The Los Angeles 100% Renewable Energy Study

Key Findings from LA100

This fact sheet describes high-level findings from the Los Angeles 100% Renewable Energy Study (LA100), a partnership between the Los Angeles Department of Water and Power (LADWP) and the National Renewable Energy Laboratory (NREL) to analyze potential pathways LA can take to achieve a 100% clean energy future. Find additional background and detail in the LA100 Executive Summary: **nrel.gov/docs/fy21osti/79444-ES.pdf**

Exploring Possible Futures: LA100 Scenarios

NREL worked with the study's LA-based Advisory Group to develop four scenarios to evaluate pathways to 100% renewable energy for Los Angeles. Each scenario explores one possible pathway toward a clean energy future. All scenarios have the same end goal—100% renewable energy—but how the goal is achieved (and what qualifies as a renewable or clean technology) varies across the scenarios.

Each scenario is evaluated under different projections of future customer electricity demand, reflecting differences among energy efficiency investments, electrification of buildings and transportation, and flexibility of this customer demand.

- The **Moderate** projection assumes moderate (above-code) improvements to energy efficiency and moderate electricity demand growth due to electrification of consumer products like cars and stoves, and moderate improvements to energy efficiency.
- The **High** projection assumes a bigger effort to decarbonize buildings and transportation. This projection assumes that almost all appliances and heating and other equipment in buildings switch from natural gas to electric, and that 80% of passenger cars on the road by 2045 are plug-in electric, and that 12% of demand is shiftable. The high energy efficiency target means that customers buy almost exclusively the most efficient building materials and appliances.
- The **Stress** projection represents all the electrification of the High projection, but with lower efficiency and demand response improvements compared to Moderate, which would otherwise help manage the electrification-driven growth in electricity demand.

Note that these scenarios do not provide a forecast or recommendation for future action, but rather a range of possibilities that can result from different decisions and investment choices.

LA100 SCENARIOS SNAPSHOT

SB100

Evaluated under Moderate, High, and Stress Load Electrification

- 100% clean energy by **2045**
- Only scenario with a target based on retail sales, not generation
- Only scenario that allows up to 10% of the target to be natural gas offset by renewable electricity credits
- Allows existing nuclear and upgrades to transmission

Early & No Biofuels

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2035**, 10 years sooner than other scenarios
- No natural gas generation or biofuels
- Allows existing nuclear and upgrades to transmission

Transmission Focus

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2045**
- Only scenario that builds new transmission corridors
- No natural gas or nuclear generation

Limited New Transmission

Evaluated under Moderate and High Load Electrification

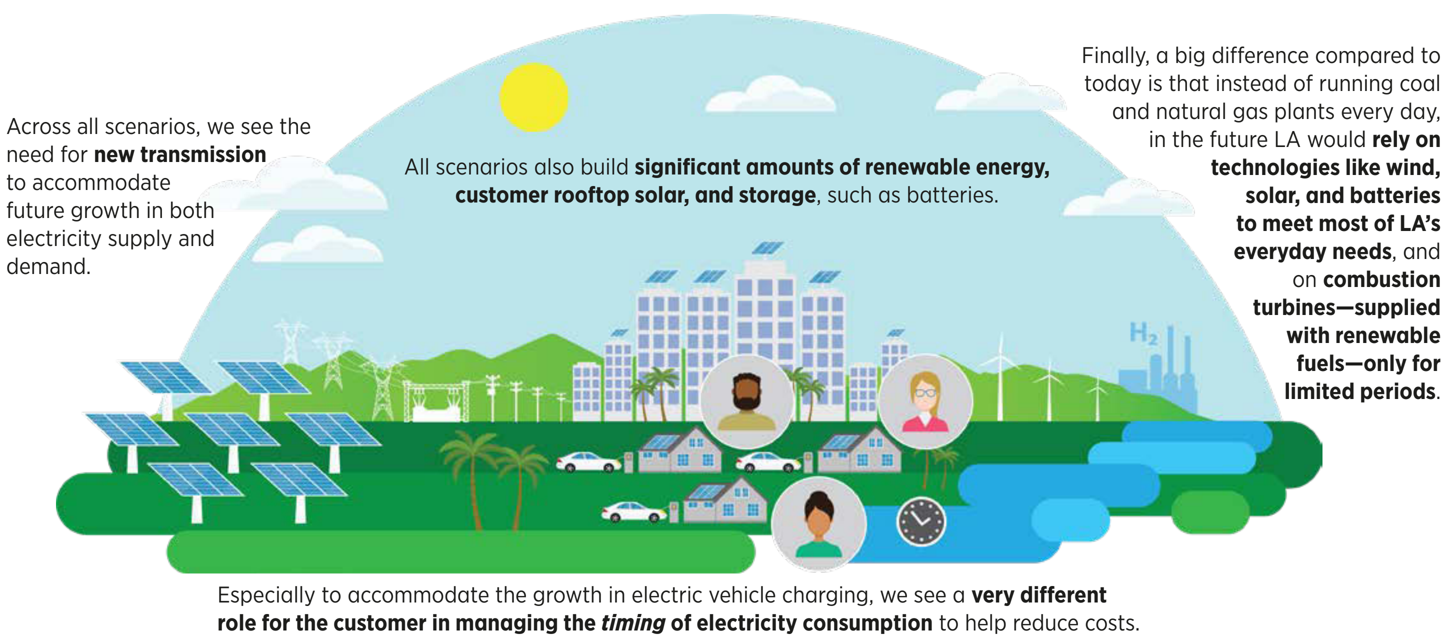
- 100% clean energy by **2045**
- Only scenario that does not allow upgrades to transmission beyond currently planned projects
- No natural gas or nuclear generation

