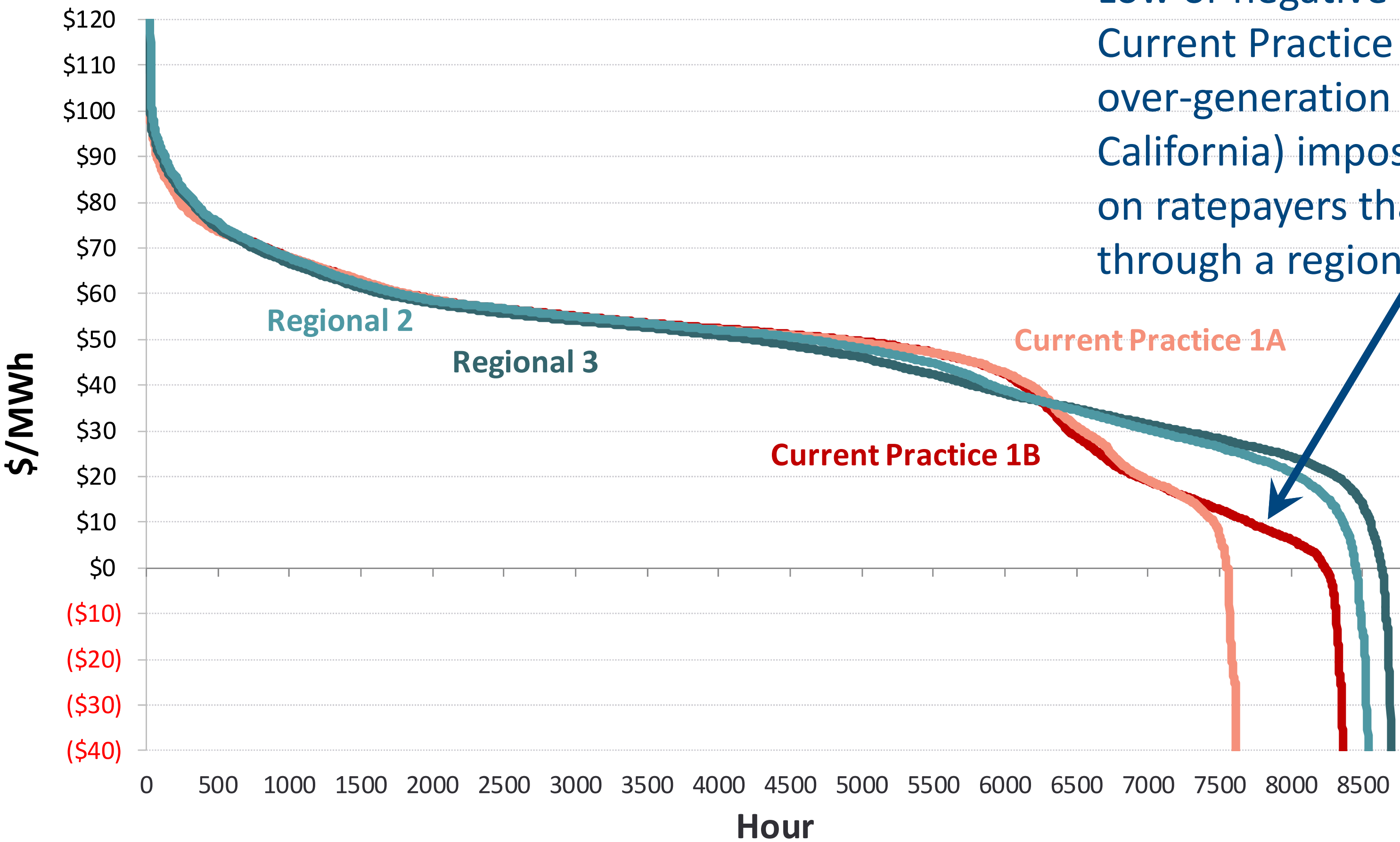
* Values are based on physical flows across CAISO's interties.

Simulation Results:
2030 CAISO Net Import Duration Curves



* Values are based on physical flows across CAISO's interties.

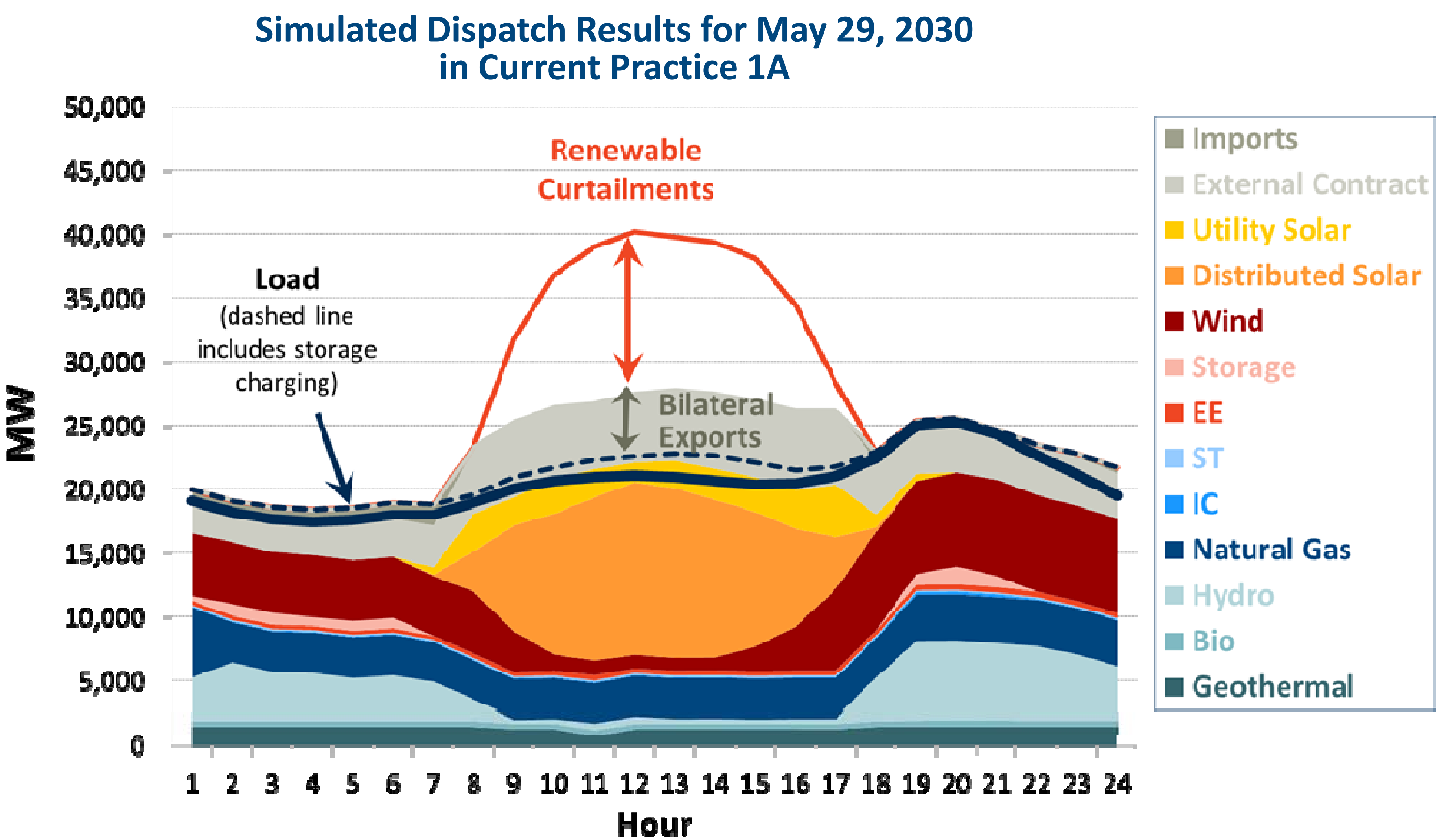
Simulation Results:
2030 CAISO Price Duration Curves



Low or negative prices in Current Practice Scenarios (due to over-generation conditions in California) impose significant costs on ratepayers that are mitigated through a regional market

Negative prices during curtailment hours are adjusted to be zero or -$40 in TEAM calculations

Simulation Results:
Example: Daily Dispatch in 2030



2020 Sensitivity: "2020 Expanded Regional ISO"

Larger Regional Footprint in 2020

- Regional footprint assumed to be the same as in 2030 (U.S. WECC w/o the PMAs)
- Expanded regional market provides about 10 times larger savings (compared to $18 million for CAISO+PAC)
- CO_2 emissions would decrease in CA and increase minimally in WECC (before consideration of facilitation of renewable generation development beyond RPS)

WECC-wide Production Cost Savings (in 2016 $MM/yr)

	2020 Current Practice	2020 Regional ISO Exp.
Fuel cost	$14,316	$14,206
Start-up cost	$436	$363
Variable O&M cost	$1,380	$1,393
TOTAL	**$16,133**	**$15,961**
Impact of Regionalization		($171)
		(1.1%)

* These simulation results likely overstate impact on coal dispatch due to the generic CC-based CO_2 hurdle rate applied to all imports into California. Contrary to the hurdle that would actually be imposed, this simplification artificially advantages coal in the simulations.

Impact on Annual CO_2 Emissions (in million tonnes/yr)

	2020 Current Practice	2020 Regional ISO Exp.
WECC TOTAL	**330.3**	**333.2**
Impact of Regionalization		2.9
		0.9%
CA In-State	51.7	51.7
CA Imports Contracted	9.2	7.6
CA Imports Generic	3.2	4.6
CA Exports Generic	(0.4)	(0.4)
CA Emissions for Load	**63.6**	**63.4**
Impact of Regionalization		(0.2)
		(0.3%)

2030 Sensitivity: "CO_2 Pricing in Rest of WECC"

Simulating Carbon Prices in Rest of U.S. WECC

- Simulated Scenarios 1A and 3 with CO_2 prices of $15/tonne in Rest of U.S. WECC
- Offers additional CO_2 emission reductions that results in CPP compliance for the Rest of WECC region. Regional market results show additional emissions reductions.

WECC-wide Production Cost Savings (in 2016 $MM/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3
Fuel cost	$17,842	$17,074
Start-up cost	$735	$558
Variable O&M cost	$1,137	$1,110
TOTAL	**$19,713**	**$18,743**
Impact of Regionalization		($971)
		(4.9%)

Impact on Annual CO_2 Emissions (in million tonnes/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3
WECC TOTAL	**291.2**	**280.6**
Impact of Regionalization		(10.6)
		(3.6%)
CA In-State	46.7	44.9
CA Imports Contracted	6.2	3.7
CA Imports Generic	1.4	1.2
CA Exports Generic	(5.2)	(5.5)
CA Emissions for Load	**49.1**	**44.4**
Impact of Regionalization		(4.7)
		(9.6%)

2030 Sensitivity: "Without Non-RPS Wind"

Scenario 3 Regional without Wind Beyond RPS

- Sensitivity without the development of additional low-cost, non-RPS renewables in WECC (3,000 MW of wind in WY and 2,000 MW wind in NM) that is assumed to be facilitated by the regional market
- Renewables facilitated by market increases production cost savings and emission reductions (both in CA and WECC-wide)

WECC-wide Production Cost Savings (in 2016 $MM/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3
Fuel cost	$17,602	$17,412
Start-up cost	$769	$622
Variable O&M cost	$1,188	$1,190
TOTAL	**$19,559**	**$19,224**
Impact of Regionalization		($335) (1.7%)

Impact on Annual CO_2 Emissions (in million tonnes/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3
WECC TOTAL	**307.3**	**306.0**
Impact of Regionalization		(1.3) (0.4%)
CA In-State	46.2	46.5
CA Imports Contracted	6.2	4.5
CA Imports Generic	1.7	2.3
CA Exports Generic	(4.8)	(6.3)
CA Emissions for Load	**49.2**	**47.0**
Impact of Regionalization		(2.2) (4.5%)

CA Cost of Production, Purchases & Sales (TEAM)

Regional market operations reduces California costs associated with the production, purchase, and sale of wholesale power

- 2020: $10 million in annual savings ($97 million w/ expanded region)
- 2030: **$104 million to $523 million in annual savings** depending on the Scenario

Estimated Savings for California Annual Power Production, Purchase and Sales Costs

(Statewide/ 2016 $MM)

	2020 CAISO +PAC	2020 Regional ISO Exp.	2030 1A vs. 2	2030 1A vs. 3
Production costs savings from owned and contracted gen	$19	$125	$193	$244
Reduction in market purchase cost from merchant gen and imports	($10)	($49)	($290)	$52
Increase in market sales revenues	$2	$21	$202	$227
Savings to CA Ratepayers	**$10**	**$97**	**$104**	**$523**

Less wind increases volume of market purchases during off-peak hours

Fewer REC purchases; more wind decreases costs when purchasing off-peak

The main drivers of the savings are from:
(a) lower production costs from owned and contracted generation to meet load; **(b)** reduced power purchase costs when load exceed owned and contracted generation (higher in scenarios with more REC purchases); and **(c)** higher revenues when selling into the wholesale market during hours with excess owned and contracted generation (we assume power is sold at no less than $0/MWh)

Negative Pricing During Over-Supply

- In the Current Practice Scenario bilateral trading hurdles limit exports of California renewable generation portfolios in hours with low load and high wind/solar output
  - Results in renewable curtailments and low or negative prices when CAISO entities cannot bilaterally sell enough power during over-supply conditions
- Negative prices represent a significant additional cost to California associated with selling power during over-supply conditions
  - Example: negative prices at Mid-C trading hub during excess hydro conditions
- Simulations of a regional market (and experience in other regions) show the mitigating effects on over-supply, reduction in renewable curtailments and frequency of negatively priced trading periods
- Our baseline estimates of California production, purchase and sales costs conservatively assumes settlement prices do not drop below zero during over-generation (give power away for free but not pay more)
  - Conservatively excludes the additional cost to California imposed by negative prices
  - Sensitivity results (on next slide) provide estimated costs with prices at negative $40/MWh, reflecting marginal REC cost

Summary of CA Ratepayer Impacts: ¢/kWh

The identified potential impacts from an expanded regional ISO market, are conservatively estimated to **decrease 2030 California total retail rates by at least 0.4–0.6 ¢/kWh or by 2.0%–3.1%**

		2020 Current Practice	2020 Regional ISO	2030 Current Practice 1A	2030 Regional ISO Exp. 2	2030 Regional ISO Exp. 3
RPS-Portfolio Related Capital Investment	($MM)	$0	$0	$3,292	$2,612	$2,492
Production, Purchase & Sales Cost (TEAM)	($MM)	$7,752	$7,742	$8,066	$7,962	$7,544
Load Diversification Benefit	($MM)	$0	($6)	$0	($120)	($120)
Grid Management Charges Savings	($MM)	$0	($39)	$0	($103)	($103)
Total Retail Revenue Requirements	**($MM)**	**$43,316**	**$43,262**	**$50,643**	**$49,636**	**$49,098**
Total Retail Sales	(GWh)	260,028	260,028	256,404	256,404	256,404
Average Retail Rate	**(cent/kWh)**	**16.7**	**16.6**	**19.8**	**19.4**	**19.1**
Impact of Regionalization Relative to CP 1A	(cent/kWh)		(0.0)		(0.4)	(0.6)
	(%)		(0.1%)		(2.0%)	(3.1%)

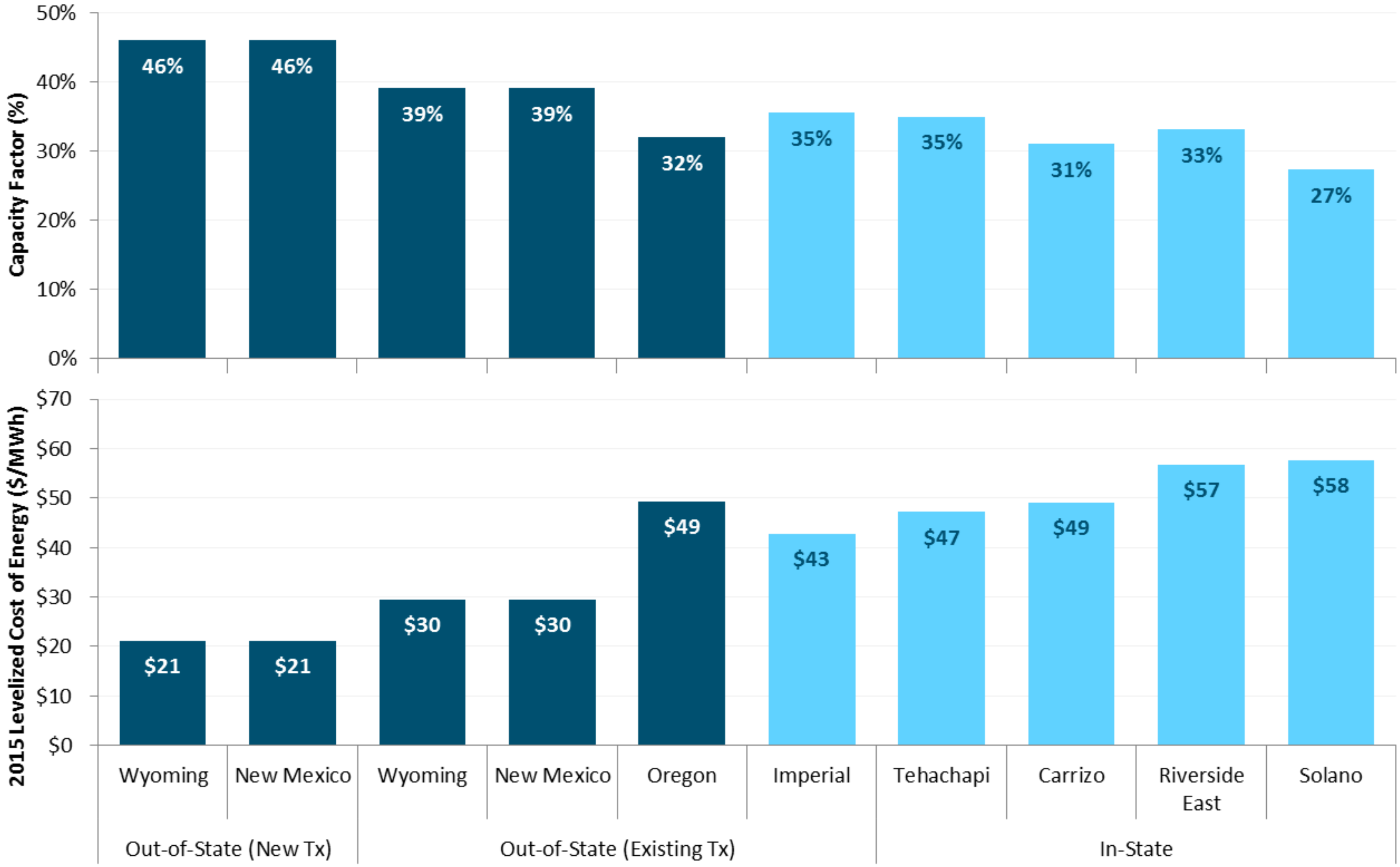
Appendix B

Portfolio and Resource Cost Assumptions

Solar costs are relatively uniform throughout Southwest region

Assumptions: single axis tracking solar PV with an inverter loading ratio of 1.3, impacts of federal tax credits are included

Wind cost is significantly lower in WY and NM



Impacts of federal tax credits are included

Energy Storage Cost Assumptions

- **Battery cost estimates are based on literature review and quotes from manufacturers, updated based on stakeholder feedback**
  - Installed cost of Li-ion is lower even at long durations, but flow battery has longer lifetime and requires fewer/no replacements
- **Capital investment and O&M costs are annualized using E3's WECC Pro Forma tool**

Technology	Charging & Discharging Efficiency	Financing Lifetime (yr)	Replac-ement (yr)	Minimum duration (hrs)	Resource Potential (MW)
Lithium Ion Battery	92%	16	8	0	N/A
Flow Battery	84%	20	N/A	0	N/A
Pumped Hydro	87%	40	N/A	12	4,000

Type	Cost Metric	2015	2030
Lithium Ion Battery	Storage Cost ($/kWh)	375	183
	Power Conversion System Cost ($/kW)	300	204
	Fixed O&M Battery/Reservoir ($/kWh-yr)	7.5	3.7
	Fixed O&M PCS ($/kW-yr)	6.0	4.1
Flow Battery	Storage Cost ($/kWh)	700	315
	Power Conversion System Cost ($/kW)	300	204
	Fixed O&M Battery/Reservoir ($/kWh-yr)	14.0	6.3
	Fixed O&M PCS ($/kW-yr)	6.0	4.1
Pumped Hydro	Storage Cost ($/kWh)	117	117
	Power Conversion System Cost ($/kW)	1,400	1,400
	Fixed O&M Battery/Reservoir ($/kWh-yr)	-	-
	Fixed O&M PCS ($/kW-yr)	15	15

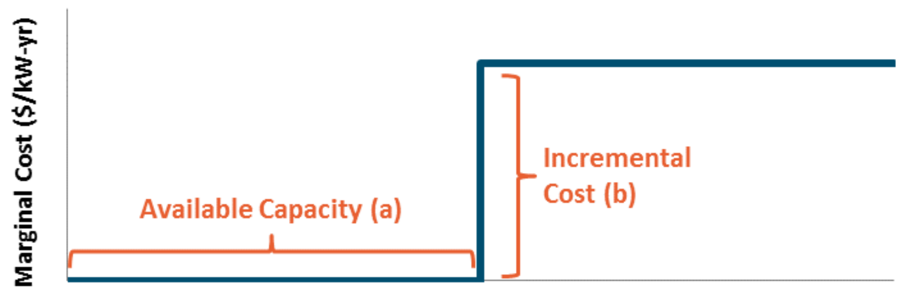
Technology	2015 Annualized Cost Components ($/kW-yr; $/kWh-yr)	2030 Annualized Cost Components ($/kW-yr; $/kWh-yr)
Lithium Ion Battery	69; 85	46; 40
Flow Battery	58; 118	39; 53
Pumped Hydro	146; 12	146; 12

Note: The first number indicates the annualized cost of the power conversion system ($/kW-yr) of the device and the second number indicates the annualized cost of the energy storage capacity or reservoir size ($/kWh-yr). Both numbers are additive.

