Clean Energy for Los Angeles

An analysis of a pathway for 100 percent renewable energy in Los Angeles by 2030

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FOREWORD

We now sit at a critical energy future crossroad that will decide the fate of the planet. If we continue to travel down our current path of fossil fuel addiction, relying principally on coal, oil, and gas to power our homes, businesses, and transportation, we will face an intensifying climate disaster of wildfires, floods, droughts, and other devastating and unavoidable public and environmental health impacts.

Or we can change course and choose the road to 100 percent renewables. We can create a society where clean, carbon-free solar, wind, and geothermal sources provide all the energy we need to maintain our current lifestyle while saving the planet. Given the consequences, the choice we must make is clear.

This report provides a roadmap to 100 percent renewable energy for Los Angeles, enabling the drive to a clean energy future. The roadmap lays out critical steps to a better future for Los Angeles while providing a model other cities and states can also follow to move away from fossil fuels toward clean energy systems.

Los Angeles' elected leaders, should they adopt this plan, will have the power to turn the fossil fuel tide by mandating that the Los Angeles Department of Water and Power (LADWP) transition to 100 percent renewable energy by 2030. LADWP is the country's largest public utility—its leadership in this transition would set a powerful example for the nation and the world. A renewably-powered Los Angeles will clean the air, create well-paid local jobs, promote energy independence, and lead to safer and healthier communities for the city's 4 million residents.

Moreover, this study demonstrates that Los Angeles' transition to 100 percent renewable energy is not only feasible, but that it will actually be cheaper for LADWP ratepayers. Prioritization of distributed rooftop solar and energy efficiency will drive down costs.

The transition contemplates a phase-out of fossil fuel infrastructure including refineries, gas-fired power plants, oil and gas wells, pipelines, and gas storage facilities that poison residents. Removing these pollution sources will clean up our communities, save money, and make Los Angeles safer during disasters, like earthquakes. It is also important that the needs of displaced workers in the fossil fuel industry are taken into account with job training and priority for employment in the renewable sector.

While this report shows that this necessary transition is possible, it is now up to Mayor Eric Garcetti and the Los Angeles City Council to take action to make it happen. And it's up to every Angeleno to exercise their political power and push their Mayor and Councilmembers to undertake this transition now. Younger and future generations are counting on us to succeed.

Wenonah Hauter
Executive Director
Food & Water Watch

EXECUTIVE SUMMARY

The Los Angeles Department of Water and Power (LADWP) is pushing ahead with ambitious goals to achieve 100 percent renewable energy and is in the process of analyzing a future with that level of renewable growth. This report provides LADWP with a road map for two possible paths to achieve 100 percent renewable energy by 2030, including a path that can save ratepayers money.

LADWP, the largest municipally-run utility in the country, serves nearly 1.5 million residential households and businesses in Los Angeles County. The county houses a quarter of the state's population and accounts for about one tenth of all of California's electricity needs.

As the state with the highest amount of renewable generation to-date, California is one of the first states to experience operational issues integrating high levels of variable generation from wind and time-concentrated output from solar facilities. For LADWP, or California for that matter, to become wholly powered by renewables it must require that demand in every hour of the year is met with renewable energy.

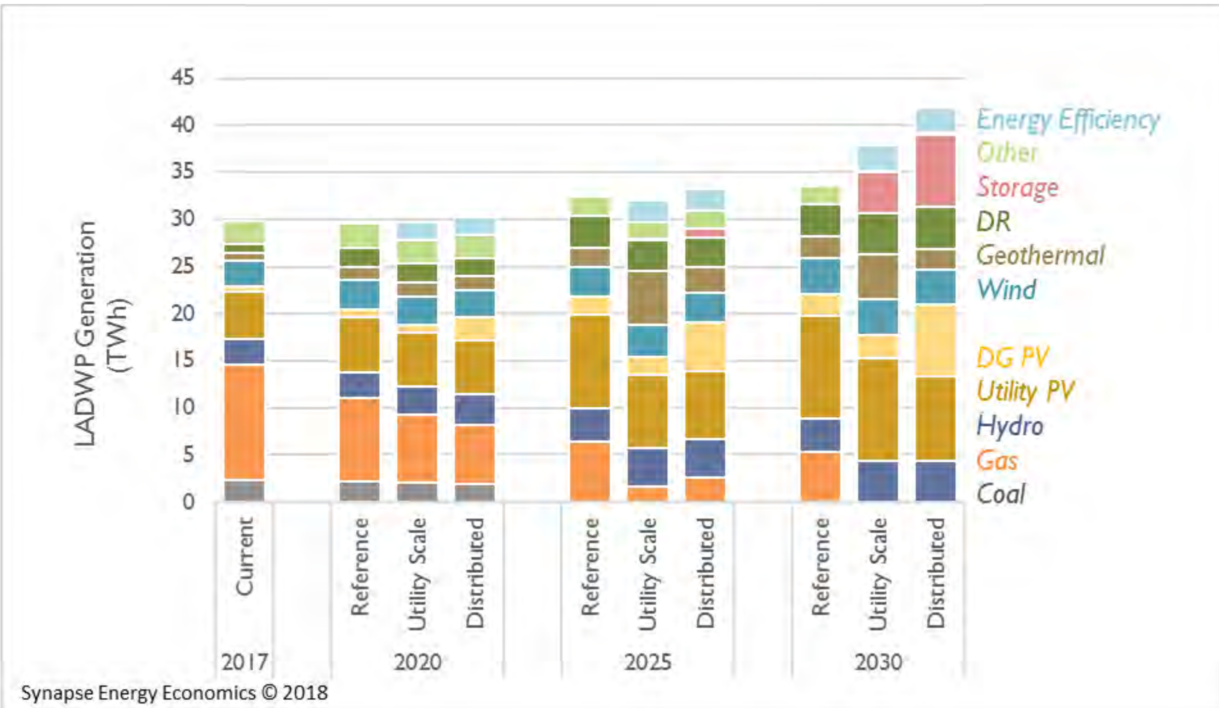
In order to understand the impact of a 100 percent renewable policy in LADWP's service territory, Food & Water Watch retained Synapse Energy Economics (Synapse) to analyze how current electrical trends in LADWP would differ from a future in which all of LADWP's needs are met through non-emitting renewables. Using the utility-grade EnCompass electricity model, Synapse modeled a business-as-usual "Reference" case and two unique 100 percent renewable LADWP cases (collectively, the Policy cases): one relies heavily upon utility-scale solar (the Utility-Scale case), and the other relies more on distributed solar and storage (the Distributed case). Our analysis and findings follow.

In this analysis of two potential LADWP futures, **we find that it is, in fact, possible for LADWP to exclusively use renewable resources to power its system in every hour of the year**. What's more, achieving very high levels of renewable integration in LADWP does not require a substantial departure from the Reference case within the first several years of the study, allowing LADWP a brief, but necessary, window to plan how to best optimize a future 100 percent renewable system.

To meet electricity needs in every hour with 100 percent renewable resources, LADWP must integrate and harness renewable energy more efficiently through additional efficiency, storage, and demand response.

In order to reach 100 percent renewable energy in every hour, LADWP will need to close or divest from all fossil-fueled generators in its current portfolio. This moves beyond ending its commitment to purchase capacity from the Intermountain coal plant and includes retiring all of its locally owned and operated natural gas and landfill gas facilities. However, aside from these changes, both our 100 percent renewable Policy cases have similar levels of overall renewable capacity as the Reference case in 2030. The key difference lies in how the grid is operated—to reach 100 percent renewable generation in every hour of the year, LADWP will need to invest in energy efficiency to reduce overall load, encourage demand response programs to reduce the strain of peak hours on the system, and build storage capacity to store and spread solar generation throughout the day. Importantly, these 100 percent renewable scenarios do not allow for compliance through the purchase of unbundled (or undeliverable) Renewable Energy Credits (RECs). Instead, the scenarios require all renewable generation used to reach the 100 percent target to be either sourced in Los Angeles County or directly deliverable to the LADWP grid. As seen in Figure 1, LADWP will rely upon efficiency, demand response, and stored solar generation to close the gap from retiring fossil resources.

Figure 1. LADWP's annual generation in select years under each modeled scenario



Note: In this chart, only capacity located in or directly connected to LADWP is shown. "Other" is primarily nuclear generation.

A 100 percent renewable future exceeds the targeted emission reductions of current regulations.

California's existing legislation requires each utility to reach 50 percent renewable generation by 2030, as well as to reduce emissions to 1990 levels by 2020 and to 80 percent below 1990 levels by 2050.[1] Under the Reference case, emissions in LADWP's service territory are expected to decrease from the 14.4 million metric tons emitted in 2015—or 19 percent below 1990 levels—to just under 2 million metric tons per year in 2030.[2] In the Policy cases emissions are eliminated, leading to a fully-decarbonized electric sector by 2030 (see Figure 2).

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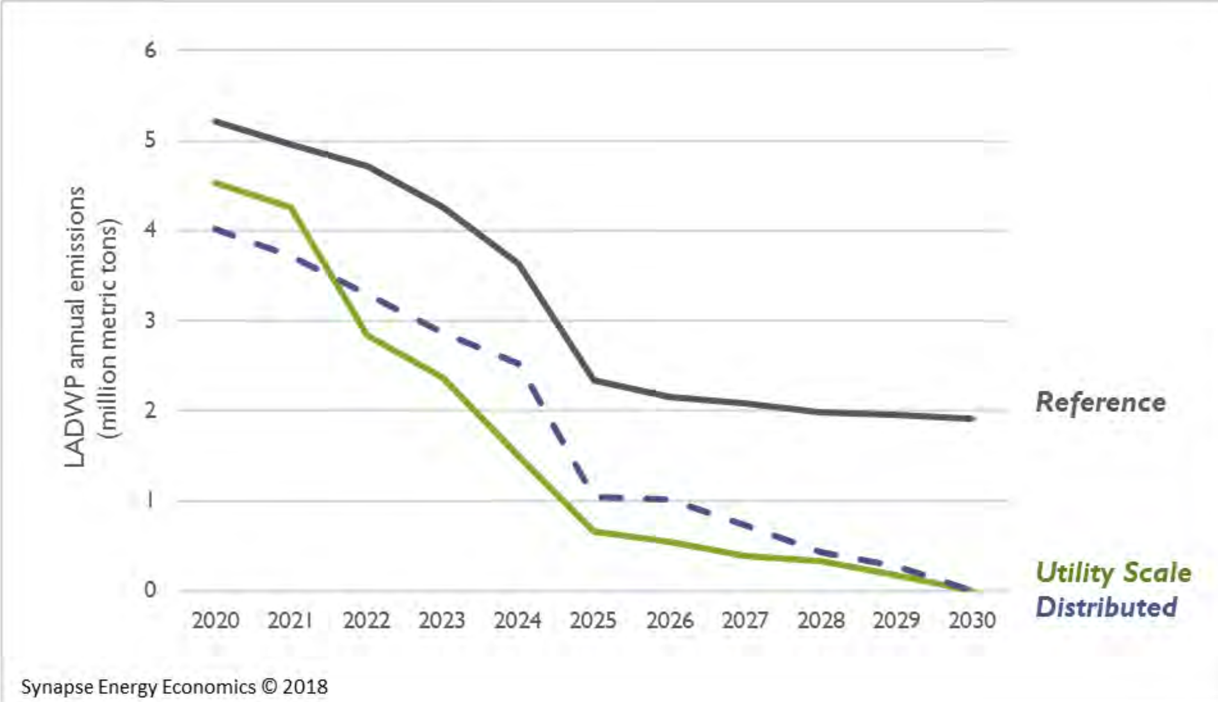
[1] California Executive Order S-3-05, available at https://www.gov.ca.gov/news.php?id=1861

[2] LADWP 2016 IRP, ES-11.

Figure 2. LADWP electric-sector CO_2 emissions from 2017 to 2030



Achieving 100 percent renewable integration in LADWP does not require a substantial departure from the Reference case within the first several years of the study.

Through 2020, the capacity mix in LADWP in both the Reference case and the Policy cases are nearly identical. The Reference case just has slightly more storage than the Utility Scale case in 2020 and slightly more distributed solar in the Distributed case in 2020. By 2025, the Reference and Policy case trajectories remain similar, but the clean energy transition is thoroughly underway: by 2025, natural gas capacity has decreased by 50 percent, a reduction offset largely by efficiency and geothermal power. By 2030, the overall renewable capacity in the Reference case and Policy cases is relatively similar, with the exception of the retirement of all of LADWP's natural gas generating capacity in the Utility Scale case. In the Distributed case, all of the gas capacity in the region still retires by 2030 and Los Angeles has over 15 percent more distributed generation capacity than the Reference case in 2030. While both distributed and utility solar are modeled as receiving the same capacity credit for planning purposes, distributed solar operates at a lower capacity factor, meaning more distributed capacity and storage capacity are necessary to truly take advantage of the available solar energy. The fact that the three scenarios are so similar over the first eight years of the study period will allow LADWP time to further study, plan for, and optimize their operations to harness the renewable generation on its grid to the level necessary to meet 100 percent of need with renewables in 2030. Importantly, the large amount of distributed generation added in the Distributed case helps to reduce the need for some of the transmission and distribution system upgrades that would otherwise be required under a 100 percent renewable scenario.

In a 100 percent renewable 2030, hourly generation on the peak summer day will leverage solar and storage.

Any electric sector future that reaches 100 percent renewable generation to meet demand in every hour of the year will necessarily rely upon a mix of storage, renewable curtailment, and new transmission lines. Synapse's modeled scenario focuses on a mix that is heavy on storage and curtailment, while light on new transmission. As a result, the hourly generation results for a peak day in 2030 in the Policy cases rely upon solar and solar-powered storage to meet demand: in the Utility Scale case, the solar generation is largely utility-scale (see Figure 3), while in the Distributed case, the solar generation is largely distributed (see Figure 4).

