Lessons from Los Angeles: Powering a Megacity with Renewable Energy

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The City of Los Angeles is nearly two thirds of the way toward its goal of generating a third of its electricity from renewable sources by 2020; cities around the world can glean valuable technical, economic, and political lessons from its experience.

On March 22, 2013, the City of Los Angeles entered into contracts to end its consumption of coal power; former US Vice President Al Gore asserted that LA had taken its place among the "five greatest cities in the world where combating global warming is concerned." This assessment will be tested over the next decade, while LA continues to deploy renewable energy and energy efficiency as the centerpieces of its coal-replacement strategy. By 2030 cities will account for 76% of global greenhouse gas emissions, under consumption-based accounting models.[1,2] If megacities like LA can demonstrate affordable clean energy, they will provide a template for urban sustainability worldwide, especially important for rapidly urbanizing regions with high emissions growth like China and India.[3]

Over the last eight years, LA has quadrupled its renewable energy generation, which now comprises 20% of the city's electricity consumption. By 2020, LA will achieve 33% renewable energy and reduce its energy use by at least 10%.[4] Critical examination of LA's ongoing experience with renewables is worthwhile for two reasons. First, LA demonstrates how a city can take control of its energy portfolio and harness state and federal policies to best meet local needs. Second, the challenges and lessons of sustainably powering a megacity are neatly packaged for display because of LA's unique vertically integrated utility, the LA Department of Water and Power (LADWP).

LA's retention of a municipally controlled utility, along with powerful public sector labor unions, may appear anachronistic and inefficient amidst a national electricity deregulation movement. However, on balance, the city has achieved surprising progress at reasonable cost, enabled by the responsiveness of the LADWP to elected officials and the interests of the utility customers they represent. In today's segmented energy sector, where electricity from independent power producers is often traded on wholesale markets and distributed within expansive service territories, cities can have limited control and visibility over where their power comes from.[5] However, procurement, generation, transmission, grid integration, and distribution of LA's renewable energy occur under one organization, elucidating the process of building a city's renewable energy portfolio largely from scratch.

Toward a Robust Renewable Energy Portfolio

California's aggressive Renewable Portfolio Standard (RPS) mandated that the three investor-owned utilities (IOUs) in California, which collectively serve 68% of the state, obtain 20% of their electricity from eligible renewable sources by 2010.[6] None of the IOUs and no other major US city achieved the 20% mark in 2010, while LA succeeded, even though LA voluntarily adopted the standard years before it became a legal mandate regardless of utility ownership in 2011. While RPS policies have been shown to encourage renewable energy development,[7,8] the RPS alone is clearly insufficient to explain LA's success. The differentiating factor for LA was the conviction of municipal elected officials to oversee the LADWP's progress toward the state target.

In 2006, that target seemed implausible. LADWP needed to quadruple its renewable generation from 5% of total consumption, whereas the California average was 11%; moreover, LA obtained nearly half its electricity from coal power, similar to the national profile but well above California's average of 15%.

To understand LA's dramatic acceleration of its renewable energy program, some background on the LADWP is warranted.[9] The City of LA owes much of its growth to its enterprising utility, founded in 1902, and LA has a strong history of controlling its generation and transmission assets. While its service territory only accounts for 10% of California's energy demand, LADWP owns 27% of California's transmission lines, affording it access to several Western states to tap a wide diversity of power sources. While IOUs suffered rolling blackouts and price volatility during California's energy crisis in 2001, LADWP emerged unscathed and actually helped stabilize the state's electricity market. The City Charter affords LADWP an exclusive monopoly to sell power in its service territory, which is largely coterminous with city boundaries.

Insulated from the obligation to meet its power supply from California's at times volatile power market, LADWP has leveraged its vast transmission systems and assembled a diverse renewable portfolio through competitive bidding and a rapid, real-world learning process. Moving beyond its voluntary 20% renewable portfolio, LADWP is bound by and plans to meet subsequent state RPS milestones enacted through recent California mandates—25% in 2016, and 33% by 2020. For each milestone, LADWP must become more sophisticated, accounting for the effect of high renewable penetration on the grid and controlling costs while diversifying the portfolio.