California in-state renewable transmission cost assumptions

+ **California transmission cost assumptions are based on CAISO's 50 Percent Renewable Energy Special Study conducted as part of the 2015-2016 Transmission Plan**
  - https://www.caiso.com/Documents/Draft2015-2016TransmissionPlan.pdf
+ **'Available Capacity (a)' represents the limit of a system to accommodate new renewables at no cost; and 'Incremental Cost (b)' reflects the cost of new transmission upgrades once the available capacity has been exhausted.**

Illustrative two-step transmission costing model for a renewable resource zone in California



Availability of energy only capacity and cost of transmission upgrades in California renewable resource zones

Zone	Available Capability (MW)	Incremental Cost ($/kW-yr)
Central Valley & Los Banos	2,000	$ 29
Greater Carrizo	1,140	$ 114
Greater Imperial	2,633	$ 68
Kramer & Inyokern	750	$ 52
Mountain Pass & El Dorado	2,982	$ 65
Northern California	3,404	$ 95
Riverside East & Palm Springs	4,917	$ 85
Solano	1,101	$ 13
Southern California Desert	-	$ 64
Tehachapi	5,000	$ 21
Westlands	2,900	$ 58

Out of state renewable transmission cost assumptions

- Out of state transmission cost assumptions vary by region and scenario

Resource		Quantity (MW)	Costs ($/kW-year)			Basis for Assumption
			Scen. 1	Scen. 2	Scen. 3	
Southwest Solar PV		1500	$39	$0	$0	Wheeling & losses on APS system
New Mexico Wind	1	1000	$72	$0	$0	Wheeling & losses on PNM & APS systems
New Mexico Wind	2	1500	N/A	N/A	$50	Assumed project capital cost ($567 million for 1,500 MW of new transmission) based on RPS Calculator transmission costs, scaled for distance for delivery to Four Corners
New Mexico Wind	3	1500	N/A	N/A	$129	Sum of public SunZia costs ($2 billion for 3,000 MW) and assumed upgrade costs from Pinal Central to Palo Verde based on RPS Calculator
Northwest Wind		2000	$34	$0	$0	Wheeling & losses on BPA system (system + southern intertie rates)
Wyoming Wind	1	500	$66	$0	$0	Wheeling & losses on Pacificorp East & NV Energy systems
Wyoming Wind	2	3000	N/A	N/A	$88	Costs of Gateway project reported ($252 million per year for 2,875 MW) reported in *Regional Coordination in the West: Benefits of PacifiCorp and California ISO Integration* (Technical Appendix)

Out-of-state resources by scenario

- **Full accounting of procurement cost and potential by Portfolio Content Category is beyond the scope of this analysis**
- **The following table shows % out-of-state resources (including Munis) for each scenario**
  - Due to potential for dynamic transfer under PCC1, scenarios modeled here may not require a change in PCC rules
  - ***No scenario selects <u>all</u> out-of-state resources***

		50% RPS Portfolio in 2030			
	33% Base Portfolio	Scenario 1a	Sensitivity 1b	Scenario 2	Scenario 3
% Out-of-State	19%	24%	21%	24%	33%
% In-State	81%	76%	79%	76%	67%

33% base portfolio for CAISO area

+ **All scenarios start with renewable resources under contract to meet a 33% RPS**
  - Base portfolio is drawn from CPUC RPS Calculator v6.1
+ **Base portfolio assumes CPUC storage mandate plus existing pumped storage**
+ **Base portfolio assumes 16,649 MW of behind-the-meter PV by 2030**
  - Based on IEPR forecast
  - Reduces sales but does qualify for RPS

CAISO Base Portfolio (MW)	
Renewables to meet 33% RPS in 2030	
	Scenarios 1 - 3
CAISO Solar	9,890
CAISO Wind	5,259
CAISO Geothermal	1,117
CAISO Small Hydro	429
CAISO Biomass	794
Northwest Wind	2,186
Northwest Biomass	1
Northwest Geothermal	32
Southwest Solar	197
Imperial Geothermal	449
Total CAISO Resources	17,489
Total Out-of-State Resources	2,417
Total Renewable Resources	20,354
Other Resources	
Energy Storage	3,157
Behind-the-meter Rooftop PV	16,649

Current Practice: Incremental Renewable Resource Portfolio Composition

	Current Practice	Regional 2	Regional 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	**7,601**		
California Wind	**3,000**		
California Geothermal	**500**		
Northwest Wind, Existing Transmission	**1,447**	562	318
Northwest Wind RECs	**1,000**	1,000	0
Utah Wind, Existing Transmission	**604**	604	420
Wyoming Wind, Existing Transmission	**500**	500	500
Wyoming Wind, New Transmission	**0**		
Southwest Solar, Existing Transmission	0		
Southwest Solar RECs	1,000	1,000	
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	11,101	10,204	5,840
Total Out-of-State Resources	5,551	5,166	7,694
Total Renewable Resources	**16,652**	**15,370**	**13,534**
Energy Storage (MW)	**972**	500	500

- **All available in-state wind resources are selected**
- **Nearly all available out-of-state resources are selected**
- **472 MW of additional battery storage selected**

Regional 2: Incremental Renewable Resource Portfolio Composition

- **Ability to export reduces curtailment; procurement of both in-state and out-of-state wind is avoided**

	Current Practice	Regional 2	Regional 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	**7,601**	**7,804**	3,440
California Wind	**3,000**	**1,900**	1,900
California Geothermal	**500**	**500**	500
Northwest Wind, Existing Transmission	**1,447**	**562**	318
Northwest Wind RECs	**1,000**	**1,000**	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	11,101	10,204	5,840
Total Out-of-State Resources	5,551	5,166	7,694
Total Renewable Resources	16,652	15,370	13,534
Energy Storage (MW)	972	500	500

- **1300 MW reduction in total procurement due to less curtailment**

Regional 3: Incremental Renewable Resource Portfolio Composition

	Current Practice	Regional 2	Regional 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	**7,601**	7,804	**3,440**
California Wind	**3,000**	1,900	**1,900**
California Geothermal	**500**		**500**
Northwest Wind, Existing Transmission	**1,447**		**318**
Northwest Wind RECs	**1,000**		**0**
Utah Wind, Existing Transmission	**604**		**420**
Wyoming Wind, Existing Transmission	**500**		**500**
Wyoming Wind, New Transmission	**0**		**1,995**
Southwest Solar, Existing Transmission	**0**		**500**
Southwest Solar RECs	**1,000**		**1,000**
New Mexico Wind, Existing Transmission	**1,000**	[illegible]	**1,000**
New Mexico Wind, New Transmission	**0**	0	**1,962**
Total CA Resources	11,101	10,204	5,840
Total Out-of-State Resources	5,551	5,166	7,694
Total Renewable Resources	16,652	15,370	13,534
Energy Storage (MW)	972	500	500

WY and NM wind displace California solar and lower-quality NW wind

- **3100 MW reduction in total procurement due to less curtailment**

A: High bilateral flexibility

- **Model selects a diverse portfolio of in-state solar and out-of-state wind across all cases**

	Scenario 1a	Sensitivity 1b	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000	8,000
Procurement	Current practice	Current practice	Current practice	WECC-wide
Operations	CAISO	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)				
California Solar	7,601	8,279	7,804	3,440
California Wind	3,000	3,000	1,900	1,900
California Geothermal	500	500	500	500
Northwest Wind, Existing Transmission	1,447	447	562	318
Northwest Wind RECs	1,000	0	1,000	0
Utah Wind, Existing Transmission	604	604	604	420
Wyoming Wind, Existing Transmission	500	500	500	500
Wyoming Wind, New Transmission	0	0	0	1,995
Southwest Solar, Existing Transmission	0	272	500	500
Southwest Solar RECs	1,000	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	0	1,962
Total CA Resources	11,101	11,779	10,204	5,840
Total Out-of-State Resources	5,551	3,823	5,166	7,694
Total Renewable Resources	**16,652**	**15,602**	**15,370**	**13,534**
Energy Storage (MW)	972	500	500	500

- **Portfolios shown are for California in 2030, incremental from 33% RPS in 2020; they include the handpicked muni portfolios**

B: High energy efficiency

Reduction in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	5,250	5,955	1,304
California Wind	3,000	1,900	1,480
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	1,144	447	318
Northwest Wind RECs	1,000	364	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	8,750	8,355	3,284
Total Out-of-State Resources	5,248	4,415	7,694
Total Renewable Resources	**13,998**	**12,770**	**10,978**
Energy Storage (MW)	888	500	500

Fewer central station resources needed, modest changes to portfolio composition

C. High flexible load deployment

Slight increase in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	8,501	8,593	3,630
California Wind	3,000	1,900	1,900
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	447	447	318
Northwest Wind RECs	1,000	455	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	12,001	10,993	6,030
Total Out-of-State Resources	4,551	4,506	7,694
Total Renewable Resources	**16,552**	**15,499**	**13,724**
Energy Storage (MW)	587	500	500

Very little battery storage selected

D. Low portfolio diversity

Significant increase in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	9,924	8,181	5,209
California Wind	2,000	2,000	1,500
California Geothermal	0	0	0
Northwest Wind, Existing Transmission	1,447	1,447	318
Northwest Wind RECs	1,000	1,000	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	500	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	11,924	10,181	6,709
Total Out-of-State Resources	6,051	6,051	7,694
Total Renewable Resources	**17,975**	**16,232**	**14,403**
Energy Storage (MW)	1,070	0	0

E. High rooftop PV

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	7,146	5,778	2,296
California Wind	3,000	1,900	1,900
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	1,447	1,447	318
Northwest Wind RECs	1,000	1,000	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	10,646	8,178	4,696
Total Out-of-State Resources	5,551	6,051	7,694
Total Renewable Resources	**16,197**	**14,229**	**12,390**
Energy Storage (MW)	1,547	500	500

Additional battery storage selected

Fewer central station resources needed, modest changes to portfolio composition

F. High Out of State Resource Availability

Reduction in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	5,724	5,337	1,304
California Wind	3,000	1,900	1,750
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	447	447	318
Northwest Wind RECs	0	0	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	4,279	4,279	3,188
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	9,224	7,737	3,554
Total Out-of-State Resources	6,830	7,330	9,882
Total Renewable Resources	**16,054**	**15,067**	**13,436**
Energy Storage (MW)	598	500	500

SW solar RECs selected but NW wind RECs are not

G. Low Cost Solar

Significant increase in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	9,729	9,016	4,056
California Wind	3,000	1,900	1,250
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	447	447	318
Northwest Wind RECs	344	0	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	1,995
Southwest Solar, Existing Transmission	0	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	13,229	11,416	5,806
Total Out-of-State Resources	3,895	4,051	7,694
Total Renewable Resources	**17,124**	**15,467**	**13,500**
Energy Storage (MW)	1,127	500	500

Significant reduction in NW wind procurement

H. 55% RPS

Significant increase in California solar procurement

	Scenario 1a	Scenario 2	Scenario 3
CAISO simultaneous export limit	2,000	8,000	8,000
Procurement	Current practice	Current practice	WECC-wide
Operations	CAISO	WECC-wide	WECC-wide
Portfolio Composition (MW)			
California Solar	12,214	9,701	5,616
California Wind	3,000	3,000	1,900
California Geothermal	500	500	500
Northwest Wind, Existing Transmission	1,447	1,447	318
Northwest Wind RECs	1,000	1,000	0
Utah Wind, Existing Transmission	604	604	420
Wyoming Wind, Existing Transmission	500	500	500
Wyoming Wind, New Transmission	0	0	3,123
Southwest Solar, Existing Transmission	500	500	500
Southwest Solar RECs	1,000	1,000	1,000
New Mexico Wind, Existing Transmission	1,000	1,000	1,000
New Mexico Wind, New Transmission	0	0	1,962
Total CA Resources	15,714	13,201	8,016
Total Out-of-State Resources	6,051	6,051	8,823
Total Renewable Resources	**21,765**	**19,252**	**16,839**
Energy Storage (MW)	1,809	500	500

Additional increment of WY wind procured

Appendix C

Load Diversity Benefits

Load Diversity Savings: 2020 Results (CAISO+PAC)

In California:

- Only the current CAISO is assumed to participate in the regional market in 2020
- $35/kW-year avoided capacity cost, reflecting average Resource Adequacy Requirement contract price for 2012–2016
- Regionalization will reduce capacity requirement for the CAISO by 184 MW, saving $6 million/year (with current transmission)

In the rest of the region:

- Only PacifiCorp is assumed to participate in 2020
- $0–$39/kW-year avoided capacity cost (higher value reflects average net new unit cost in PacifiCorp region)
- Reduces capacity requirement by 776 MW, saving up to $30 million/year (with current transmission)

2020 Load Diversity Benefit and Annual Capacity Cost Savings

	CAISO	PacifiCorp
Capacity Benefit of Load Diversity with Current Transmission	**184 MW** (0.39%)	**776 MW** (5.86%)
Additional Capacity Savings with Transmission Upgrades	-	392 MW (2.96%)
Value of Capacity Benefit with Current Transmission ($ millions/year)	**$6MM**	**$0–30MM**
Additional Value of Capacity Benefit with Transmission Upgrades ($ millions/year)	-	$0–15MM

Note: In 2016 dollars; savings with current transmission used as base study results.

Load Diversity Savings: Transmission Constraints

Potential savings are limited by transmission

- To achieve savings, capacity must be transferred on peak
- Transmission constraints limit these transfers

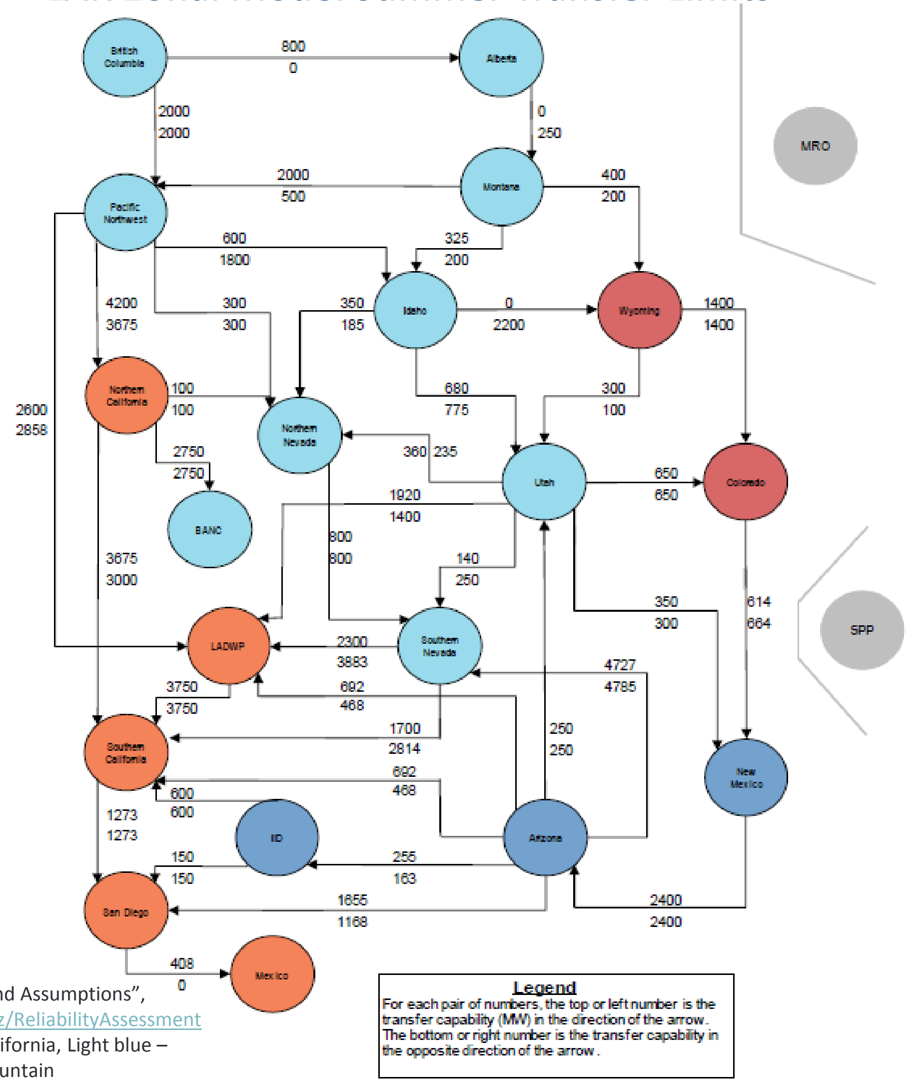
For 2020 PAC-ISO Scenario:

- ISO to PAC: 776 MW
- PAC to ISO: 982 MW

For 2030 Regional Scenarios: transfer capabilities from WECC LAR zonal model

- Provides summer and winter transfer limits between 19 zones in the WECC
  - Used the lower of the two seasonal limits, which usually occurs in the summer
- Relied on capacity of single largest intertie into each BA as very conservative proxy for simultaneous limit

LAR Zonal Model Summer Transfer Limits



Sources and Notes:
Table 4 of WECC, "Loads and Resources Methods and Assumptions", November 2015, Available at: https://www.wecc.biz/ReliabilityAssessment
Zone colors correspond to subregions: Orange – California, Light blue – Northwest, Dark blue – Southwest, Red – Rocky Mountain

Appendix D

GHG Emissions

Sensitivity Analysis: Carbon Price in Rest of WECC

Simulated 2030 scenarios with a carbon price in rest of WECC as proxy of CPP compliance:

- In 2030 Scenario 1A (without CO_2 pricing), CO_2 emissions are **23 million tonnes/year below 2020 emissions**
- CO_2 pricing in 2030 for the rest of WECC reduces WECC-wide emissions by an additional **5% or 16 million tonnes/year**
- Creation of an ISO-operated regional market further magnifies this CO_2 emission reduction by **10 million tonnes/year (or 3.6%)** WECC-wide
- Additional renewables in WECC assumed to be facilitated by the regional market contribute to this reduction of CO_2 emissions
- CO_2 emissions for serving CA load reduces by **4.7 million tonnes/year** (similar results as with no carbon price in rest of WECC)