Figure 3. 2030 hourly generation, representative peak day, Utility Scale case

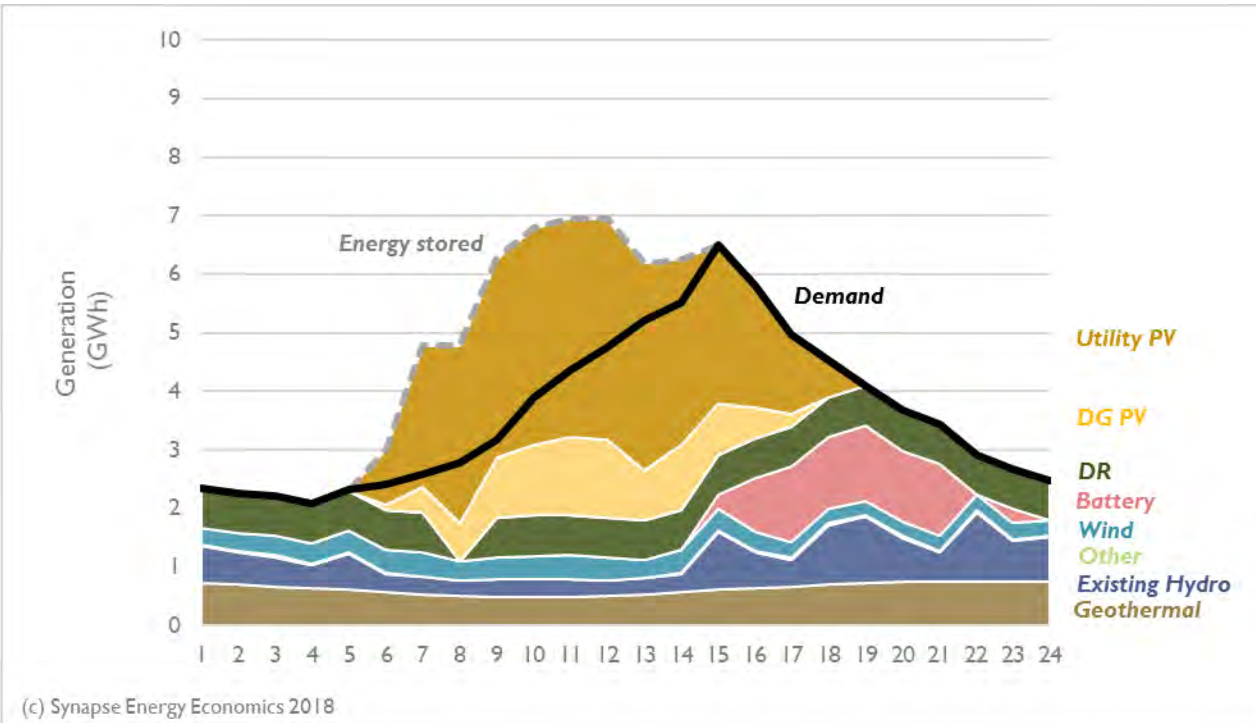
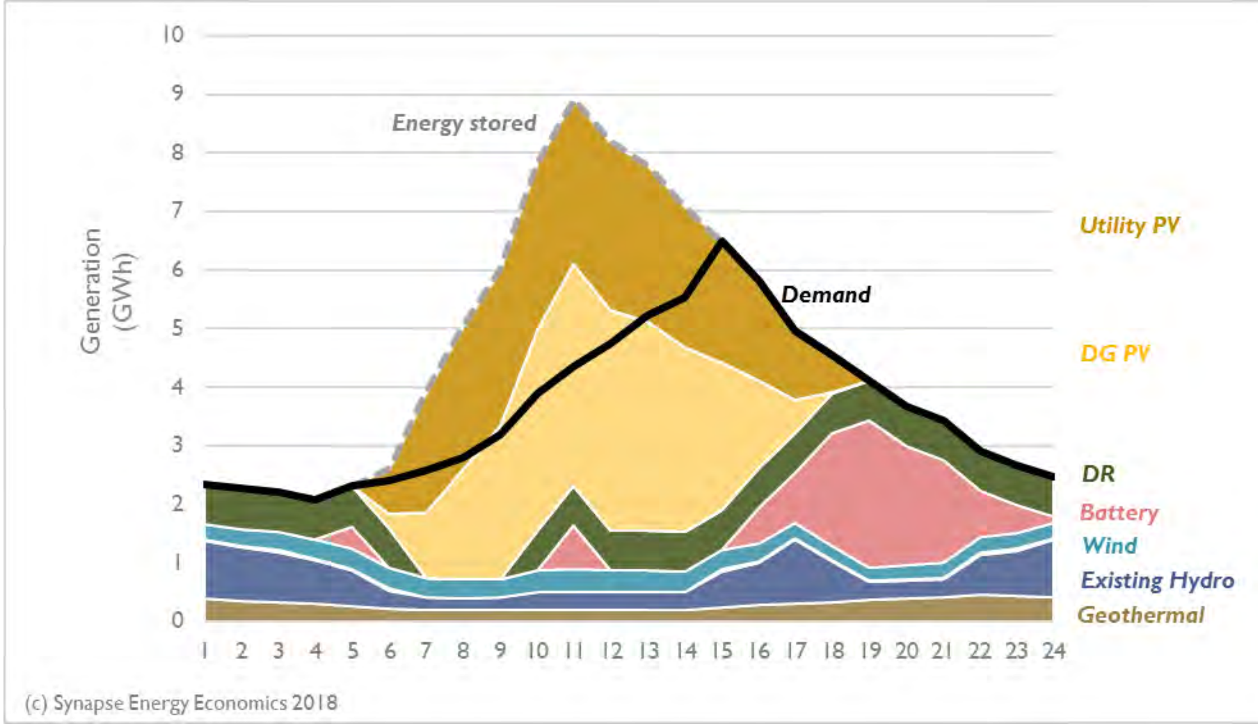


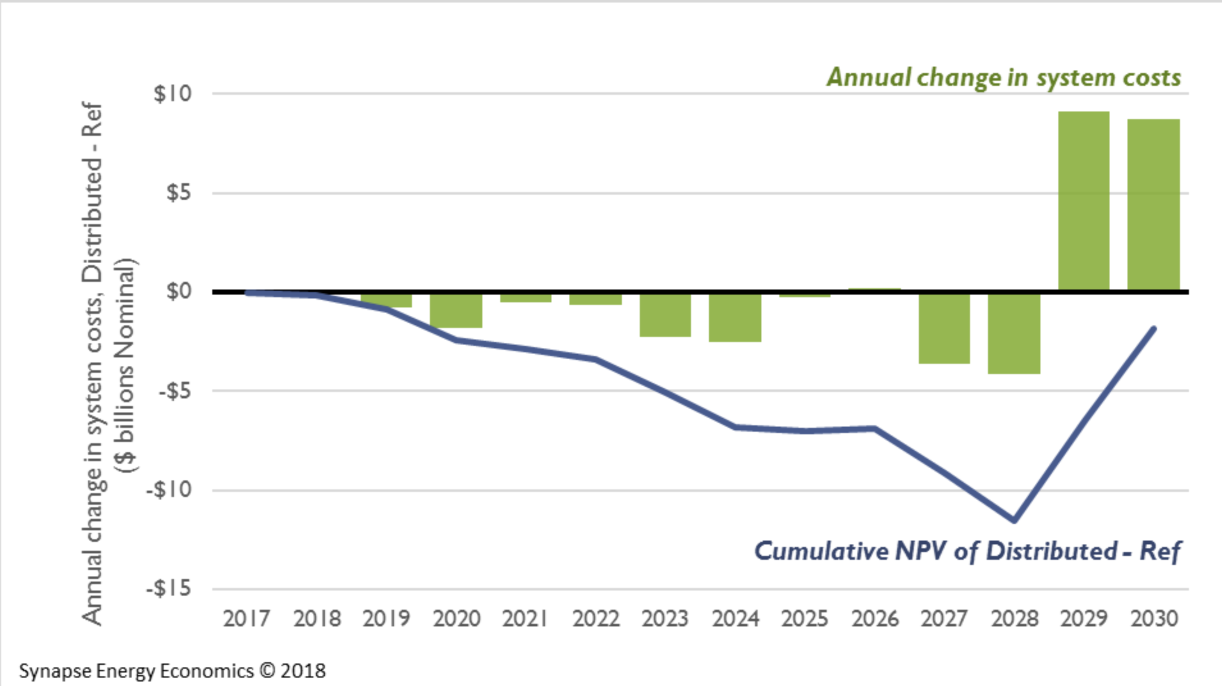
Figure 4. 2030 hourly generation, representative peak day, Distributed case



A 100 percent renewable LADWP is possible, and it costs nearly the same as the Reference case on a Net Present Value basis.

Not only did we find that it is technically possible to operate LADWP's system with 100 percent renewable resources in every hour of the year, the net present value of the difference in cost between the Reference case and Distributed case is nearly even (see Figure 5). While none of the scenarios are inexpensive, however, the production cost savings to LADWP throughout the study period mean that the cost of the last push to 100 percent renewables in 2029 and 2030 are mitigated in the Distributed case. Importantly, these cost results present the utility system costs and do not include the consumer-side costs of installing rooftop solar.

Figure 5. Difference in annual electric system expenditure Distributed case savings in LADWP, relative to Reference case



Conclusion

A 100 percent renewable future may be ambitious but it is achievable. The pages that follow will demonstrate that it is, in fact, possible for LADWP to use exclusively renewable resources to power its system in every hour of the year. Achieving very high levels of renewable integration in LADWP does not require a substantial departure from the Reference case within the first several years of the study, allowing LADWP a brief, but necessary, window to plan how to best optimize a future 100 percent renewable system. To secure this clean energy future, LADWAP will need to strengthen its operation of the system by leveraging storage, demand response, and energy efficiency.

This study illustrates the ability of the grid to provide generation to meet demand assuming a future with high reliance on non-dispatchable generation. It does not address all of the technical operations of the grid under this type of resource mix. While the Policy cases do not require a substantial departure from the renewable capacity builds of the Reference case, they do require a new approach to system planning and operation from LADWP. From a system cost perspective, a 100 percent renewable future for LADWP may be possible at no incremental cost to the Reference case.

We intend for this analysis to support ongoing planning processes and provide a benchmark in comparing potential high renewables futures for Los Angeles. The scenarios discussed in this report are only two of multiple paths LADWP could choose to reach 100 percent renewables.

Within this analysis, for instance, the costs associated with a scenario that leans heavily on utility-scale solar are borne out differently than the costs resulting from distributed solar scenario. With greater levels of utility scale solar, the overall system costs increase, representative of utilities building and integrating new, large scale capacity. On the contrary, higher levels of distributed generation result in lower system costs, as the need for capacity and distribution system upgrades are avoided, but higher costs to individual consumers, representative of the responsibility to procure capacity shifting from the utility to the customer. Neither of the Policy cases incorporates the costs associated with avoiding adverse health impacts and other externalities associated with fossil fuel generation; the Policy cases may in fact be even more economical in comparison to the Reference case than this study shows.

Other potential 100 percent renewable scenarios may lean more heavily on storage resources, allow for compliance through out-of-region purchases of clean generation, or rely upon on nascent technology, such as floating offshore wind turbines. This analysis does not suggest that one possibility is better or more realistic than another; rather, our findings clearly show that a 100 percent renewable future *is* possible, that it can potentially be achieved at no incremental cost, and that Los Angeles should mobilize now in order to meet its goal.

1. BACKGROUND

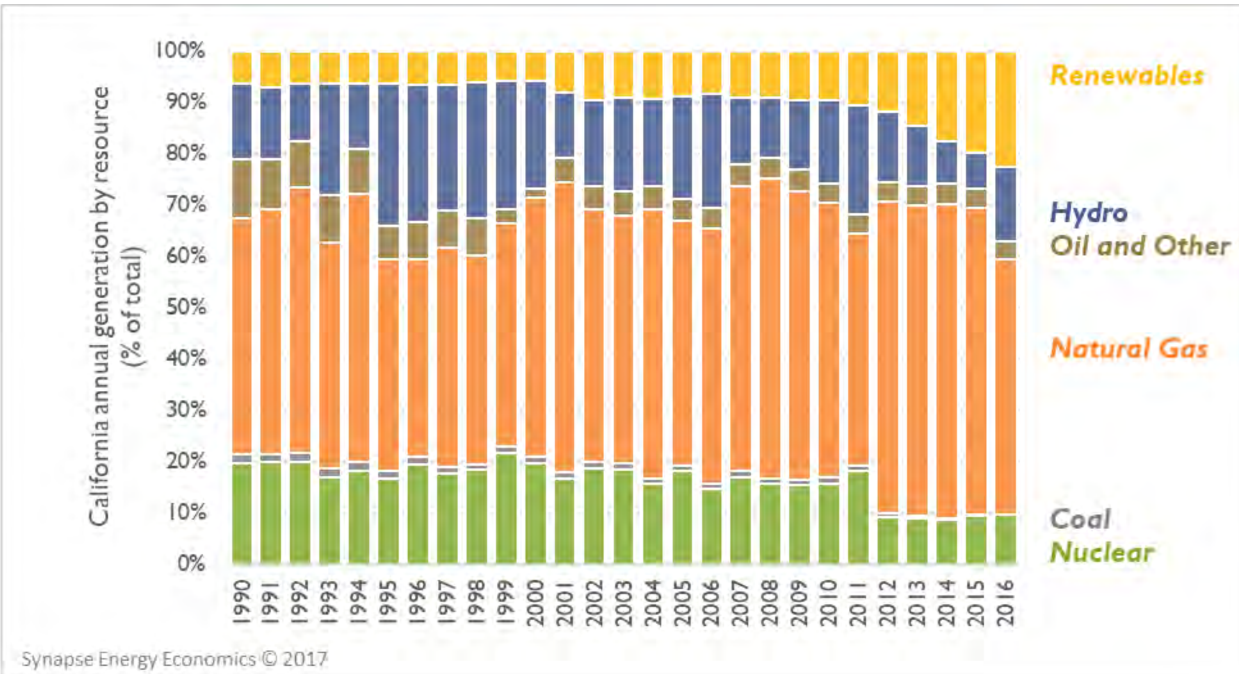
California is the most populous state in the country with nearly 40 million residents. The majority of the state is served by three main investor-owned utilities (IOUs)—Southern California Edison, San Diego Gas and Electric, and Pacific Gas and Electric—which account for three-quarters of California's electric sales. While these three utilities are collectively dispatched by California's central Independent System Operator (CAISO), other areas of the state act independently to procure supply and meet electricity demand. One such area is Los Angeles County, where electricity is provided by the Los Angeles Department of Water and Power (LADWP).

1.1. California's electric grid

Since 1990, California's electric sector has been served by a mix of natural gas, nuclear, and renewable capacity, in addition to imports from out of state. Natural gas has dominated the state's electricity output for nearly three decades, fluctuating between 40 and 60 percent of overall in-state generation each year (see Figure 6). In the last five years, the nature of California's electric grid has begun to undergo a transition, as evidenced by recent increases of in-state renewable generation and declining generation from both nuclear and coal units. While coal has never represented more than a few percent of in-state generation in the past 30 years, nuclear resources have historically provided about 20 percent of the state's annual generation. Following the retirement of the San Onofre Nuclear Generating Station (SONGS) in 2012, only the Diablo Canyon nuclear facility remains, providing about 10 percent of the state's generation. However, with its licenses set to expire in the mid-2020s, Diablo Canyon's owners have announced it will go the way of SONGS, with its two units retiring in 2024 and 2025.[3]

[3] See http://www.latimes.com/business/la-fi-diablo-canyon-nuclear-20160621-snap-story.html

Figure 6. Historical in-state electricity generation in California, percent of state total



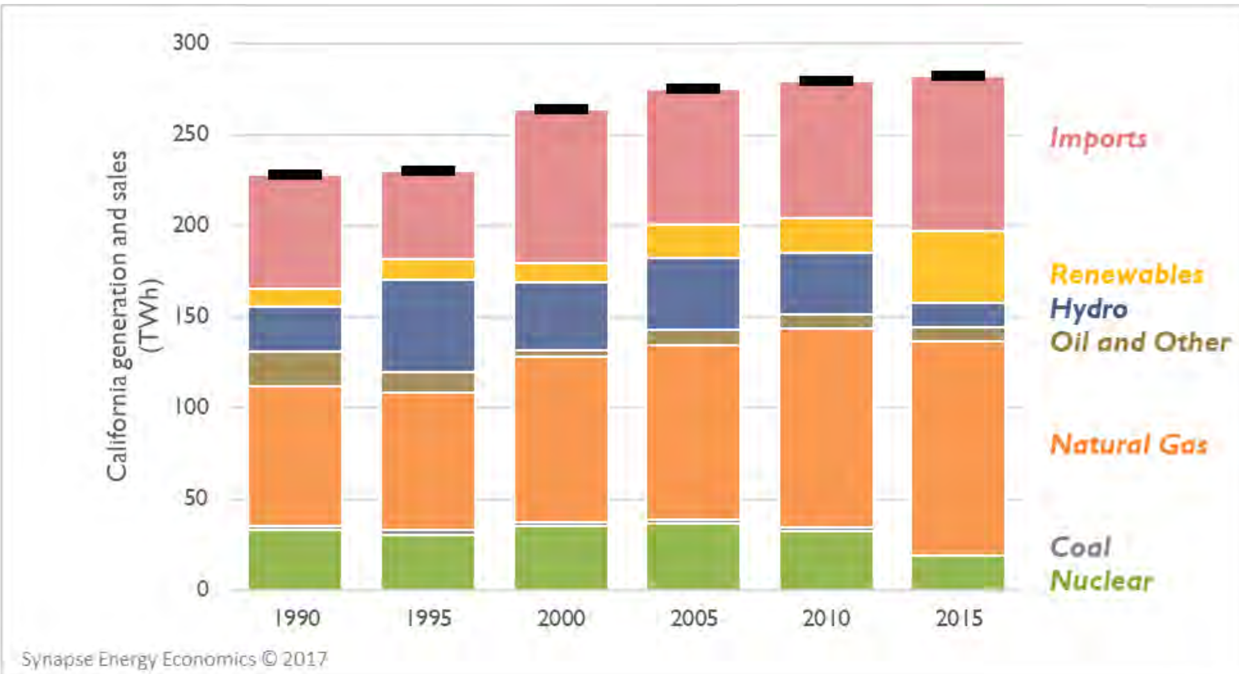
Source: EIA 923 data. Note: Other includes oil, biomass, municipal solid waste, landfill gas, and other biofuels and waste fuels. Renewables includes geothermal, solar PV and solar thermal, and wind.