Looking across the scenarios, the LA100 study reveals key insights about what a high-renewable-energy future could look like in LA—and beyond.

- On the road to achieving 100% renewables by 2045, all LA100 scenarios include significant deployment of renewable and zero-carbon energy by 2035, accounting for 84%–100% of energy and a decline of 76%–100% greenhouse gas (GHG) emissions from power plant operations in 2035 compared to 2020, depending on the scenario. Each of the scenarios builds new wind, solar, batteries, and transmission, coupled with operational practices that make more efficient use of these investments.
- By 2045, electricity demand (both annual consumption and peak demand) is likely to grow. High levels of energy efficiency can offset this growth in the buildings sector due to hotter climate, population growth, and electrification. It is the electrification of the transportation sector that propels overall growth in electricity demand.
- Also by 2045, with the incentives evaluated in the study, customers are likely to drive significant growth in rooftop solar: 3–4 gigawatts (GW), including up to a third of customers in existing single-family homes, based on favorable economics to the customer. LADWP might also deploy an additional 300–1,000 megawatts (MW) of non-rooftop, in-basin solar. The distribution grid can manage this growth in local solar—along with the projected growth in electricity demand. While almost all parts of the distribution grid will need some upgrades, the LA100 study estimates that, after correcting deferred maintenance on the existing system, a modest number of equipment upgrades would be sufficient to manage growth in demand and local solar. These distribution upgrade costs represent a small fraction of the total cost of the clean energy transition.

Additional results by scenario and topic, links to download each chapter of the full report, a glossary of terms, and an interactive data viewer can be found on the study website at: maps.nrel.gov/la100

- Electrification of vehicles and buildings leads to substantial improvements in air quality and associated benefits to health—widespread across both disadvantaged and non-disadvantaged communities. LA100's results indicate that realizing these health benefits is principally a matter of achieving high energy efficiency and electrification, independent of any particular renewable energy pathway for the power sector.
- Also regardless of the pathway, economic impacts to the city of the 100% renewable energy transition are projected to be small relative to the overall size of LA's economy—so while the transition could create thousands of clean energy jobs annually, the clean energy investments alone are not anticipated to notably impact LA's economy overall.