Figure 1(a) graphs the historic and future composition of LADWP's renewable energy portfolio. The salient characteristic of this portfolio is diversity—in technology, geography, and competitively bid supplier. By 2020, renewable generation will be divided between geothermal, solar, wind, and qualifying small hydro power to smooth the overall generation profile. LA will acquire its renewable energy from seven different Western states (see Supplementary Information), helping insulate the portfolio from potentially monolithic patterns of intermittent wind and solar generation. Finally, LADWP will procure its renewable energy through power purchase agreements (PPAs), proprietary installations, and wholesale purchases, to determine the optimal mode of procurement.

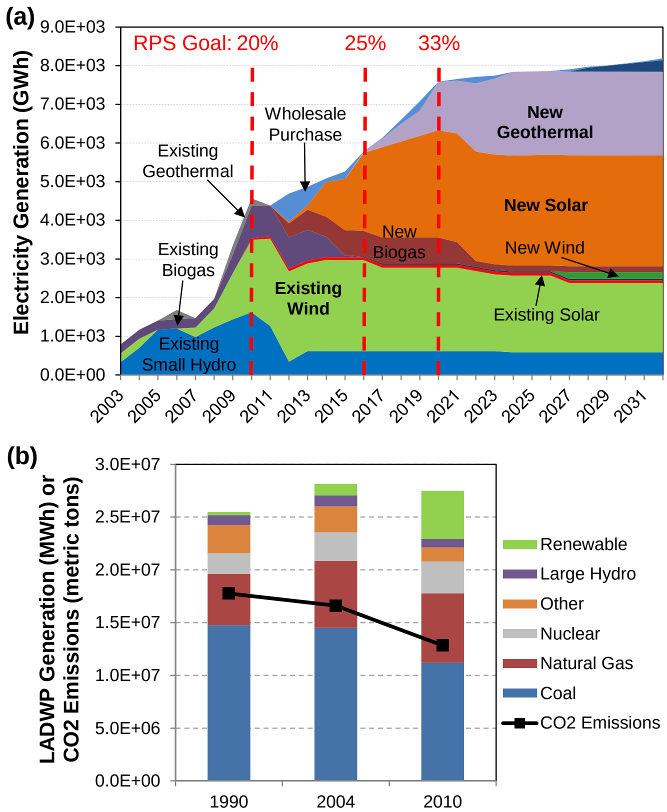

***Figure 1**: **(a)** LADWP renewable energy generation, historical and projected. "Existing" sources refer to those in operation by 2012, while "New" sources will be constructed subsequently. RPS milestones are delineated in red and the major portfolio components to meet the 33% RPS target are listed in bold.[4] **(b)** LADWP total historical electricity generation broken down by source, with carbon dioxide emissions overlaid.*

The first phase of renewable development, meeting the 2010 milestone of 20%, exhibited relatively little technological diversity. The LADWP, unfamiliar with large-scale renewable generation, had long relied upon existing small hydro resources along the LA Aqueduct, but that resource was insufficient to meet the target. To meet the 20% level, LADWP invested heavily in wind and to a lesser extent biogas displacing some of the natural gas supply required for gas-fired generation plants. By 2010, wind energy dominated the renewable portfolio; at the time, wind was far more economical than solar power, and the industry was more mature.

Figure 1(b) illustrates the effect of increasing renewable penetration through 2010 on LADWP carbon dioxide emissions. Using the popular Kyoto protocol benchmark of 1990 emissions levels, LA succeeded in reducing emissions by 28% in the electricity sector by 2010.

The present and second phase of the renewable portfolio development, to meet the 2016 milestone of 25%, is a period of transition for LADWP. Following the precipitous decline in prices of solar panels and the upcoming expiration of federal tax incentives in 2016, LADWP intends to ramp to 25% penetration largely through utility-scale photovoltaic (PV) installations in the desert and a new feed-in tariff for in-city solar generation. To access the high insolation Mojave Desert, LADWP is constructing a new transmission line explicitly for renewables and conducting a comprehensive competitive bidding process to ultimately construct over 1 GW of solar PV.