Today, California's annual demand for electricity is about 280 TWh.[4] To meet this demand, California imports 30 percent of its electricity from neighboring states. Of the electricity generated in-state, around half comes from natural gas, while the remaining half is split between nuclear, hydro, wind, solar, and other resources (see Figure 7). California's electricity demand comprises 7 percent of the total national electricity demand.[5]

[4] A TWh is equal to one million MWh.

[5] Nationally, about one one-third of electricity is generated from coal, one-third from natural gas, 20 percent from nuclear, with hydro, wind, solar, and other resources making up the remaining 15 percent.

Figure 7. Electricity generation and sales for California



California's load is served by three main IOUs—Southern California Edison, San Diego Gas and Electric, and Pacific Gas and Electric—as well as nearly fifty municipal utilities and irrigation districts (see Figure 8). These three major IOUs serve nearly 75 percent of all customers in the state and about 70 percent of all load. However, LADWP is actually the third largest utility in the state, serving more customers and greater load than San Diego Gas and Electric.

Figure 8. Map of California utility service areas

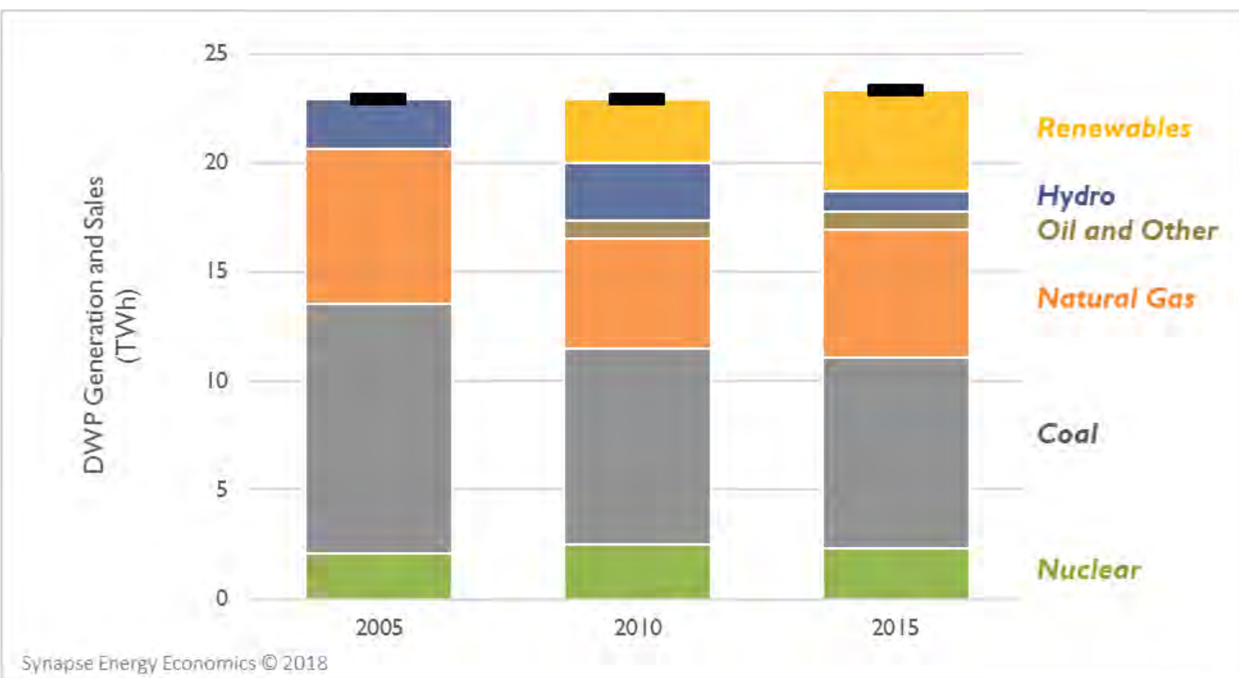
Source: http://www.energy.ca.gov/maps/serviceareas/electric_service_areas.html

1.2. Los Angeles Department of Water and Power

LADWP was founded over a century ago when the city of Los Angeles purchased a privately held water company. Soon after, LADWP began serving electrical load in addition to water deliveries throughout Los Angeles County. With 10 million residents, Los Angeles County is the largest county in the state, more than double the size of the next largest county by population. LADWP provides electricity for nearly 1.5 million residential and business customers throughout Los Angeles County. Currently, LADWP provides about 23 TWh of energy consumption to its customers, more than the electricity consumption of 13 entire states.

As an independent system dispatcher, LADWP is not only responsible for providing electricity to retail consumers, but also for producing and procuring electricity from power generators. While there currently are about three dozen power plants located within Los Angeles County, LADWP also holds contracts for imported electricity from generators located elsewhere in California and in other states. Currently, about one-third of this electricity is contracted from the coal-fired Intermountain Power Plant in Utah, which LADWP plans to divest from by 2025. This ownership and operation of coal capacity is a significant departure from the three main IOUs in the state, all of which have completely divested from coal resources. In addition to Intermountain Power Plant, one-quarter of LADWP's electricity comes from natural gas-fired generation, much of which is located in Los Angeles County. One-tenth of its electricity comes from contracted imports for nuclear generation from the Palo Verde power plant in Arizona (see Figure 9). The remaining one-third of electricity comes from wind, solar, hydro, and other miscellaneous power plants, some of which are located in Los Angeles County and some as far away as the Pacific Northwest.

Figure 9. Electricity generation serving the LADWP region

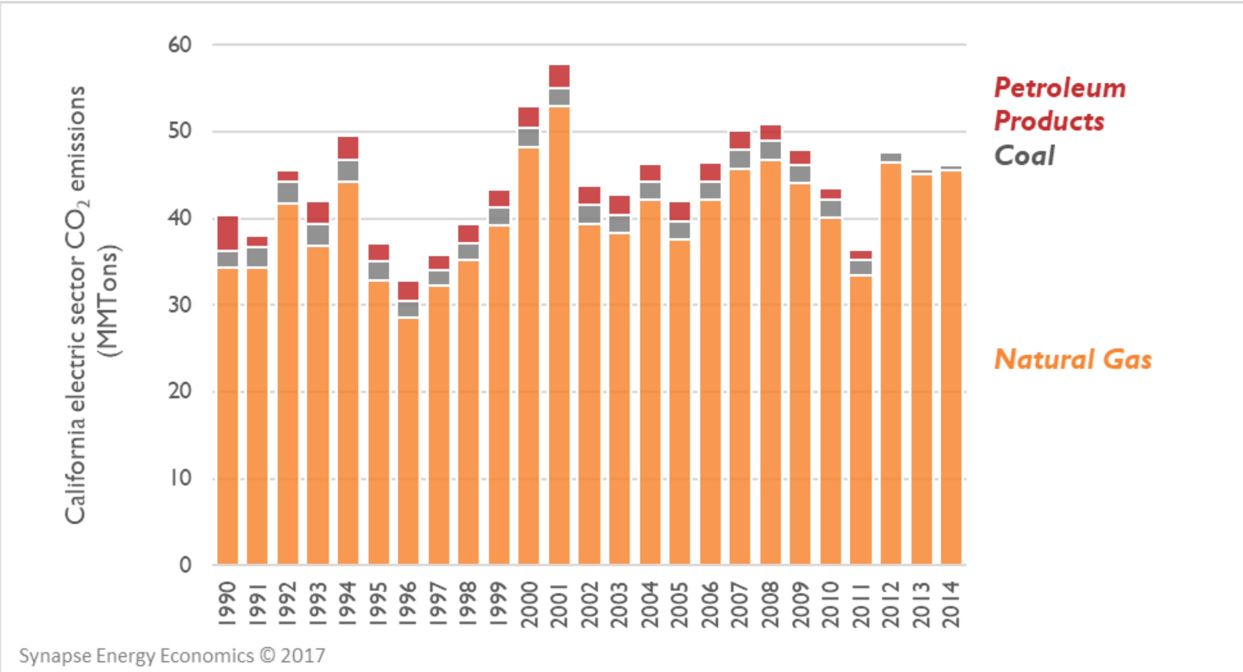


Source: LADWP 2016 IRP, Figure 2-14

1.3. Renewable policy in California and Los Angeles

California's electric-sector greenhouse gas (GHG) emissions have long been dominated by natural gas (see Figure 10). While the absolute value of annual emissions in individual years may have varied over the last two and a half decades, variations in hydropower output and economic recessions have resulted in an overall trend in electric sector emissions of steady, if slim, growth. Most recently, electric sector emissions have been about 10 percent above 1990 levels. However, multiple pieces of legislation are now in place that aim to reduce GHG emissions in both the LADWP service territory and statewide. Among those policies is the renewable portfolio standard (RPS).

Figure 10. Historical emissions in California's electric sector, million metric tons



Source: EIA State level emissions data, available at: https://www.eia.gov/environment/emissions/state/

History of climate legislation in California

California has a long history of renewable expansion and carbon emission reduction legislation in-state. Today's renewable policies build and expand upon the ongoing legacy of California's AB 32, the Global Warming Solutions Act of 2006. Under this current legislation, California is required to reduce sector-wide and statewide emissions to 1990 levels by 2020 and to 80 percent below 1990 levels by 2050.[6]

Such levels of emission reductions will necessitate that all sectors begin the process of decarbonizing, which often places an added burden on the electric industry, as industries once run on fossil fuel sources begin to electrify. The pathways that various sectors take to achieve electrification will impact the

[6] For more detail on AB 32, see https://www.arb.ca.gov/cc/ab32/ab32.htm

electric sector, increasing demand that already must be met by renewable resources due to other legislation.[7]

History of renewable legislation in California

In addition to legislation that places caps on emissions—and generation—from fossil-fired units, California has enacted legislation to require new renewable generation. In 2002, the California State Senate passed SB 1078, creating a RPS for the state that required utilities to increase the share of renewables in their system by 1 percent per year.[8] Four years later, SB 107 was passed, confirming the previously proposed target of 20 percent renewable generation by 2010.[9] As that target was set to expire, Governor Arnold Schwarzenegger continued the RPS program, signing Executive Order S-14-08 to increase the RPS targets to 33 percent by 2020.[10] Finally, in 2015, the state passed SB 350, requiring load serving entities to meet 50 percent of their demand with renewable resources by 2030.[11]

Throughout the history of California's renewable portfolio standard, renewables have been defined as biomass, solar thermal, solar photovoltaics (PV), wind, geothermal, fuel cells with renewable fuel sources, small hydro, digester gas, municipal solid waste, landfill gas, ocean wave, and ocean thermal or tidal energy.[12] Importantly, energy from municipal solid waste and landfill gas still emits carbon dioxide (CO_2) and other co-pollutants during the generation process. In addition, to date, none of the state's RPS policies have required that a certain level of renewable generation be met during every hour, but rather have required that a portion of *annual* sales are met by renewable resources each year.

Considering 100 percent renewable targets

California legislators continue to debate legislation that would require that the state reach 100 percent renewable generation. As the fifth largest economy in the world, California would have a substantial impact on the future of clean energy in the United States and the rest of the world if it passed such a bill. It would provide a much larger-scale example of a 100 percent renewable future than Hawaii, currently the only state with as high of a renewable integration target.

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7 While a number of studies present potential decarbonization and electrification pathways, two resources in particular are worth calling to attention. First, a California-specific 2013 paper: Wei, M., et al. 2013. "Deep carbon reductions in California require electrification and integration across economic sectors." *Environmental Research Letters.* Available at: http://iopscience.iop.org/article/10.1088/1748-9326/8/1/014038/pdf. Second, the more recent New England-wide Synapse and Northeast Energy Efficiency Partnerships collaborative report: Hopkins, A. et al. 2017. "Northeastern Regional Assessment of Strategic Electrification." NEEP and Synapse. Available at http://neep.org/sites/default/files/Strategic%20Electrification%20Regional%20Assessment.pdf

8 http://www.energy.ca.gov/portfolio/documents/documents/SB1078.PDF

9 http://www.energy.ca.gov/portfolio/documents/documents/sb_107_bill_20060926_chaptered.pdf

10 http://www.energy.ca.gov/portfolio/

11 http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

12 California SB X 1-2, Section 6 (a) (1) http://www.energy.ca.gov/portfolio/documents/sbx1_2_bill_20110412_chaptered.pdf

Achieving a 100 percent renewable future is a significant task with many obstacles—political, economic, or operational—to overcome. In addition to a significant buildout of new renewable generators, meeting this target will require strong commitments to energy efficiency and distributed generation to reduce overall demand on the system, as well as storage and demand response (DR) programs to shift load and save excess renewable generation for times of need.

California has already experienced the ramifications of adding substantial levels of solar—both utility scale and distributed—to the grid. It is the first state to reckon with the operational constraints posed by these resources. The resulting effective load shape from integrating high levels of solar has come to be known as the "duck curve." In the duck curve, load increases steadily in the morning before dropping abruptly and remaining low throughout the day as solar resources produce energy behind the meter. A large ramp-up in generation is then required toward the end of the day when gross load is high and solar is no longer generating at high levels.

LADWP moving to 100 percent renewable generation

In September 2016, the Los Angeles City Council voted to direct LADWP to develop a plan to meet 100 percent of the region's needs through renewable generation.[13] In response, LADWP published an updated version of its 2015 Integrated Resource Plan (IRP) studying more aspirational scenarios than previously analyzed.[14] However, scenarios in LADWP's 2016 IRP still fall short of 100 percent renewables, only seeking to increase renewables from 25 percent today to 55 percent by 2030 and 65 percent by 2036.

In its 2016 IRP, LADWP recommends a case in which coal is replaced in 2025, its RPS is increased from 33 percent in 2020 to 65 percent in 2036, local solar capacity is expanded by 1,500 megawatts (MW) by 2035, cumulative energy efficiency reaches 15 percent of sales by 2020, and over 400 MW of energy storage is built by 2025.[15]

Further, in 2017, Mayor Eric Garcetti commissioned the "Sustainable City pLAn" for Los Angeles. Recognizing that the City receives more than 250 days of sunshine and has enough rooftop space to hold 5,500 MW of solar power, the pLAn recommends building 900 to 1,500 MW of local solar capacity by 2025 and a total of 1,500 to 1,800 MW by 2035. Additionally, the report suggests building 1,645 MW of energy storage capacity in the region. Finally, the pLAn suggests improving building efficiency in order to

[13] Page, S. 2016. "Los Angeles City Council backs planning for 100 percent renewable energy." *ThinkProgress*. Published September 16, 2016. Available at https://thinkprogress.org/los-angeles-renewable-plan-passes-693daae39d82/

[14] Los Angeles Department of Water & Power. 2016. "2016 Power Integrated Resource Plan." December 2016. Available at https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB562207&RevisionSelectionMethod=LatestReleased

[15] 2016 LADWP IRP. Page ES-17.

reduce energy usage per square foot by 30 percent, as well as meeting 15 percent of the city's overall energy needs with efficiency by 2020.[16]

Along with Hawaii, California is the state furthest along the trajectory toward a renewable future. As such, it is the first one to truly grapple with the implications of such a future from a grid, reliability, and integration cost perspective. The state that first explored the notion of a duck curve will also lead national discussions on how best to integrate even higher levels of renewables in the near future. This analysis unearths what a system that can meet 100 percent of hourly demand with renewable sources of generation might look like. By studying the implications of such a policy for Los Angeles, this study presents a possible resource mix for a not-too-distant 100 percent renewable future for Los Angeles that will help inform how clean energy decisions are made in the County, the state, and other jurisdictions nationwide.

