The Los Angeles 100% Renewable Energy Study

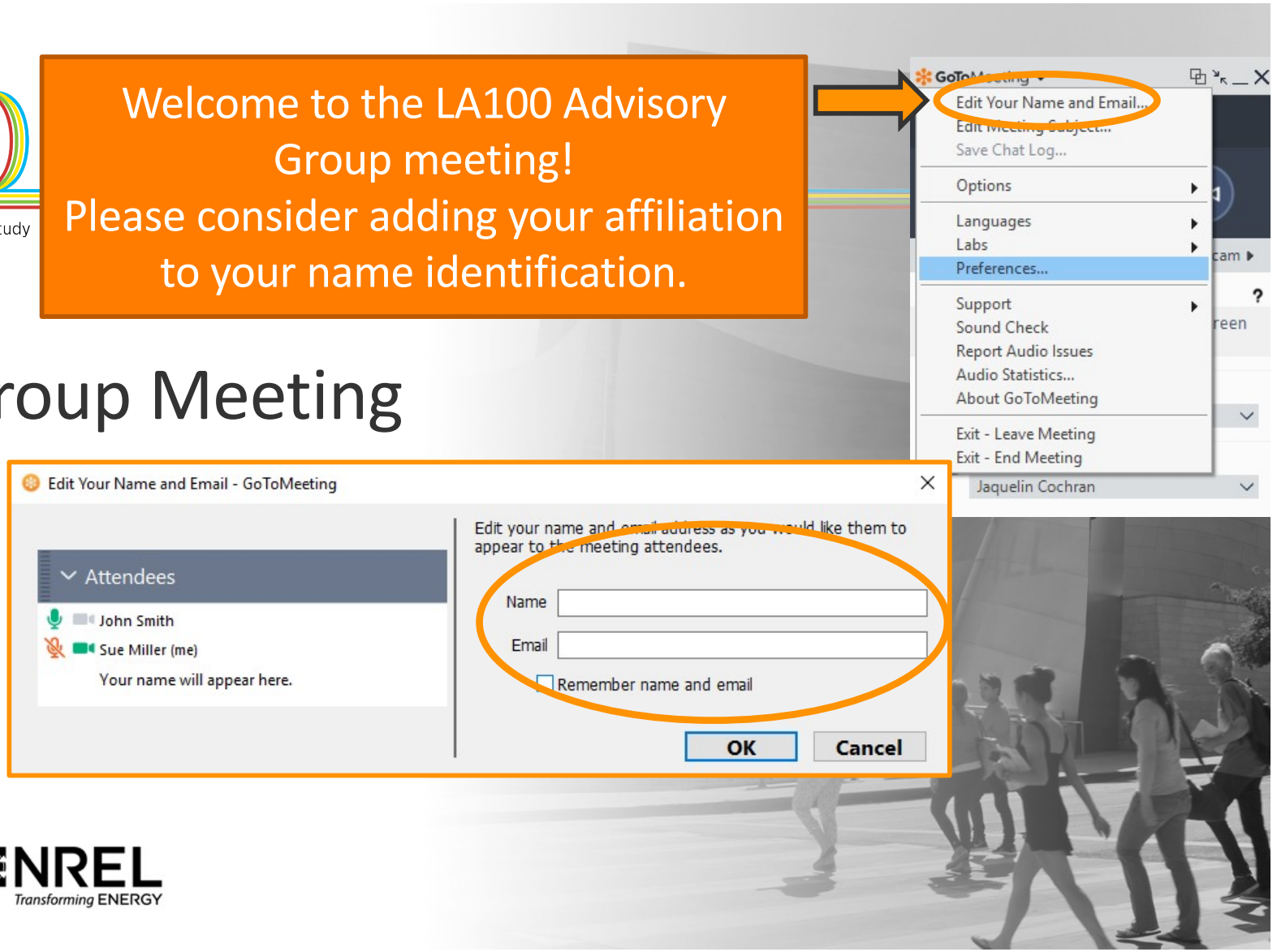
Advisory Group Meeting #15

Virtual Meeting #3

Los Angeles Department of Water & Power | NREL Transforming ENERGY

The Los Angeles 100% Renewable Energy Study

Welcome to the LA100 Advisory Group meeting!
Please consider adding your affiliation to your name identification.



Advisory Group Meeting #15

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Los Angeles Department of Water & Power | NREL Transforming ENERGY

Tips for Productive Discussions

Let one person speak at a time

Keep phone/computer on mute until ready to speak

Help ensure everyone gets equal time to give input

Type “Hand” in Chat Function to raise hand

Keep input concise so others have time to participate

Also make use of Chat function

Actively listen to others, seek to understand perspectives

Offer ideas to address questions and concerns raised by others

Hold questions until after presentations

Advisory Group #15 Agenda

March 3
- Welcome
- Final Air Quality Results
- Final Public Health Results
- Discussion/Q&A

March 4
- Environmental Justice
- Discussion/Q&A

Today (March 11)
- Economic Impact Analysis
- Workforce Analysis
- Discussion/Q&A

March 18
- LA100 Results: Costs and Benefits
- Summary of Key Findings
- Discussion/Q&A

