The Los Angeles 100% Renewable Energy Study

What Is LA100?

The City of Los Angeles has set ambitious goals to transform its energy economy. At the direction of its Mayor and City Council, LA embarked on a plan to modernize its electricity system infrastructure—aiming for a 100% renewable energy supply by 2045, along with aggressive electrification targets for buildings and vehicles. The Los Angeles Department of Water and Power (LADWP) partnered with the National Renewable Energy Laboratory (NREL) on the Los Angeles 100% Renewable Energy Study (LA100), a first-of-its-kind objective, rigorous, and science-based power systems analysis to determine what investments could be made to achieve LA's goals.

NREL is modeling and analyzing LADWP's existing power system generation, transmission, and distribution network with unprecedented detail and scale, and is examining the potential for high-quality careers, economic development, and improvements to environmental justice. The goal of these integrated modeling activities is to shed light on the options and tradeoffs among different approaches to achieving 100% renewables for LA.

Scenario Descriptions[1]

The scenarios reflect variations in projections of both electricity demand and supply.

Demand Projections

The scenarios include three demand projections: moderate, high, and high load stress.

- **Moderate**: The Moderate load projection assumes easy, low-hanging-fruit electrification and moderate (above-code) improvements to efficiency and demand response.
- **High**: The High projection is designed to match most of the electrification and efficiency goals set forth in the Mayor's Office's Green New Deal 2019 pLAn,[2] including 80% light-duty vehicle electrification by 2045. Very high electrification results in significantly more demand, even with high levels of energy efficiency.
- **High Load Stress**: The High Load Stress load projection reflects aggressive electrification assumptions (same as High) but without the efficiency and demand response improvements to manage the growth. This scenario represents the most challenging load conditions.

1 A ***scenario*** is one possible future electric generation system. Scenarios in a 100% renewable energy study provide the basis for exploring how different options for the future power generation fleet, transmission network, and/or operational practices impact power system reliability, economics, and other objectives such as emissions reduction.

2 https://plan.lamayor.org/

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Supply Projections

- **SB100**: The power system meets all requirements associated with existing California law (60% renewable energy by 2030 & 100% carbon-free energy by 2050). In line with SB100, clean energy targets are based on a fraction of load,[3] and renewable electricity certificates (RECs) are allowed to be used for a portion of compliance[4]
  - Evaluated under **Moderate** and **High Load Electrification**, and **High Load Stress**
- **LA Leads, Emissions Free (No Biofuels)**: Scenario with the earliest compliance (2035) and which excludes combustion-based generation (namely, biofuels)
  - Evaluated under **Moderate** and **High Load Electrification**
- **Transmission Renaissance**: Scenario that assumes lower barriers and costs to new transmission
  - Evaluated under **Moderate** and **High Load Electrification**
- **High Distributed Energy Future**: Scenario that prohibits new transmission capacity and includes higher levels of in-basin, distributed generation
  - Evaluated under **Moderate** and **High Load Electrification**

Definitions of Renewable Resource Technologies for Producing Electricity (Sources: EIA, EPA, and DOE)

The descriptions of technologies are differentiated by those that use renewable resources to directly produce electricity (e.g., solar, wind, hydro) and those that convert the resources to storable liquids, solids, and gases, and then produce electricity (e.g., biofuels, hydrogen).

Direct Renewable Resource-to-Electricity Generation

- **Hydropower:** Hydropower was LADWP's original source of electricity and is the largest single renewable energy source for electricity generation in the United States. LADWP uses reservoir-based hydropower (e.g., Hoover Dam). When electricity is needed, water is released, which pushes on blades in a turbine, which in turn produces electricity. LA100 allows upgrades to existing hydropower plants to increase plant capacity but does not allow plants in new locations.
- **Wind:** With a wind turbine, wind flows over the blades, creating lift (similar to the effect on airplane wings), which causes the blades to turn. The blades are connected to a drive shaft that turns an electric generator, which produces the electricity. LA100 considers both on- and offshore wind. For onshore wind in the West, wind resources are strongest (and steadiest) in

[3] A target specified as a fraction of load is less stringent because it does not require transmission and distribution energy losses to be covered by renewable generation. This type of specification effectively allows a small amount of generation from conventional or non-renewable technologies.

[4] It is assumed that REC usage is constrained by the existing SB350 CA RPS compliance categories.

Wyoming, although many other locations closer to LA have cost-competitive wind resources. Compared to onshore wind, offshore wind typically has steadier wind resources, which helps smooth the variability of wind, but costs for offshore wind are higher.