[16] City of Los Angeles. 2017. *Sustainable City pLAn*. Available at http://plan.lamayor.org/wp-content/uploads/2017/03/the-plan.pdf

2. ANALYSIS APPROACH AND MODELING METHODOLOGY

In order to analyze the ability of LADWP to meet a 100 percent renewable future exclusively with non-emitting resources in every hour of the year, Synapse applied scenario analysis, an analytical approach that allows us to examine numerous possible future outcomes. Important in any scenario analysis is the construction of a Reference case. This case represents a business-as-usual future that outlines what will happen if current policies, technology costs, and other relevant assumptions do not change. Using a Reference case to establish what the future will look like is critical because—even without any policy changes—it will look substantially different than today. In this analysis, we assume that a Reference case is one in which LADWP follows the recommendations laid out in its 2016 IRP (i.e., 65 percent renewables by 2036) and electric utilities in the rest of California meet the laws and regulations that are currently in place.

Separate from the Reference case are the Policy cases. In this analysis, we use the Policy cases to examine a future in which 100 percent of LADWP's demand is met by non-emitting, renewable resources in every hour of the year by 2030. In this analysis, we evaluate two Policy cases, one in which system planning approaches to distributed solar are largely unchanged from the present, resulting in a case with relatively higher levels of utility-scale solar (Utility Scale case) and a second case in which three-quarters of all available rooftops in Los Angeles construct rooftop solar (Distributed case).[17] The adjustments to solar resources are not the only changes to the scenarios, but rather are the outcomes that are representative of other decisions made. For instance, the Distributed case relies upon the assumption that LADWP would change their approach to system planning with regard to the capacity credit afforded distributed generation and the ability to integrated storage onto the system. The following section outlines the inputs, assumptions, and modeling methodology applied during our analysis.

2.1. The EnCompass Model

Synapse utilized the EnCompass model for our scenario analysis. EnCompass is a single, fully-integrated power system platform that allows for utility-scale generation planning and operations analysis. EnCompass provides unit-specific, detailed forecasts of the composition, operations, and costs of the regional generation fleet given the specified assumptions.[18] Synapse set up EnCompass to analyze LADWP, the rest of California, and the entire Western Interconnect on an annual basis from 2016 through 2030. This included specifying load and generation regions (of which LADWP is one) and

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[17] See Los Angeles' *Sustainable City pLAn* at http://plan.lamayor.org/wp-content/uploads/2017/03/the-plan.pdf for more information on rooftop solar potential in Los Angeles.

[18] Synapse used EnCompass Version 2.7. More information on EnCompass is available at www.anchor-power.com.

specifying attributes for all existing power plants, such as operating costs, heat rates, and emission rates.[19]

2.2. Key input assumptions

Any modeling exercise is highly reliant upon the input assumptions used. For this analysis, Synapse relied mostly upon the base dataset from California's IRP proceeding, while adjusting a number of key elements, as described below. Importantly, from an input assumption perspective, the two Policy cases are identical aside from their treatment of solar capacity within LADWP. Differences in the results of the two Policy cases are representative of this one key change in input assumptions.

Demand forecast

The main part of a sales forecast is the econometric sales component. For this analysis, we assumed that econometric electric sales for LADWP and the rest of California follow the projection described in the February 2017 edition of the California Energy Demand Update (CEDU).[20] Additionally, Synapse assumed a baseline amount of increased electrification in all scenarios. The California Energy Commission's 2016 Integrated Energy Policy Report (IEPR) assumes that by 2025, LADWP will feature about 600 gigawatt-hours (GWh) of increased sales from electric vehicles, and California as a whole features 2,100 GWh of electric vehicle-related sales.[21] For LADWP, this represents an increase in sales by about 3 percent in 2025.

In addition to estimating the main demand forecast, it is necessary to also develop a projection for programmatic energy efficiency.[22] California is among the leading states in terms of energy efficiency: in the 2017 ACEEE State Energy Efficiency Scorecard, California is ranked second in the nation, while according to the 2016 ACEEE Scorecard, it tied for first along with Massachusetts. In 2015, California achieved annual incremental savings of 2 percent per year, on par with Vermont, but trailing the savings achieved by Rhode Island and Massachusetts (which reached 3 percent per year). In Los Angeles, energy

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[19] Many of the Reference case inputs for this study were taken from planning processes conducted by LADWP, the California Public Utilities Commission (CPUC), or the Western Electricity Coordinating Council (WECC). In particular, we used load forecast provided by LADWP to the CPUC and relied on resource cost and availability assumptions that were formulated as part of the California state IRP process. Our base modeling dataset, including unit-specific cost and performance assumptions and transmission topology, was adapted from the publicly-available WECC Transmission Expansion Planning Policy Committee 2026 reference case database.

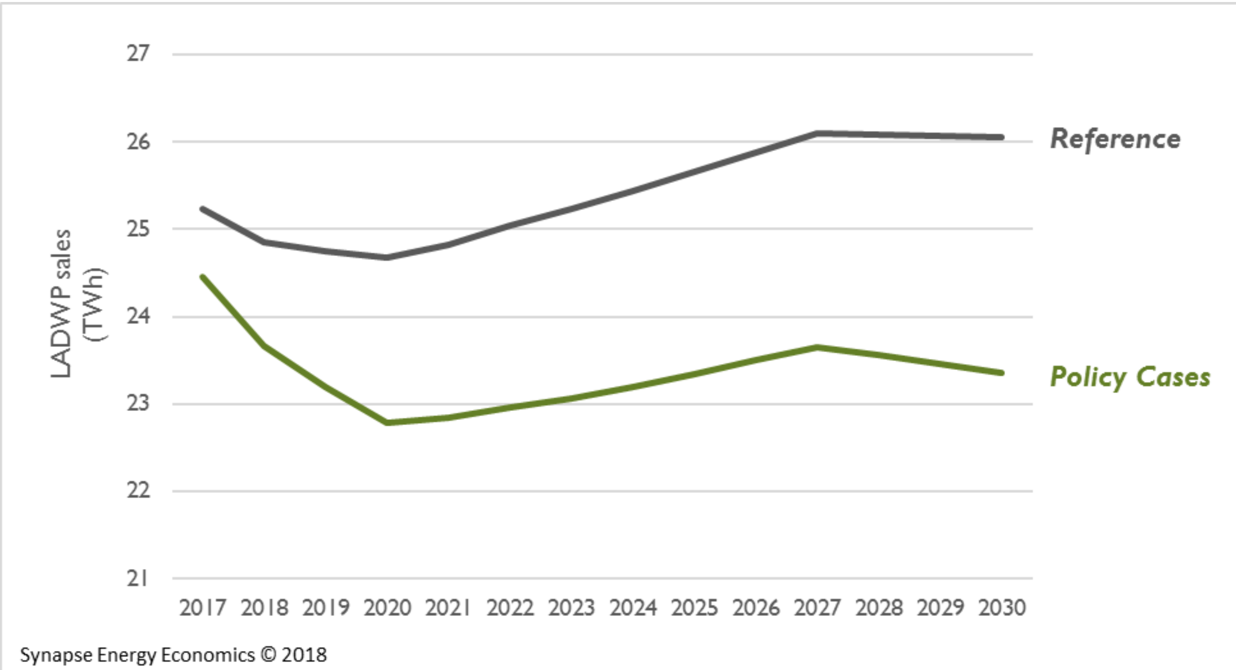
[20] Referred to as the IEPR 2016 Update. Available at http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215745_20170202T125433_FINAL_California_Energy_Demand_Updated_Forecast_20172027.pdf

[21] See http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215504_20170123T111108_FINAL_CEDU2016_LADWP_Mid_Demand_Case.xls and http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215506_20170123T111112_FINAL_CEDU2016_STATEWIDE_Mid_Demand_Case.xls for more information

[22] Because sales are treated as a constraint by the EnCompass model, the energy efficiency forecast has to be hard-coded: we cannot give the model a cost for energy efficiency and allow it to "choose" to build it, like it can with renewables or other types of resources.

efficiency potential is particularly high. In the city, 4 percent of buildings consume 50 percent of LADWP's energy, indicating that intelligent, cost-effective programs at those buildings could lead to significant energy use reductions to LADWP's system.[23] Given this historical level of achievement in energy efficiency savings in conjunction with Los Angeles' energy consumption profile, Synapse modeled a Reference case forecast based upon the CEDU report, and a High EE case forecast that assumed 3 percent savings per year as of 2024. The final demand forecast is demonstrated in Figure 11.

Figure 11. Forecasted demand for electricity in LADWP, inclusive of energy efficiency and electric vehicles



While any fully zero-carbon or carbon-neutral future will require industry-wide changes to the transportation, residential, commercial, and the industrial sectors, our analysis does not take into account any load of a fully decarbonized for all sectors in Los Angeles.[24]

LADWP renewable portfolio standard requirements

Currently, California's RPS requires California utilities (including LADWP) to procure 50 percent of their electric sales from renewables by 2030. LADWP proposes to exceed this standard in their 2016 IRP,

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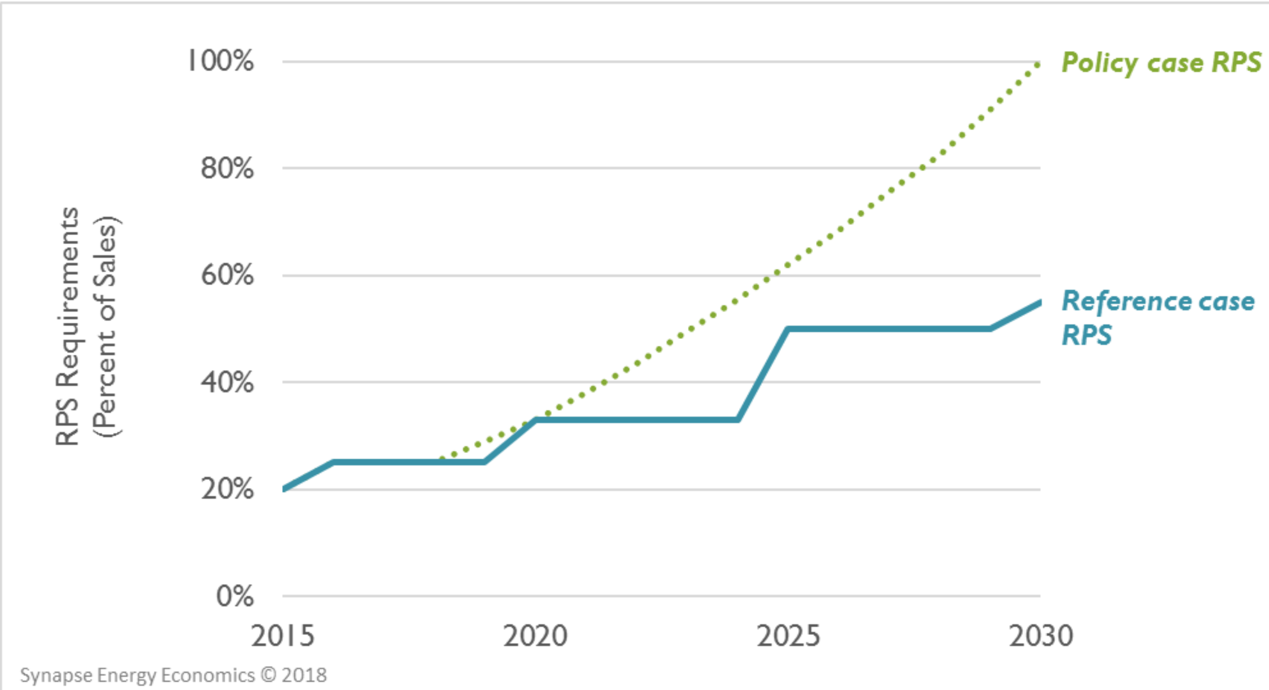
[23] For more information, see the Energy Atlas at California Center for Sustainable Communities (CCSC) at UCLA Institute of the Environment and Sustainability. Available at http://www.energyatlas.ucla.edu/profiles/kWh/cities49 and https://mynewsla.com/government/2016/12/13/la-takes-major-step-in-reducing-building-energy-consumption/.

[24] The one exception to this is a buildout of an electrified bus fleet within Los Angeles, leading to an increase in LADWP's sales of 3 percent by 2025. Our treatment of electric vehicles is high-level. We make no assumption about the ability of EVs to store energy or assist with grid dispatch.

reaching 55 percent in 2030, which we have applied as the RPS trajectory in the Reference case. As seen in Figure 12, the 100 percent RPS trajectory represents a significant departure from the current target.

Los Angeles already has 180 MW of installed local solar, making it the city with the most installed solar capacity in the country, and it has plans to build even more.[25] The city's inaugural sustainability plan from 2015-2016 poses a goal to achieve 900 to 1,500 MW of local solar in Los Angeles by 2025.

Figure 12. Modeled RPS requirements in the LADWP region



Note: The "Policy case RPS" trajectory is applied in both the Utility Scale case and the Distributed case.

Storage procurement targets

LADWP currently plans to procure 155 MW of energy storage by 2021.[26] In line with California's overall storage mandate, and recognizing the declining costs of storage as a resource, LADWP plans to procure nearly 130 MW at the generation and transmission levels, 25 MW at the distribution level, and an additional 2 MW at the customer level by 2021. This is in addition to the over 20 MW of storage already operating on its grid.

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[25] "LA Sustainable City pLAn", available at https://www.lamayor.org/sites/g/files/wph446/f/landing_pages/files/pLAn%20first%20annual%20report%202015-2016_0.pdf

[26] https://s3-us-west-2.amazonaws.com/ladwp-jtti/wp-content/uploads/sites/3/2017/08/16111845/Energy-Storage-Presentation-August-15-2017.pdf

Resource retirements

LADWP has announced that it will cease to purchase electricity from the coal-fired Intermountain Power Project in 2025. With the end of that commitment also comes the end of coal-fired generation anywhere within the LADWP system, leaving natural gas and landfill gas units as the only sources of GHG emissions on the LADWP grid. In the Reference case, these resources remain online until the end of their useful life or until an already announced retirement date within the study period. In the Policy cases, however, all of these carbon emitting resources are retired by 2030.

Demand response

A key element of a future grid that integrates high levels of renewable generation will be the ability to shift, delay, or altogether reduce load. Unlike the output from conventional fossil fuel-fired resources, renewable generation cannot be scheduled. As a result, it is important to be able to not only store renewable generation that occurs at times of low demand in order to use it during times of high demand, but also to be able to adjust demand so that it occurs more in line with when renewable resources are generating. Demand response programs at the residential, commercial, and industrial levels are an ideal way to achieve just that goal. In fact, LADWP already provides a demand response program available to commercial, industrial, and institutional customers.[27]

In 2015, the DR Pilot Program curtailed nearly 98 MWh. While a significant step in the right direction, these 98 MWh represent only half a percent of overall annual generation in LADWP. As the region moves towards 100 percent renewables in all hours, however, this number will necessarily increase substantially.

2.3. What counts as renewable generation?

Although "clean energy" and "renewable energy" are often used interchangeably, there are important differences between the two types of resources. Clean energy is often considered to include any type of resource with carbon-free generation. Notably, this definition may include nuclear resources.[28] Renewable resources, on the other hand, have a regenerating source of energy. For instance, wind resources are renewable because wind regenerates and cannot be depleted. The same can be said for solar powered resources. On the contrary, biomass-type resources rely upon the combustion of biofuels such as wood, algae, methane, and other biologically-created substances. While the fuel sources for biomass and landfill gas regenerate, they do not necessarily do so on a timeline short enough to be considered renewable.