Scenario	Total Clean Energy (Renewable, Hydro, and Nuclear) Penetration Achieved 2035 vs. 2045	Present Value of Cumulative (2021–2045) Costs* at Alternative Discount Rates (Billion 2019$)	Cumulative (2020–2045) Life Cycle GHG Emissions, All Sectors (MMT CO_2e)	Reduction in Annual Life Cycle GHG Emissions in 2045 Compared to 2020, All Sectors	Cumulative (2021–2045) Monetized Emissions Costs of GHG Emissions at Discount Rates of 2.5% and 5% (Billion 2019$)	Annual Mean Value** of Avoided Health Impacts in 2045 Only (Undiscounted, 2019$) Compared to 2012	Average Annual Employment from LADWP Power-Sector Spending (2026–2045) by Location of Investment: In-basin / Out-of-basin / Total
SB100 MODERATE	90% / 90%	0%: $57B 2.5%: $40B 5.0%: $28B	570 MMT	54%	2.5%: $61B 5.0%: $16B	$900M	In: 4,900 Out: 3,000 Total: 7,900
Early & No Biofuels MODERATE	100% / 100%	0%: $87B 2.5%: $59B 5.0%: $42B	510 MMT	61%	2.5%: $55B 5.0%: $14B	Very similar results to SB100 – Moderate, likely***	In: 8,200 Out: 4,200 Total: 12,400
Transmission Focus MODERATE	90% / 100%	0%: $67B 2.5%: $46B 5.0%: $33B	540 MMT	59%	2.5%: $58B 5.0%: $15B		In: 6,400 Out: 3,500 Total: 9,900
Limited New Transmission MODERATE	91% / 100%	0%: $62B 2.5%: $43B 5.0%: $31B	540 MMT	59%	2.5%: $59B 5.0%: $15B		In: 6,700 Out: 3,000 Total: 9,700
SB100 HIGH	84% / 88%	0%: $61B 2.5%: $42B 5.0%: $30B	460 MMT	79%	2.5%: $50B 5.0%: $13B	Very similar results to Early & No Biofuels – High, likely***	In: 5,500 Out: 3,500 Total: 9,000
Early & No Biofuels HIGH	100% / 100%	0%: $86B 2.5%: $59B 5.0%: $41B	390 MMT	88%	2.5%: $43B 5.0%: $11B	$1,400M	In: 8,700 Out: 4,500 Total: 13,200
Transmission Focus HIGH	89% / 100%	0%: $72B 2.5%: $49B 5.0%: $35B	425 MMT	86%	2.5%: $46B 5.0%: $12B		In: 7,200 Out: 4,300 Total: 11,500
Limited New Transmission HIGH	90% / 100%	0%: $67B 2.5%: $46B 5.0%: $33B	420 MMT	87%	2.5%: $46B 5.0%: $12B		In: 7,600 Out: 3,900 Total: 11,500
SB100 STRESS	85% / 87%	0%: $69B 2.5%: $47B 5.0%: $34B	480 MMT	77%	2.5%: $53B 5.0%: $14B		In: 6,500 Out: 3,700 Total: 10,200
Axis scale		$0 – $90B	0 – 600		$0 – $63B	$0 – $1,500M	0 – 15,000

*Costs, as measured in the study, represent costs of expanding and operating of the power system from 2021. Present values calculated with a discount rate of 0% are equivalent to an undiscounted value.
**95% confidence interval of values of avoided health impacts in 2045 compared to 2012 is SB100 – M is (-$480M–$3,000M) and of Early & No Biofuels – H is (-$470M–$4,400 M).
***Because the contribution to emissions reductions from the power sector is small (ranging from 0.8%–1% for NOx among LA100-evaluated reductions), it is reasonable to qualitatively estimate the results stated.

Comparison of scenarios across select metrics analyzed in LA100

Major Trends Across All Pathways to 100%

1. **Reliable, 100% renewable electricity is achievable—and, if coupled with electrification of other sectors, provides significant greenhouse gas, air quality, and public health benefits.**

- While achieving a reliable, 100% renewable electricity power system is a significant undertaking requiring substantial investments, the LA100 analysis identifies multiple pathways to get there.
- Wind and solar resources—enabled by storage—are fundamental to providing the majority of energy required to meet future load: **69%–87%** depending on the scenario.
- New in-basin, renewable firm capacity—resources that use renewably produced and storable fuels, can come online within minutes, and can run for hours to days—will become a key element of maintaining reliability (represented in the figure below as hydrogen- and renewably [RE]-fueled combustion turbines and fuel cells).