The Los Angeles 100% Renewable Energy Study

LA100: Jobs and Economic Impact Modeling

Advisory Group Meeting #15, Virtual Meeting #3

Adam Rose

Dan Wei

University of Southern California

David Keyser

National Renewable Energy Laboratory

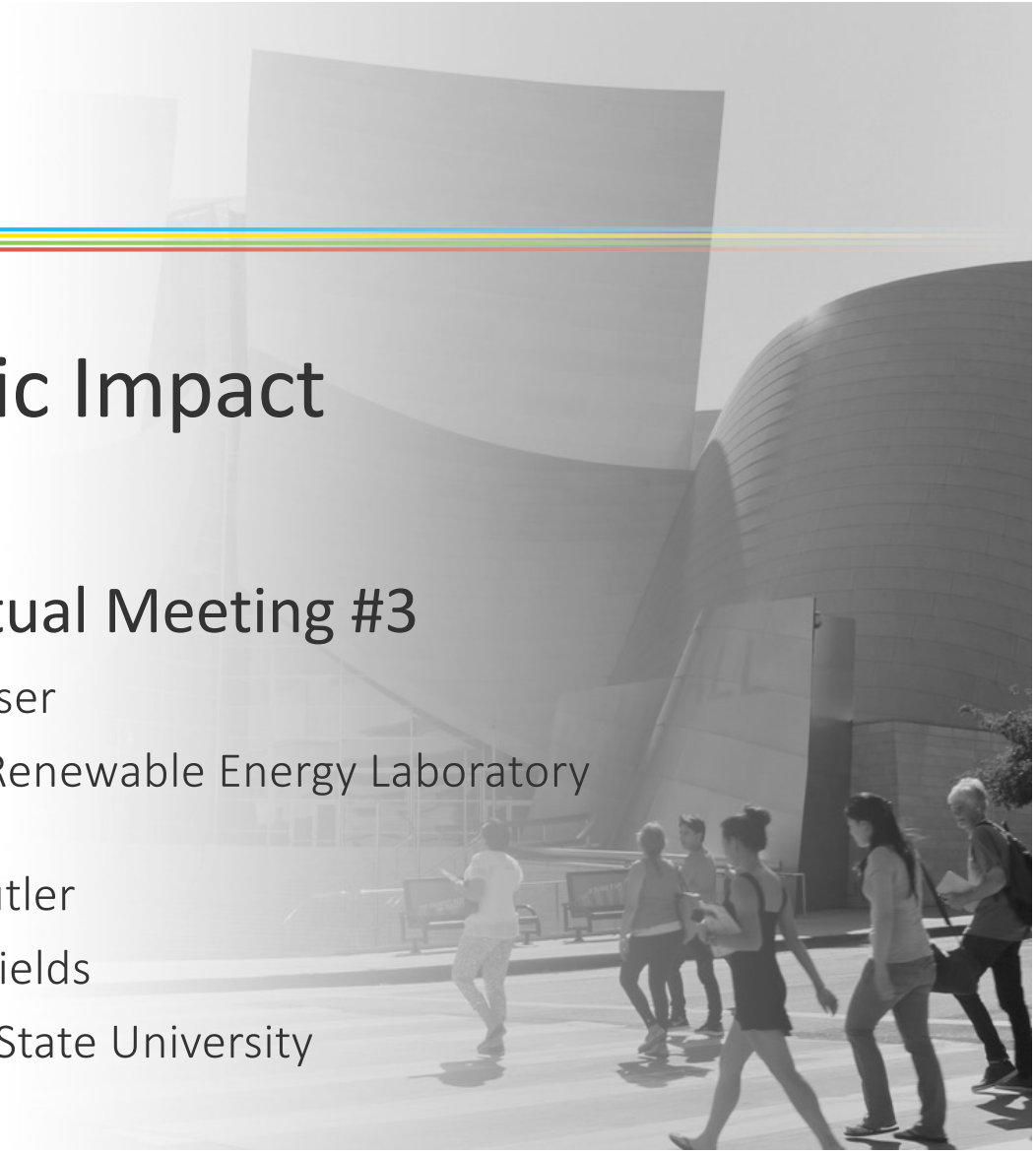
Harvey Cutler

Martin Shields

Colorado State University

March 11, 2021

Los Angeles Department of Water & Power | NREL Transforming ENERGY



Today's presentation and discussion

Agenda:

- Review types of impacts included in economic analysis
- Net impacts on employment and household income within LA
- In- and out-basin workforce needs and types of jobs by technology

Requested feedback:

- Feedback on results
- Questions about models and assumptions

Models used

- Two types of models: Computable General Equilibrium (CGE) and the NREL Jobs and Economic Development Impacts (JEDI) suite of input-output models
- Both share sets of underlying data
- Both needed: **CGE** to estimate a broad set of overall economic impacts within LA and **JEDI** to estimate detailed impacts that are solely associated with the power sector

CGE Model
Economy-wide

- Used to estimate **net** impacts within the City of LA
- **Net** impacts consider potentially positive impacts from investment, operation & price decreases and negative impacts from price increases & electricity displacement elsewhere in the economy.

JEDI Model
Workforce

- Used to estimate in- and out-basin **gross** impacts from increased activities in power sector
- **Gross** impacts only account for positive changes such as jobs created and supported by LA 100 scenarios
- Captures workforce needs and associated economic activity

CGE Model
Economy-wide

Preview: net impacts

- Net modeling of power sector expansion estimates impacts on **employment and income by household group** within the city of LA
- Some LA100 scenarios have slightly positive impacts and others are negative, but these are **very small when compared with the size of the LA economy**
- **Lower-income households are more affected** by changes because, while they spend less on electricity than higher income households, electricity is a larger portion of their income
- Some scenarios slightly **increase income inequality** in LA when compared with SB100 while others **do not**

JEDI Model
Workforce

Preview: gross impacts

- All scenarios have associated **workforce needs** that vary with levels of expenditure and technologies that are deployed
- **Construction and installation** expenditures under the Early & No Biofuels scenarios support the most in-basin jobs, while these expenditures out-of-basin support the most jobs under SB100 – Stress
- Conversely, **O&M expenditures** support the most in-basin jobs under SB100 – Stress and the least out-basin jobs under the Early & No Biofuels scenarios
- Most jobs supported by these expenditures earn **wages that are higher than average earnings in LA**

Input data

JEDI Model
Workforce

CGE Model
Economy-wide

- Both models are parameterized with capital and operations & maintenance (O&M) expenditures from rooftop solar and capacity planning models
- CGE additionally uses estimated cost data (translated to changes in electricity prices), which includes existing debt
  - This is determined by taking the difference between the 2017 IRP, which includes debt, and LA100's results using 2017 IRP, which does not