- **Solar:** Solar photovoltaic (PV) devices convert sunlight directly into electricity. Concentrating solar power (CSP) systems collect and concentrate sunlight to produce high-temperature heat needed to generate steam for electricity (similar to a conventional generator). Solar PV systems cannot store electricity but they can be located anywhere, including residential homes. CSP plants can store energy in the form of heat, which enables CSP plants to operate after sundown, but they are large plants located remotely in desert areas. The LA100 study differentiates types of solar PV as **utility PV** (large, MW-scale, stand-alone sites), **utility PV + battery** (co-located and which share grid connection resources), and **distributed PV** (located on the distributed grid, such as rooftop PV).

- **Geothermal:** Geothermal power plants use heat from deep wells (e.g., mile deep), which is used to produce steam and is piped to a turbine that generates electricity. Geothermal heat is constant and therefore can supply 24x7 electricity, but high-quality (cost competitive) locations are more limited compared to solar and wind.

Generation through Conversion of Renewable Resources to Fuels

The ability to store fuels for later use is a valuable characteristic in systems that must meet 100% of demand with renewable-supplied electricity at all times. The generation technologies featured in this section include biofuels (which can be stored prior to generation) and fuels derived from converting clean electricity to a storable fuel. How the fuels are then converted to electricity has implications for air quality. Figure 1 shows multiple pathways for conversion of renewable resources into electricity via the production of storable liquid, solid, and gas fuels.

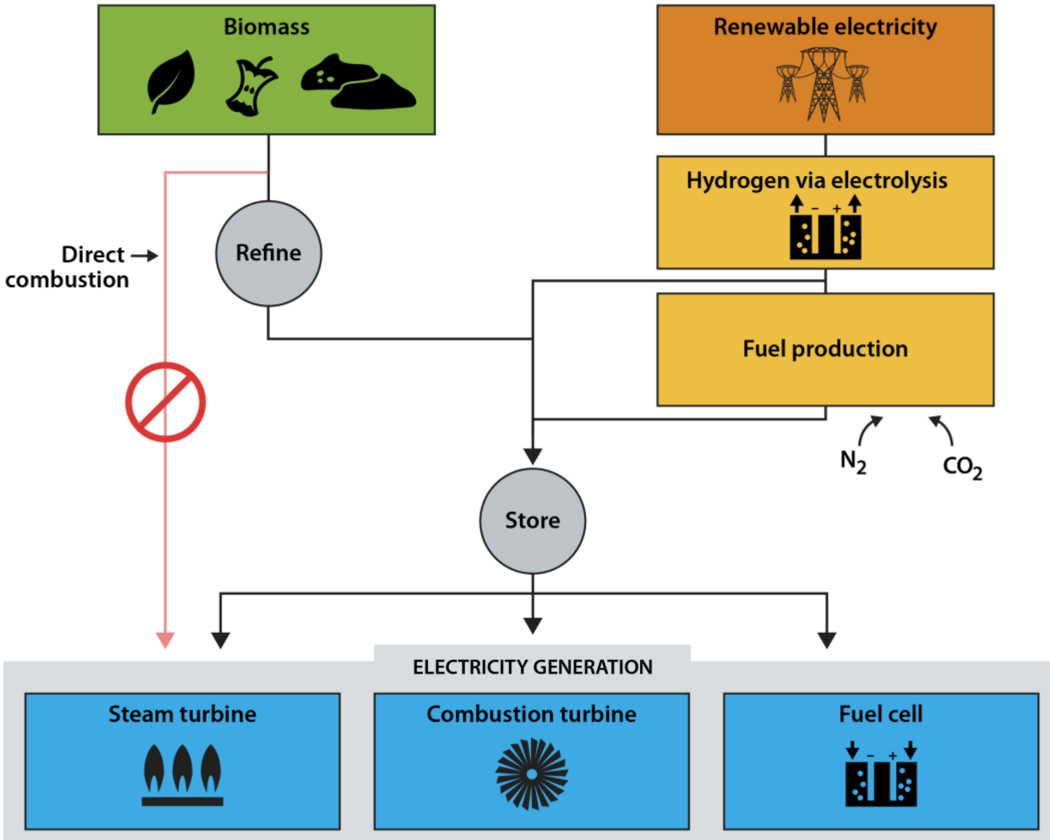

Figure 1. Sources and pathways to convert biomass and renewable-derived electricity to storable fuels and then to generate electricity.

- **Solid Biomass (direct combustion):** Solid biomass (such as forest waste) or organic trash (such as paper) can be burned directly to produce steam and turn a turbine in a generation process similar to burning fossil fuels. The LA100 study prohibits technologies that burn biomass directly due to associated air pollution. Biogas is allowed in many scenarios and is described separately, below.