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[27] For more details, see https://www.ladwp.com/ladwp/faces/ladwp/commercial/c-savemoney/c-sm-rebatesandprograms/c-sm-rp-demandresponse

[28] Nevertheless, nuclear units require large amounts of concrete – a large source of carbon emissions – during construction, leading some observers to suggest that nuclear units are not carbon-free after all.

Often when biofuels are considered renewable, it is because of two key underlying assumptions: (1) the energy produced is carbon neutral and (2) the fuel sources burned for electric generation will regrow and are, thus, renewable resources. However, this is often not the case in practice. A 2010 report in the *Journal of Forestry* expressed concern at the sustainability of current practices associated with harvesting the fuel sources used for biofuel combustion, calling into question the renewable nature of wood fuels used for electricity generation.[29] In 2012, Synapse published a report outlining the lifecycle carbon footprint of electricity production from biofuels, pointing out that woody biomass is far from carbon neutral and its emissions should be accounted for in GHG inventorying.[30]

In this study, we assume that wind, solar, hydro, and geothermal resources are non-emitting renewables. This also includes storage resources powered by these resource types. Importantly, we exclude landfill gas, biomass, and biogas resources. If LADWP is serious about achieving deep emission reductions in the timeframe necessary to avoid the worst impacts of catastrophic climate change, then it will need to phase out the use of these nonrenewable, emitting resources.

Additionally, in this study, we assume that the entirety of compliance with the 100 percent RPS occurs either with resources located within Los Angeles County, or through the purchase of bundled Renewable Energy Credits (RECs), which requires that the renewable energy be delivered directly to LADWP. While some states allow for RPS compliance through the purchase of unbundled RECs—i.e., as a credit for investing in renewable energy, without actually needing to deliver the renewable energy to customers in that state or utility service territory—we only allow bundled RECs to be used for compliance in our modeling. If LADWP intends to meet every hour of demand with renewable generation, it must focus on delivering renewable energy directly to LADWP customers and not on achieving compliance through token investments in non-deliverable renewables located elsewhere.

2.4. Difference in policy case inputs

The Utility Scale and Distributed cases result in different levels of installed capacity at the utility and distributed scales, as well as different levels of storage capacity. A few key differences in input assumptions drive those outputs. The Distributed case requires the model to build a higher level of rooftop solar than in the Utility Scale case, in line with a goal of placing solar on three-quarters of all rooftops. Additionally, in the Distributed case, we adjusted the effective load carrying capability of distributed solar—i.e., the ability of the resource to contribute to peak demand for system planning purposes—to 50 percent. These two adjusted inputs, taken in line with the fact that utility scale solar operates at a higher annual capacity factor than distributed, lead to the differences in storage: the Distributed case requires more storage capacity to fully take advantage of the distributed resources.

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[29] Janowiak, M. and C. Webster. 2010. "Promoting Ecological Sustainability in Woody Biomass Harvesting." *Journal of Forestry*. January/February 2010. Available at http://cemendocino.ucanr.edu/files/131364.pdf

[30] Fisher, J., S. Jackson, and B. Biewald. 2012. "The Carbon Footprint of Electricity from Biomass." *Synapse Energy Economics*. Available at http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-06.0.Biomass-CO2-Report.11-056.pdf

3. FINDINGS

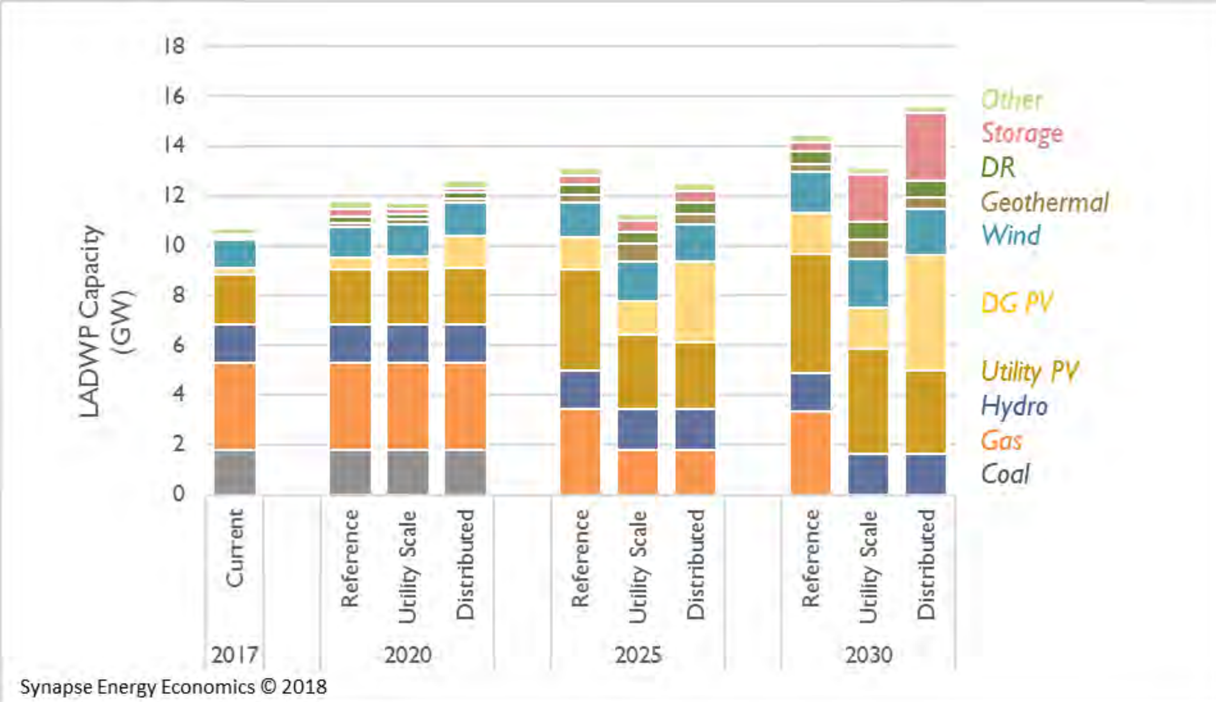
The following section details initial results from Synapse's modeling of a business-as-usual Reference case and two distinct 100 percent renewable futures in the LADWP Policy Cases. The key outputs of the EnCompass model presented within are LADWP-specific capacity, generation, emissions. Costs by resource type are relative to present operations.

3.1. Capacity

In LADWP, the largest difference between the Reference case and the Policy cases is in the displacement of existing natural gas capacity and the growth of storage. In the Reference case, renewable capacity more than doubles by 2030 as compared to today by adding 4 gigawatts (GW) of solar capacity and over 500 MW of wind (see Figure 13). In the Utility Scale case, energy efficiency and an increase in storage means that LADWP builds a similar amount of solar and wind and nearly 2 GW of storage capacity. The Distributed case, on the other hand, builds 16 percent more capacity than the Reference case, mostly in the form of solar (4.3 GW of distributed solar alone, and 5.7 GW total) and storage capacity (2.7 GW). This increased level of both distributed solar and storage capacity in the Distributed case as compared to the other scenarios is largely due to the fact that distributed solar has a lower capacity factor and is more distributed in nature than utility scale solar; thus, more storage capacity is necessary to fully take advantage of the increase in distributed solar capacity. While a small amount of the wind that is built in both scenarios is located within Los Angeles County, LADWP also contracts with wind resources in the Northwest to transmit directly into the region.[31]

[31] Importantly, the resources in the Northwest are not connected to LADWP through a high-voltage, direct current (HVDC) line. Rather, they are electrically deliverable to LADWP due to pre-existing connections between LADWP and the Northwest.

Figure 13. LADWP's electric generating capacity in select years under each modeled scenario



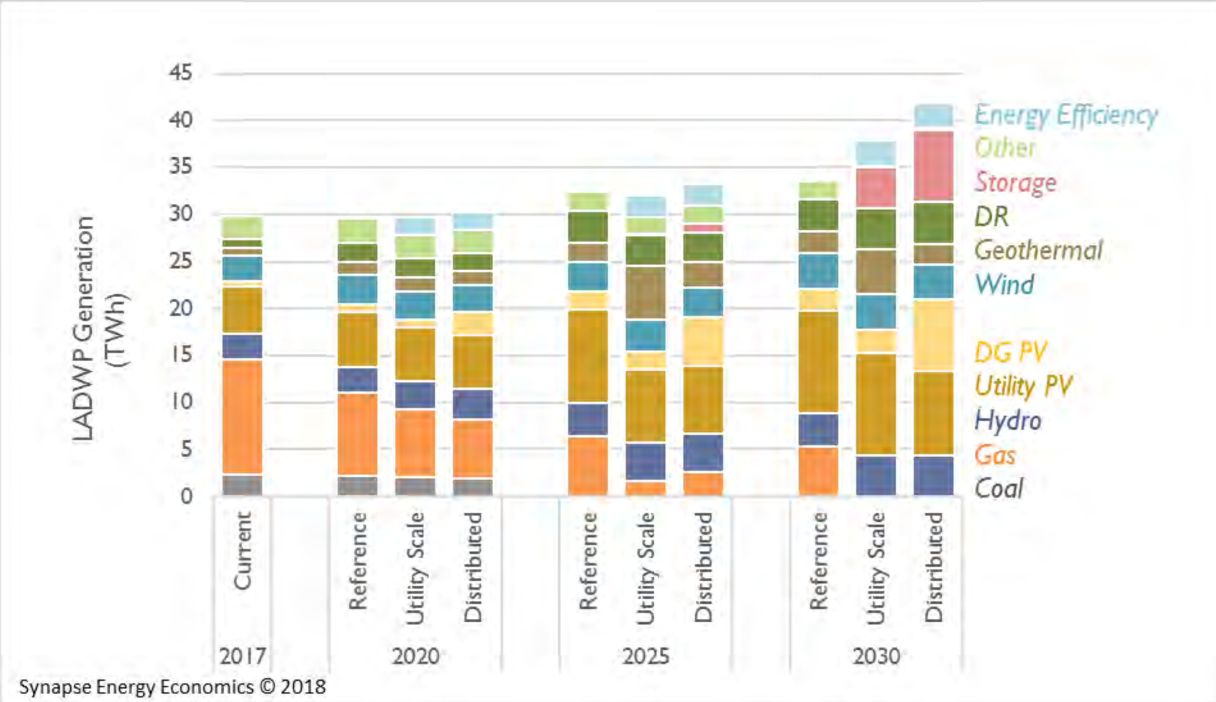
Note: This figure only presents information on capacity for resources within the LA basin and for those resources that have a direct link to LADWP – such as Intermountain Power Plant—but not contracted resources outside of the LADWP territory.

3.2. Generation

Given the similar levels of overall renewable capacity procured for LADWP in the Reference and Policy cases, the key difference between the Reference case and a 100 percent renewable future is in the operation of LADWP's grid (see Figure 14). Both Policy Cases must find 6.6 TWh of clean generation with which to replace the generation lost from the retirement of the Palo Verde nuclear facility in 2029, as well as from the retirement of the entire fossil fleet.[32] Although both the Reference and Utility Scale case dispatch a similar level of solar generation in real time, the Utility Scale case stores over 4 TWh of solar generation to dispatch later throughout the day or week. In the Distributed case, this difference is even more apparent, with LADWP storing 7.7 TWh of solar generation for future use. Both Policy cases invest in 2.7 TWh of energy efficiency, reducing the overall need in the region, while also receiving an additional 1 TWh of energy reductions from demand response than in the Reference case. In the Reference case, natural gas generation in LADWP decreases by 50 percent over the study horizon, while it is completely phased out by 2030 in the Policy cases.

[32] Note that this analysis does not attempt to quantify the cost impacts of LADWP withdrawing from its contract with Palo Verde ahead of the 2047 expiration.

Figure 14. Electric generation in LADWP in select years under each modeled scenario



3.3. 100 percent renewable operation

Importantly, the results presented in Figure 14 are representative of meeting LADWP load exclusively with renewable resources in every hour of the year. By constraining the model to not allow LADWP to import generation from any non-renewable resources, we were able to ensure that every hour of demand in LADWP was met by renewable generation. Notably, the majority of load is met by solar generation, either directly at the time of generation, or after having been used to charge batteries. As indicated by its name, the Utility Scale case sees the majority of generation come from utility scale solar; meanwhile, daily load in the Distributed case is met mostly by distributed generation. Additionally, demand response plays a large role in balancing loads in future years, reaching 10 percent of load in LADWP in the Reference case, 11 percent in the Distributed case, and 12.5 percent in the Utility Scale case.

These annual trends hold true at hourly resolution. In the Reference case, LADWP meets its peak August day primarily with solar, fossil generation, and imports (see Figure 15). In both Policy cases, on the other hand, all fossil resources have been retired, while even more solar and storage resources have been built. For the Utility Scale case, this means that LADWP stores utility scale solar for use later on a representative peak day (see Figure 16); for the Distributed case, on the other hand, regional need is met mostly by distributed solar resources (see Figure 17.)