Energy efficiency

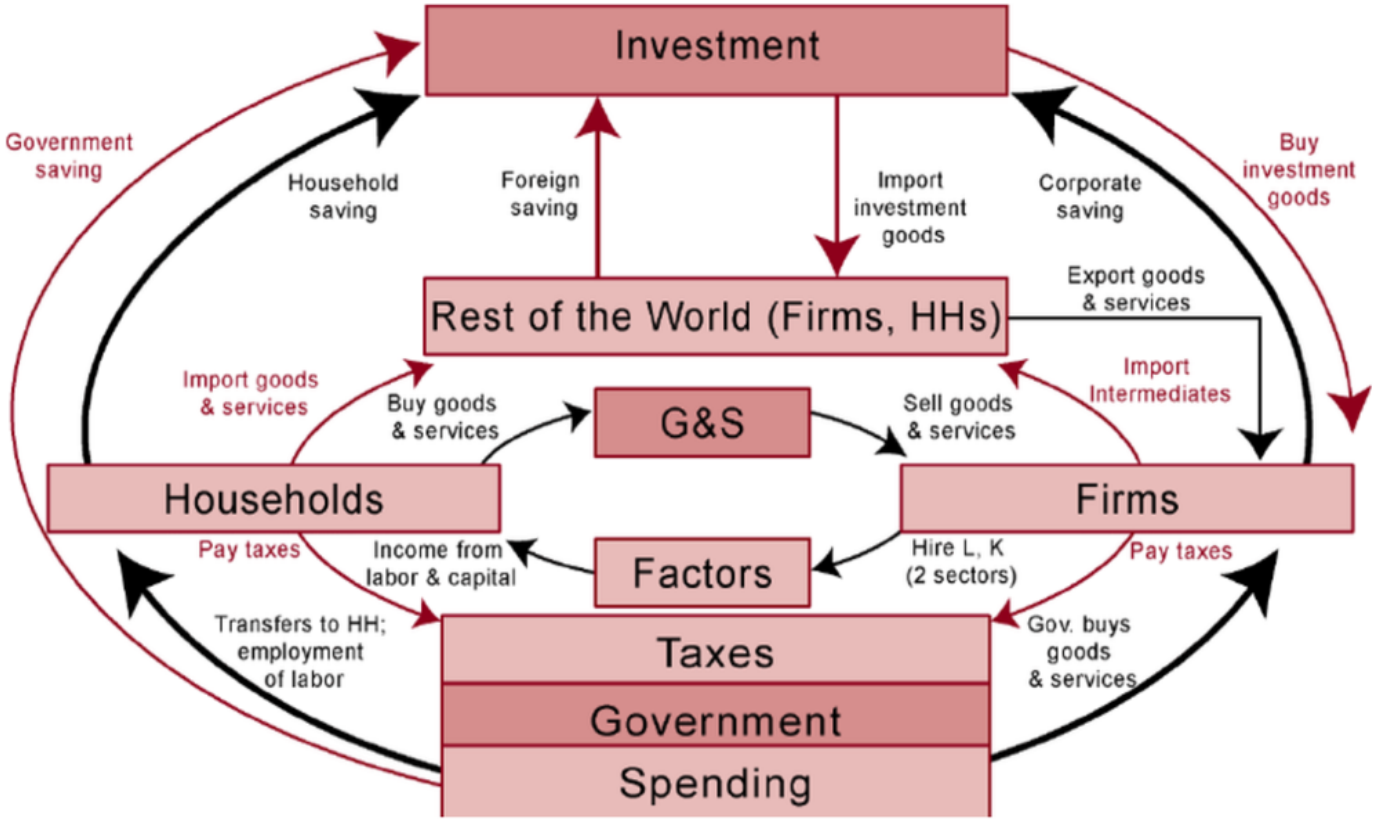
JEDI Model
Workforce

CGE Model
Economy-wide

- Energy efficiency is not included in these impacts
- Economic modeling in this study requires inputs to be monetized
- Efficiency is only included as part of electrification in this study, and neither costs of implementing measures nor savings from reduced energy use are monetized
- Other studies have looked at this and shown that economy-wide impacts of efficiency would likely be positive, thereby making power sector impacts in this study lower bounds
- Gross (JEDI-type) impacts would show workforce needed to build, install, and maintain efficiency investments

CGE Model
Economy-wide

CGE model flow diagram



- Models the economy as a set of interrelated supply chains
- Mimics role of markets & prices

CGE Model
Economy-wide

CGE model specifics

- **Commercial Producing sectors** – generate output using labor, capital and intermediate inputs purchased from other industries
  - Labor
  - Physical capital (buildings, equipment)
  - Intermediate inputs, including electricity (inputs used in production)
- **Households earn income** - wages and capital income
  - Purchase goods and services
  - Purchase or rent housing
  - Purchase electricity
- **Electricity expenditures increase with household income**
- Impacts are **in addition** to changes that would otherwise occur

CGE Model
Economy-wide

Absolute and relative analysis

- **Scenario Analysis Decisions**
  - Electricity infrastructure and prices will not stagnate in the future
  - Basic changes already set in motion
  - Holding prices constant at Year 2020 levels would be misleading
- **Used SB100 – Moderate as a minimal compliance (reference) scenario**
  - But also calculated impacts in relation to 2020 constant prices

CGE Model
Economy-wide

Summary of net impacts

- Annual average employment impacts from 2026 to 2045 range from:
  -3,600 under Early & No Biofuels – Moderate to
  +4,700 under SB100 – Stress when compared with SB100 – Moderate
- These impacts are affected by cost changes relative to SB100 – Moderate:
  - **Higher costs result in lower (or negative) impacts, while lower costs result in higher impacts**
- Stress and High electrification scenarios have the highest positive impacts
- Early & No Biofuels (both) and Moderate electrification scenarios have negative impacts relative to SB100 – Moderate

CGE Model
Economy-wide

Key overarching takeaway

- Regardless of the pathway, economic impacts to the city from changes in electricity rates and renewable energy investments are projected to be **small relative to the overall size of LA's economy**

- So, while the transition to 100% renewables could create thousands of clean energy jobs annually, overall, the **clean energy investments alone are not anticipated to notably impact LA's economy**

CGE Model
Economy-wide

Cost per kWh changes relative to SB100 – Moderate

Compare changes in per unit costs with cost changes (from 2020) in the SB100-Moderate Scenario

Higher-cost scenarios

- Early & No Biofuels (both)
- All Moderate electrification scenarios

Lower-cost scenarios

- SB100 – Stress
- All High electrification scenarios except Early & No Biofuels – High

Scenarios	2026 - 2030	2031 - 2035	2036 - 2040	2041 - 2045
SB100 - Moderate	n.a.	n.a.	n.a.	n.a.
SB100 - High	-5.2%	-8.2%	-10.7%	-12.9%
SB100 - Stress	-6.3%	-9.9%	-13.0%	-15.6%
Early & No Biofuels - Moderate	17.4%	27.5%	25.2%	16.4%
Early & No Biofuels - High	8.4%	13.3%	9.8%	2.1%
Transmission Focus - Moderate	2.5%	3.9%	5.1%	6.1%
Transmission Focus - High	-2.9%	-4.5%	-6.0%	-7.2%
Limited New Transmission - Moderate	3.1%	5.0%	6.5%	7.8%
Limited New Transmission - High	-2.3%	-3.6%	-4.7%	-5.7%

CGE Model
Economy-wide

Net employment impacts of the LA100 scenarios relative to SB100 in a given year – Moderate

	Annual Average, 2026 to 2030		Annual Average, 2041 to 2045	
	Employment	Percent Change	Employment	Percent Change
SB100 - Moderate	n.a.	n.a.	n.a.	n.a.
SB100 – High	2,200	0.13%	3,500	0.19%
SB100 – Stress	3,000	0.17%	6,000	0.33%
Early & No Biofuels – Moderate	-2,500	-0.14%	-3,900	-0.22%
Early & No Biofuels – High	300	0.02%	-760	-0.04%
Transmission Focus – Moderate	1,700	0.09%	-800	-0.04%
Transmission Focus – High	1,700	0.10%	3,300	0.18%
Limited New Transmission – Moderate	5	0.00%	2,300	-0.13%
Limited New Transmission – High	2,200	0.12%	4,100	0.23%

- Largest projected **increase**: SB100-Stress
- Largest projected **decrease**: Early & No Biofuels – Moderate
- Time-paths of changes affected by a combination of three causal factors
- Percentage changes are relatively small

CGE Model
Economy-wide

Income Distribution Impacts
SB100 – High example

- All numbers are positive, indicating increased aggregate income compared to SB100 – Moderate scenario
- Lower-income households receive a higher proportion of increased income
  - Relatively smaller absolute *levels* of income gains
  - But relatively larger *percentage* increases of total income

	2026-2030		2041-2045	
Household (HH) Income Bracket	Amount (mil of $)	Percent Change	Amount (mil of $)	Percent Change
HH1 < $10,000	1.1	0.16%	2.7	0.38%
$10,000 < HH2 < $25,000	2.1	0.09%	7.2	0.32%
$25,000 < HH3 < $30,000	4.0	0.12%	11.4	0.35%
$30,000 < HH4 < $40,000	6.2	0.14%	16.8	0.39%
$40,000 < HH5 < $60,000	12.8	0.13%	35.5	0.37%
$60,000 < HH6 < $80,000	13.8	0.08%	32.9	0.19%
$80,000 < HH7 < $125,000	15.1	0.07%	42.0	0.20%
$125,000 < HH8 < $150,000	30.6	0.14%	64.6	0.30%
$150,000 < HH9	31.5	0.06%	68.5	0.13%