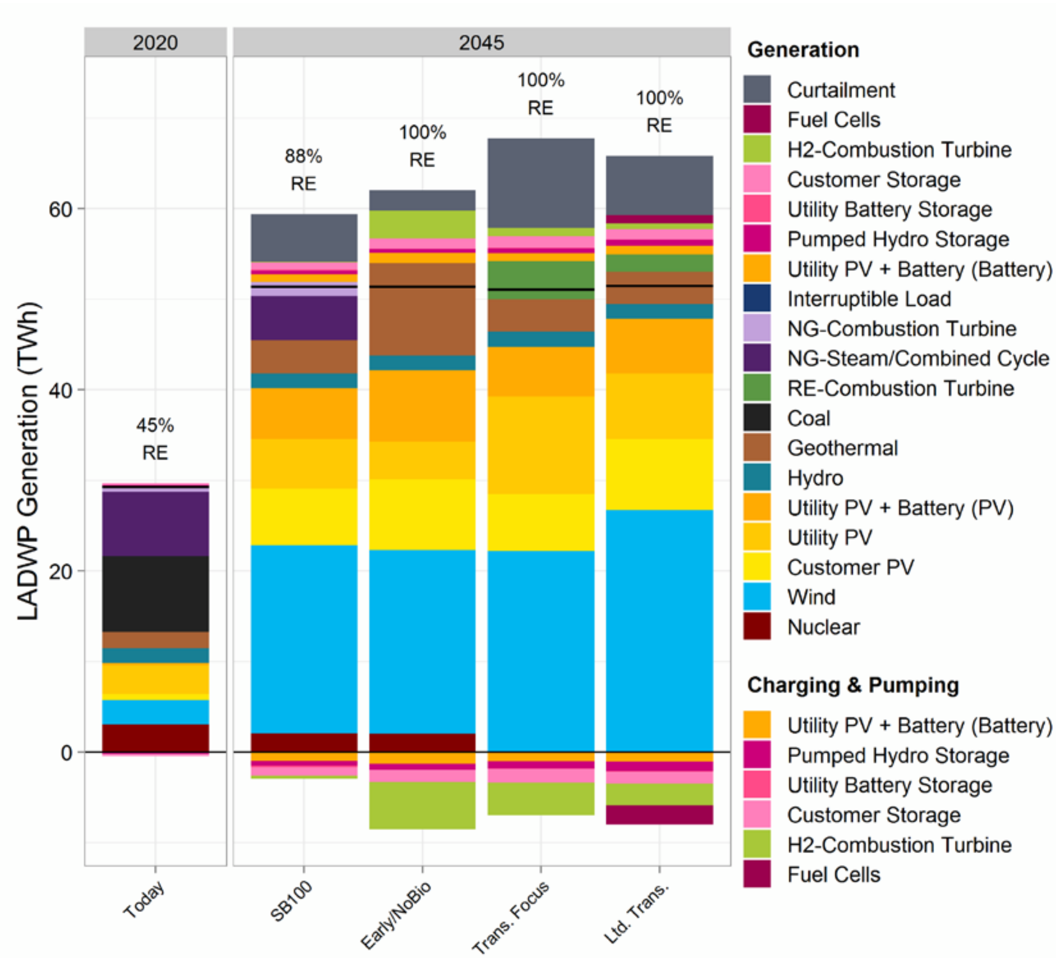
Customer-oriented actions that help complement a renewable energy transition include:

Energy efficiency → helps offset climate- and electrification-driven load growth and potentially higher electricity rates; lowers energy burden for low-income residents

Greater electrification → contributes to higher public health and GHG benefits; helps reduce per-unit electricity costs

Customer demand flexibility → helps contain costs of adding electrification and achieving 100% renewable energy; also supports reliability

- Decarbonizing the power sector through renewable deployment helps create the enabling conditions for decarbonization of the buildings and transportation sectors through electrification. While the power sector itself contributes few non-GHG air pollutant emissions in a 100% renewable future, the electrification of combustion sources in other sectors enables more significant emissions reductions, and thus improved health for Los Angeles residents.



Annual generation mix in 2045 for all High load scenarios compared to 2020

The percent RE refers to percent of generation that is carbon neutral (renewable and nuclear). Negative values indicate the amount of electricity consumed by the plants (e.g., to charge a battery, pump hydro, or produce hydrogen fuel). Load (solid line) is customer electricity consumption exclusive of charging. Curtailment includes available energy that is curtailed to provide reserves.

2. All communities will share in the benefits of the clean energy transition—but improving equity in participation and outcomes will require intentionally designed policies and programs.

- Disadvantaged communities (as defined by CalEnviroScreen scores) could expect to see many benefits in a clean energy transition, including reduced local and regional air pollution, improved indoor air quality from electrification, reduced vulnerability to climate change and improved health outcomes.
- Ensuring prioritization of these neighborhoods, however, is not an inevitable result of the power-system transition. A just, equitable clean energy future would require intentionally designed decision-making processes and policies/programs that prioritize these communities (see the text box below).

3. Net economic assessment shows that achieving the LA100 scenarios will not affect LA's overall economy in any meaningful manner.