Figure 15. 2030 hourly generation, representative peak day, Reference case

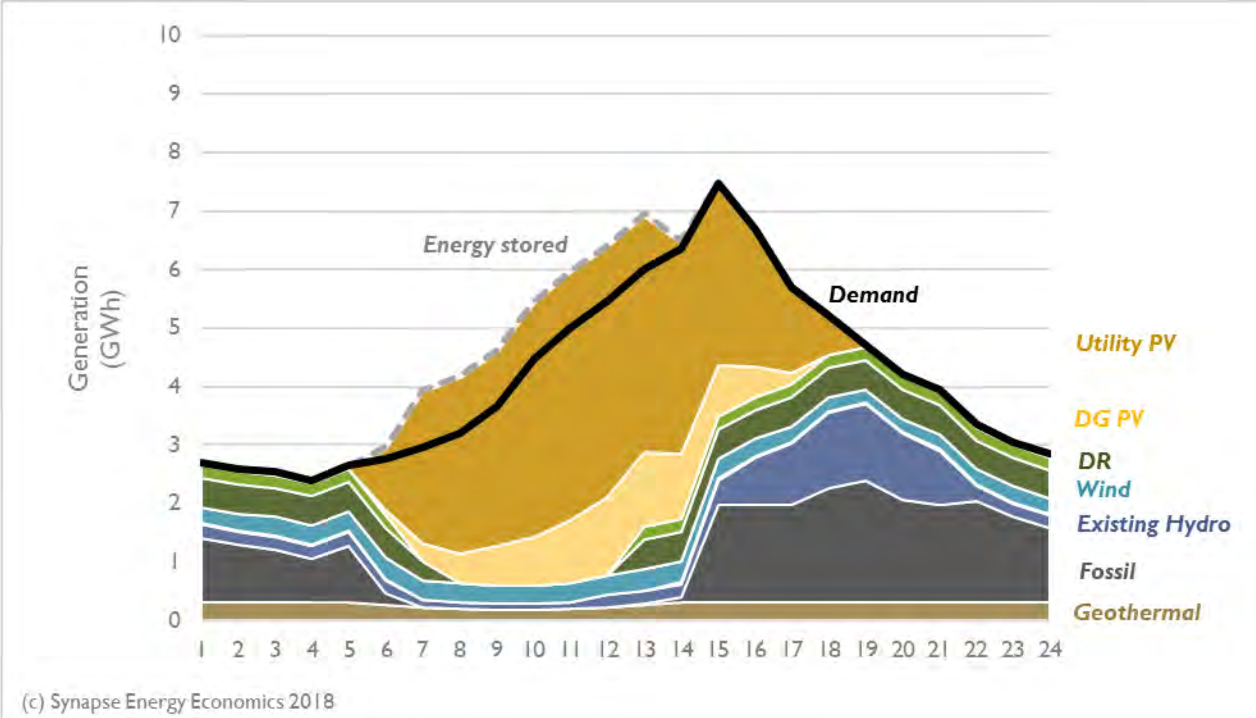


Figure 16. 2030 hourly generation, representative peak day, Utility Scale case

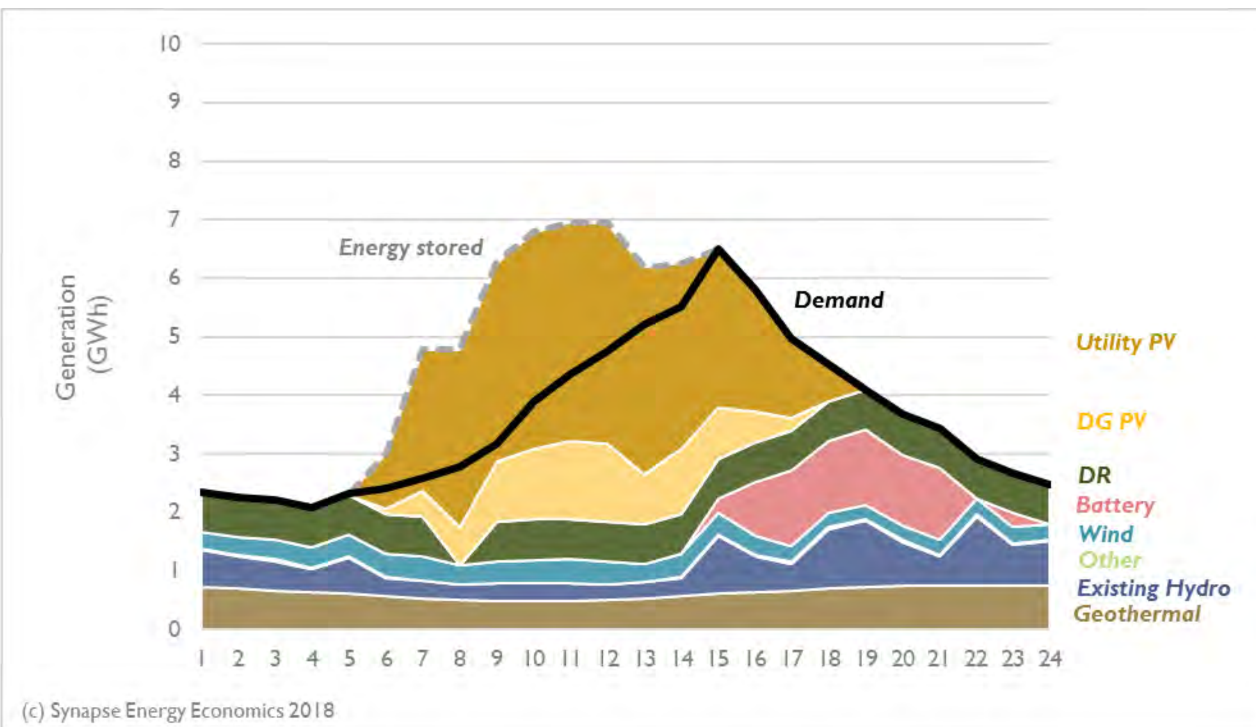
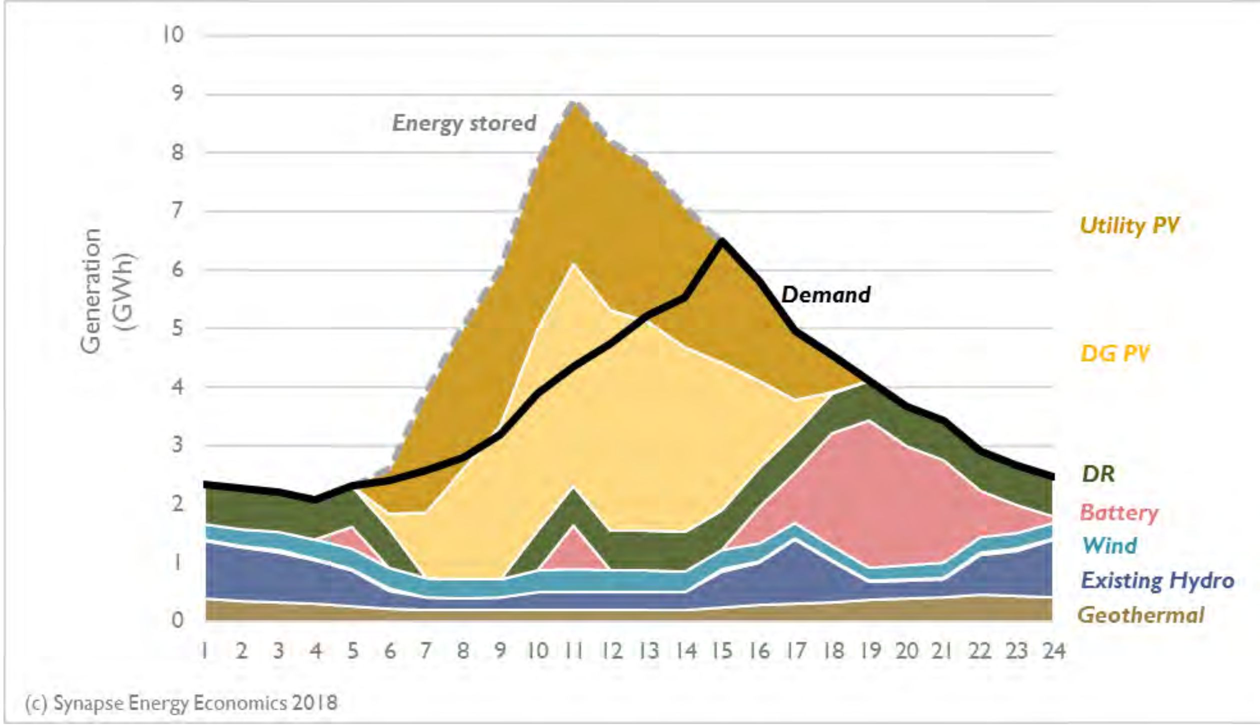


Figure 17. 2030 hourly generation, representative peak day, Distributed case



The results present two key takeaways for 100 percent renewable futures. First, both of our Policy cases result in significant curtailment of renewables at the end of the study period, as a result of not building any new transmission into and around LADWP. To get to 100 percent renewable energy in every hour will require a mix of storage capacity, curtailment of renewables and new transmission; our scenario selected a mix that is heavier on curtailment and storage than transmission, but that is not the only possible mix to reach 100 percent renewables. Second, the resource build-out in these cases represent only two of many potential generation and capacity mixes that can reach 100 percent renewables. While we optimized our modeling based upon current cost trends for various renewable technologies, it is possible that in future years the costs of renewable and storage technologies may change, making a different 100 percent renewable scenario more cost-effective and feasible than those presented here.

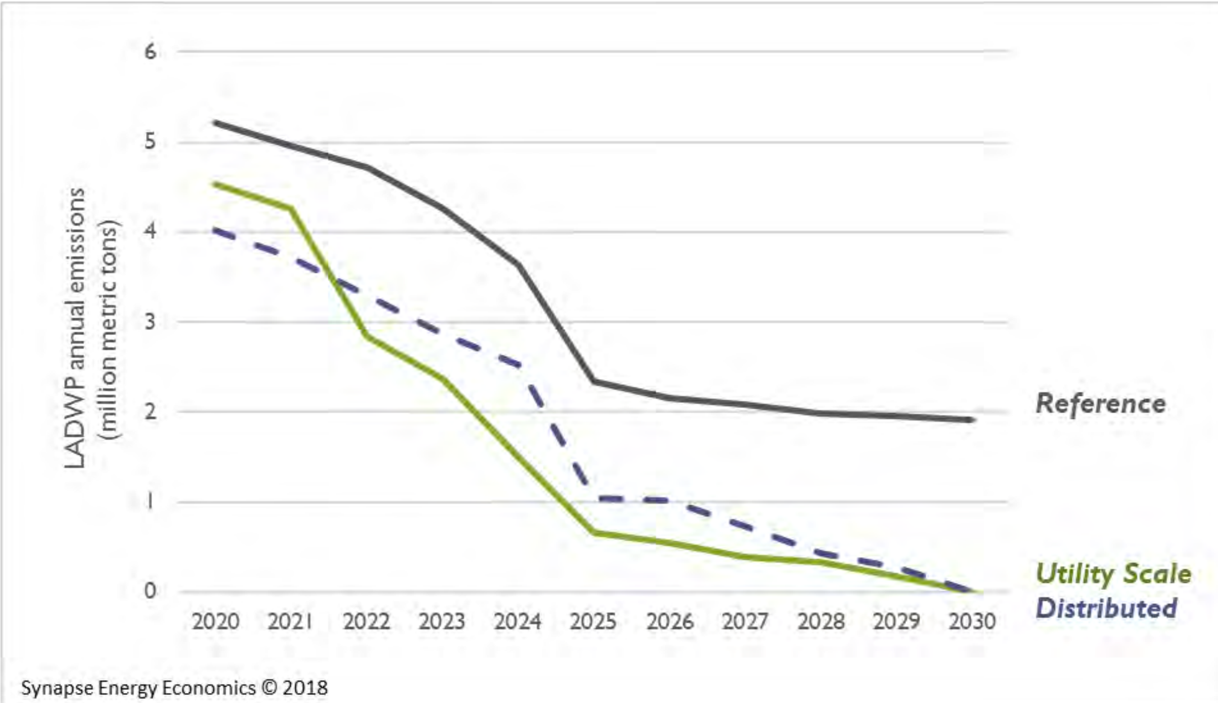
3.4. Emissions

Three bills in California combine to aim to reduce statewide GHG emissions by 40 percent below 1990 levels by 2030.[33] As described above, Los Angeles has an even more stringent GHG emission reduction target than California, aiming for 35 percent below 1990 levels by 2030. As of 2015, LADWP's 14.4 million metric tons of CO_2 emissions were already 19 percent below 1990 levels. The Reference case sees electric sector emissions decreasing even further, to 1.9 million metric tons in 2030, a reduction of

[33] AB 32, SB 32 and AB 197. See 2016 LADWP IRP, p. ES-4.

over 80 percent from 2015 emissions. Meanwhile, both Policy cases reduce emissions entirely by 2030 (see Figure 18).

Figure 18. LADWP electric-sector CO_2 emissions from 2017 to 2030



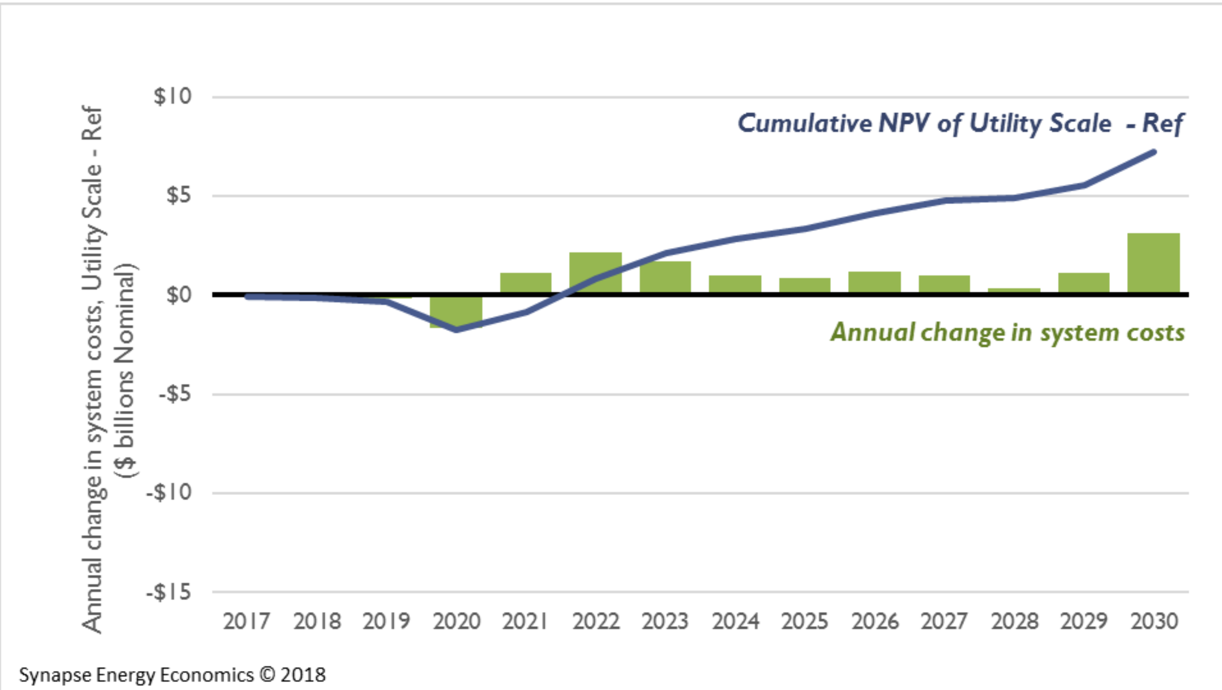
3.5. System costs

Figure 19 illustrates the projected difference in annual system costs to LADWP from 2020 through 2030 in both the Reference case and Utility Scale case. Figure 20 shows the difference in costs between the Reference case and Distributed case. These costs are a product of total region-wide generation requirements and the balancing area's load-weighted energy price. Both figures also display the cumulative NPV of the difference between scenarios over time. Between 2017 and 2030, the cost of the Reference case is at an NPV of $49 billion at a 5 percent discount rate. Meanwhile, the Utility Scale case as modeled would cost $56 billion, and the Distributed case would cost $47 billion in NPV terms. As such, the Utility Scale case results in a cumulative NPV increase of $7 billion (14 percent) relative to the

Reference case, while the Distributed case results in a $2 billion decrease (4 percent), relative to the Reference case.[34]

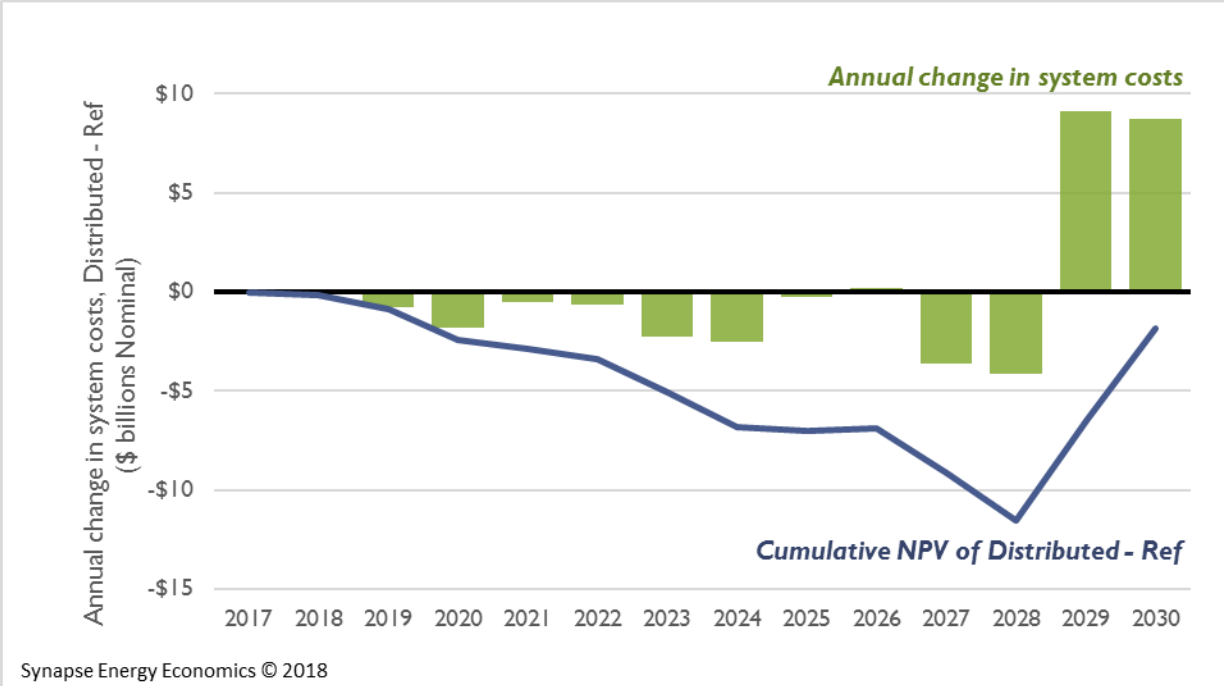
The overall increase in system cost in the Utility Scale case (relative to the Reference case) involves the costs associated with building additional storage and geothermal capacity, as well as with increasing investments in energy efficiency and demand response. Although the Distributed case builds even more solar and storage capacity than the Utility Scale case, overall system costs are offset by the fact that the majority of the solar capacity procured occurs behind the meter. Importantly, the customer costs associated with procuring distributed generation are not included in the total system costs presented in this report. The total system cost is representative of the costs that will be passed through to all consumers by LADWP; however, costs for individual consumers may be higher depending upon their procurement of distributed solar technologies. On the other hand, total system costs may be mitigated even further in a future that incorporates a greater number of electric vehicles or if other storage-like resources become available at a reasonable cost.