CGE Model
Economy-wide

Income Distribution Impacts
Early & No Biofuels – High example

- Downward signs indicate aggregate income losses compared to SB100 – Moderate scenario; upward signs indicate income gains
- In 2026-2030, lower-income households more adversely impacted
  - Relatively smaller absolute *levels* of income losses
  - But relatively larger *percentage* decreases of total income
- In 2041-2045, more income gains distributed to higher-income households; lowest-income households estimated to have income losses

	2026-2030		2041-2045	
Household (HH) Income Bracket	Amount (mil of $)	Percent Change	Amount (mil of $)	Percent Change
HH1 < $10,000	-1.0	-0.14%	-0.4	-0.05%
$10,000 < HH2 < $25,000	-6.6	-0.29%	-0.5	-0.02%
$25,000 < HH3 < $30,000	-11.8	-0.36%	0.3	0.01%
$30,000 < HH4 < $40,000	-15.9	-0.37%	0.3	0.01%
$40,000 < HH5 < $60,000	-33.4	-0.35%	0.6	0.01%
$60,000 < HH6 < $80,000	-36.2	-0.21%	5.5	0.03%
$80,000 < HH7 < $125,000	-42.4	-0.20%	4.1	0.02%
$125,000 < HH8 < $150,000	-43.7	-0.20%	5.5	0.03%
$150,000 < HH9	-82.4	-0.15%	36.5	0.07%

CGE Model
Economy-wide

Income inequality: Gini coefficients

- For some scenarios, results are less easy to interpret
- Gini coefficient is a better way of determining welfare effects than looking at household income changes in levels
- Gini coefficient is a one-parameter estimate of income inequality (between 0 and 1; higher values indicating higher income inequality)
- Baseline Gini coefficient for Los Angeles: 0.4582
- Changes in Gini coefficients, i.e., inequality, are very small

CGE Model
Economy-wide

Income inequality: Gini coefficients

- All scenarios contribute towards greater income inequality in absolute terms but when compared with SB100 – Moderate there are increases and decreases
- Scenarios that project increased earnings relative to the SB100 – Moderate scenario result in a more equal income distribution
- Scenarios that project decreased earnings relative to SB100 – Moderate scenario increase income inequality
- However, **all impacts remain small in absolute and relative terms**

CGE Model
Economy-wide

Conclusions

- Compared to SB100 – Moderate, employment impacts of LA100 scenarios vary from:
  - Nearly **3,600 average annual job-year losses** in the Early & No Biofuels – Moderate scenario.
  - About **4,700 gains** in the SB100 – Stress scenario between 2026 and 2045.
- Time-paths of the changes in economic impacts are affected by three causal factors (capital, O&M, costs/prices), with changes in capital investments over time being most variable across scenarios
- Although many of the aggregate impacts are large in terms of absolute levels, they are relatively small compared to the overall Los Angeles economy.
- Almost all impacts are <0.5% compared with SB100 – Moderate.

Questions?

Up Next: Jobs

JEDI Model
Workforce

Gross impact analysis

- Uses much of the same underlying data as the CGE model but JEDI use this data differently
- Increases in power sector expenditures support jobs and associated economic activity: earnings, gross domestic product (GDP), and output (overall economic activity/sales revenue)
- Who installs solar panels? Who supplies racking hardware? Design services? Where do those workers spend their money – retail, leisure and hospitality, health care?
- Workforce needs, including “ripple effects”
- Does not explain where employees live – just where jobs are

JEDI Model
Workforce

Summary of gross impacts: averages across scenarios

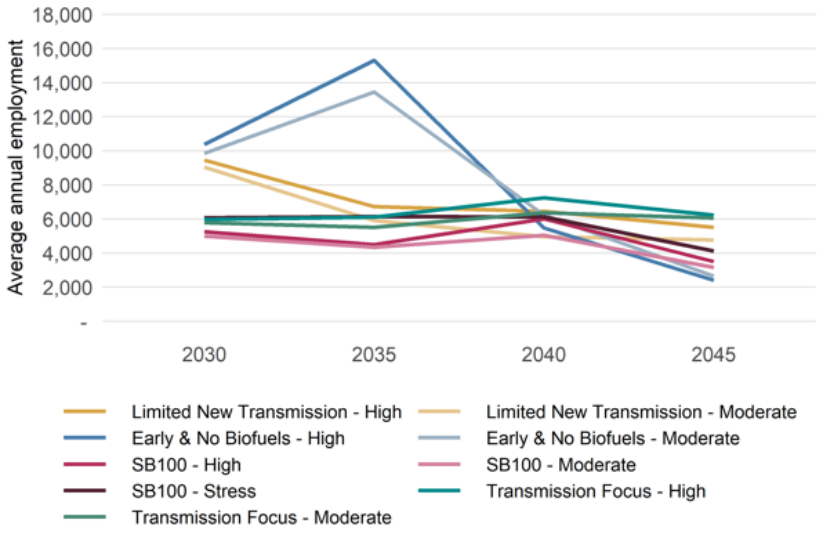
- Scenarios with the highest expenditure levels tend to support the most jobs, although this is also affected by technologies deployed
- Across all scenarios:
  - 8,600 construction and installation workers are supported annually
  - 2,000 are supported annually due to O&M
    - O&M employment is expected to continue after 2045 for the life of installed infrastructure
- Transmission and solar support the most construction and installation jobs while geothermal, wind, and natural gas support the most O&M jobs

JEDI Model
Workforce

Construction and installation jobs supported by in- and out-basin expenditures

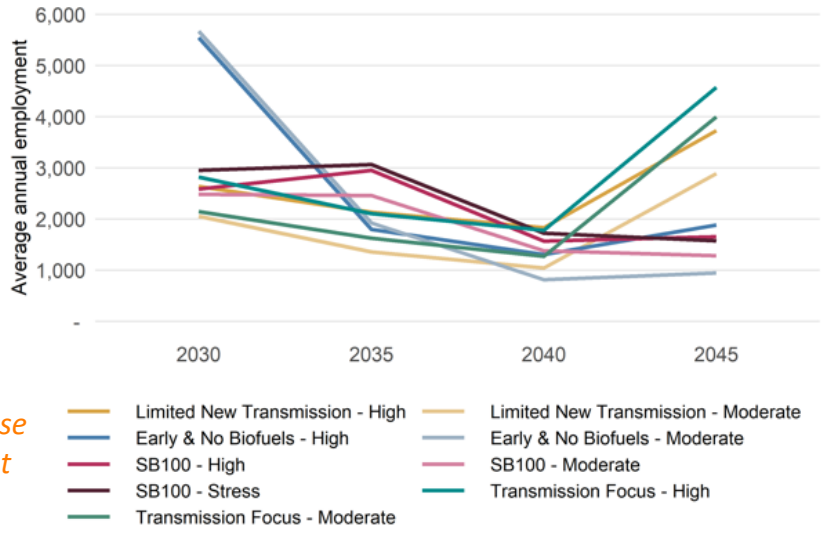
- More employment in-basin (left); scenarios except Early & No Biofuels tend to have steady employment supported by in-basin investments but increase after 2040 out-basin
- Early/NoBio peak in-basin by 2035 in-basin and 2030 out-basin, fewest jobs by 2045
- Transmission Focus scenarios have most in- and out-basin jobs by 2045
- SB100 scenarios lowest in-basin and among highest out-basin until 2040