- Using SB100 – Moderate as a reference scenario, the net impact to employment within the city (reflecting combined positive and negative impacts of economic activity measured in LA100, from 2026 to 2045) ranges from a low of 3,600 fewer jobs annually under the Early & No Biofuels – Moderate scenario to 4,700 additional jobs under the SB100 – Stress scenario. While there may be slight positive or negative impacts, these changes are small in relationship to the 3.9 million jobs and $200 billion in annual output of LA's economy as a whole, so they have an almost negligible impact.
- Specific to jobs associated with LADWP expenditures as measured in LA100, both in and outside of the LA Basin, higher expenditures on new infrastructure and operations of both existing and new infrastructure (exclusive of the distribution grid) correlate with higher numbers of jobs. The number of gross annual jobs (onsite and ripple effect) supported by these expenditures ranges from an average of 7,900 jobs per year in SB100 – Moderate to 13,200 jobs per year in Early & No Biofuels – High.

Example Actions to Support Prioritization of Environmental Justice

Participation in decision-making: Identifying barriers to procedural justice can inform improvements to who is included in decision-making, how decisions get made, and what resources are needed to enable parity of participation.

Energy infrastructure: LA100 shows strong potential for electrification, efficiency, demand response, and rooftop solar in environmental justice neighborhoods—but the modeling does not capture real-world experiences and barriers to adoption. Actions to prioritize environmental justice include improved input modeling data on characteristics significant to environmental justice (e.g., household size, access to smart energy devices) and more comprehensive representation of benefits, such as improved resilience to extreme weather events through energy efficiency upgrades.

Jobs: Identifying workforce needs for each energy technology identified in the study has important implications for potential future hiring and training needs. The City of LA could facilitate programs for in-demand occupations that may be hard to fill and for other high-quality jobs. The City of LA could also include in clean energy program design some of the workforce objectives sought by the community. For example, some have requested solar installations within disadvantaged communities as a way to support clean energy jobs that do not require long commutes.

Maintaining support for electrification: Electrification of transportation, building end uses, and the Ports of Los Angeles and Long Beach provide significant air quality and related public health benefits. Hence, a prioritization of disadvantaged communities as first immediate beneficiaries of localized air quality improvements would include a focus on electrification. But electrification can be hindered by increasing electricity rates. Toward the end of the 100% renewable energy transition, the cost of fully decarbonizing the power sector, if reflected in increased rates, could lead to public pressure to reduce the pace of electrification. Further analysis could consider options that maintain decarbonization and improved health as a goal, but with a better understanding of the interaction among the costs of power system decarbonization, pace of electrification, and rate design.

Neighborhood-level health impacts: Quantifying neighborhood-level impacts could be an important component of further analysis after LA100 with regard to achieving outcomes beneficial to disadvantaged communities. For example, the design and evaluation of any EV incentives could be coupled with analysis of local air quality benefits, especially in neighborhoods along roadways that suffer high local pollution. As another example, LA100 results suggest value to reliability in building new, state-of-the-art combustion turbines at current thermal generating station sites fueled by renewable-electricity-derived fuels (such as hydrogen) and operated less frequently compared to natural gas today. One step that LADWP and the City of LA can consider to prepare for this change is to establish expectations of anticipated neighborhood environmental impacts (based on local-scale air quality modeling), monitor these impacts, and revise operating protocols as needed.

4. LA can get started now, with many no-regrets options that achieve significant emissions reduction (76%–99%) by 2030.

- The LA100 study finds many no-regrets options. On the customer side, the study shows significant benefits from electrification in terms of improving GHG emissions, air quality, and health, and emphasizes the critical role of customer demand flexibility to reduce per-unit electricity costs and contribute to reliability.
- When it comes to the LADWP power system, the no-regrets options include new wind, solar, batteries, and transmission—deployed in or out of the LA Basin, and coupled with smart-grid operational practices that make more efficient use of these investments. LADWP can also address existing distribution maintenance needs to enable changes on the customer side, which were assumed to have already occurred as the starting point for LA100.

Key Distinctions Between Pathways to 100%

1. The LA100 scenarios show similar cost increases until approximately 80%–90% renewable energy. The pathways diverge with differences in the technologies deployed to meet the last 10%–20% of energy demand that cannot be easily served by wind, solar, and conventional storage technologies—and to maintain reliability in the face of extreme events.