Annual CO_2 Emissions With $15/Tonne in Rest of WECC

(million tonne/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3
WECC TOTAL	**291.2**	**280.6**
Impact of Regionalization		(10.6) (3.6%)
CA In-State	46.7	44.9
CA Imports Contracted	6.2	3.7
CA Imports Generic	1.4	1.2
CA Export Generic	(5.2)	(5.5)
CA Emissions for Load	**49.1**	**44.4**
Impact of Regionalization		(4.7) (9.6%)

Impact on GHG Emissions

Sensitivity Analysis: Impact of Renewables Beyond RPS

- Without the 5,000 MW of beyond-RPS wind assumed to be enabled by the regional market, CO_2 emissions are still estimated to be lower than under Current Practice
  - WECC-wide CO_2 emissions drop by 1.3 million tons (0.4%)
  - CO_2 emissions associated with serving California load decrease by 2.2 million tons (4.5%)
    - Slight increase of CO_2 emissions from in-state resources is more than offset by reduced emissions from contracted resources and credits for net exports

Annual CO_2 Emissions
(million tonne/yr)

	2030 Current Practice 1A	2030 Regional ISO Exp. 3	2030 Regional ISO Exp. 3
WECC TOTAL	**307.3**	**297.5**	**306.0**
Impact of Regionalization		(9.8) (3.2%)	(1.3) (0.4%)
CA In-State	46.2	43.3	46.5
CA Imports Contracted	6.2	3.3	4.5
CA Imports Generic	1.7	1.5	2.3
CA Exports Generic	(4.8)	(8.7)	(6.3)
CA Emissions for Load	**49.2**	**39.5**	**47.0**
Impact of Regionalization		(9.7) (19.8%)	(2.2) (4.5%)
		with 5 GW wind beyond RPS	without 5 GW wind beyond RPS

For a discussion of the how regional markets facilitate renewable developments and the reasonableness of the assumed 5,000 MW of additional wind, see Section 9 and Appendix B

Clean Power Plan (CPP) Compliance

- CPP only covers coal, natural gas CCs (existing or existing *plus* new), and some cogen facilities larger than 25 MW
- **California easily complies with CPP in all scenarios examined**
- Rest of WECC does not comply with no simulated CO_2 price despite significant coal retirements through 2030
- At a CO_2 price of $15/tonne, the emissions from rest of U.S. WECC would drop below CPP mass-based standards (for both existing only and existing *plus* new CC)
- Compliance with $15/tonne CO_2 price is greater with regional market, signifying **CPP compliance can be achieved at a lower cost with regional market**

Mass-Based CPP Standard

With and Without Covering New CC Units (million tonne/yr)

	2030 Mass-based Target	2030 CP1A	2030 CP1A $15 CO2	2030 Reg.3 $15 CO2
Existing Units				
California	**43.9**	**27.2**	**27.6**	**26.2**
Target – Simulated		*16.7*	*16.3*	*17.8*
Rest of WECC U.S.	**179.3**	**183.8**	**164.4**	**156.6**
Target – Simulated		*(4.5)*	*14.9*	*22.7*
Existing + New Units				
California	**47.9**	**27.6**	**28.0**	**26.6**
Target – Simulated		*20.4*	*19.9*	*21.3*
Rest of WECC U.S.	**191.3**	**201.8**	**185.6**	**179.1**
Target – Simulated		*(10.5)*	*5.8*	*12.2*

Appendix E

Renewable Generation Development Stimulated by Regional Markets

Renewable Development Beyond RPS

Regional markets facilitate the development and integration of low-cost renewable resources <u>beyond RPS requirements</u> through:

- Integrating into centralized unit commitment and dispatch that incorporates:
  - 5-minute real-time pricing for all energy generated by intermittent resources
  - Availability of ancillary service markets with lower-cost balancing options
  - Coordination of dispatch over a broader region with a more diverse set of resources
  - Fewer curtailments through improved utilization of transmission infrastructure
- Streamlined access to existing and new transmission to deliver low-cost renewables:
  - One-stop shopping for interconnection and transmission service requests
  - Improved regional transmission planning to provide access to low-cost regions
  - Easier contracting for load-serving entities (including coops/munis) and commercial/industrial customers who do not have transmission access to the low-cost renewable generation areas within the region
- Better financial and hedging options:
  - Day-ahead markets, congestion management, and financial hedging mechanisms
  - More transparent pricing and more competitive access to a larger regional market
  - Improved access to more liquid trading hubs offering financial hedges and forward contracting for full or partial merchant entry (e.g., prior to signing PPAs)

(See Volume XI of report for experience and magnitude in other markets)

Types of Additional Renewable Development

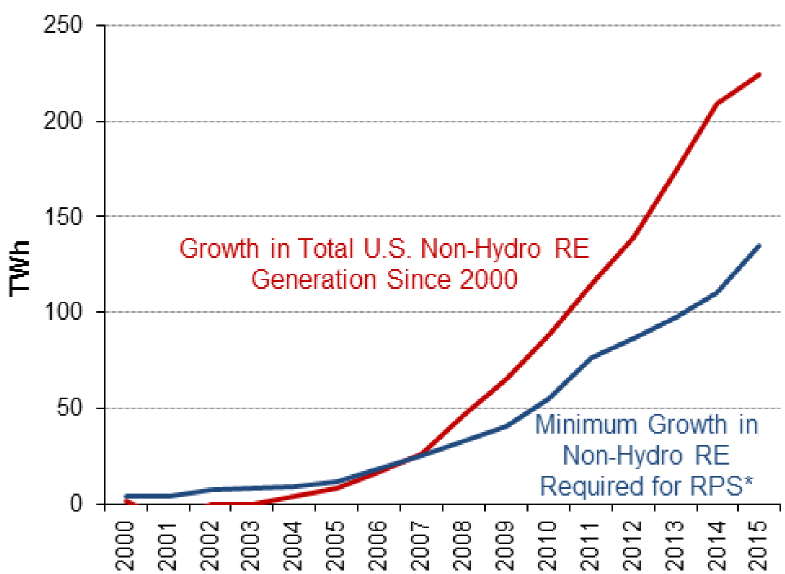
Based on the experience in other regional markets with low-cost renewable resources (ERCOT, MISO, SPP), renewable development beyond RPS comes in the form of:

1. **Voluntary utility/muni/coop purchases** due to low cost (e.g., $20–25/MWh with PTC) and fuel-cost hedge value
2. **Merchant renewable generation** developed with financial hedges
3. **Renewable PPAs with large C&I customers** that support investments beyond RPS

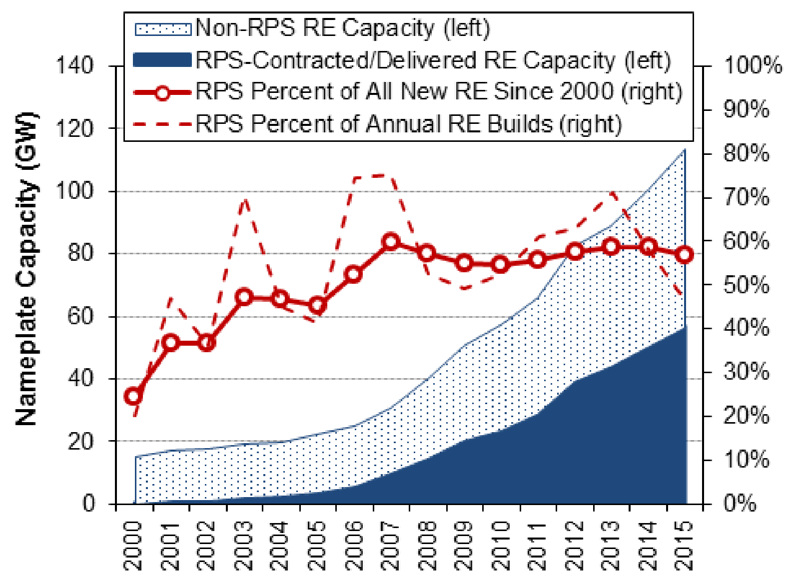
Actual Market-Based Renewable Additions beyond RPS

- Since 2006, RPS mandates account for only 50–60% of total (non-hydro) renewable generation development
  - Most of the approx. 50,000 MW of additions beyond RPS is wind in low-cost RTO/ISO regions
  - In MISO, SPP, and ERCOT, the incremental RPS demand is only 1,000 MW through 2030, while over 8,000 MW of renewable generation is already permitted or under construction today

RPS requirements comprised 60% of total growth in U.S. renewable electricity generation since 2000



More than half (57%) of all new renewable generation capacity is sold to entities with RPS obligations



BERKELEY LAB

Source: Barbose, Galen. 2016. "U.S. Renewables Portfolio Standards: 2016 Annual Status Report." Lawrence Berkeley National Laboratory. http://rps.lbl.gov

Actual Market-Based Renewable Additions Beyond RPS (cont'd)

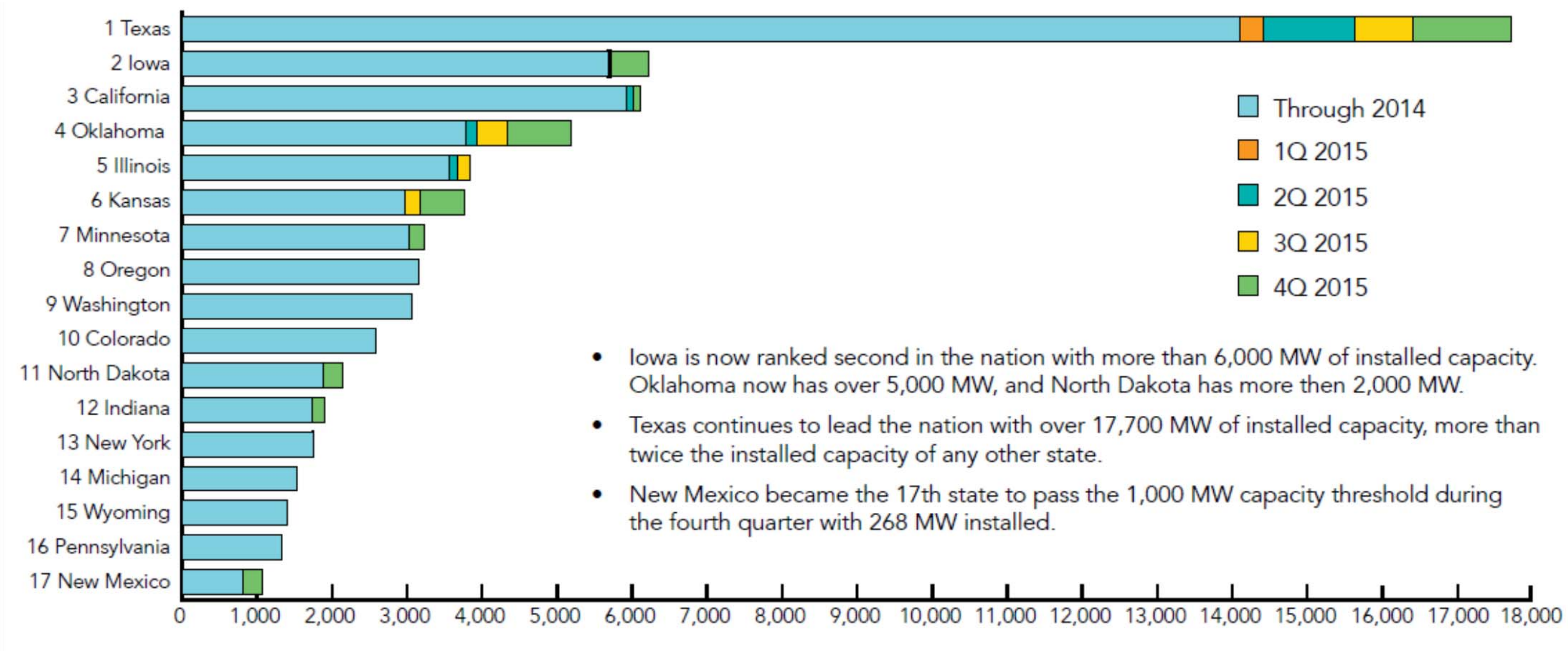
Data provided by the Lawrence Berkeley National Laboratory shows:*

- 44,000 MW of "non-RPS-related" renewable additions nationwide account for 44% of total renewable generation additions for 2000–2015 (59% in 2015)
  - 80% of these non-RPS-related renewable resource additions are wind generation
  - 77% of non-RPS-related renewable additions in 2000–2015 happened in seven states (TX, IA, OK, CA, KS, IL, IN) all of which have ISO-operated markets
  - In 2015, these seven states accounted for 88% of all non-RPS-related renewable additions
- 35,000 MW of non-RPS-related wind additions account for 49% of all wind additions in 2000–2015 (76% in 2015)
  - 80% of non-RPS-related wind additions for 2000-2015 happened in six states with ISO-operated markets (TX, IA, OK, KS, IL, IN)
  - In 2015, these six states accounted for 95% of all non-RPS-related wind additions
- Example Texas:
  - 72% of ERCOT's 17,600 MW of wind capacity installed by the end of 2015 was added beyond RPS mandates
  - 7,690 MW of these non-RPS-related wind plants have been added in the last 5 years
  - Transmission, improved wholesale market design, and liquid forward markets allowed ERCOT to attract over 1,400 MW of pure "merchant" wind projects in 2014**

* Source: Dr. Galen Barbose LBNL (2016). ** LBNL Wind Technology Report (2015)

States with Most Wind Additions are in ISO Markets

- The seven states with the highest total installed wind generating capacity (TX, IA, CA, OK, IL, KS, MN) are all located in areas with regional ISO markets*
- Highest 2015 additions in lowest-cost locations with ISO markets (e.g., TX, OK, KS, IA)



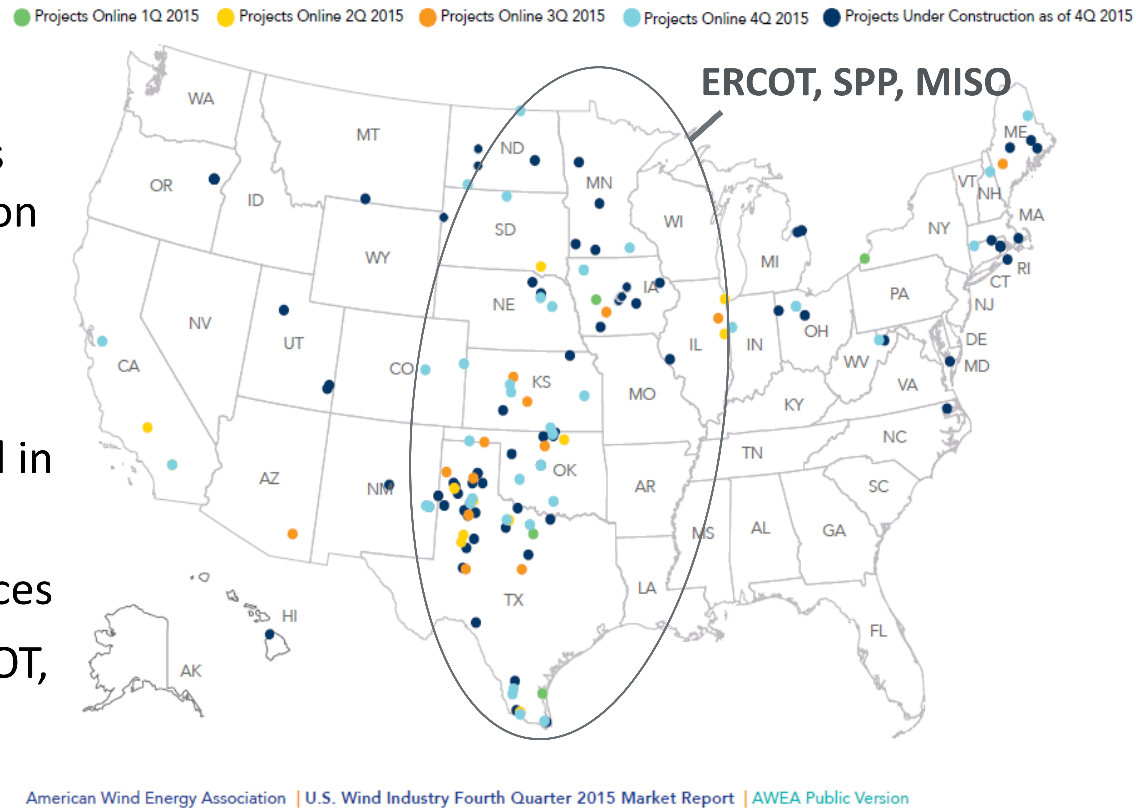
* Source: http://awea.files.cms-plus.com/FileDownloads/pdfs/4Q2015%20AWEA%20Market%20Report%20Public%20Version.pdf

2015 Wind Additions and Construction

Wind-rich areas with ISO markets show high market-based renewables development

- AWEA data shows that the majority of the 2015 additions and projects under construction (shown on this map) was not related to RPS requirements
- The map shows that most of these 2015 additions occurred in areas that offer both
  - Low-cost renewable resources
  - ISO-operated markets (ERCOT, SPP, MISO)
- Little market-based (non-RPS) development in WECC today

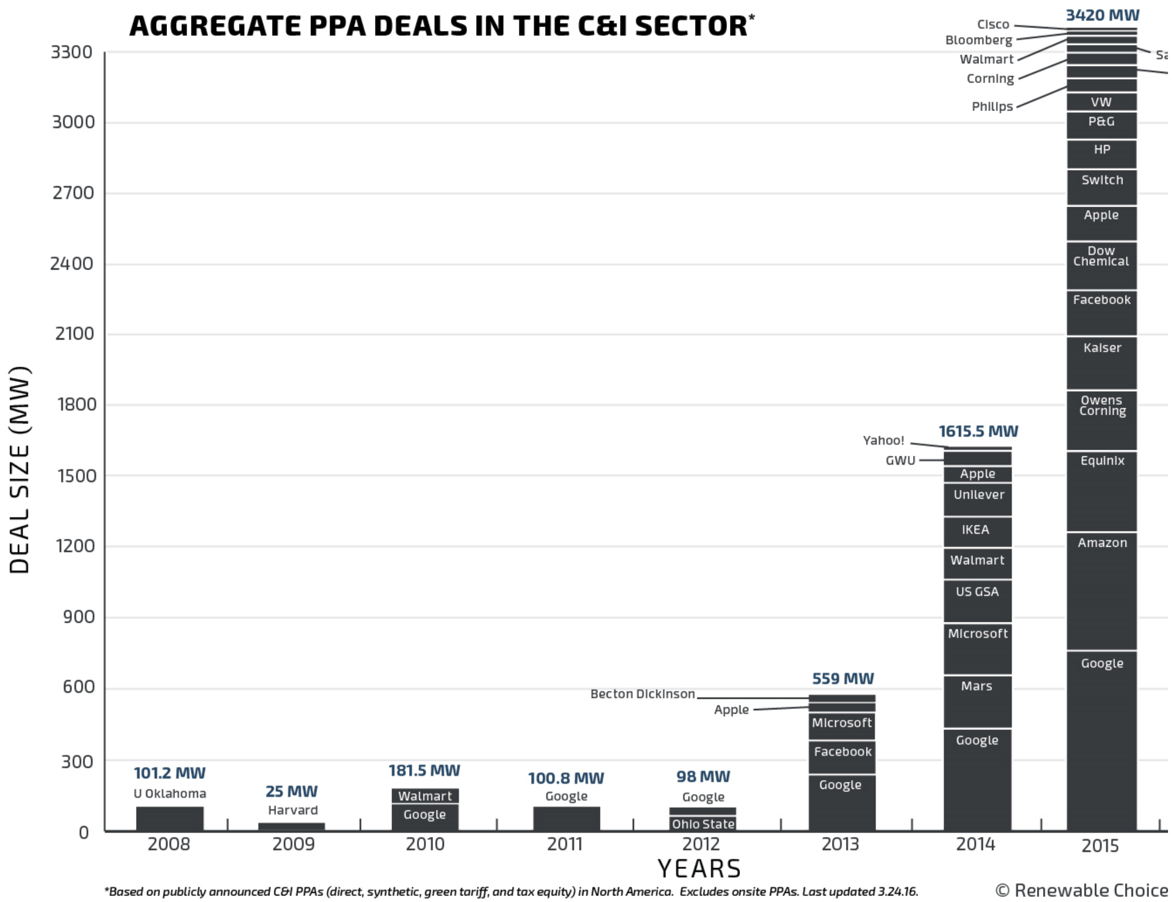
2015 Wind Generation Additions and Projects under Construction