Employment supported by construction & installation in-basin



Note: Graphs use different axes

Employment supported by construction & installation out-basin

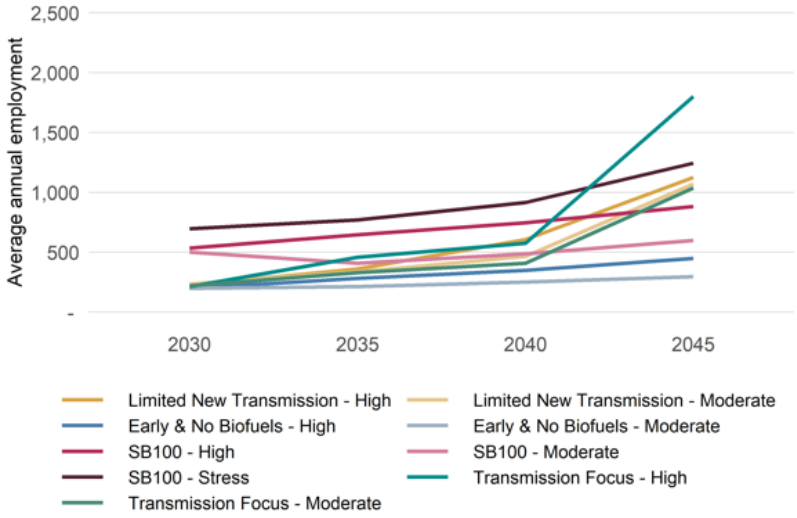


JEDI Model
Workforce

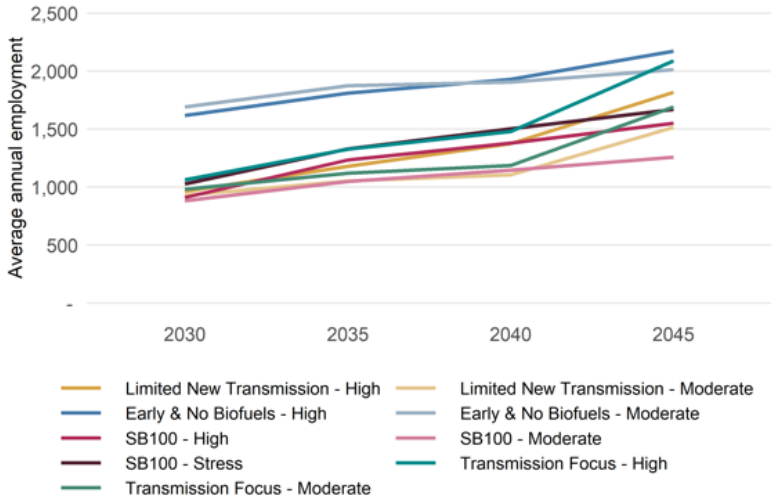
O&M jobs supported by in- and out-basin expenditures

- Early/NoBio scenarios do not support as many jobs from in-basin O&M investments
  - Solar does not require much while out-basin wind and geothermal do
- SB100 scenarios in-basin O&M supports the most jobs due to natural gas

Employment supported by O&M in-basin



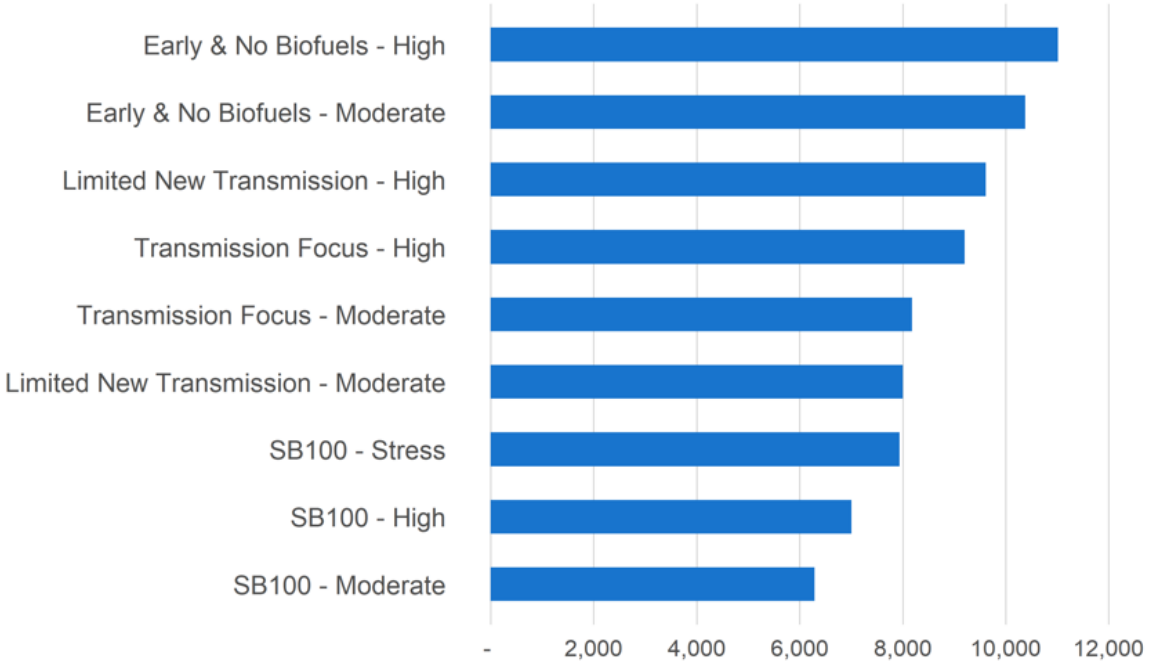
Employment supported by O&M out-basin



JEDI Model
Workforce

Aggregate jobs supported by construction and installation expenditures

- Early/No Bio scenarios support the highest number of job-years for construction and installation
- Limited New Transmission and Transmission Focus construction jobs grouped by electrification