- In-basin renewable capacity that can come online within minutes and run for days serves a critical role: it provides energy during periods of lower wind and solar generation, extremely high demand, and unplanned events like transmission line outages.
- Today, the cheapest option for this type of peaking capacity is a storable renewable fuel used in a combustion turbine. Biofuels are commercially available today and could serve as a transition fuel until commercially available, electricity-derived fuels become more widespread.
- If the City of LA does not want to use biofuels, LADWP can produce its own clean fuel in the form of hydrogen (produced from renewable electricity).
    - This option is not yet commercially available at scale, so building the necessary infrastructure could represent a significant portion of total costs associated with the clean energy transition.
    - In the Early & No Biofuels scenario, hydrogen technology represents a 20+% increase in cumulative (2021–2045) costs compared to cases that allow biofuels.
- The resources used to help meet this last 10% and maintain reliability can produce local air emissions, particularly when based on combustion generation.
- However, even accounting for future growth in energy demand, these new resources would be used much less often than current natural-gas plants, resulting in lower emissions—both in the power sector and economy-wide.

2. The combination of higher energy efficiency, electrification, and demand flexibility, while associated with increased total costs, offers both greater benefits and reduced per-unit electricity costs compared to alternative scenarios.

- While LA100 does not represent a complete analysis of tradeoffs (e.g., it does not address costs of demand-side equipment, employment benefits from energy efficiency, and impact to overall energy expenditures, among others), the benefits as measured within the study are significant. For example, comparing a scenario with Moderate and High electrification levels, while the High electrification version has higher total costs, it offers lower per-unit costs, higher GHG and air pollutant emissions reductions, and higher public health benefits (see the figures on the next page).
- In addition, comparing SB100 – Stress to SB100 – High shows the value of energy efficiency and demand flexibility (as the scenarios are otherwise the same). SB100 – Stress has an 8.5% higher annual electricity consumption and 17% higher peak demand compared to SB100 – High. The combination of efficiency and demand flexibility assumed in the High version reduces the cumulative (2021–2045) costs of that scenario by 13%.

This study is unique for a 100% renewable energy analysis in that it includes vulnerabilities to many types of events (heat waves, fires, earthquakes, among others).

Keeping the lights on was a foundational part of this study, as the City of LA recognizes the critical role of a reliable power grid—especially in a future with more consumer products, like cars, electrified. A 100% renewable grid cannot compromise on reliability, particularly when electricity is playing a greater role in heating, cooking, and transportation.

Increasingly, studies of the evolving grid, regardless of the contribution of renewables, are examining the impact of climate change on demand for electricity, and the vulnerability of the grid to increased temperatures and climate-change-driven natural disasters, whether they be wildfires or earthquakes.

Minimizing climate vulnerabilities requires careful planning and use of a mix of resources, including continued deployment of the cleanest resources that can maintain reliability (which today include combustion-based resources), while aggressively pursuing lower-emitting technologies, such as hydrogen fuel cells.

Scenario	Cumulative (2021–2045) Costs* per MWh (2019$)	Reduction in Annual Life Cycle GHG Emissions, All Sectors, in 2045 Compared to 2020	Reductions in Annual Emissions from LA100-Influenced Sources in 2045 Compared to SB100 – Moderate	Annual Mean Value** of Avoided Health Impacts in 2045 (Million 2019$) Compared to SB100 – Moderate	Annual Mean Avoided Incidences in 2045 Compared to SB100 – Moderate
Early & No Biofuels MODERATE	$93/MWh	61%	2% NO_x; 1% $PM_{2.5}$	$9M	**1 prevented** premature death **0 change** in cardiovascular hospital admissions **0 change** in asthma ER visits
Early & No Biofuels HIGH	$83/MWh	88%	63% NO_x; 39% $PM_{2.5}$	$500M	**53 prevented** premature deaths **23 fewer** cardiovascular hospital admissions **19 fewer** asthma ER visits
	$0 – $100			$0 – $500M	

*Annual per-MWh costs do not equal rates—these costs represent the revenue requirement (per unit of generation) to cover the annualized costs associated with expenditures measured in LA100.
**95% confidence interval of values of avoided health impacts in 2045 compared to SB100 – M is: Early & No Biofuels – M ($1M–$24M) and Early & No Biofuels – H ($19M–$1,400 M).

Scenario	Cumulative (2021–2045) Costs* per MWh (2019$)	Reduction in Annual Life Cycle GHG Emissions, All Sectors, in 2045 Compared to 2020	Reductions in Annual Emissions from LA100-Influenced Sources in 2045 Compared to SB100 – Moderate	Annual Mean Value** of Avoided Health Impacts in 2045 (Million 2019$) Compared to SB100 – Moderate	Annual Mean Avoided Incidences in 2045 Compared to SB100 – Moderate
SB100 MODERATE	$62/MWh	54%	n/a	n/a	n/a
SB100 HIGH	$61/MWh	79%	63% NO_x; 39% $PM_{2.5}$	$490M	**53 prevented** premature deaths **23 fewer** cardiovascular hospital admissions **19 fewer** asthma ER visits
	$0 – $100			$0 – $500M	

*Annual per-MWh costs do not equal rates—these costs represent the revenue requirement (per unit of generation) to cover the annualized costs associated with expenditures measured in LA100.
**95% confidence interval of values of avoided health impacts in 2045 compared to SB100 – M for SB100 – H is ($18M–$1,400M).