* Source: http://awea.files.cms-plus.com/FileDownloads/pdfs/4Q2015%20AWEA%20Market%20Report%20Public%20Version.pdf

Renewable PPAs with Commercial/Industrial Customers

- In 2015, 3,420 MW of low-cost wind resources were developed through PPAs with large C/I customers (up from 1,615 MW in 2014 and 559 MW in 2013)*
  - These C/I contracts are greatly facilitated by regional ISO-operated markets**



* Source: http://www.renewablechoice.com/blog-corporate-energy-buyer/

** For a discussion see: http://www.renewablechoice.com/blog-electricity-corporate-ppa-buyers/

Factors Contributing to Increased Renewables Penetrations in ISO/RTOs

Main factors lead to increased support for renewables in ISO/RTO markets

Factor	Description
Improved Market Designs	• Increased granularity in time (5-minute) and location (nodal) improves price signals and stimulates efficient transmission and generation investment • Increased granularity increases the ability of prices to reflect avoided cost and improves dispatch of low carbon resources • ISO/RTO markets provide a mechanisms for non-transmission owners (such as most renewables developers) to hedge against congestion
Larger Markets	• The larger geographic reach of ISO/RTO markets allows the development of renewable resources in lower-cost locations • Allows a larger set of low-cost resources to provide balancing services for renewables • Large footprints of ISO/RTO markets reduce balancing costs by taking advantage of the diversity of renewables output • Liquidity of RTO spot markets further reduces the cost of addressing wind's variability and uncertainty compared to illiquid markets
Transparency, Open Access, and Fairness	• Fair, transparent pricing rules give confidence to investors • Markets reduce the potential for conflicts of interest in selecting new transmission projects and allocating the costs of these projects • ISO/RTOs help promote Open Access to transmission, which is particularly important to the largely independent producers who develop renewables

Studies of Markets Facilitating Renewables

Study	Finding
Brookings Clean Economy Study (2011)	• ISO/RTOs facilitate renewables through geographic diversity • ISO/RTOs also reduce barriers to expanding transmission capacity to allow additional renewables
AWEA Green Power Superhighways (2009)	• Markets that incentivize flexibility minimize the cost of integrating renewables • RTOs have been more effective in administering large balancing areas, using short scheduling intervals, and operating sophisticated energy markets
Hogan Markets In a Low Carbon Future (2010)	• Wind installations are disproportionately in RTO markets • Markets facilitate integration of low-carbon technology through improved granularity of pricing and dispatch
COMPETE Markets and Environmental Challenges (2014)	• Renewables developers are attracted to ISO/RTO markets due to transparency, fairness of rules, and geographic diversity
ISO/RTO Metrics Report (2015)	• ISO/RTOs facilitate renewables by establishing simple interconnection processes for new resources, providing access to spot markets, and allowing resources to take advantage of geographic diversity
IRC Increasing Renewables (2007)	• ISO/RTO markets facilitate renewables by having transparent pricing, highly granular dispatch, and geographic diversity

Appendix F

Reliability Impacts

Detail on Reliability Impacts

	Function	Western Interconnection Operations/Standard Practice	Regional Operations/ISO Practice
1	Locational 5-Minute Real-Time (and Hourly Day-Ahead) Price Signals	Bilateral markets achieve reliability based on contractual rights and industry standards with little guidance from locational prices or focus on economic impacts	• ISO enhances reliability by informing all market participants on the state of grid conditions and market operations through locational electricity prices and the day-ahead and real-time posting of other key system information • As a reflection of actual real-time (and projected day-ahead) system conditions, market prices in the ISO energy market provides specific locational signals where more (or less) generation is needed to maintain reliability
2	Congestion Management	• Performed using WECC Unscheduled Flow Mitigation Procedure or internally developed operating procedure based on congestion management system • 30 – 60 minute response time	• Market-based congestion management that relies on a five minute security constrained economic dispatch to mitigate transmission congestion on a least-cost basis allows for more timely and efficient congestion management • Look Ahead Commitment Tool provides unit commitments, de-commitments, online extension recommendations for congestion management, and models near-real-time conditions to utilize resource capabilities • Simultaneous feasibility tests performed to capture transmission security constraints in DA market processes, while Real-time contingency analysis of Energy Management System provides real-time security constraints for real-time clearing and pricing
3	Unscheduled Flow Management	• Unscheduled flows are managed sub-optimally on a limited set of qualified paths	• A regional integration allows congestion management to more effectively manage unscheduled flows in the entire grid and also solve the related congestion
4	Regional Unit Commitment	Decentralized unit commitment decisions without region-wide perspective and differing granularity can lead to inconsitencies and unintended reliability	Regional unit commitment to address footprint-wide reliability needs: • Advisory 2-day ahead process • Multi-day residual unit commitment (RUC) • Regional Reserve Requirements Calculation • Day-Ahead RUC • Intra-Day RUC

Detail on Reliability Impacts (cont'd)

	Function	Western Interconnection Operations/Standard Practice	Regional Operations/ISO Practice
5	Sytem Monitoring and Visualization	• Real-time monitoring using SCADA on a local area basis (Some has limited Real Time Contingency Analysis) • Use of standard vendor supplied displays • Operator interface of standard monitor display screen augmented with static map board (some has digital dynamic map board) • Ad-hoc and off-line voltage security analysis review	• Regional view/monitoring of the power system including: – A State Estimator - runs every 60 seconds – Contingency analysis of over 2000 contingencies every five minutes that is scallable to higher number of contingencies – 24-hour shift engineer coverage responsible for maintaining security application performance - Advanced real-time voltage stability and security application • Extended use of custom tools and displays to allow for faster analysis and better situational awareness • Large video wallboard (80 feet) that provides operators with live data reflecting the state of the power system and real-time market results • Real-time Voltage Stability Analysis Tool (VSAT) and Transmission Security Assessment Tool (TSAT), which allow comprehensive analyses of system operating conditions for predicting and preventing voltage insecurity and transient instability
6	Backup Capabilities	• Offline and/or scaled down backup facility • Significant time to bring backup facility up in the event a failover or failback is needed • Testing of failover process performed annually	• 24 x 7 staffed back-up control center • On-line back-up facility with full coverage of power system and market applications immediately available • Less than 30 minutes required for failover or failback for critical applications • Testing of failover process is performed quarterly for critical applications
7	Operator Training	• Classroom training only (some has limited simulators) • Train to meet minimum NERC requirements • Five-person rotation (no training rotation) and some has six person rotation • Offline power system restoration procedure review	• Training methods include extensive use of full-dispatch training simulator • Training exceeds NERC requirements • Six-person rotation at key operator positions (allowing a training week during each cycle) • Annually conduct a regional "live" power system restoration drill that includes dozens of companies in the region

Detail on Reliability Impacts (cont'd)

	Function	Western Interconnection Operations/Standard Practice	Regional Operations/ISO Practice
8	Performancve Monitoring	• Performance reviewed on a "post-event" basis • Operator call review on a "post-event" basis	• Daily review of operational performance including: – Frequent near-term performance feedback to operators and support personnel – Routine review of upcoming operational events • Standardized operator call review process • Feedback provided to each operator
9	Procedure Updates	• Procedures updated on an ad-hoc, as-needed basis	• Annual procedure review conducted on all control room procedures • Routine drills including member participation conducted on capacity emergency procedures • Annual Emergency Operating Procedures training session with members, neigboring entities, and reliability coordinator
10	Standards Development	• Utilities are varied in their approach to standards engagement. • Many are "standards takers," relying on the good judgment of others in the industry to develop standards	• By collaborating and participating in the standards creation, the ISO and its members can better manage the ultimate compliance responsibilities • ISO engages in several WECC/NERC drafting teams to actively manage the scope of standards development and to limit the number of changes required to MISO and stakeholders • ISO's integrated efforts lighten the workload on all members for a given level of input and control of the process
11	NERC Compliance	• Many parties in the WECC region are responsible for managing NERC compliance • 30+ Interchange Authorities, Transmission Service Providers, Balancing Authorities (BA) • Several Planning Authorities • Individual Reserve Sharing Groups	• With ISO as a regional balancing authority, many compliance responsibilities are consolidated (and member responsibilities decreased) • Single regional Transmission Service Provider • Significantly fewer BAs and related compliance requirements • Fewer Planning Authorities • Consolidated Reserve Sharing Administrator • Centralization of some Transmission Operator Requirements • Allows members to avoid hiring compliance-dedicated staff or reduce existing compliance-driven staff to track these compliance-related issues

Detail on Reliability Impacts (cont'd)

	Function	Western Interconnection Operations/Standard Practice	Regional Operations/ISO Practice
12	Regional Planning	• Planning by many individual utilities focused on local needs • Regional and interregional planning require complex coordination among many utilities and planning groups	• Single regional view and planning can address reliability needs more accurately and consistently • Offers opportunities to find most efficient solutions across multiple transmission owners
13	Fuel Diversity	• 38 WECC Balancing Areas with limited fuel diversity within many of the areas	• Regional market can mitigiate reliability risks associated with fuel supply risks (Gas, Hydro/Drought, Renewable Intermittency)
14	Long-Term Investment Signals	Bilateral markets provide less granular price signals which can result in less efficient investment and placement of generation resources and transmission infrastructure	Price signals sent by the ISO's market provides investors in generation assets with more economic signals upon which they can anchor their forecasts for future wholesale prices and provide the basis for market driven investments

Appendix G

Review of Other Market Integration Studies

Review of Market Integration Studies

We leveraged insights from relevant existing studies to inform the analysis and provide bookends to estimated impacts

Study Type	Examples of Studies
Day-2 Market Studies Evaluate benefits of moving from de-pancaked transmission and energy imbalance market to full Day-2 market	SPP IM Retrospective (2015), SPP IM Prospective (2009), Navigant Markets Study (2009), Chan Efficiency Study (2012), MISO Value Proposition (2015), MISO Retrospective Study (2009), Wolak Nodal Study (2011), NYISO Plant Efficiency Study (2009), ERCOT Nodal Study (2014)
RTO Participation Studies Evaluate benefits and costs to a utility of joining an existing RTO	E3 PAC Integration Study (2015), Basin/WAPA Study (2013), Entergy-MISO (2011), SPP/Entergy Cost-Benefit Analysis (2010), Mansur PJM Efficiency Study (2012)
Post Order 2000 Studies Benefit-cost studies of forming RTOs that followed issuance of FERC Order 2000 in late 1999	LBNL RTO Review Study (2005), RTO West Study (2002), National RTO Study (2002)
Energy Imbalance Market (EIM) Studies Evaluate the benefits of the Western EIM, or the benefits of a utility joining the EIM	WECC-Wide EIM (2011), APS-EIM (2015), PGE-EIM (2015), NV Energy-EIM (2014), Puget Sound-EIM (2014), PacifiCorp-EIM (2013)
European Market Integration Studies Evaluate the benefits of market integration in the European context	EPRG Integrating European Markets (2015), EU Single Market Study (2013)
WECC Renewable Integration Studies Studying the challenges of higher penetration of renewable resources	NREL/DOE WWSIS 2 (2013), NREL/DOE WWSIS 3 (2014), CEERT/NREL Low Carbon Grid Study (2016), CAISO/GE Stability Study (2011), WGA Least-Cost Integration (2012), SPP Renewable Integration (2016)
Markets and Merchant Renewables Studies Discussing the function of markets in facilitating renewables development	Brookings Clean Economy Study (2011), AWEA Green Power Superhighways (2009), Hogan Markets In a Low Carbon Future (2010), COMPETE Markets and Environmental Challenges (2014), ISO/RTO Metrics Report (2015), IRC Increasing Renewables Study (2007)

Findings from Other Regional Market Studies

Two general types of studies: Prospective and Retrospective Studies

- Most **prospective market integration studies estimated production cost savings from implementing regional energy markets at 1–3%** of total production costs (including when starting from EIM-type markets)
  - Studies generally evaluated Day-2 market features (day-ahead energy, real-time energy, and ancillary services markets) with full de-pancaking of transmission charges for all transactions (not just EIM)
  - Savings associated with unit commitment and day-ahead dispatch
- Most **prospective studies also emphasize their limitations**, which tend to not capture certain benefits and underestimate the overall benefits:
  - Studies generally analyze only <u>normal weather, hydrology, load, and generation</u> and do <u>not</u> consider the effects of <u>transmission outages</u>
  - Most studies do not assess benefit of improved <u>management of uncertainties</u> between day-ahead and real-time operations
  - Only some studies analyzed more efficient <u>utilization of the existing grid</u>
  - Only some studies assessed improvements in <u>generator efficiency and availability</u>

Findings from Other Regional Market Studies

- Most **retrospective studies of market integration benefits document higher benefits** than those estimated in prospective studies
  - Production cost savings of 2–8%
  - Higher impact confirms limitations of prospective studies
- In addition to production cost savings, **studies document that market integration can reduce investment costs** associated with:
  - Reduced need for generating capacity and associated investment costs
  - Improved access to lower-cost renewable resources and reduce the investment costs of meeting RPS goals
  - Reduced balancing resources to address variable renewable generation output

Overall Benefits Documented in Other Studies

Type of Benefit		Estimated Savings as % of Total Production Costs
Savings Captured by Real-Time Energy Imbalance Markets (similar to EIM)	[1]	0.1% – 1%
Other Production Cost Savings Estimated by Prospective Studies	[2]	0.9% – 2%
Total Production Cost Savings Estimated by Prospective Studies	**[3]**	**1% – 3%**
Plant Efficiency and Availability Improvement	[4]	2% – 3%
Additional Real-Time Savings (Considering Daily Uncertainties)	[5]	1% – 2%
Additional Operational Savings with High Renewables	[6]	0.1% – 1%
Total Additional Production Cost Savings Estimated by Some Studies	**[7]**	**3.1% – 6%**
Load Diversity Benefits (Generation Investment Cost Savings)	[8]	1% – 1.4%
Renewable Capacity Cost Savings	[9]	1% – 4%
Total Investment Cost Savings (Expressed as Equivalent to % of Production Costs)	**[10]**	**2% – 5.4%**
Total Overall Savings as Share of Total Production Costs	**[11]**	**6% – 13%**

[1]: Range from E3's utility-specific and WECC-wide EIM studies
[2] = [3] – [1] Includes benefits of Transmission Charge De-Pancaking and Day Ahead Markets in all studies, Ancillary Service Markets in some studies, and Full Real Time Benefits and Improved Transmission Utilization in some studies
[3]: Based on summary table for prospective studies (see Appendix)
[4]: Based on Chan et al. (2012)
[5]: Difference between savings in retrospective studies and sum of savings in prospective studies and efficiency and availability savings
[6]: Low end of range based on "Overgeneration Management" savings in PAC Integration study. High end based on savings of "Enhanced Flexibility" in high renewables scenario in NREL Low Carbon Grid study.
[7] = [4] + [5] + [6]
[8]: Low end of range based on the PAC Integration study. High end based on average of savings from the PAC Integration, National RTO, and Entergy/SPP MISO studies.
[9]: Based on reduced resource cost estimated in PAC Integration study.
[10] = [8] + [9]

The CEERT/NREL Low Carbon Grid Study (2016)

- NREL studied the impacts on the Western power grid and costs of California pursuing a goal of reducing 2030 CO_2 emissions from California's electric power sector by 50% relative to 2012 levels
  - Goal is reach a 2030 emission level of 48 million metric tons/year
  - The study found that a 50% CO_2 emissions reduction goal requires the development of 56% renewable generation, increased energy efficiency, and the retirement of all California-contracted (out of state) coal plants
  - Evaluated the production costs impacts of achieving this level of renewable generation development for (1) a "conventional flexibility" case reflecting current grid operating practices; and (2) a "enhanced flexibility" case based on operation and institutional that (similar to the flexibility provided by regional market) eliminates the need to physically import contracted resources and provides for higher operating flexibility
- Estimated production cost savings from enhanced trading and system flexibility:
  - 2030 WECC-wide production cost savings of $440-610 million/year (1.5-2.1% of total production costs) moving from conventional to partially/fully enhanced flexibility (see Appendix D)
  - $550 million/yr reduction in 2030 CA power production, purchase, and sales costs
  - Savings are much higher in scenarios with high penetration of renewables

Other Regional Market Impact Studies

Production Cost Savings Estimated by Prospective Studies

Market Design Features Captured in Production Cost Savings	National RTO (2002) [1]	LBNL Review (2005) [2]	RTO West (2002) [3]	SPP Prospective (2009) [4]	Basin/ WAPA (2013) [5]	Entergy SPP/MISO (2011) [6]	E3 PAC Integration (2015) [7]
Transmission Charge De-Pancaking	✓	✓	✓	✓	✓	✓	✓
Day-Ahead Market		✓		✓	✓	✓	✓
Full Real-Time Imbalance Market	✓	Varies	✓		✓	✓	Varies
Ancillary Services Market		Varies	✓	✓			Varies
Improved Transmission Utilization	✓	Varies	✓			✓	Varies
Generator Efficiency and Availability Improvements	✓	Varies					Varies
% Reduction in Total Production Costs	**0.3%–5%**	**<1% to 8%**	**Not Reported**	**1.3%–2.0%**	**0.9%–2.1%**	**3.4%–3.8%**	**1.6%–3.6%**

[1]: The range represents savings in the "Transmission Only" scenario (de-pancaked transmission charges and increased transmission capacity) on the low end and "RTO Policy" scenario (includes 6% efficiency and 2.5% availability improvement for fossil units) on the high end. This study used a single-stage dispatch model to estimate benefits. It did not model unit commitment.

[2]: This was a study review report. Studies in the review modeled different market designs. Inter-quartile range of reported savings was 1%–3%. Some of the reviewed studies reported other savings in addition to production cost (*e.g.*, congestion revenues).

[3]: Study did not provide baseline production costs, so % savings could not be calculated.

[4]: Total production cost savings over 2009–2016 time horizon with low end of range from across case I (DA market-only) and high end from case IIB (DA + AS markets).

[5]: WAPA 'Enhanced Adjusted Production Cost" savings of joining SPP as a percentage of "Standalone" LMP-based charges. Range reflects 2013–2020 savings.