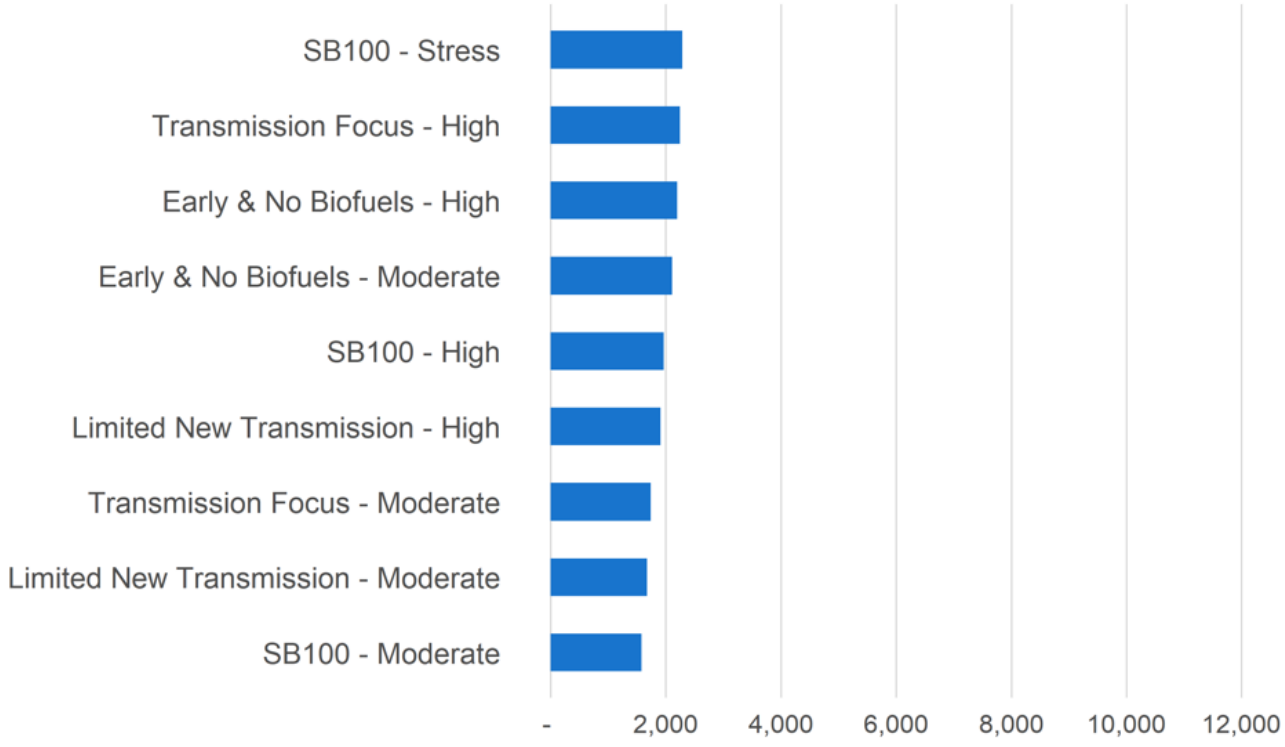
Aggregation of jobs supported by construction & installation, 2026 - 2045

JEDI Model
Workforce

Aggregate jobs supported by O&M expenditures

- High electrification and stress support the most O&M job-years except Early/No Bio - Moderate

Aggregation of jobs supported by O&M, 2026 - 2045

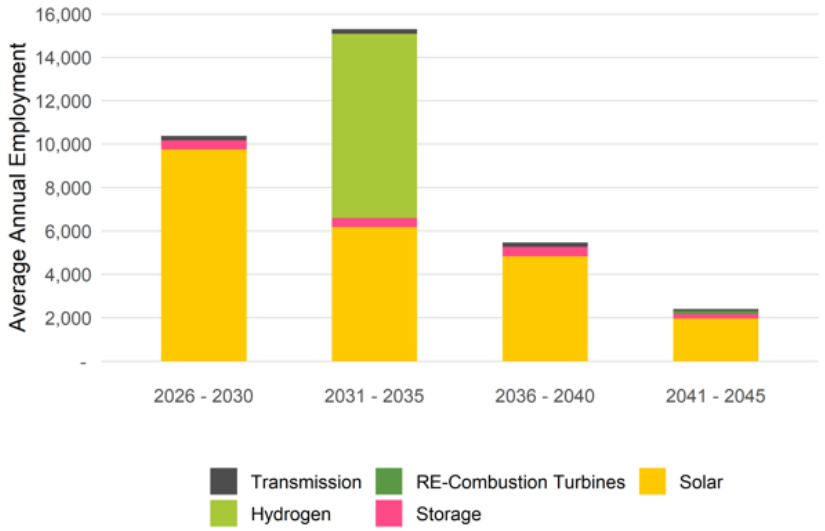


JEDI Model
Workforce

Early & No Biofuels – High jobs supported by construction and installation expenditures

- Large amount of in-basin solar, peaking from 2031 - 2035 along with hydrogen – high associated construction jobs
- Construction mixed with ongoing capital investments, thus solar past 2035
- Out-basin geothermal and mostly transmission (no associated O&M) and wind

Average annual in-basin jobs supported by construction & installation by technology



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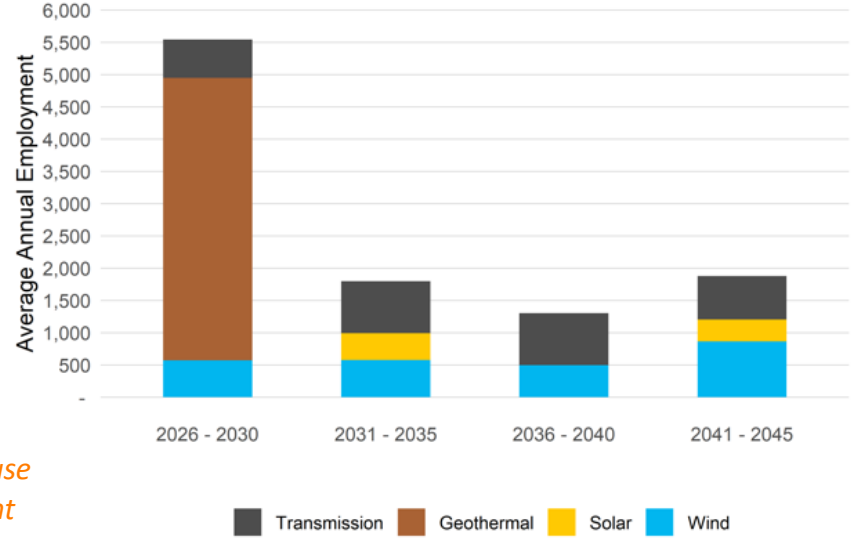
Average annual out-basin jobs supported by construction & installation by technology