Figure 19. Annual electric system expenditure Utility Scale case savings in LADWP, relative to Reference case



[34] This analysis was conducted before President Donald Trump approved the Office of the U.S. Trade Representative's recommendations on solar tariffs. However, we believe this decision will have little overall impact on our findings. First, the full impacts of these tariffs are not yet known—it is possible that some companies or countries will be able to obtain exemptions from the tariffs, lessening their overall impact on module costs. Second, the tariffs are only in effect for the years 2019 through 2022. While they are high at the beginning (30 percent), they decline over time. Because this analysis was conducted through 2030, and because there is relatively little difference between the scenarios in the early years, the tariffs would likely only have a moderate impact in a few early years of the study.

Figure 20. Annual electric system expenditure Distributed case savings in LADWP, relative to Reference case



The costs in the two Policy cases ramp up toward the end of the study timeframe as LADWP finalizes its push to 100 percent renewable generation in each hour. While the Utility Scale case is more expensive on a net present value than the Reference case, and while the Distributed case is less expensive from a total system cost perspective, there are some cost benefits of transitioning to a 100 percent renewable grid. For instance, during most hours of the year, the production cost in LADWP in the Policy cases is lower than during those same hours in the Reference case. As a result of running on resources with marginal, if any, variable costs, the Distributed case sees a reduction in overall production costs. In fact, the overall NPV of the difference between the two scenarios is nearly even, with the Distributed case slightly less expensive than the Reference case over the study period.

3.6. Key differences between Policy cases

Our two Policy cases differ in their treatment of solar. Both Policy cases model futures with large amounts of solar generation. However, the Utility Scale case focuses on meeting load requirements with utility scale solar and additional geothermal generation, while the Distributed case focuses on meeting LADWP's needs with behind the meter, distributed generation. The Distributed case builds nearly 6 GW of solar capacity, with over 4 GW of distributed solar capacity. The Utility Scale case only builds 3.6 GW of solar capacity, with the majority—2.2 GW—as utility scale.

Importantly, the Distributed case is representative of a future in which LADWP takes a different approach to system planning. The level of distributed generation built is only possible if system planners increase the capacity credit received by behind the meter generation and recognize the benefits associated with linking distributed generation and storage from a grid-operations perspective. This scenario incorporates a level of distributed solar capacity that is consistent with a target of covering three-quarters of rooftops in the LADWP service territory.

The 100 percent renewable scenarios discussed in this report represent only two possibilities for LADWP to move away entirely from traditional generating resources. All potential clean energy futures for Los Angeles involve distinct opportunities and tradeoffs. Within this analysis, for instance, the costs associated with our utility scale solar case are borne out differently than the costs as a result of the distributed solar case. With greater levels of utility scale solar, the overall system costs increase, representative of utilities building and integrating new, large scale capacity. On the contrary, higher levels of distributed generation result in lower system costs, as the need for capacity and distribution system upgrades are avoided, but higher costs to individual consumers (not calculated in this analysis) who take on the responsibility to invest in their own renewable generation and storage.

CONCLUSIONS

A 100 percent renewable future is possible. With policymakers in California and the LADWP considering legislation to mandate this ambitious trajectory, it is time for system operators to actively begin to analyze 100 percent renewable futures. In this analysis of two potential LADWP futures, we find that it is, in fact, possible for LADWP to use exclusively renewable resources to power its system in every hour of the year. What's more, achieving very high levels of renewable integration in LADWP does not require a substantial departure from the Reference case within the first several years of the study, allowing LADWP a brief, but necessary, window to plan how to best optimize a future 100 percent renewable system.

In fact, the Utility Scale case does not require substantially more renewables than the Reference case. Instead, it requires smarter operation of the system by leveraging storage, demand response, and energy efficiency. Like many other 100 percent renewable studies, this is an illustrative study—it demonstrates the ability of the grid to provide generation to meet demand assuming a future with high reliance on non-dispatchable generation. This study is not meant to be a deep-dive into all of the technical operations of the grid under this type of resource mix. While the Policy Cases do not require a substantial departure from the renewable capacity builds of the Reference case, it does require a new approach to system planning and operation from LADWP. From a system cost perspective, a 100 percent renewable future for LADWP may be possible at no incremental cost to the Reference case.

We intend for this analysis to support ongoing planning processes during which analyses by LADWP and stakeholders can inform and build off each other. This study serves as a benchmark in comparing potential high renewables futures for Los Angeles and acknowledges that there will be tradeoffs amongst all of the options at hand. Importantly, the 100 percent renewable scenarios discussed in this report represent only two possibilities for LADWP to move away entirely from traditional generating resources.

Within this analysis, for instance, the costs associated with a scenario that leans heavily on utility-scale solar are borne out differently than the costs resulting from distributed solar scenario. With greater levels of utility scale solar, the overall system costs increase, representative of utilities building and integrating new, large scale capacity. On the contrary, higher levels of distributed generation result in lower system costs, as the need for capacity and distribution system upgrades are avoided, but higher costs to individual consumers, representative of the responsibility to procure capacity shifting from the utility to the customer. Neither of the Policy cases incorporates the costs associated with avoiding adverse health impacts and other externalities associated with fossil fuel generation; the Policy cases may in fact be even more economical in comparison to the Reference case than this study shows.

The 100 percent renewable scenarios analyzed in this study are representative of only two of the many potential paths towards a 100 percent renewable future. Any path taken will require explicit decisions to be made by policy makers, grid regulators, and utilities alike. For instance, other potential scenarios may lean more heavily on storage resources, allow for compliance through out-of-region purchases of clean generation, or rely upon on nascent technology, such as floating offshore wind turbines. Regardless of the path taken, however, a 100 percent renewable future is possible, that it can potentially be achieved at no incremental cost, and Los Angeles needs to get started right away to meet its goal

Appendix A. The EnCompass Model

In this analysis, Synapse utilized EnCompass (Version 2.7), a state-of-the-art capacity expansion and production cost model produced by Anchor Power Solutions.

EnCompass is a single, fully integrated power system platform that provides an enterprise solution for utility-scale generation planning and operations analysis. EnCompass is an optimization model that covers all facets of power system planning, including:

- Short-term scheduling including detailed unit commitment and economic dispatch
- Mid-term energy budgeting analysis including maintenance scheduling and risk analysis
- Long-term integrated resource planning including capital project optimization and environmental compliance
- Market price forecasting for energy, ancillary services, capacity, and environmental programs

EnCompass provides unit-specific, detailed forecasts of the composition, operations, and costs of the regional generation fleet given the assumptions described in Appendix B. Synapse populated the model with a Western Interconnect-specific dataset, based on CAISO's Transmission Expansion Planning Policy Committee dataset, and made adjustments to improve resolution within the DWP region.

Synapse used EnCompass to optimize the generation mix in DWP and California and to estimate the costs of a changing energy system over time. Because this study focuses on annual generation, costs, and emissions, the model was run in "partial" optimization mode with typical peak/off-peak day temporal resolution. These parameters enabled faster processing time at the expense of some detail at the unit operation level.

More information on EnCompass is available at www.anchor-power.com.

APPENDIX B. MODELING INPUT ASSUMPTIONS

Modeling Background

Synapse's analysis compared a Reference case to two Policy cases by modeling two main scenarios:

- **Reference case:** This is a business-as-usual future in which no changes are made to current policies in California or at the federal level. In this future, we assume renewable and storage technology costs continue to decrease at a baseline rate and that utilities in California meet their requirements for renewable procurement under the RPS and GHG reductions required by AB 32 and the 2016 SB 32. We assume a statewide electric sector 2030 emissions goal of 62 thousand metric tons (MMT), consistent with the upper bound of the California Air Resources Board Scoping Plan.[35]

- **Policy cases:** The Policy cases differ from the Reference case in one key way: they establish a requirement for LADWP to meet 100 percent of its electricity sales through renewables (e.g., wind, solar, and storage) by 2030. In addition, we explore the use of battery storage, energy efficiency, and demand response resources to help achieve this energy transformation.

Modeling Inputs

Electricity demand

The main component of a sales forecast is the econometric sales component. This is the forecast for annual energy consumption, absent any incremental energy efficiency. It is typically linked to factors like gross domestic product (GDP) growth, population growth, and weather. In EnCompass (and in all other electricity dispatch models), annual sales and peak demand are treated as a constraint. For this analysis, we assumed that econometric electric sales for LADWP and the rest of California follow the projection described in the February 2017 edition of the California Energy Demand Update (CEDU).[36]

Energy efficiency

After calculating the main annual sales forecast, it is necessary to develop a projection for energy efficiency. Because sales are treated as a constraint by the model, the energy efficiency forecast must be

[35] "The 2017 Climate Change Scoping Plan Update," January 20, 2017, pp. 42-43. Available at https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf

[36] Referred to as the IEPR 2016 Update. Available at http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215745_20170202T125433_FINAL_California_Energy_Demand_Updated_Forecast_20172027.pdf

hard-coded: we cannot give the model a cost for energy efficiency and allow it to choose to build it, like it can with renewables or other types of resources.

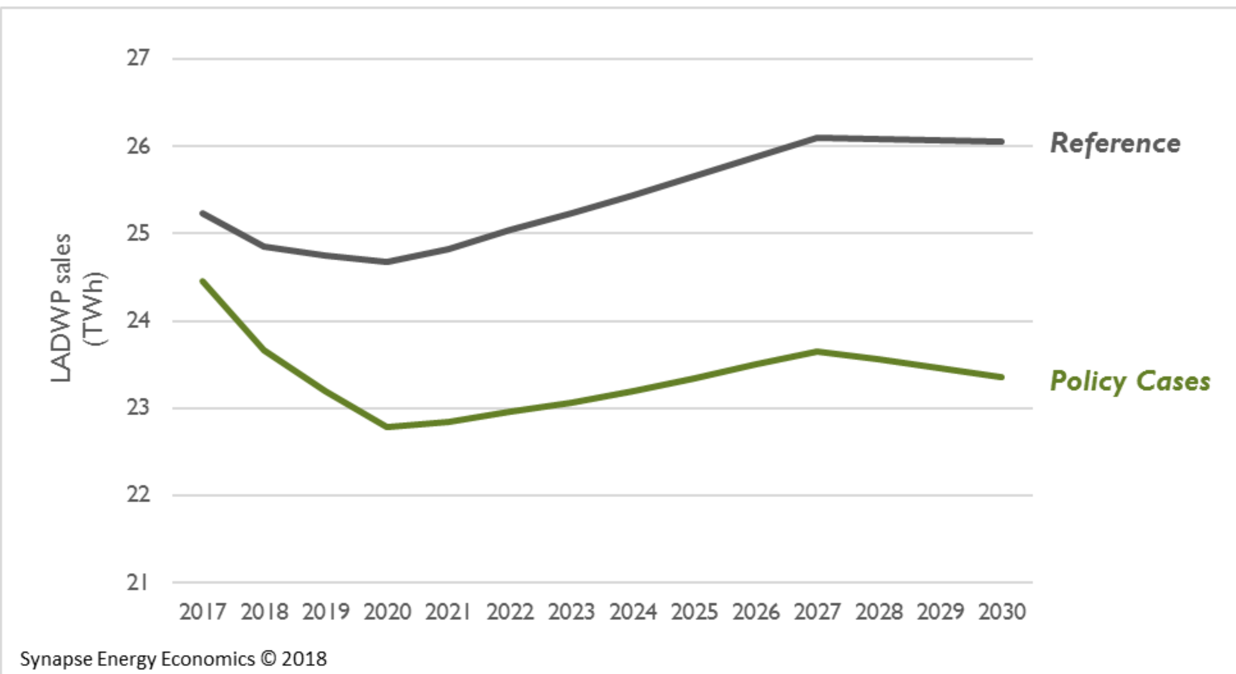
California is among the leading states in terms of energy efficiency: according to the 2016 American Council for an Energy-Efficiency Economy (ACEEE) State Energy Efficiency Scorecard, it tied for first along with Massachusetts. In 2015, California achieved annual incremental savings of 2 percent per year, on par with Vermont, but trailing the savings achieved by Rhode Island and Massachusetts (which reached 3 percent per year).

For this analysis, we assume two separate energy efficiency forecasts:

1. Our **Base case** forecast is based on the energy efficiency forecast described in the CEDU 2017 "Mid Demand Baseline Case" (see Figure 21). In this forecast, LADWP and the rest of California achieve reasonably high levels of energy efficiency in the near-term (e.g., 1.75 to 2.0 percent), but feature lower levels of savings (e.g., 0.30 percent) in later years. We use this energy efficiency forecast in the Reference case.

2. Our **High EE case** forecast assumes that LADWP increases its annual incremental level of energy efficiency savings beginning in 2019 by 0.2 percent per year, until a level of 3.0 percent is reached in 2024. It then sustains this level of energy efficiency throughout the rest of the study. We assume that no changes are made to energy efficiency levels in the rest of California.

Figure 21. Forecasted demand for electricity, inclusive of energy efficiency and electric vehicles



Energy efficiency costs

Recent studies on the cost of energy efficiency indicate that energy savings can be procured at a very low cost of saved energy. While costs may vary based on geography, sector (e.g., residential versus industrial), the size of the program, or the maturity of the program, recent analyses by Synapse, the ACEEE, and the Lawrence Berkeley National Laboratory (LBNL) all indicate levelized costs for utilities below $0.04 per kWh.[37] This analysis uses the 2017 work published by LBNL in *Energy Policy*, which concludes that the levelized cost of saved energy for utilities is 2.3 cents per kilowatt hour (kWh).[38]

Demand-side management

In addition to passive energy efficiency measures, we also specify a trajectory for active demand-side management measures. Customers can be incentivized to reduce load in the hours at which the system is most constrained, via lower rates or rebates. Such resources are typically only called upon for a small number of hours per year. Our modeled scenarios follow the demand response assumptions in the LADWP 2016 IRP, which grows active demand response resources from 55 MW today to 200 MW in 2020 and 506 MW in 2026.[39]

Electrification

For the purposes of this analysis, we assume a baseline amount of increased electrification in all scenarios. The 2016 IEPR assumes that by 2025, LADWP will feature about 600 GWh of increased sales from electric vehicles, and California as a whole features 2,100 GWh of electric vehicle-related sales.[40] For LADWP, this represents an increase in sales by about 3 percent in 2025.

Natural gas price forecast

Our analysis relies upon the delivered fuel price for the electric power sector forecasts from the Energy Information Administration's (EIA) Annual Energy Outlook 2017 (see Figure 22). Prices at regional hubs in the West largely all track each other, rising steadily over time after a brief drop in the last two years.