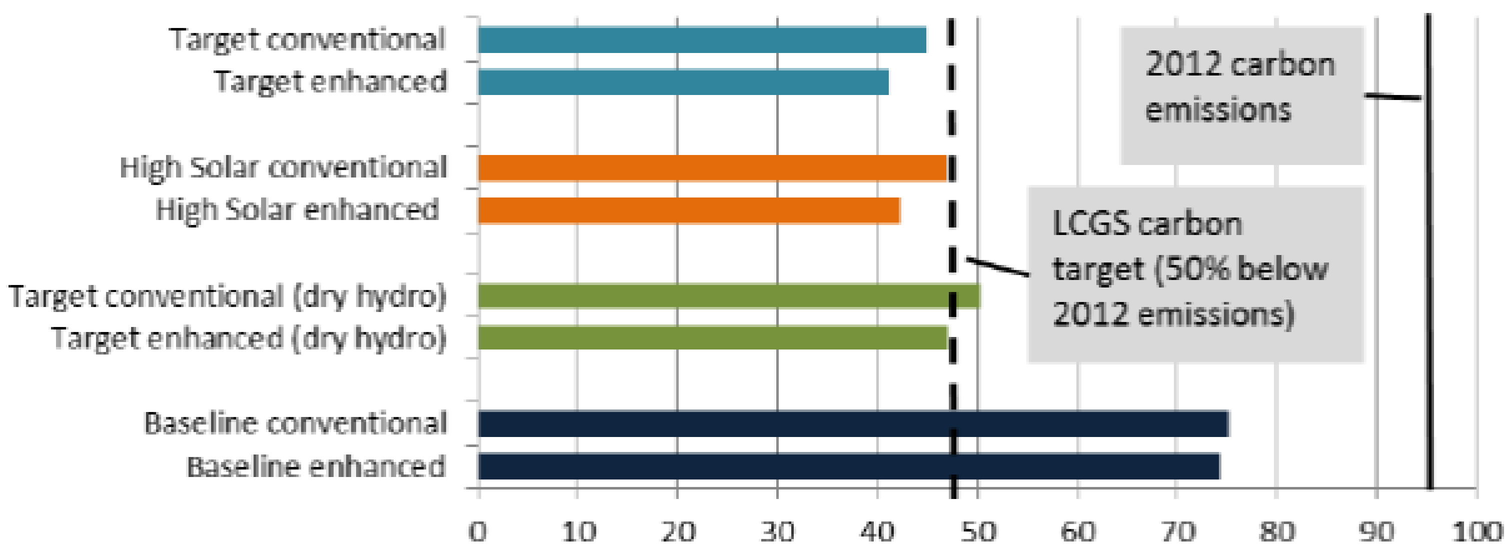
[6]: Range reflects Entergy adjusted production cost savings of joining SPP and MISO as estimated using production cost simulation. Savings do not include spinning and regulation reserve savings estimated using MISO's Value Proposition methodology.

[7]: This was a study review. Studies in the review modeled different market designs.

Emissions in CEERT/NREL Low Carbon Grid Study

The Low Carbon Grid Study also reports WECC-wide and CA GHG emissions for several study cases:

- 2030 "Baseline" cases with 33% CA RPS
- 2030 "Target" cases with 56% CA RPS (to yield a 50% emissions reduction)
- Cases with "Conventional" flexibility (as a proxy for current practices) and "Enhanced" flexibility (similar to the flexibility provided by a regional market)
- Additional sensitivity cases (Dry Hydro, High Solar, High WECC RPS)



Emissions in CEERT/NREL Low Carbon Grid Study

GHG emissions as reported in CEERT/NREL Low Carbon Grid Study

Table 10. Annual Carbon Accounting, in Million Metric Tons (MMT)

Scenario	CO_2 from CA gas generators	CO_2 assigned to imports and exports	CO_2 assigned to CA load	Change in assigned California CO_2 emissions compared to Baseline	Total* WECC CO_2 emissions	Change in WECC CO_2 emissions compared to Baseline
Baseline Enhanced	67.7	6.7	74.4	-	380.9	-
Baseline Conventional	68.9	6.3	75.2	0.8	381.0	0.2
Target Enhanced	43.7	-2.5	41.1	-33.2	345.1	-35.8
Target Conventional	48.9	-3.9	45.0	-29.4	349.3	-32.4

- Exports in this context include both net exports and specified imports that are not imported. This is zero-carbon energy that is sold out of state.
- Total WECC emissions not only include the western United States but also parts of Mexico and Canada (Alberta and British Columbia).
- Unspecified imports and exports are assumed to have a 0.432 MT/MWh carbon penalty (or credit). Unspecified imports from the Northwest have a penalty of 20% of 0.432 MT/MWh, which is consistent with the California Air Resources Board 2012 assumptions (CARB 2014) and the California ISO LTPP modeling (Liu 2014). CARB uses 0.022 MT/MWh for data year 2015.

* Coal plant retirements as reported in TEPPC 2022 Common Case plus Intermountain

Load Diversity Benefits

Several other studies estimated load diversity capacity savings in the range of 0.6–8% of peak load

- MISO and Entergy confirmed 6–7% capacity savings in their retrospective analyses[1,4]
  - Confirms estimates for capacity savings made in prospective studies
- PAC Integration also accounted for transmission limitations

Load Diversity Capacity Savings in Other Studies

Study	Reported Capacity Reduction (% of Peak Load)	Note
MISO 2015 Value Proposition[1]	**6%–7%**	Capacity savings to all MISO members of participating in the RTO market
Entergy SPP/MISO (2011)[2]	**6%**	Capacity savings to Entergy of joining MISO
E3 PAC Integration (2015)[3]	**0.6% (ISO)** **8% (PAC)**	Capacity savings with an integrated market consisting of the California ISO (ISO) and PacifiCorp (PAC)

Sources and Notes:

1. MISO, "2015 Value Proposition Stakeholder Review Meeting," January 21, 2016, Available at: https://www.misoenergy.org/WhatWeDo/ValueProposition
2. Entergy, "An Evaluation of the Alternative Transmission Arrangements Available to the Entergy Operating Companies And Support for Proposal to Join MISO," May 12, 2011, Available at: http://lpscstar.louisiana.gov/star/ViewFile.aspx?Id=bc5c1788-4ce0-4daa-9ad0-71f09ad43643
3. Energy + Environmental Economics (E3), "Regional Coordination in the West: Benefits of PacifiCorp and California ISO Integration," October 2015, Available at: http://www.caiso.com/informed/Pages/RegionalEnergyMarket/BenefitsofaRegionalEnergyMarket.aspx
4. Entergy, "Estimate of MISO Savings," Presented by: Entergy Operating Companies, August 2015, Available at: https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/ICT%20Materials/ERSC/2015/20150811/20150811%20ERSC%20Item%2006%20Benefits%20of%20MISO%20Membership.pdf

Appendix H

Environmental Study Details

Land Use and Acreage Required

Summary of Environmental Study Key Findings			
Study Topic	**2020 CAISO + PAC Relative to Current Practice**	**2030 Regional 2 Relative to Current Practice Scenario 1**	**2030 Regional 3 Relative to Current Practice Scenario 1**
Land Use and Acreage Required in California	No change	• Comparable impacts for solar • More solar acreage (+1,400 ac) • Fewer impacts for wind • Less wind acreage (–44,000 ac)	• Fewest impacts for solar • Lowest solar acreage (–29,100 ac) • Fewer impacts for wind • Less wind acreage (–44,000 ac)
Land Use and Acreage Required Outside California	No change	• More solar acreage (+3,500 ac) • Impacts substantially similar except fewer impacts in Northwest (wind) • Lowest wind acreage for RPS (–35,400 ac) • Facilitates development beyond RPS (+200,000 ac, wind)	• More solar acreage (+3,500 ac) • Impacts increase in Wyoming, New Mexico • Fewest impacts in Northwest and Utah (wind) • Most wind acreage for RPS (+65,800 ac) • Adds acreage for out-of-state transmission for California RPS • Facilitates development beyond RPS (+200,000 ac, wind)

Biological Resources

Summary of Environmental Study Key Findings

Study Topic	2020 CAISO + PAC Relative to Current Practice	2030 Regional 2 Relative to Current Practice Scenario 1	2030 Regional 3 Relative to Current Practice Scenario 1
Biological Resources in California	No change	• Impacts slightly increased from solar • Fewer impacts from wind	• Fewest impacts from solar • Fewer impacts from wind
Biological Resources Outside California	No change	• Increased avian mortality due to wind beyond RPS	• Fewest impacts in Northwest and Utah (wind) • Most avian mortality for wind beyond RPS plus RPS portfolio wind • Adds impacts of out-of-state transmission for California RPS

Water Use

Summary of Environmental Study Key Findings

Study Topic	2020 CAISO + PAC Relative to Current Practice	2030 Regional 2 Relative to Current Practice Scenario 1	2030 Regional 3 Relative to Current Practice Scenario 1
Water in California	• Slight decrease in water used for operation of generators	• Less water used during construction in high risk water areas • Less water used for operation of generators	• Least water used during construction in high risk water areas • Least water used for operation of generators
Water Outside California	• Slight increase in water used for operation of generators	• More water used during construction in high risk water areas • Least water used for operation of generators	• Most water used during construction in high risk water areas • Less water used for operation of generators

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Air Emissions and Disadvantaged Communities

Summary of Environmental Study Key Findings

Study Topic	2020 CAISO + PAC Relative to Current Practice	2030 Regional 2 Relative to Current Practice Scenario 1	2030 Regional 3 Relative to Current Practice Scenario 1
Air Emissions Changes in California	• Slight decrease in emissions	• Lower emissions of NOx (–6.5%) • Lower emissions of PM2.5 and SO_2 (–4.0%)	• Lowest emissions of NOx (–10.2%) • Lowest emissions of PM2.5 and SO_2 • (–6.8%)
Air Emissions Changes Outside California	• Slight increase in emissions	• Lowest emissions of NOx (–1.9%) • Lowest emissions of SO_2 (–0.9%)	• Lower emissions of NOx (–1.3%) • Lower emissions of SO_2 (–0.2%)
Environmental Impacts on Disadvantaged Communities in California	• No incremental buildout. • Decrease in the power sector's use of water (–1.5%) • Lower NOx; slightly higher PM2.5 and SO_2 (some areas)	• Fewer community-scale impacts from renewable buildout in California • Lower emissions from California power plants in air basins of greatest concern	• Fewest community-scale impacts from renewable buildout in California • Lowest emissions from California power plants in air basins of greatest concern

Air Emissions Details:

NOx from California fleet decreases overall in 2020 and 2030

Modeled NOx Emissions Rates, California Natural Gas Fleet by Air Basin					
Air Basin	**2020 Current Practice (tons/day)**	**2020 CAISO + PAC (tons/day)**	**2030 Current Practice 1 (tons/day)**	**2030 Regional 2 (tons/day)**	**2030 Regional 3 (tons/day)**
Mojave Desert	0.74	0.74	0.55	0.46	0.40
North Central Coast	0.41	0.41	0.47	0.46	0.46
North Coast	0.22	0.22	0.21	0.22	0.21
Sacramento Valley	1.30	1.27	1.35	1.21	1.13
Salton Sea	0.06	0.05	0.10	0.00	0.00
San Diego County	0.49	0.46	0.48	0.36	0.35
San Francisco Bay	2.63	2.58	2.75	2.67	2.51
San Joaquin Valley	6.46	6.43	6.44	6.22	6.06
South Central Coast	0.20	0.20	0.20	0.19	0.19
South Coast	2.74	2.70	2.67	2.42	2.33
Statewide Total	**15.24**	**15.06**	**15.21**	**14.23**	**13.66**
(% of All CA Sources)	*1.0%*	*1.0%*	*1.2%*	*1.2%*	*1.1%*
Impact of Regionalization		**–0.18**		**–0.99**	**–1.56**
(Relative to Current Practice)		*–1.2%*		*–6.5%*	*–10.2%*
Difference from 2020 Current Practice			**–0.03**	**–1.01**	**–1.58**
(Relative to 2020)			*–0.2%*	*–6.6%*	*–10.4%*

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Air Emissions Details:

PM2.5 from California fleet decreases overall, although dispatch modeling shows some air basins increase slightly

Modeled PM2.5 Emissions Rates, California Natural Gas Fleet by Air Basin

Air Basin	**2020 Current Practice (tons/day)**	**2020 CAISO + PAC (tons/day)**	**2030 Current Practice 1 (tons/day)**	**2030 Regional 2 (tons/day)**	**2030 Regional 3 (tons/day)**
Mojave Desert	0.45	0.46	0.26	0.22	0.20
North Central Coast	0.24	0.24	0.25	0.25	0.25
North Coast	0.03	0.03	0.03	0.03	0.03
Sacramento Valley	0.88	0.87	0.80	0.74	0.70
Salton Sea	0.02	0.02	0.02	0.00	0.00
San Diego County	0.31	0.29	0.26	0.22	0.21
San Francisco Bay	1.64	1.61	1.45	1.52	1.46
San Joaquin Valley	2.60	2.61	2.28	2.24	2.20
South Central Coast	0.16	0.16	0.16	0.16	0.16
South Coast	1.45	1.46	1.31	1.19	1.15
Statewide Total	**7.78**	**7.75**	**6.82**	**6.55**	**6.36**
(% of All CA Sources)	*1.9%*	*1.9%*	*1.6%*	*1.5%*	*1.5%*
Impact of Regionalization		**–0.04**		**–0.27**	**–0.47**
(Relative to Current Practice)		*–0.5%*		*–4.0%*	*–6.8%*
Difference from 2020 Current Practice			**–0.96**	**–1.24**	**–1.43**
(Relative to 2020)			*–12.4%*	*–15.9%*	*–18.4%*

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Air Emissions Details:

SO_2 from California fleet decreases overall, although dispatch modeling shows some air basins increase, as with PM2.5

Modeled SO_2 Emissions Rates, California Natural Gas Fleet by Air Basin

Air Basin	2020 Current Practice (tons/day)	2020 CAISO + PAC (tons/day)	2030 Current Practice 1 (tons/day)	2030 Regional 2 (tons/day)	2030 Regional 3 (tons/day)
Mojave Desert	0.05	0.05	0.03	0.02	0.02
North Central Coast	0.03	0.03	0.03	0.03	0.03
North Coast	0.00	0.00	0.00	0.00	0.00
Sacramento Valley	0.09	0.09	0.09	0.08	0.07
Salton Sea	0.00	0.00	0.00	0.00	0.00
San Diego County	0.03	0.03	0.03	0.02	0.02
San Francisco Bay	0.17	0.17	0.15	0.16	0.15
San Joaquin Valley	0.28	0.28	0.24	0.24	0.23
South Central Coast	0.02	0.02	0.02	0.02	0.02
South Coast	0.15	0.15	0.14	0.13	0.12
Statewide Total	**0.82**	**0.82**	**0.72**	**0.69**	**0.67**
(% of All CA Sources)	*1.0%*	*1.0%*	*0.8%*	*0.7%*	*0.7%*
Impact of Regionalization		**0.00**		**–0.03**	**–0.05**
(Relative to Current Practice)		*–0.5%*		*–4.0%*	*–6.8%*
Difference from 2020 Current Practice			**–0.10**	**–0.13**	**–0.15**
(Relative to 2020)			*–12.4%*	*–15.9%*	*–18.4%*

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Appendix I

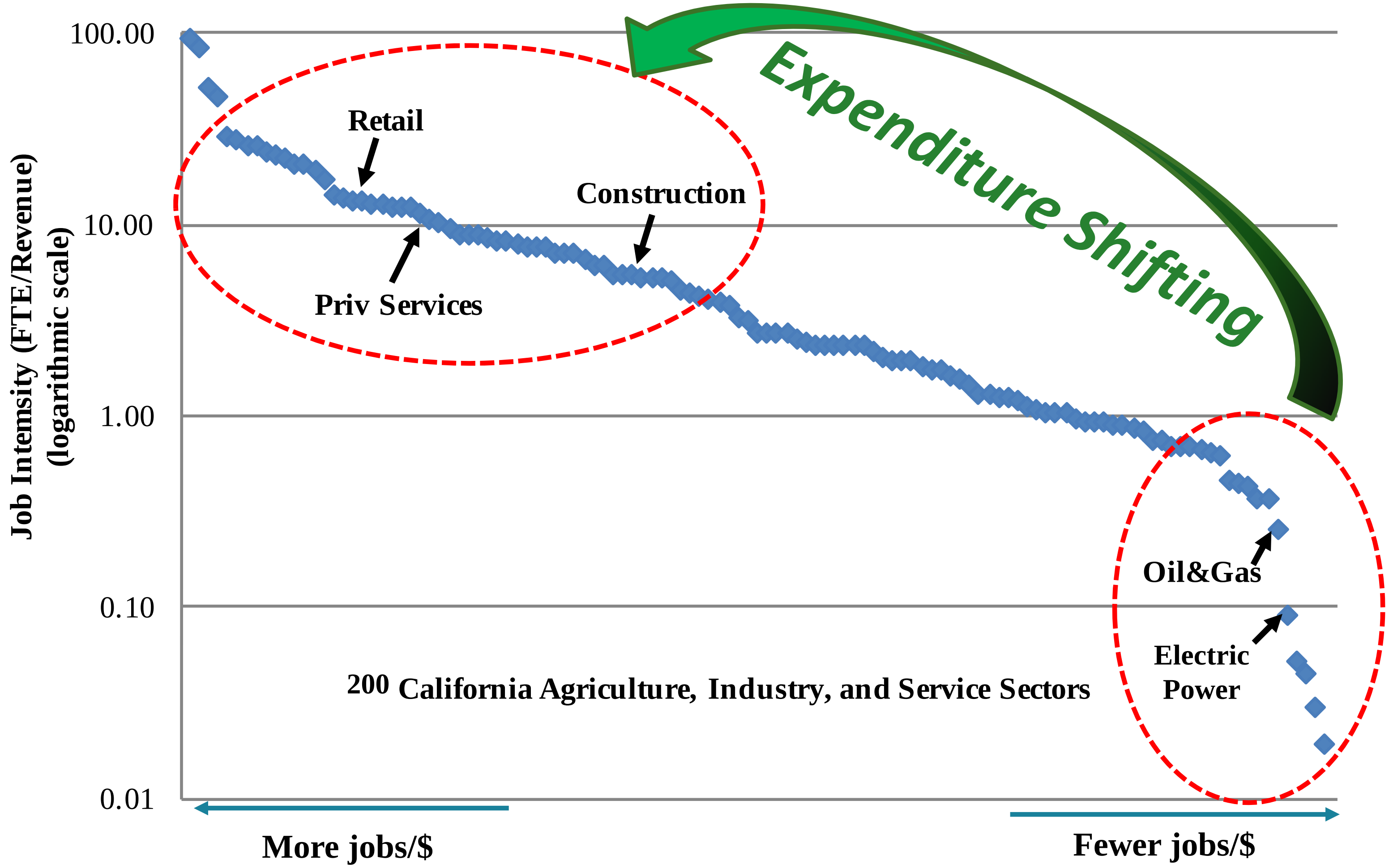
Economic Assessment

Appendix H:
Economic Assessment

A Few Economic Principles

1. Infrastructure investment creates short-term employment.
2. Capacity investment creates short and long term jobs, depending on import content of renewable technology and O&M budgets.
3. Expenditure Shifting: Demand funded by energy savings is a potent and pervasive source of long term, diverse job creation. These jobs are more likely to be for instate services that cannot be outsourced