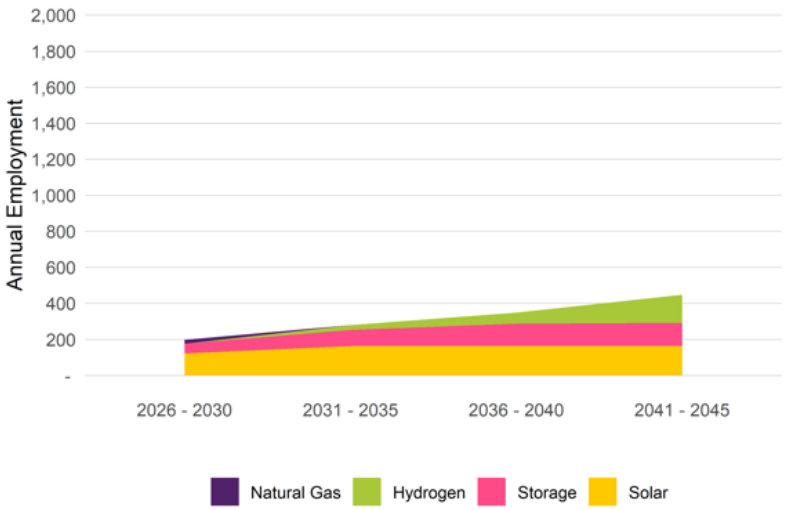


JEDI Model

Early & No Biofuels – High jobs supported by O&M expenditures

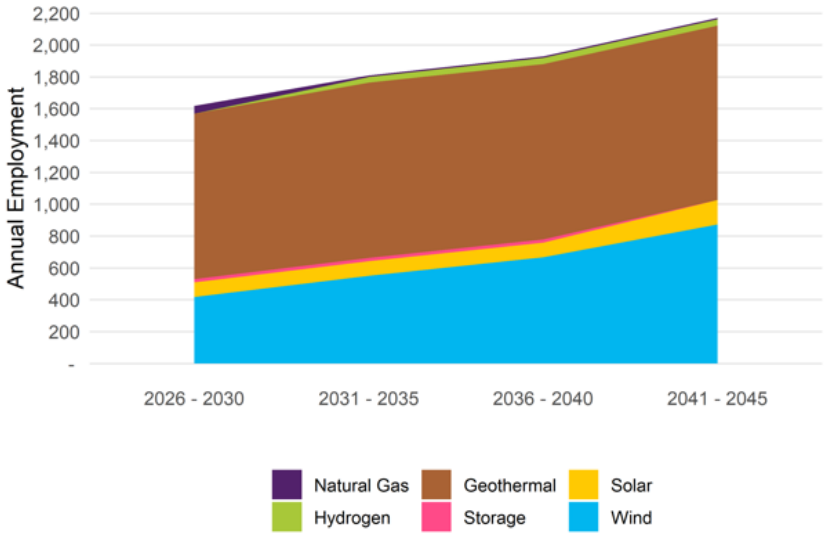
- In-basin O&M mostly solar, but numbers are still relatively low
- Out-basin early geothermal, wind
- Natural gas jobs phased out by 2035, levels maintained by other technologies

Annual in-basin jobs supported by O&M by technology



Note: Graphs use different axes

Annual out-basin jobs supported by O&M by technology

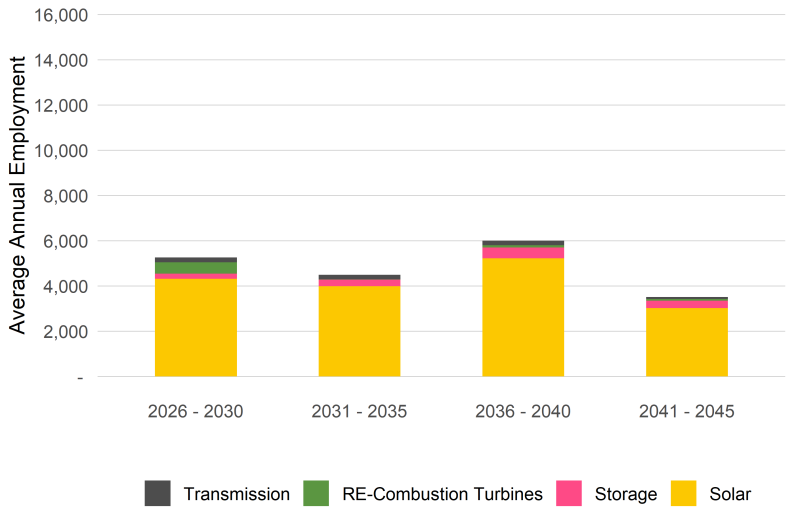


JEDI Model
Workforce

SB100 – High jobs supported by construction and installation expenditures

- Primarily solar in-basin, although levels vary over time with lower levels of RE-CT in early years and storage over time
- Out-basin wind, geothermal will contribute to higher O&M – no O&M from transmission and lower O&M from solar

Average annual in-basin jobs supported by construction & installation by technology



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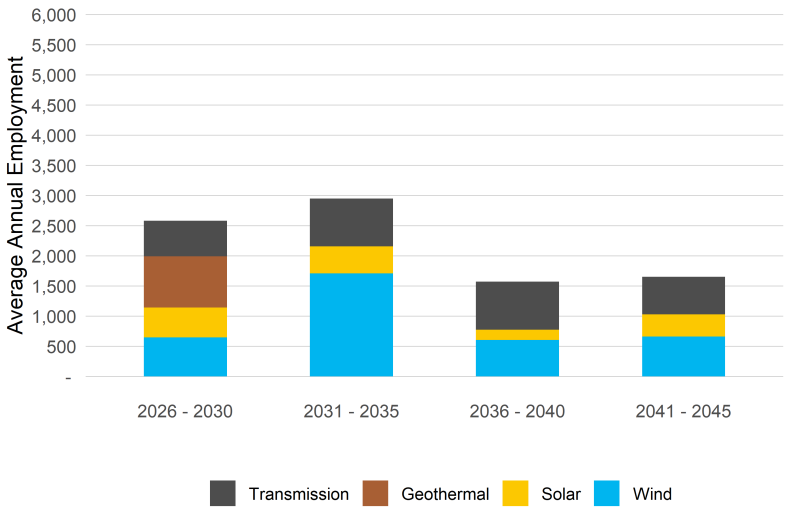
Average annual out-basin jobs supported by construction & installation by technology