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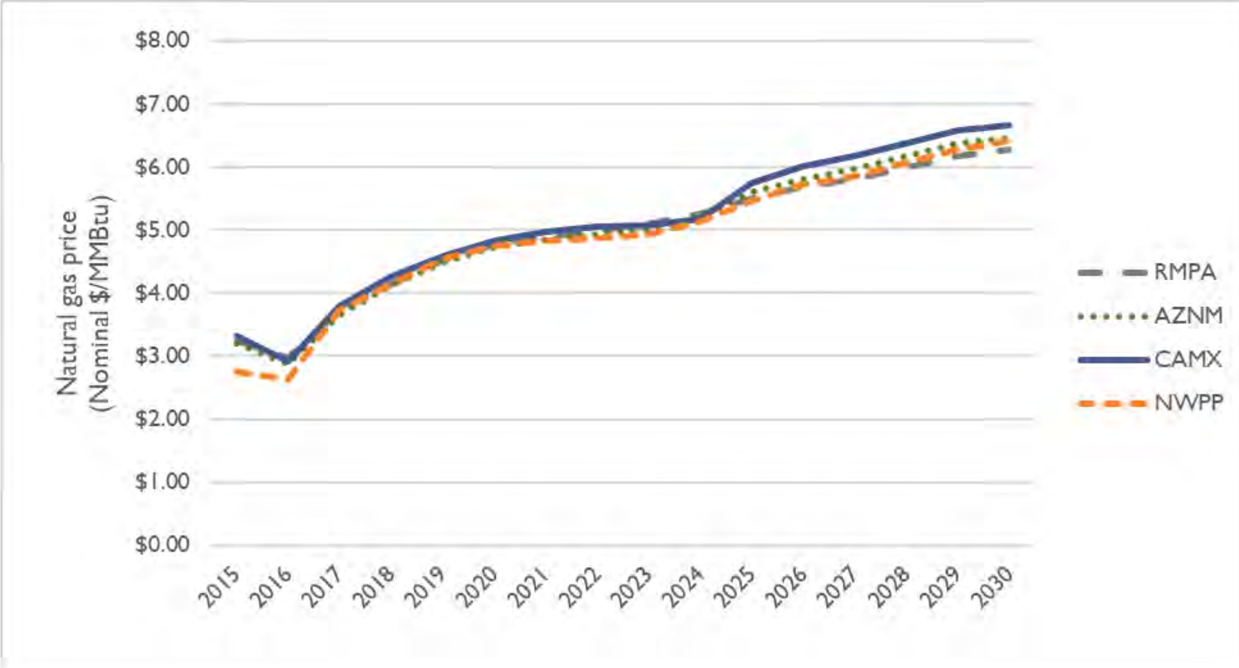
[37] More information available at http://www.synapse-energy.com/sites/default/files/COSE-EIA-861-Database-66-017.pdf.

[38] Hoffman, I., et al. 2017. "Estimating the cost of saving electricity through U.S. utility customer-funded energy efficiency programs." *Energy Policy*. Published January 24, 2017.

[39] LADWP 2016 IRP pp. 88.

[40] See http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215504_20170123T111108_FINAL_CEDU2016_LADWP_Mid_Demand_Case.xls and http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-05/TN215506_20170123T111112_FINAL_CEDU2016_STATEWIDE_Mid_Demand_Case.xls for more information

Figure 22. AEO 2017 natural gas price forecast by region, Nominal $/MMBtu

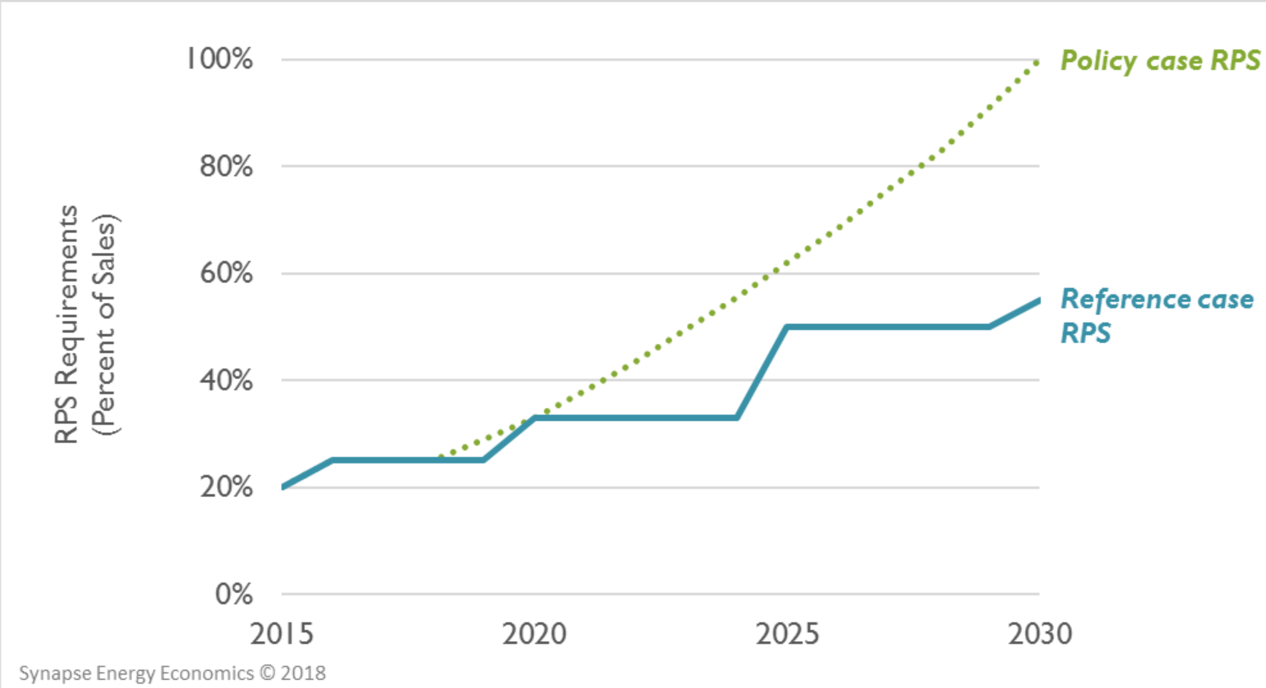


Renewable resource potentials and costs

Even in the Reference case, California and the LADWP region will see significant increases in renewable capacity during the study period. Currently, California's RPS requires California utilities (including LADWP) to procure 50 percent of their electric sales from renewables by 2030. LADWP proposes to exceed this standard in their 2016 IRP, reaching 55 percent in 2030 (see Figure 23). Under current laws and regulations, solar thermal, solar photovoltaic, wind, biomass, geothermal, small hydro, landfill gas, and other miscellaneous resources are eligible to sell RECs, which can be retired to meet RPS compliance. Under the current RPS policy, renewable facilities that are either physically located in California or are able to sell electricity directly to California are eligible to sell RECs to California utilities. Notably, our 100 percent renewable scenarios do not rely upon purchasing unbundled RECs from other regions.

Under the EnCompass modeling construct, the model selects the most cost-effective resources to build and meet the RPS constraint, based on assumptions we use for resource potential and resource costs.

Figure 23. Modeled RPS requirements in the LADWP region



Note: The "Policy case RPS" trajectory is applied in both the Utility Scale case and the Distributed case.

In the Policy cases, we assume that a separate additional RPS policy is established in the LADWP load region. Under this new policy, LADWP is required to meet 100 percent of its electricity demand through renewables by 2030. Other important distinctions include:

- **Temporal requirement:** This analysis requires LADWP to procure electricity from renewables at all times of the day, every day. LADWP is restricted from purchasing electricity from natural gas generators (for example) and procuring energy "offsets" in other hours.

- **Geographic eligibility:** In our analysis, we assume that renewable resources located in the LADWP region, elsewhere in California, or directly connected to California are eligible for the LADWP RPS.

- **Resource eligibility:** This analysis is meant to assess Policy cases in which the LADWP load region's electric sector is non-emitting. As such, we only consider non-emitting, low environmental impact, fully-commercial resources as being eligible for compliance. In practice, this restricts the LADWP RPS-eligible resources for newly built capacity in Los Angeles to solar and wind. Biogas and biomass resources are specifically prohibited from being eligible for compliance in the LADWP RPS.

Renewable and storage potential

For this analysis, we rely on renewable resource potentials as described in the December 2016 version of the RESOLVE model.[41] According to RESOLVE, there are about 102 GW of incremental renewables available in Los Angeles County and 8,700 GW California-wide. This is in comparison to the 20 GW currently installed statewide. Note that California currently has about 80 GW of installed capacity from all types of resource, including nuclear, coal, and natural gas.

Table 1. Existing installed renewable capacity and potential incremental renewable capacity (GW)

	2015 Installed Capacity, California	Incremental resource potential, California	Incremental resource potential, LA County
Utility-scale PV	6	8,406	102
Utility-scale solar thermal	1	133	5
Distributed PV	4	37	11
Wind	5	157	0
Geothermal	3	5	0
Small hydro	1	7	0

Today, LADWP has 1,275 MW of pumped hydro storage at the Castaic facility, plus about 12 MW of small scale thermal and battery storage. In both our Reference case and Policy cases, we include 404 MW of battery storage by 2025, as planned in the 2016 IRP.[42]

Renewable and storage costs

We rely on RESOLVE for projecting costs of renewables through the study period.[43] According to the RESOLVE model assumptions, in 2018 utility-scale solar is estimated to cost $46 per MWh, distributed solar is estimated to cost $104/MWh, and wind is estimated to cost $59 per MWh. Note that these costs are inclusive of current production tax credits and investment tax credits, which are scheduled to decline over the next several years.

Storage costs are also modeled based on RESOLVE inputs, the latest version of which models Li-ion battery capacity at $248 per kW in 2018, declining to $166 per kW by 2030.[44] Figure 24 and Figure 25

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[41] The RESOLVE model is a spreadsheet based capacity expansion model currently being used in the California State Integrated Resource Plan process. RESOLVE is a more simplified tool than the EnCompass model but it uses a number of similar inputs. For more information, see the RESOLVE Inputs and Assumptions Document and Scenario Tool at http://www.cpuc.ca.gov/irp_proposal/

[42] 2016 IRP pp. 131

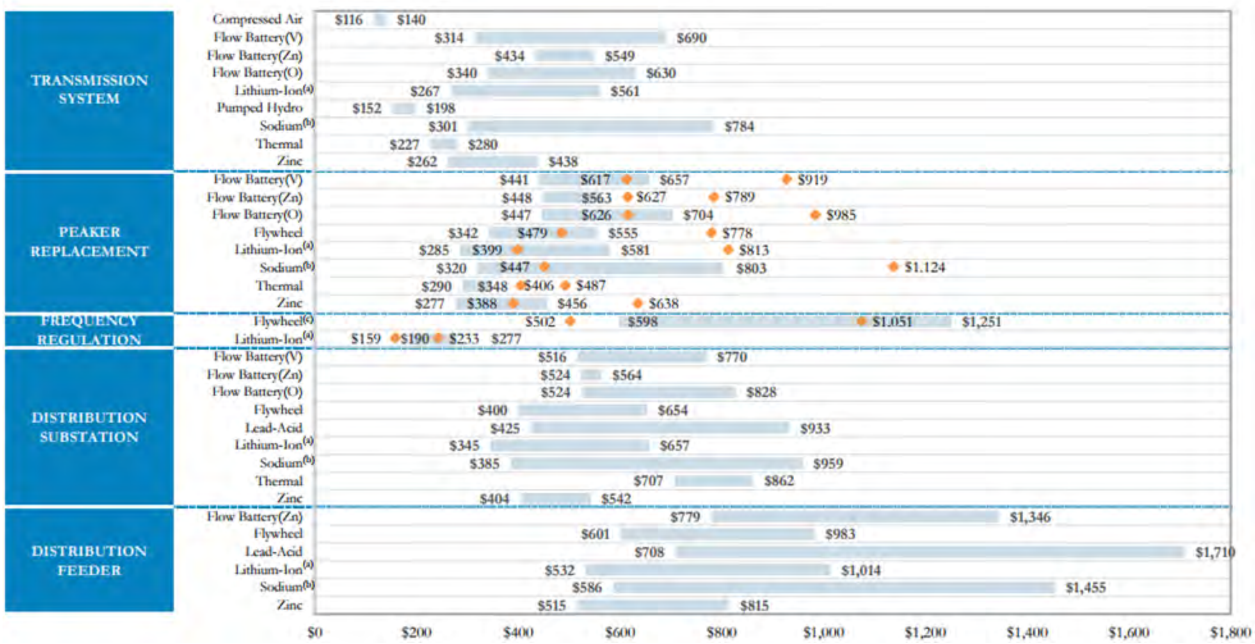
[43] For more information, see Table 20 at http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/LTPP/2017/RESOLVE_CPUC_IRP_Inputs_Assumptions_2017-05-15.pdf

[44] The RESOLVE inputs are derived from Lazard's Levelized Cost of Storage 2.0 (2016), available at: https://www.lazard.com/perspective/levelized-cost-of-storage-analysis-20/

compare the cost of a peaker in Lazard's Levelized Cost of Energy 11.0 to the storage cost assumptions from Lazard's Levelized Cost of Storage 2.0.

Figure 24. Levelized cost of energy of conventional resources, Lazard version 11.0

Figure 25. Levelized cost of storage resources, Lazard version 2.0



Unit additions

According to the EIA's Form 860 dataset, there are 1,650 MW of known unit additions that are currently under construction and expected to be online between 2017 and 2019 (see Table 2).[45]

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[45] More information available at https://www.eia.gov/electricity/data/eia860m/.

Table 2. Known unit additions (GW)

		2017	2018	2019
Los Angeles		**79**	**-**	**-**
	Batteries	2	-	-
	Onshore Wind Turbine	2	-	-
	Other Waste Biomass	33	-	-
	Solar Photovoltaic	42	-	-
California		**837**	**674**	**134**
	Batteries	42	-	2
	Conventional Hydroelectric	7	-	-
	Landfill Gas	5	-	-
	Natural Gas Fired Combined Cycle	-	672	-
	Natural Gas Fired Combustion Turbine	7	-	-
	Onshore Wind Turbine	187	-	131
	Other Waste Biomass	37	2	-
	Solar Photovoltaic	553	-	-

Unit retirements

The same EIA dataset shows us that between 2017 and 2020, over 5,500 MW has been announced to be retired in California (see Table 3). Nearly all of these retirements are old natural gas-fired steam turbines located in Los Angeles County. This includes the Scattergood 1 and 2 repowering projects. In a June 6 Board of Water and Power Commissioners presentation, LADWP noted that all repowering projects, including these, were being reassessed.[46] As that assessment will not be completed before the completion of this study, our plan would be to include the Scattergood, Haynes, and Harbor repowerings as specified in the LADWP 2016 IRP in our Reference case. This list also includes independent power producers located in Los Angeles County—specifically the AES Alamitos and AES Redondo Beach gas plants. In our Policy cases, we do not include the repowering of natural gas units; instead retiring these units by 2030.

[46] More information available at http://www.scpr.org/news/2017/06/06/72616/ladwp-puts-a-hold-on-new-power-plants-to-consider/

Table 3. Known unit retirements (GW)

		2017	2018	2019	2020
Los Angeles		**-**	**-**	**1,302**	**2,264**
	Natural Gas Steam Turbine	-	-	1,302	2,263
	Other Waste Biomass	-	-	-	1
California		**1,074**	**17**	**1,533**	**2,926**
	Conventional Hydroelectric	0	0	4	0
	Natural Gas Fired Combustion Turbine	90	0	0	0
	Natural Gas Internal Combustion Engine	0	0	8	8
	Natural Gas Steam Turbine	982	0	1,520	2,917
	Onshore Wind Turbine	0	17	0	0
	Other Waste Biomass	3	0	0	1

Additional gas retirements

In line with a 100 percent renewable future, LADWP will be forced to retire all existing natural gas and landfill gas units operating in their service territory. Rather than retire them all in 2030, however, we exogenously force their retirements earlier in the study period, better allowing LADWP to ramp towards the operational constraints associated with a 100 percent renewable future.