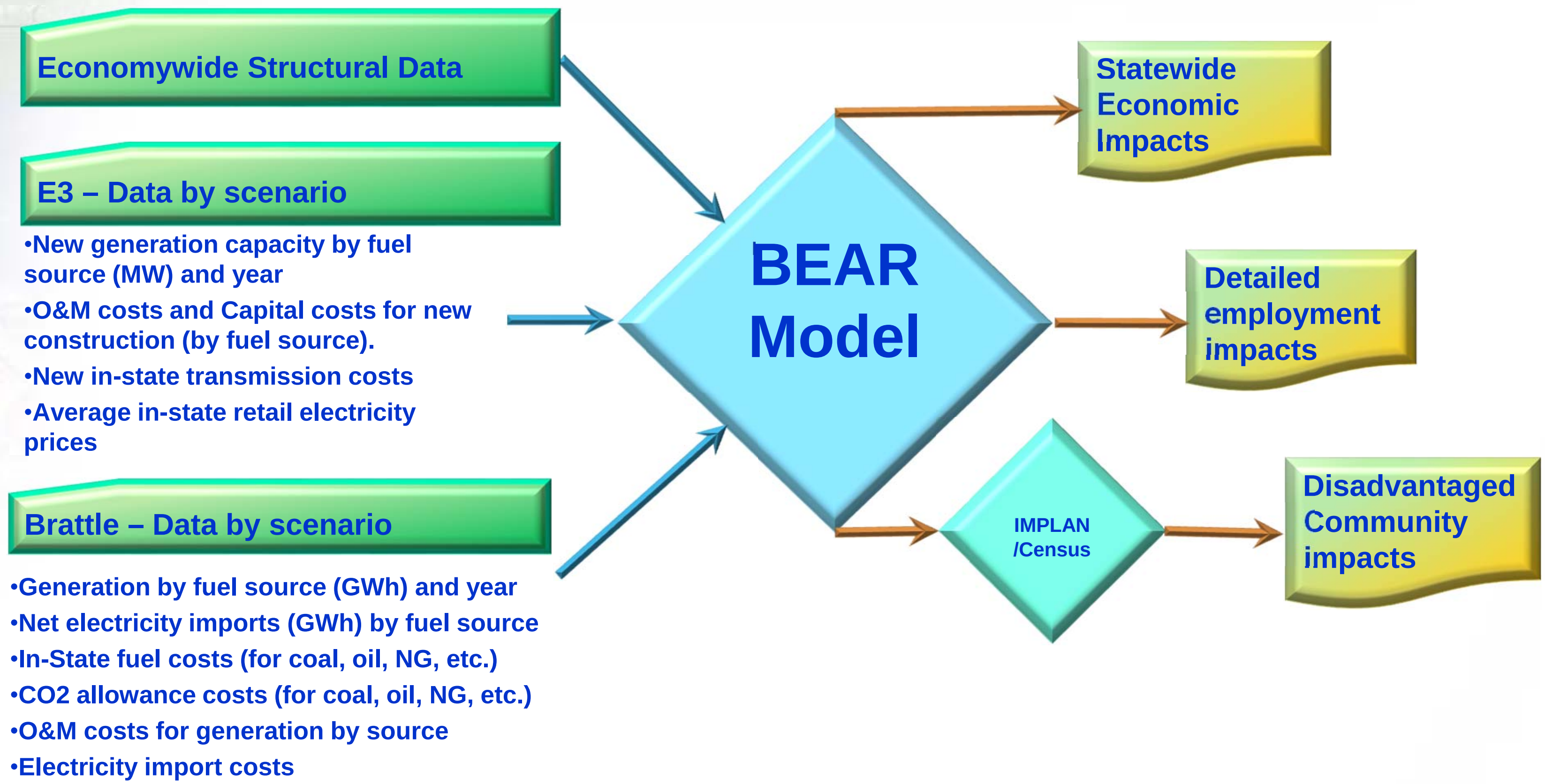
How Energy Savings Create Jobs



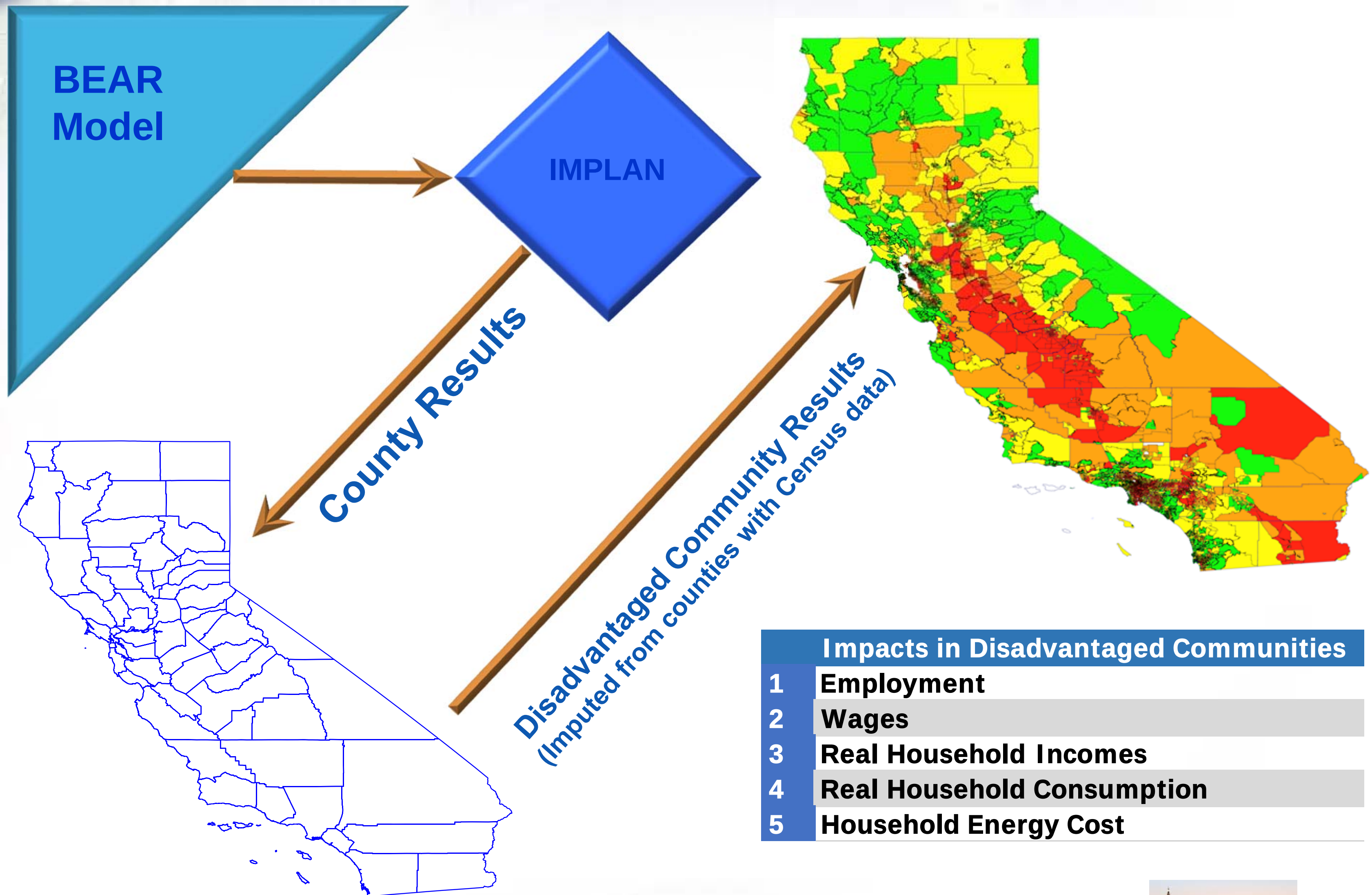
Forecasting Model: General Features

- A state economy model
  - California's economic structure is unique
  - Our stakeholders need clear information on the adjustment process
  - National and regional assessments can mask extensive interstate and regional spillovers and trade-offs
- A dynamic general equilibrium model
  - Traces pathways of growth and job creation
  - Captures detailed interactions and linkages across markets and between institutions
  - Captures extensive direct, indirect, and induced impacts
  - Evaluates policies ex ante, identifying benefits and adjustment needs to facilitate dialog and implementation

Economic Assessment Framework



Detailed Livelihoods Impacts



	Impacts in Disadvantaged Communities
1	Employment
2	Wages
3	Real Household Incomes
4	Real Household Consumption
5	Household Energy Cost

25 July 2016

Economic Data for California, 2013

- 200 production activities
- 200 commodities (includes trade and transport margins)
- 24 factors of production
  - 22 labor categories
  - Capital
  - Land
- 10 Household income groups
- Enterprises
- Federal Government (7 fiscal accounts)
- State Government (27 fiscal accounts)
- Local Government (11 fiscal accounts)
- Consolidated capital account
- External Trade Accounts
  - Rest of United States
  - Rest of the World

Detailed Occupational Analysis

The BEAR Model tracks employment by sector (200) and by 9, 22, or 95 occupations

1. Management occupations
2. Business and financial operations occupations
3. Computer and mathematical science occupations
4. Architecture and engineering occupations
5. Life, physical, and social science occupations
6. Community and social services occupations
7. Legal occupations
8. Education, training, and library occupations
9. Arts, design, entertainment, sports, and media occupations
10. Healthcare practitioners and technical occupations
11. Healthcare support occupations
12. Protective service occupations
13. Food preparation and serving related occupations
14. Building and grounds cleaning and maintenance occupations
15. Personal care and service occupations
16. Sales and related occupations
17. Office and administrative support occupations
18. Farming, fishing, and forestry occupations
19. Construction and extraction occupations
20. Installation, maintenance, and repair occupations
21. Production occupations
22. Transportation and material moving occupations

DC Regions Studied in Detail

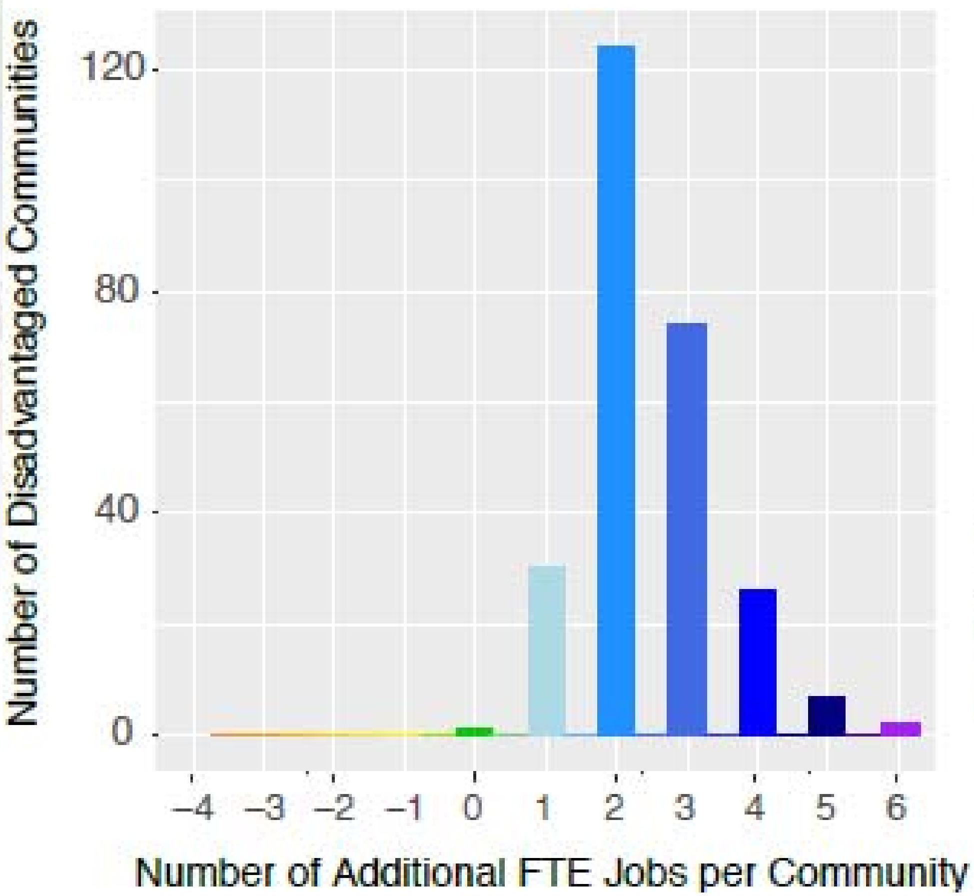
Regions	Counties within Region	% of DC's
San Diego and Imperial	San Diego, Imperial	2%
Inland Valley	San Bernardino, Riverside	13%
Los Angeles	Los Angeles, Ventura, Orange	56%
Central Coast	Monterey, San Luis Obispo, Santa Barbara, Santa Cruz, San Benito	<1%
Bay Area	San Francisco, Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo	4%
Sacramento	El Dorado, Placer, Sacramento, Yolo, Sutter, Yuba	2.5%
North State	Del Norte, Siskiyou, Modoc, Humboldt, Trinity, Shasta, Lassen, Tehama, Plumas, Sierra, Nevada, Butte, Glenn, Colusa, Lake, Mendocino	<1%
Central Valley	San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, Kern, Mariposa, Tuolumne, Calaveras, Amador	22%
Southern Sierra	Alpine, Mono, Inyo	None

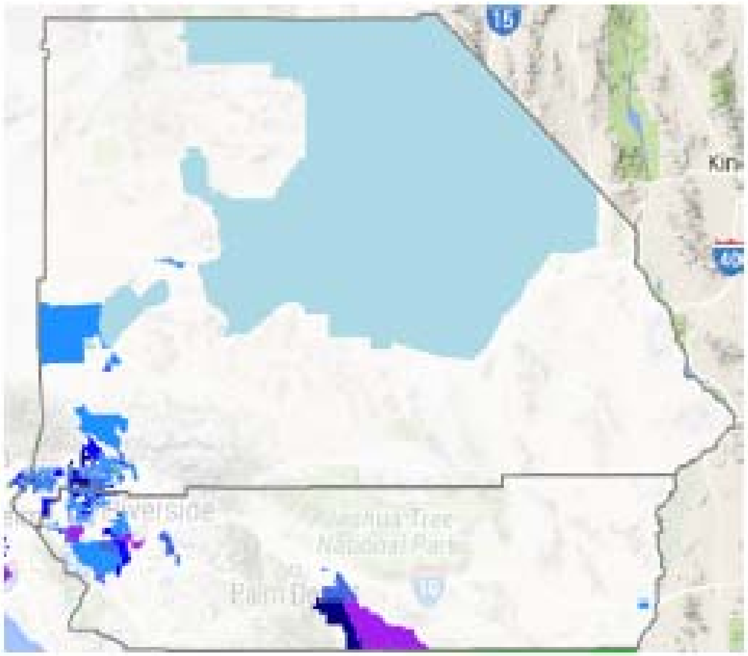
Inland Valley

- 11.4% of state population
- 6.6% unemployment rate
- Average household Income = $71,867
- 265 disadvantaged communities (13% of state total)

Inland Valley

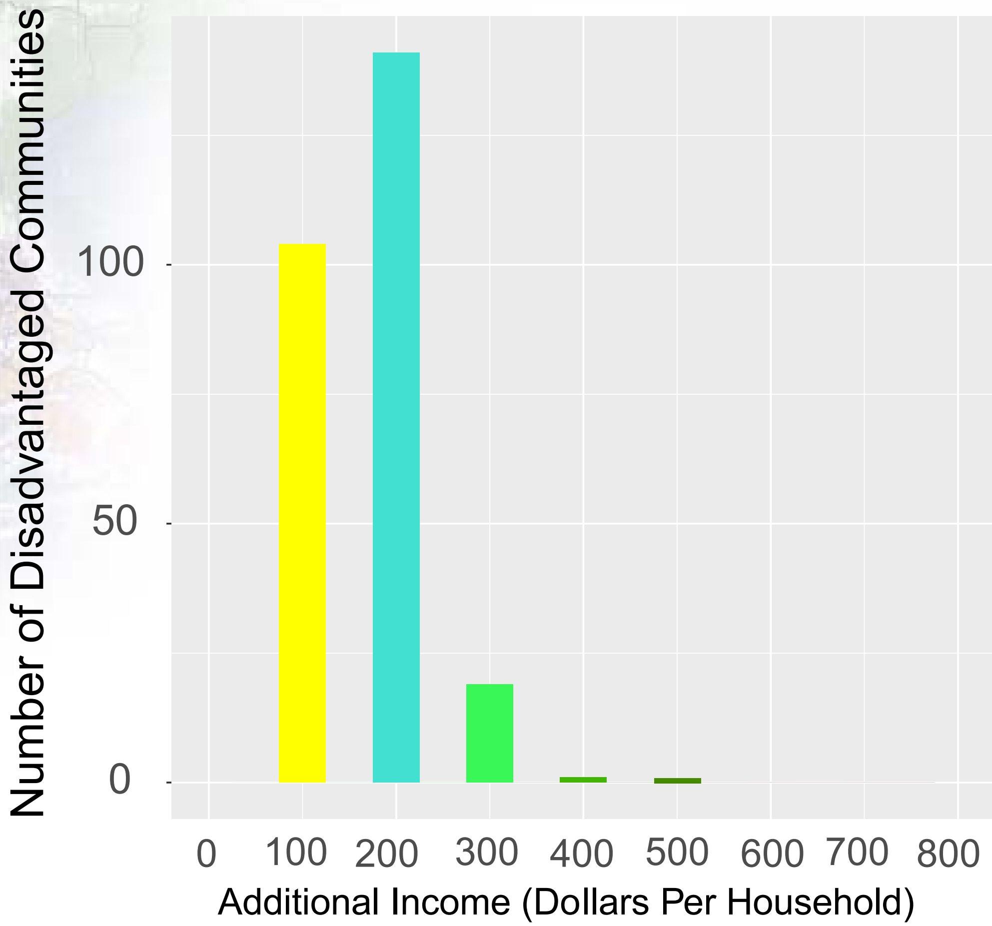
Difference in Jobs Created, (R2-CP)

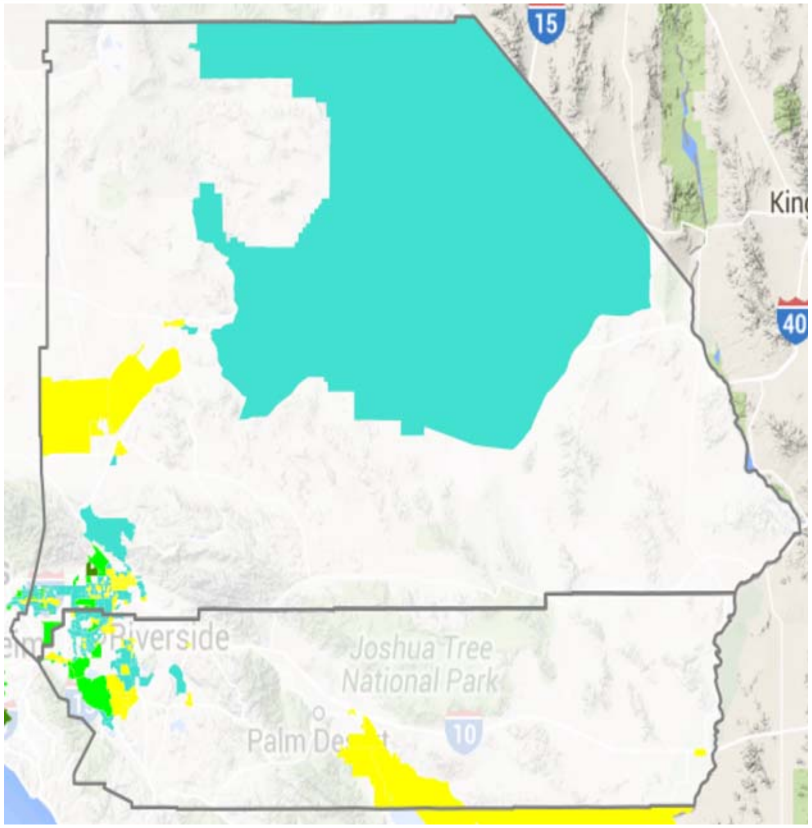




Inland Valley

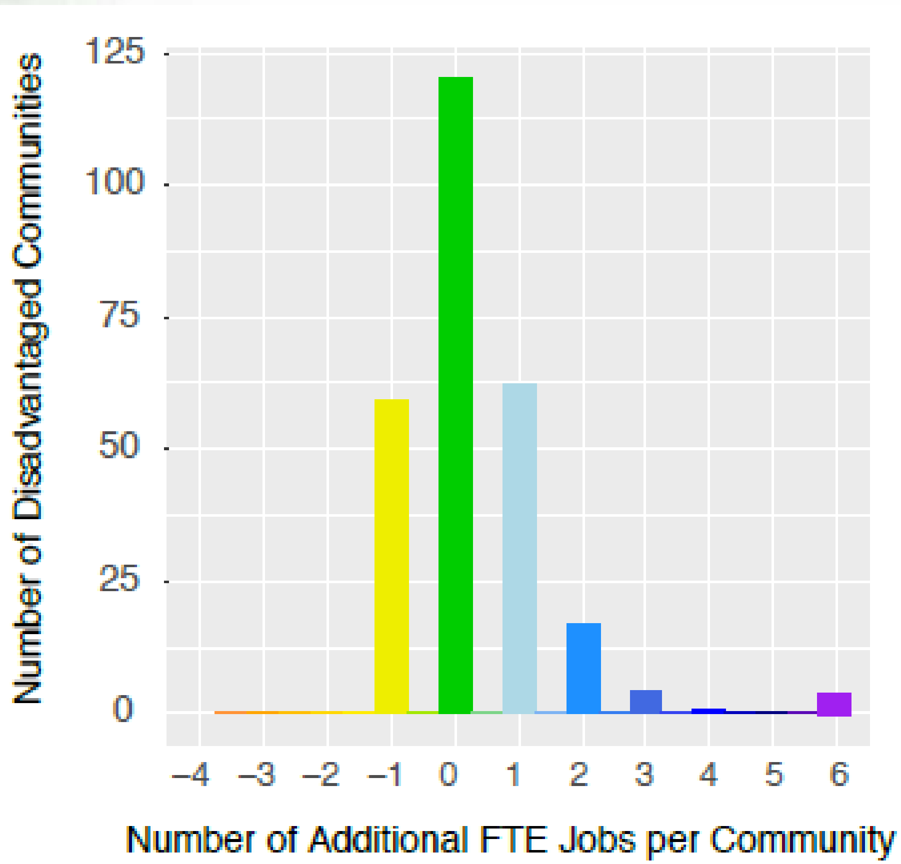
Difference in Income ($/hh), (R2-CP)