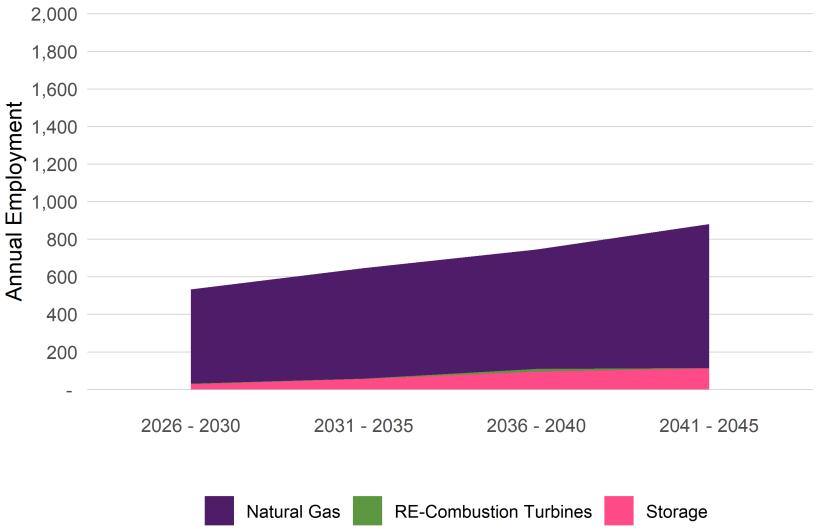


JEDI Model

SB100 – High jobs supported by O&M expenditures

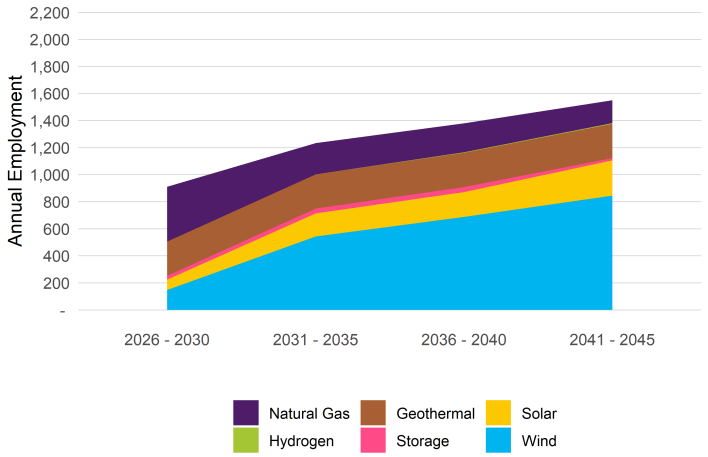
- In-basin continued operation of existing natural gas with slight increases in storage
- Out-basin continued but ramped down operation of natural gas with increased wind over time and level geothermal employment from early capital investments

Annual in-basin jobs supported by O&M by technology



Note: Graphs use different axes

Annual out-basin jobs supported by O&M by technology



JEDI Model
Workforce

Scenario Averages

- Average of 8,600 annual jobs supported by construction and installation, associated with $856 million in value added or gross domestic product (GDP)
- Average of 2,000 O&M workers associated with $201 million annually in value added
- 2,700 ongoing O&M jobs by 2045 with $270 million in GDP
- $67,000 average construction and installation annual earnings per worker; $65,000 average O&M earnings

Average construction and installation supported impacts

Scenarios	2026 - 2030	2031 - 2035	2036 - 2040	2041 - 2045	Average
Jobs	10,600	9,700	7,400	6,800	8,600
Earnings	$ 696	$ 661	$ 488	$ 461	$ 577
Output	$ 1,705	$ 1,541	$ 1,126	$ 1,042	$ 1,353
Value Added	$ 1,058	$ 965	$ 724	$ 675	$ 856

Average O&M supported impacts

Scenarios	2026 - 2030	2031 - 2035	2036 - 2040	2041 - 2045	Average
Jobs	1,500	1,800	2,000	2,700	2,000
Earnings	$ 96	$ 117	$ 131	$ 172	$ 129
Output	$ 241	$ 288	$ 326	$ 423	$ 320
Value Added	$ 148	$ 180	$ 204	$ 270	$ 201

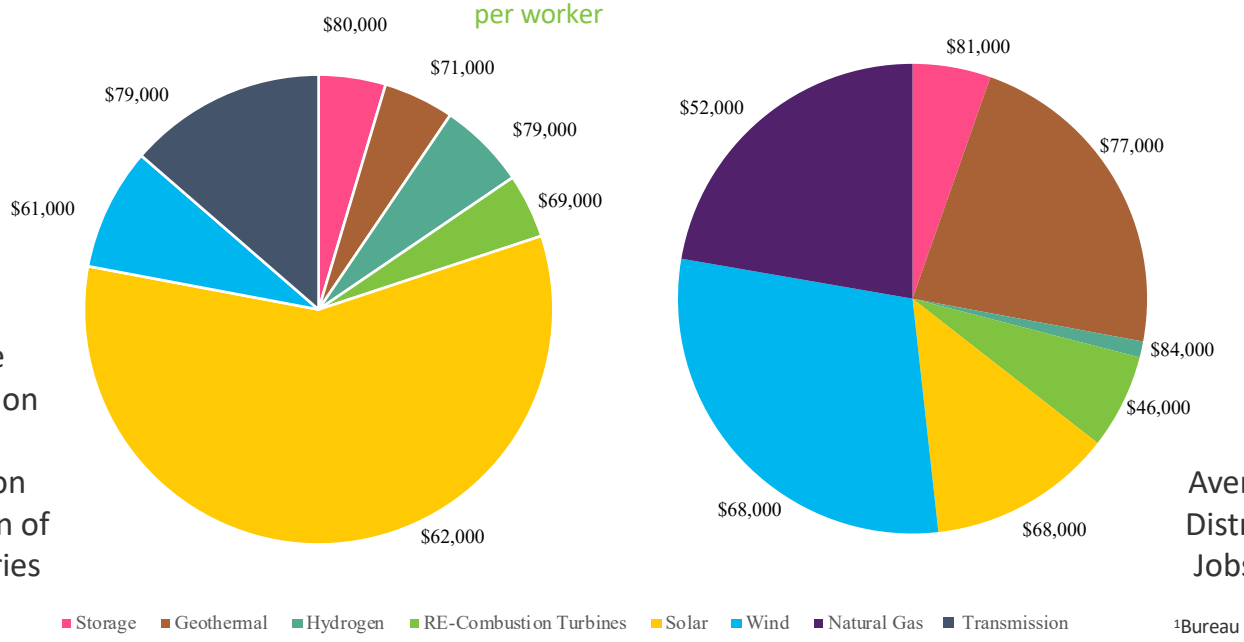
All dollar figures are millions of 2019 dollars

JEDI Model
Workforce

Average Earnings Across LA100 Scenarios

- Are these good jobs? LA average earnings: $60,000[1]
- RE-CT, natural gas O&M, including ripple effects, are below this while others are above
- Earnings include all impacts: onsite, throughout the supply chain, and induced

Figure 11. Proportions of jobs supported by construction (left) and O&M (right) on average across all scenarios and annual earnings per worker



Average Construction and Installation Distribution of Jobs, Salaries

Average O&M Distribution of Jobs, Salaries

We have a good idea about what wages are for onsite workers in mature technologies such as wind. These were modeled for nascent technologies such as hydrogen and RE-CT; as these mature actual wages will be better known

[1]Bureau of Labor Statistics, Occupational Employment Survey

JEDI Model
Workforce

Results in context

- Workforce needs results can inform opportunities
- Simply having a need does not mean that a worker easily fills that role
- In the wind industry, NREL found that employers report difficulty finding qualified workers across most occupations
- Trade workers (i.e., electricians) is the largest occupational group within the industry and second most difficult for employers to fill
- Utility in-house workforce training programs and state certified apprenticeships
- See where emerging technologies fit within existing occupations

JEDI Model
Workforce

Conclusions

- LA100 scenarios will have workforce needs. Generally, solar PV is among the largest drivers of construction and installation jobs but lower O&M jobs. Transmission can also be significant during the construction phase but not for O&M.
- Geothermal, wind, RE-CT support more O&M workers
- The average earnings for workers across all LA100 scenarios are higher than the average for LA as a whole for most technologies

Thank You

The Los Angeles 100% Renewable Energy Study