Comparison of costs and benefits between two different electrification levels for the Early & No Biofuels (top) and SB100 (bottom) scenario. The High electrification level offers higher benefits and lower per-unit electricity costs.

3. Accelerating the target year to 2035 increases both costs and benefits.

- All else equal, an earlier target year means LADWP must make the necessary investments to achieve 100% renewable electricity more quickly. This results in earlier accumulation of debt, ultimately leading to greater costs over the timeframe of this study (2021–2045).
- However, benefits also accrue more quickly, though not necessarily at the same rate as costs. The earlier LADWP achieves a zero-GHG-emission or 100% renewable system, the earlier the avoided emissions accumulate. Reducing emissions earlier has value in terms of reducing the magnitude of the effects of climate change. Similarly, new renewable energy jobs accrue more quickly.
- The Early & No Biofuels scenario accumulates both the costs (from annualized payments for renewable technologies) and benefits (GHG emissions, renewable energy jobs) of this transition due to the 10-year head start.
- If the earlier target is pursued, success would also require an accelerated schedule for renewable energy procurement, permitting, siting, and workforce training, among other activities that are outside the scope of the study but are essential components of implementation.

4. Technology restrictions result in higher costs when it comes to meeting the last 10%–20% of energy demand—but almost no additional air quality or public health benefits.

- The costs, GHG emissions, air quality, and public health trajectories across scenarios (within any given electrification level) are similar until each scenario reaches approximately 90% renewable and zero-carbon electricity. After 90%, the costs diverge for different scenarios, but the overall benefits plateau.
- SB100 remains around 90% renewable and zero-carbon electricity through 2045 due to how this scenario is defined. But all the other scenarios move from 90% to 100% renewable electricity by 2045—and they exhibit sharp increases in costs in the last 10%.
- The additional benefits of restricting technology eligibility in terms of air quality and public health, as measured in the selected scenarios analyzed in the study, are minimal when electrification levels are constant because natural gas consumption across

LA100 does not address all benefits related to this analysis of technology eligibility. Potential benefits of technology restrictions not captured include reducing neighborhood-level pollutants, achieving global leadership in attaining a 100% renewable target without renewable energy credits (i.e., without natural gas) and/or without biofuels, and addressing sustainability concerns about biofuels.

Scenario	Reduction in Power-Sector Life Cycle GHG Emissions in 2045 Relative to 2020
SB100 HIGH	68%
Early & No Biofuels HIGH	93%

Annual Health Impacts Metrics* Compared to SB100 – High, 2045 Only

1 prevented premature death
0 change in cardiovascular hospital admissions
0 change in asthma ER visits
$6M annual mean value* of these avoided health impacts

*95% confidence interval of values of avoided health impacts in 2045 of Early & No Biofuels – H compared to SB100 – H is -$1M–$17M

Comparison of GHG emissions and health impacts in 2045 between SB100 – High and Early & No Biofuels – High. "Life cycle" GHG emissions consider all phases of both the generation facility and its fuel: plant construction; plant operation including fuel combustion (if applicable) and other operations and maintenance as well as emissions from the acquisition, treatment, and transport of fuels, when applicable; and finally plant decommissioning and disposal.

all scenarios is significantly reduced or eliminated compared to today. Because changes to the power sector only contribute 0.8%–1% of the NOx emissions reductions among LA100 scenarios compared to 2012, and 10%–18% of the particulate-matter emission reductions, it is clear that changes to energy efficiency and electrification levels (for vehicles, buildings, and the Ports of Los Angeles and Long Beach) are the predominant cause of health benefits.

Looking Ahead: Addressing Uncertainty, Prioritizing Future Decisions

1. Identifying alternative options for firm, in-basin capacity likely represents the largest opportunity to reduce the costs of the transition and points to the highest priorities for R&D: hydrogen and extended demand response.