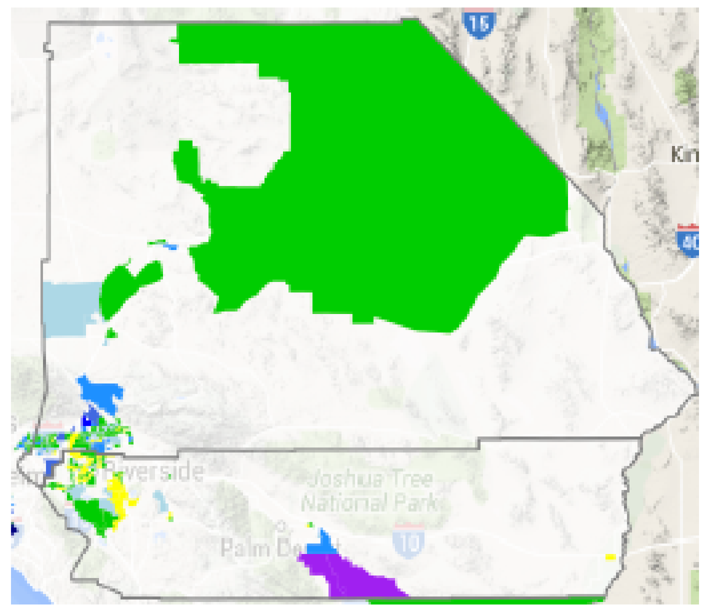




Inland Valley

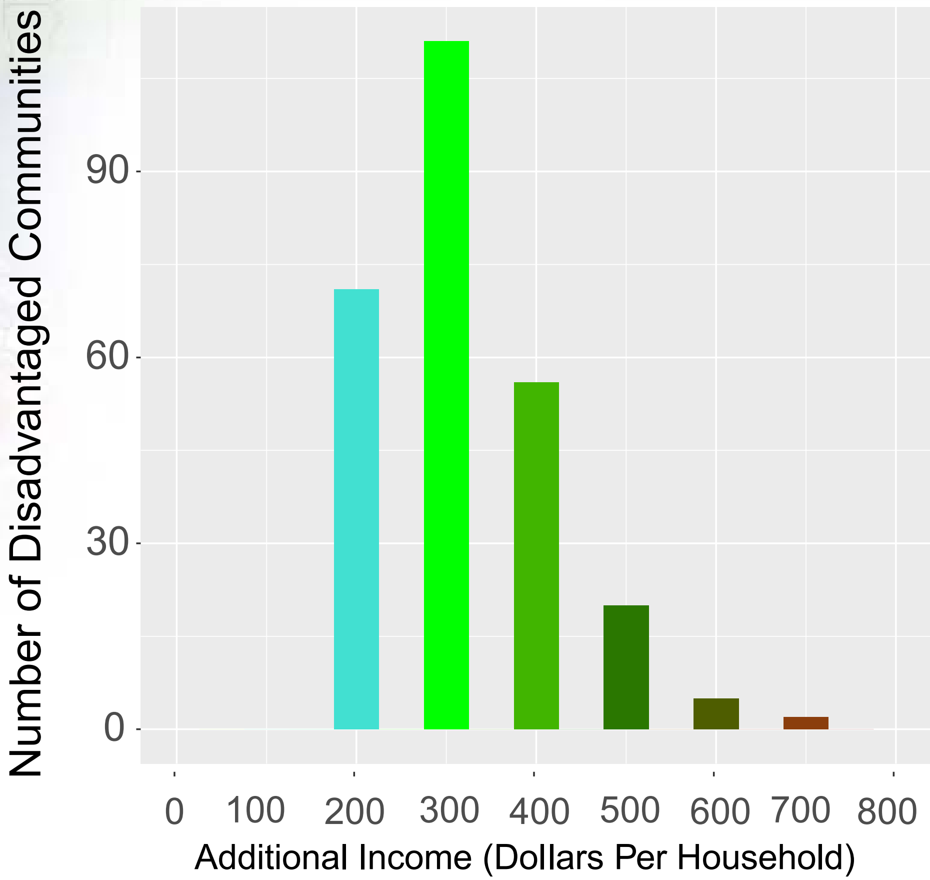
Difference in Jobs Created, (R3-CP)

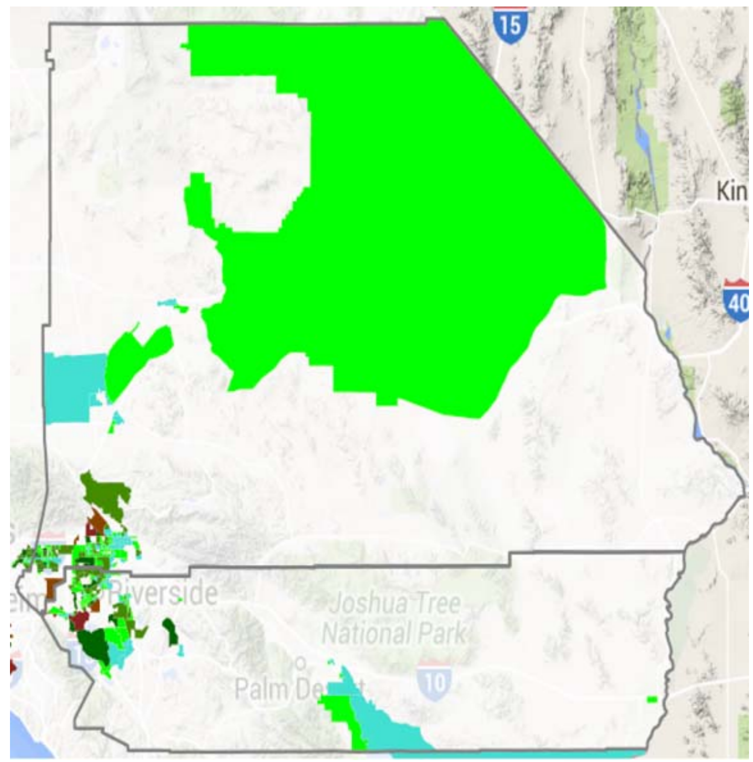




Inland Valley

Difference in Income ($/hh), (R3-CP)





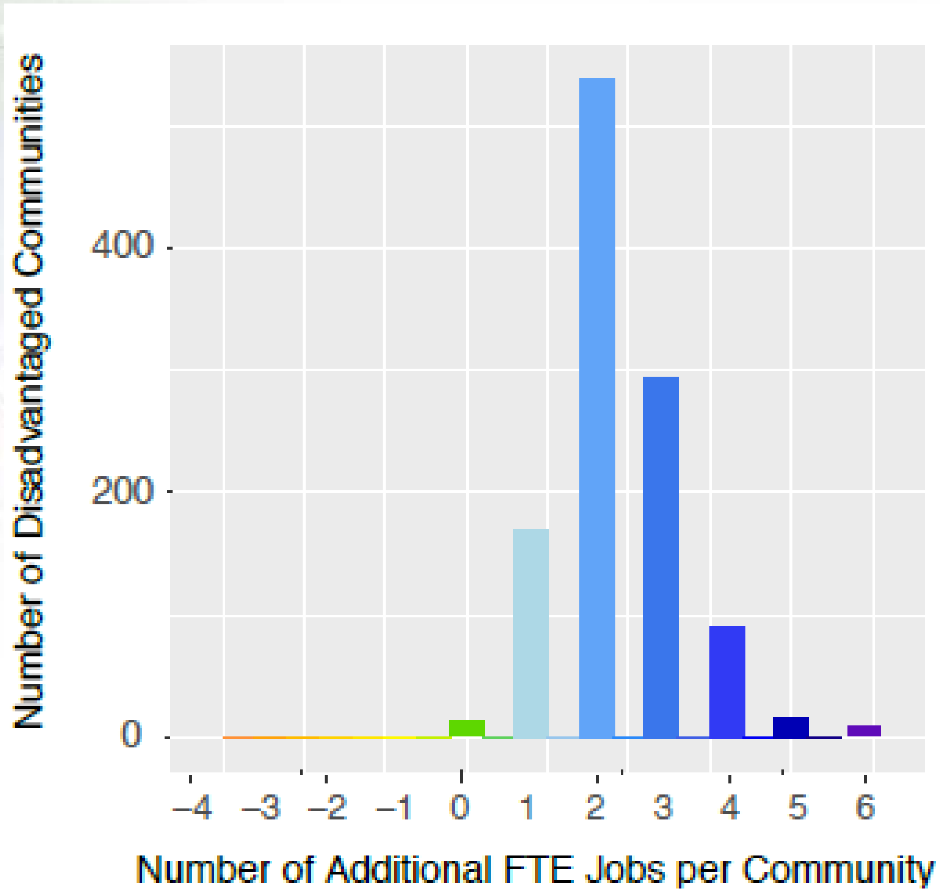
Greater Los Angeles Area

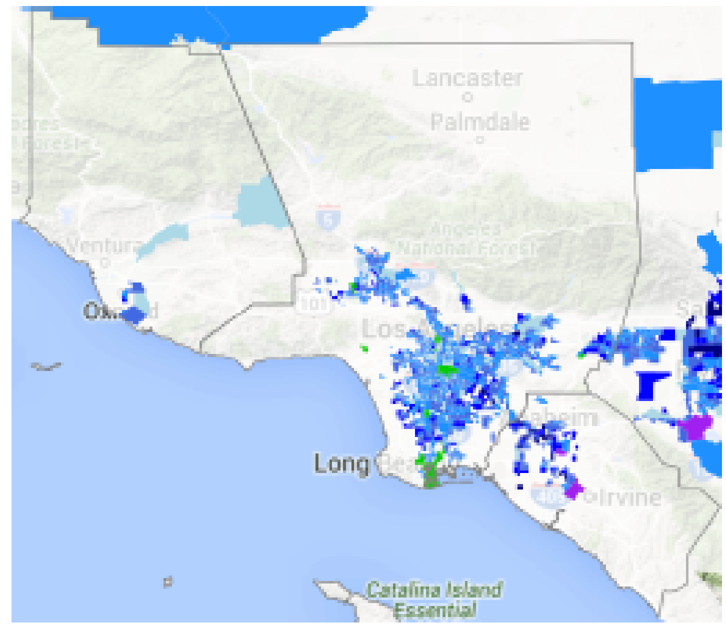
- 36.5% of state population
- 6.1% unemployment rate
- Average household Income = $87,728
- 1120 disadvantaged communities

  (56% of state total)

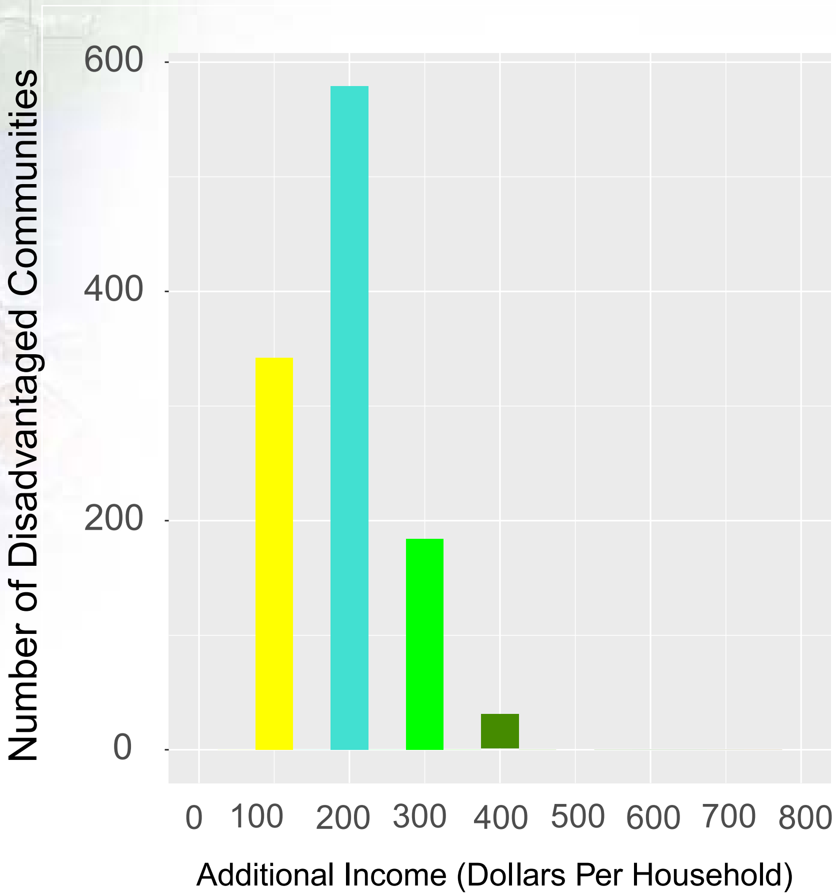
Greater Los Angeles Area

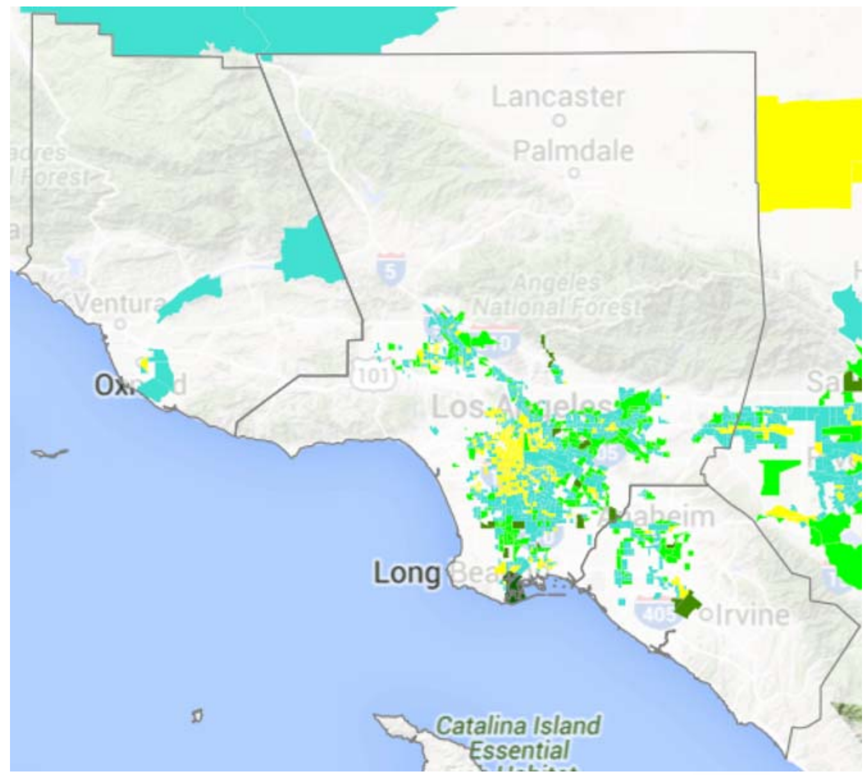
Difference in Jobs Created, (R2-CP)





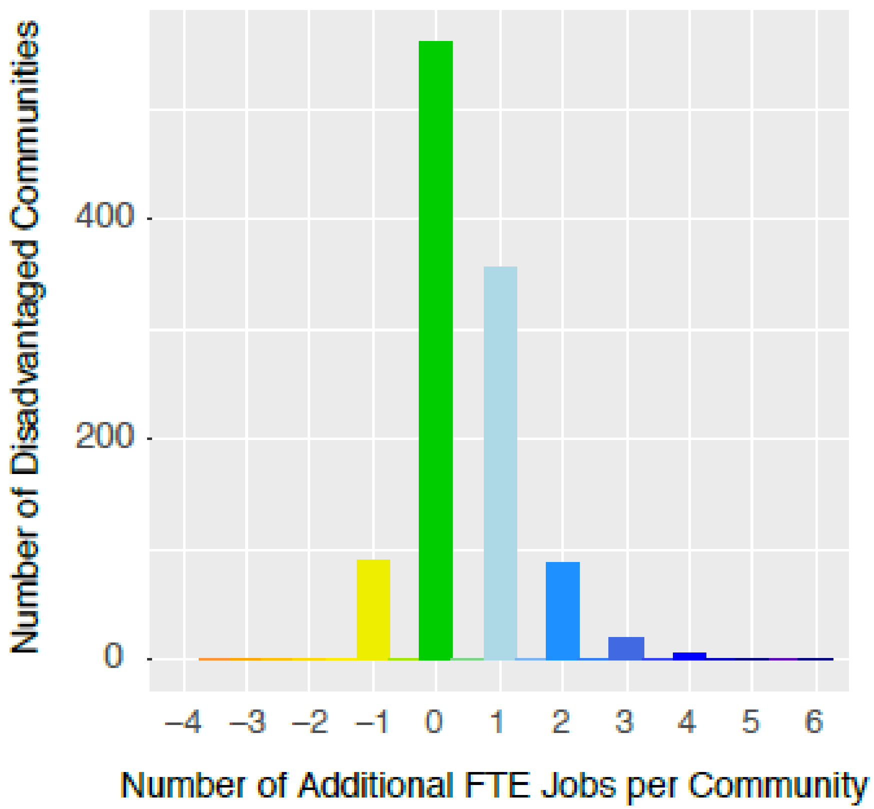
Greater Los Angeles Area
Difference in Income ($/hh), (R2-CP)

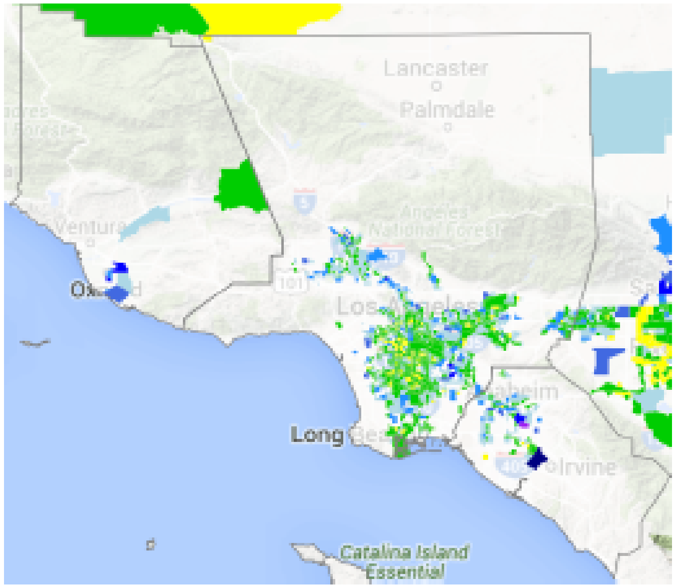




Greater Los Angeles Area

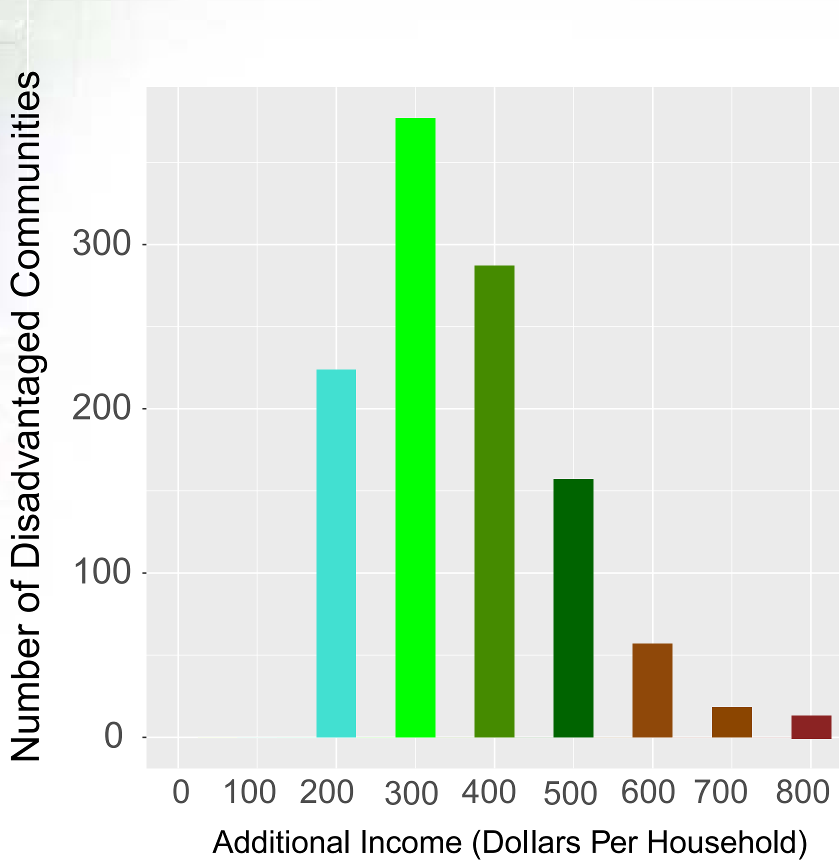
Difference in Jobs Created, (R3-CP)