- **Biofuel Combustion:** Biomass including certain crops or animal waste can be converted into a clean-burning fuel through two main pathways. The first is via biofuel refining, which can produce products such as ethanol or biodiesel. The second is biogas, typically produced by anaerobic decomposition of municipal solid waste in landfills or from livestock manure. Biogas is primarily methane (natural gas). Both biofuels and biogas can then be combusted in a combustion turbine, similar to natural gas. (A more complete description of combustion turbine generation is described in the description of natural gas below.) While this process releases carbon dioxide (CO_2), and some small amounts of NOx, the process is considered CO_2 neutral, as the original biomass was produced by capturing CO_2 from the atmosphere via photosynthesis.

- **Renewable Electricity-derived Fuel Combustion**: Renewable electricity sources (e.g., wind, solar) can be used to produce various fuels for storage, to be used for electricity generation at a later date. The first step is electrolysis, which turns water into hydrogen and oxygen. This hydrogen gas may then be stored and used in a combustion turbine to make electricity. Alternatively, hydrogen can be converted into a fuel that is easier to store and transport, such as natural gas (methane) or ammonia. The combustion process can produce small amounts of NOx.

- **Fuel Cells (using renewable fuels)**: Fuel cells use chemical energy of a fuel to produce electricity (similar to a battery). Fuel cells may use a number of renewable-electricity derived fuels (e.g., hydrogen) or may use a limited number of biofuels. Fuel cells produce no NOx, and very little noise. However, they are currently more expensive then combustion options.

Renewable Electricity Storage

Electricity can be stored in a variety of ways. The two main characteristics of a storage device are its power capacity, using the same measure as conventional power plants, and energy capacity, measured by its storage duration (the amount of time it can discharge at full capacity before depletion). For example, many batteries being deployed for grid applications have about 4 hours of discharge capacity. Most storage plants, such as batteries or pumped storage plants, frequently cycle to respond to hour-to-hour variations in demand, charging when demand is low in the middle of the night, or when PV output is high, and then discharging when demand peaks in the afternoon and evening. As a result, the storage device is not expected to charge and then hold energy for extended periods (weeks to months). However, in 100% renewable energy scenarios, long-duration storage—the ability to store days or weeks of energy capacity and hold this stored energy for weeks or months without significant losses—will likely be valuable. The LA100 study considers the following types of storage.

- **Battery storage** is currently represented by lithium-ion batteries with 4 to 8 hours of capacity, which are similar to the types used in electric vehicles.

- **Pumped hydro storage** pumps water up to a reservoir when electricity prices are low and releases this water for generation when the electricity is needed. Typically, these devices have 8–12 hours of storage.

- **Compressed air energy storage (CAES)** compresses air into a large underground formation and releases the compressed air via a turbine. Current CAES plants require some fuel combustion and use natural gas, but could utilize renewable-electricity derived fuels (such as hydrogen) or advance cycles that involve no fuel combustion. CAES typically has 12 or more hours of capacity.

- **Thermal storage** is utilized in CSP plants, discussed previously. Currently deployed CSP plants have 6–12 hours of storage.

- **Long-term storage** typically involves using renewable energy to produce a liquid or gas fuel (such as hydrogen, ammonia, or synthetic natural gas) and storing this fuel in a tank or underground formation, and then using this fuel to make electricity in a fuel cell or gas turbine.

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Non-Renewable Technologies Represented in LA100

- **Natural Gas:** Natural gas is a fossil energy source that formed deep beneath the earth's surface. The largest component of natural gas is methane, a compound with one carbon atom and four hydrogen atoms (CH_4). The gas is combusted to either heat air (**combustion turbine**) or create steam (**steam turbine**), the heat of which in turn drives the turbine to produce electricity. **Natural gas combined-cycle** uses both of these processes to improve the energy efficiency of the plant. Combustion turbines, with lower efficiencies and also lower capital costs, can be operated more flexibly (e.g., faster changes in output) compared to combined-cycle plants, and have traditionally been used as peaker plants to meet the extreme periods of demand. Combined-cycle plants with higher efficiencies, and therefore lower operating costs, are operated more continually in today's LADWP system.

- **Nuclear:** Nuclear power plants use heat produced during nuclear fission to heat water, which produces steam. The steam is used to spin large turbines that generate electricity. Unlike fossil-fuel-fired power plants, nuclear reactors do not produce air pollution or carbon dioxide while operating, although greenhouse gases are emitted as part of mining, fuel production, and plant construction. LADWP generates electricity from its share of the Palo Verde nuclear power plant located in western Arizona. No LA100 scenario allows new nuclear generation, but the scenarios vary on whether Palo Verde is allowed to contribute to the 100% target.