- All LA100 scenarios build in-basin combustion-based resources to help meet the last 10%–20% of electricity demand that is not easily met by low-cost wind, solar, and batteries. The timing of building these new resources can be cost-effectively delayed somewhat with a combination of energy efficiency, local solar and storage, new transmission, and technologies and techniques to increase the capacity of existing, in-basin transmission. But delays in deploying these *other* options could accelerate the need for new in-basin resources.

Demand response—the change in the amount or timing of electricity use in response to a price or other signal from the utility—is most often used today to reduce system peaks and thereby reduce the need for additional power plants or transmission lines. Demand response may also be used, as it was in LA100, to shift demand for electricity to times when more renewable energy is available.

- The fuel for new in-basin resources varies by scenario. Several scenarios use biofuels, which are commercially available and serve as a net-zero-carbon transition fuel while technologies such as hydrogen-based fuels mature.

- Alternatives to biofuels include renewable electricity-derived hydrogen fuel, or hydrogen derivatives, such as synthetic methane or ammonia. There is considerable uncertainty regarding hydrogen's long-term cost and commercial availability, as well as generator modifications needed to use these fuels. There is also uncertainty as to how long it will take to develop infrastructure for transportation and storage.

  To reduce hydrogen costs, the City of LA could partner with industry as part of economy-wide decarbonization where hydrogen-derived fuels are used to power industry, non-electrified transportation, and serve as feedstocks for chemicals and materials that currently rely on fossil fuels.

- Across the scenarios, allowing fuel flexibility (biofuels inclusive) allows LADWP to start now without committing to hydrogen infrastructure. Allowing renewable electricity credits (RECs) (to continue limited use of natural gas) could mitigate risk; limiting use of RECs to a few percent could provide the needed reliability benefits and still provide nearly all the GHG, air quality, and public health benefits associated with the transition to 100% renewable electricity.

- In addition to fuel flexibility and RECs to mitigate uncertainty in the use of hydrogen and biofuels, one alternative yet to be deployed and tested at scale is multi-day (or extended) demand response. Such a program could be initiated now to enable more rapid roll-out should the City of LA proceed with biofuel or hydrogen options and find those paths infeasible or cost-prohibitive.

- A multi-day demand response program would require a detailed analysis of the customer base to identify customers with flexible loads, and the necessary compensation needed to reduce these loads for extended periods. Exploring this option would likely require pilot programs and new rate designs that compensate customers for reduced energy consumption, as these types of programs do not exist at scale in the United States outside of very large industrial customers.

2. What if LA wants to pursue an earlier target?

- The LA100 study did not evaluate achieving 100% renewable energy prior to 2035. However, in 2030 the scenarios achieve a decline of 76%–99% GHG emissions from power plant operations compared to 2020, and an overall renewable and zero-carbon energy contribution of 77%–99% of energy, depending on the scenario—so significant progress can be made in the next decade if LA starts now.

- A faster transition to 100% renewables would likely require deployment of technologies at a higher cost, reflecting both technology maturity and commercial availability. The costs could be particularly high for firm capacity resources needed to fully replace natural gas, given the current role of natural gas in responding to extreme events. We assume this complete transition is feasible by 2035, but we have not evaluated the supply chain and other aspects of feasibility that would be required to effect this change in less than 10 years.

- Availability of this type of firm capacity resource (e.g., hydrogen production, renewably fueled combustion turbines, fuel cells) would benefit greatly from a robust RD&D program at the financial scale of national and international initiatives rather than a single city's budget.
- Expediting regional transmission development would likely require state- and federal-level support.

3. This study marks an important but not final analysis in LA's pivot towards a clean and equitable energy future.

- LA100 establishes a methodology that could serve as a foundation for additional and updated analyses that could help reassess costs, benefits, and tradeoffs over time. Continued analyses are needed to understand how to improve implementation, monitor results, and adjust decisions.
- In particular, using current-generation, forward-looking models to anticipate implications for environmental justice does not capture real-world experiences and barriers to adoption. Therefore, effectively prioritizing environmental justice in implementation, per the City Council motion, would require ongoing monitoring and adjustments.
- In addition, aspects related to customer demand (efficiency, electrification, demand response, and customer solar and storage) also represent high-priority areas for ongoing analyses. The changes on the demand side occur, to a large degree, outside of LADWP's immediate control and planning, but can be substantially impacted by rate structures, incentives, or local policies, and have significant potential to affect the costs and benefits of the 100% renewable transition.

Additional results by scenario and topic, links to download each chapter of the full report, a glossary of terms, and an interactive data viewer can be found on the study website at: maps.nrel.gov/la100

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LA DWP Los Angeles Department of Water & Power

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