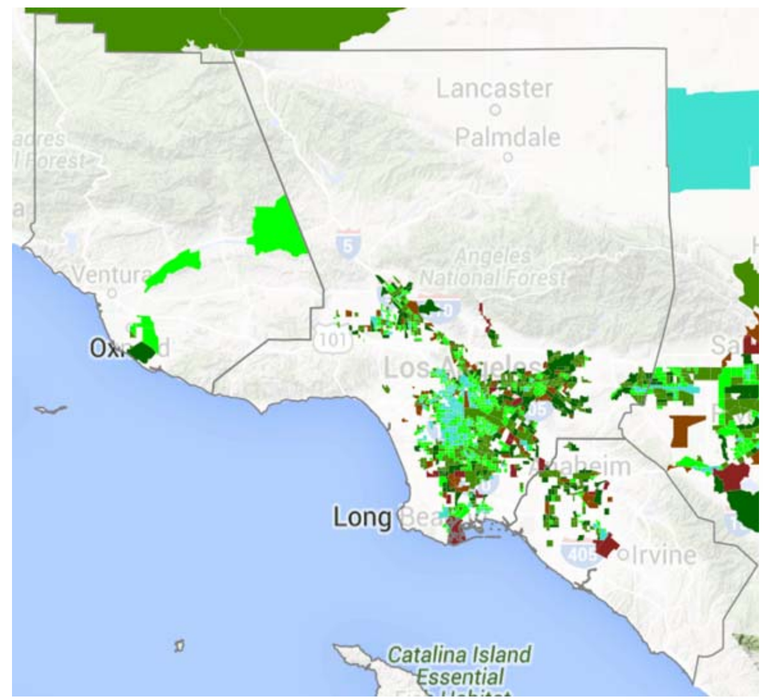




Greater Los Angeles Area

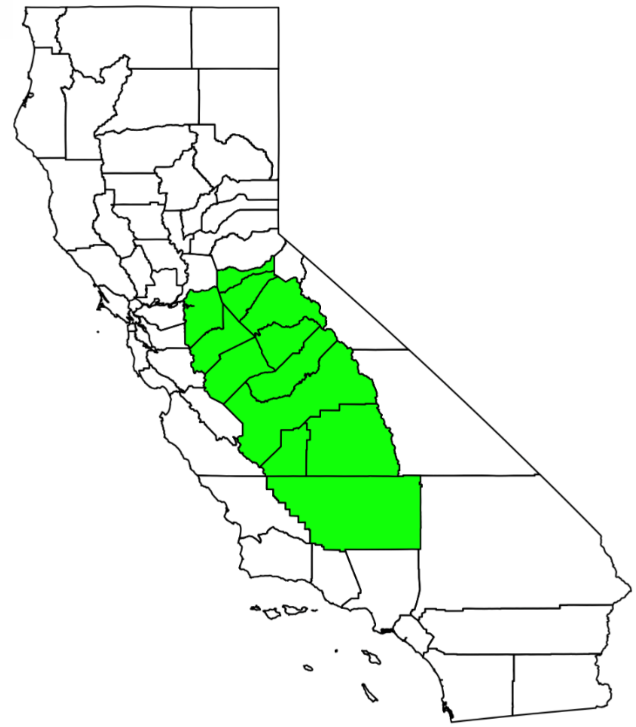
Difference in Income ($/hh), (R3-CP)





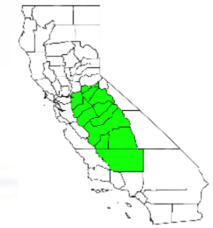
Central Valley

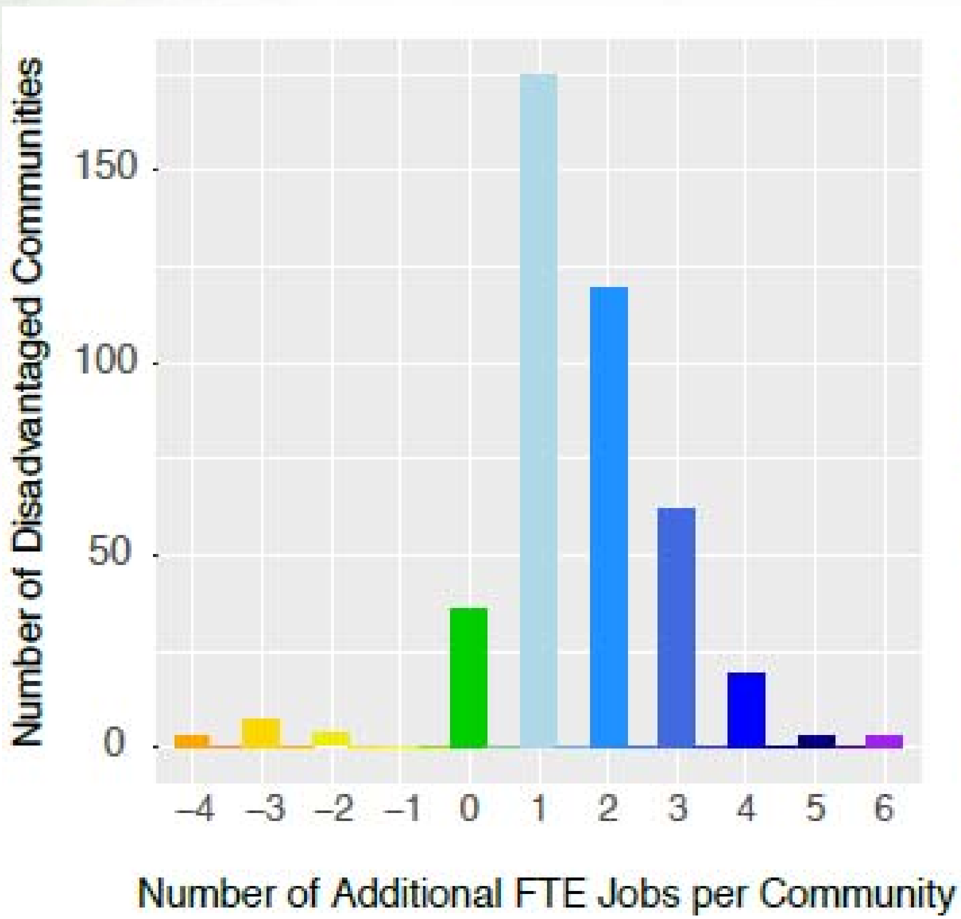
- 10.6% of state population
- 10% unemployment rate
- Average household Income = $64,756
- 433 disadvantaged communities (22% of state total)

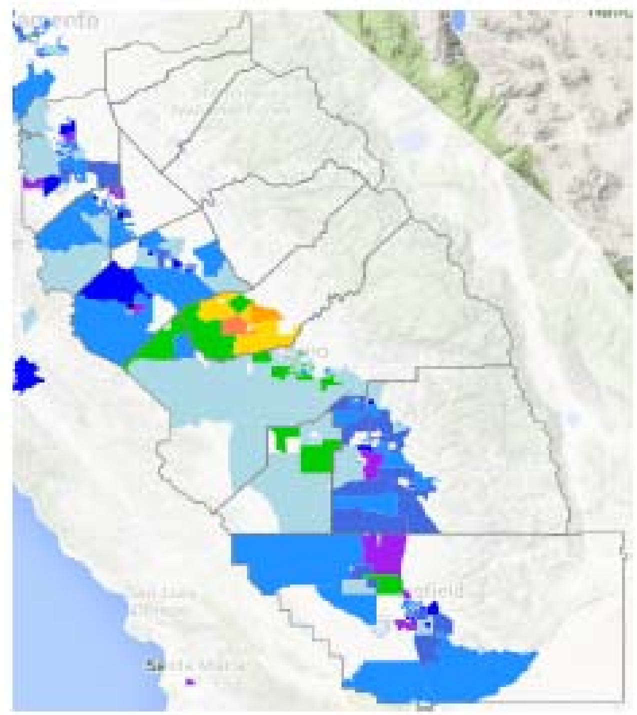


Central Valley

Difference in Jobs Created, (R2-CP)

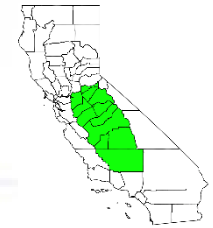


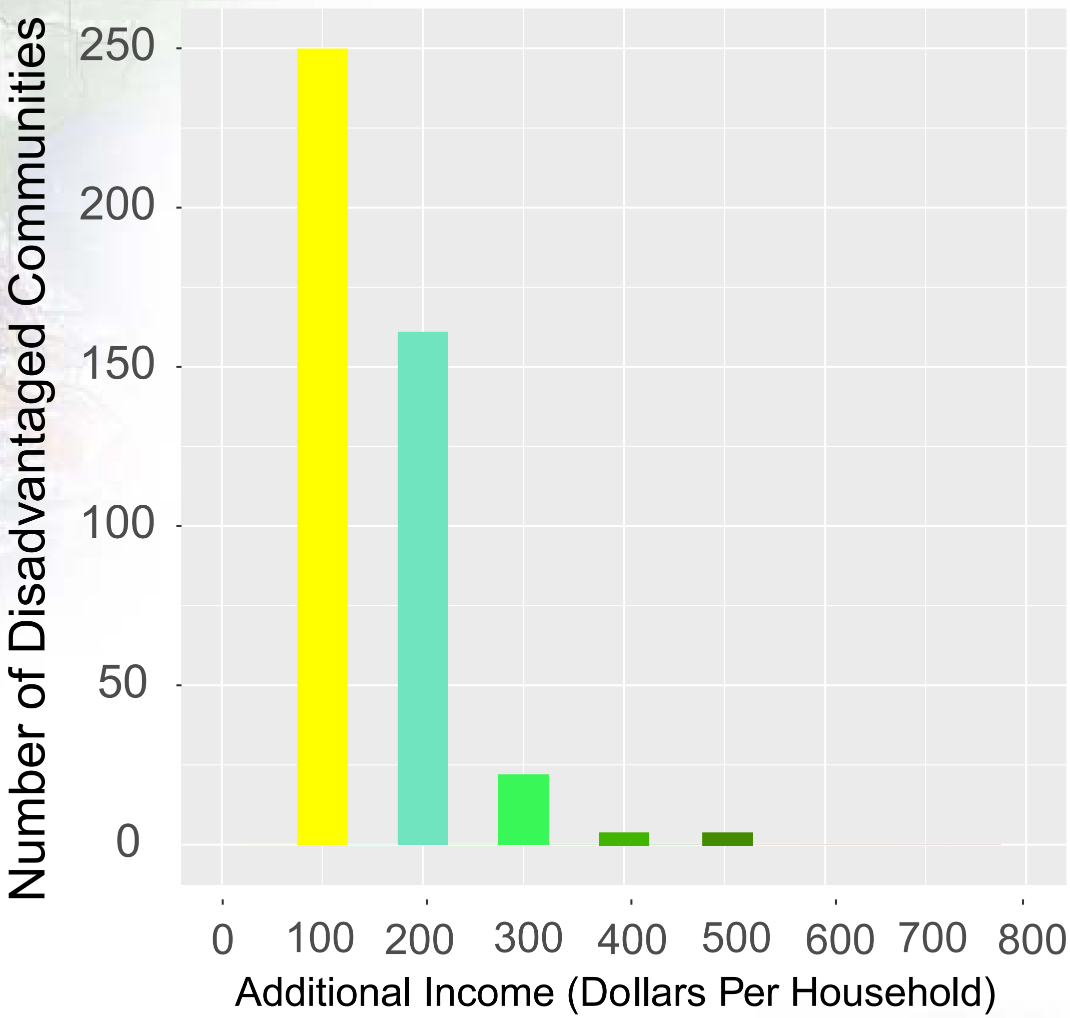


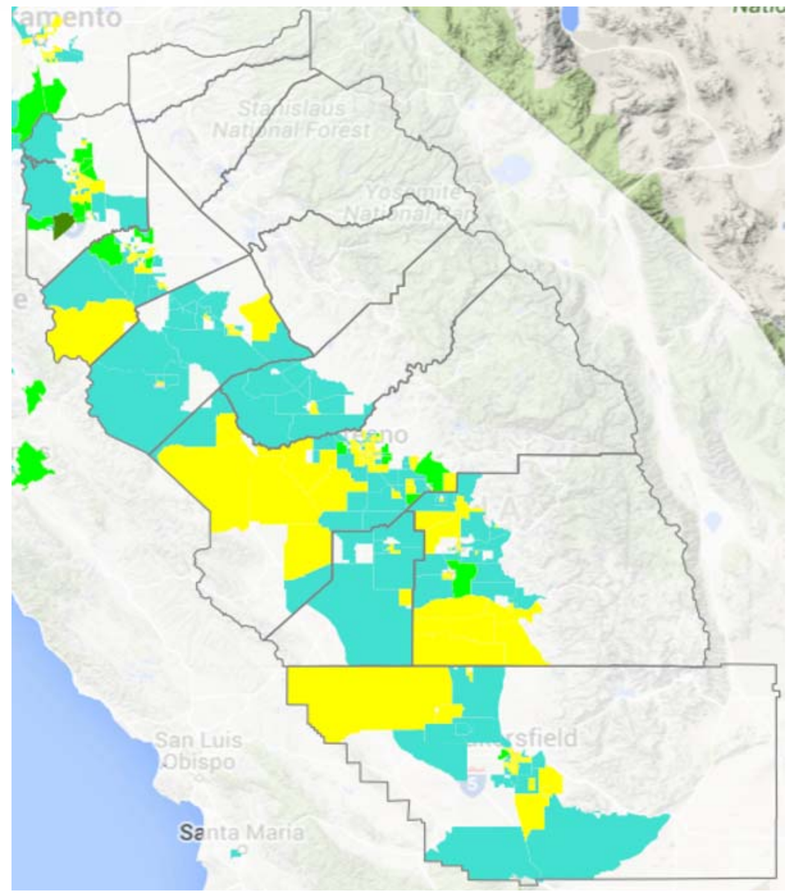


Central Valley

Difference in Income ($/hh), (R2-CP)

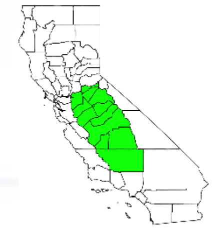


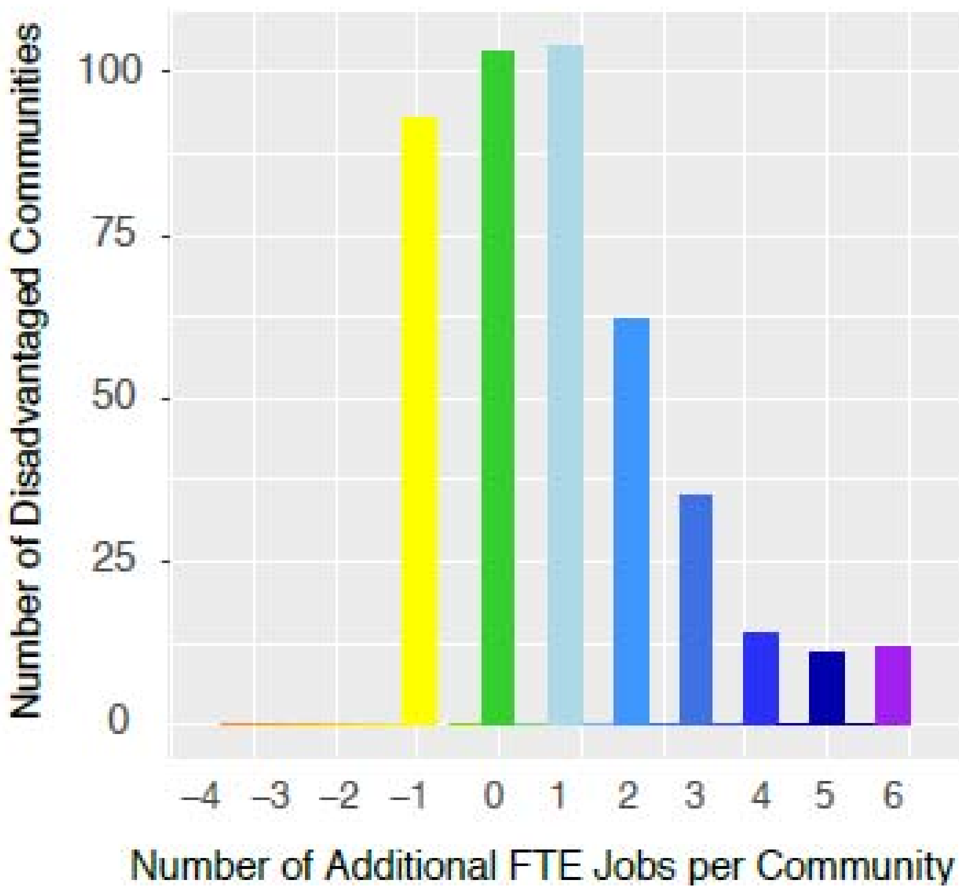


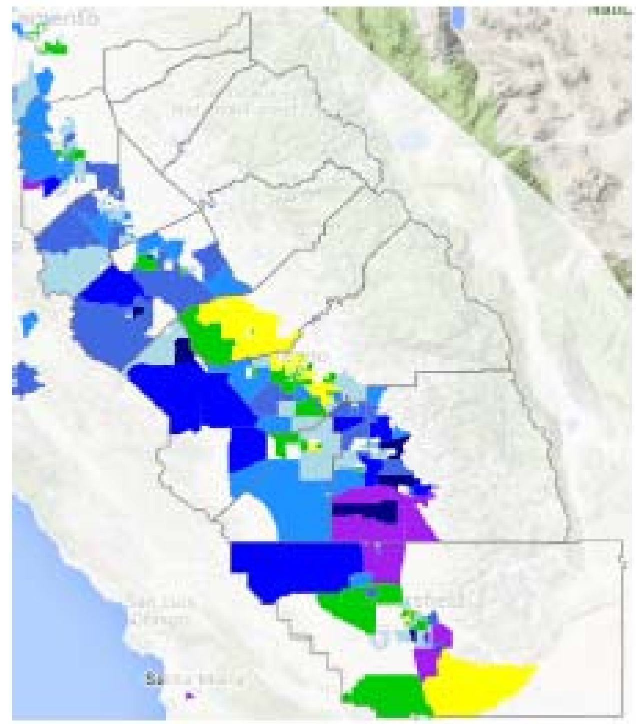


Central Valley

Difference in Jobs Created, (R3-CP)







Central Valley

Difference in Income ($/hh), (R3-CP)