LADWP has become increasingly sophisticated in its process for soliciting and evaluating renewable energy sources as it enters the second phase to ramp beyond 20% RPS. As renewable penetration increases, the grid impacts of intermittent generation could affect reliable operation and demand expensive contingent power supply reserves. Solar PV provides a more predictable generation profile that coincides far better with peak load than do wind energy resources, which are strongest during off-peak hours. Moreover, LADWP observed the solar PV procurement processes of IOUs elsewhere in the state and now enjoys a buyer's market, pitting hundreds of developers against each other to deliver less expensive and more bankable projects; this is in contrast to LADWP's earlier experience with wind contracting, where it resembled a price-taker.

Finally, the third phase of portfolio development, to meet the 33% milestone by 2020, will require LADWP to supplement its intermittent wind and solar with baseload geothermal energy. Geothermal will be the only significant part of the portfolio that is comparable to the 24/7 operational characteristics of the coal-fired power plants LADWP is replacing and helps enable the utility to adjust to the high intermittent penetration of solar and wind while continuing to increase its share of renewable energy.

Challenges and Lessons

While the previous section may imply a smooth learning curve of increasing sophistication toward a growing renewable penetration, LA has had to contend with setbacks and constraints both technical and political, yielding lessons of both varieties. Securing constituent support and political unity for rate hikes complicates the already complex challenge of radically altering the electricity supply; LA's success is predicated upon continued cooperation between the LADWP and City Hall.

Over the next 10-12 years, LADWP will replace 70% of its generation, an infrastructure built over a century. Renewable generation, along with energy efficiency, coal divestment, and requirements to repower 2800 MW of gas-fired generation with new power plants that do not use ocean water for cooling, is driving this transformation. However, the costs are non-trivial, as displayed in Figure 2. To achieve the initial 20% goal, LA utility customers saw an estimated 0.9¢/kWh rate increase, but as the complexity of integrating a high proportion of renewables increases, customers are projected to see around 2¢/kWh more, due to RPS fulfillment, over the next two decades.

We have engaged in extensive outreach to educate Angelenos about the merits of renewable energy and the necessity for rate increases. The political process behind these increases is arduous, however, and we have faced setbacks when proposals to

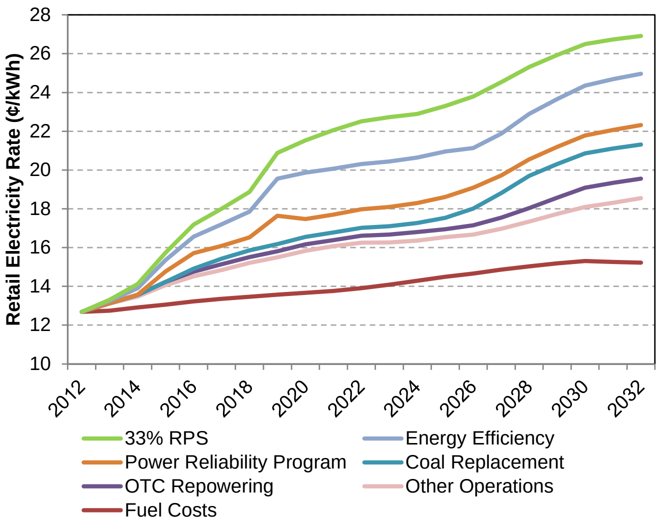

Figure 2*: Incremental rate impacts of LADWP costs and initiatives over the next twenty years. "OTC Repowering" refers to retrofitting of coastal power plants that employ inefficient once-through-cooling using ocean water; "Power Reliability Program" refers to basic infrastructural upgrades like pole and transformer replacement.*[4]

fund future renewable projects failed to gain support at the ballot box and in the City Council. We learned that demonstrating a clear vision and implementation plan, including projections for mandate fulfillment like Figure 1(a), is crucial for securing political support; this approach led to Council approval for a rate increase in 2012. However as rates escalate further, the subsequent Mayor and City Council will face the need to maintain a clear vision, prudently compromise, and recognize customer and voter concerns in order to secure RPS fulfillment.

Another challenge LA faces is state policy that may not be as easily focused toward a locally optimal solution. While California's RPS requirements created an ambitious level of renewable penetration with the flexibility for LA to construct an appropriate portfolio, the state has also proposed a target (though not yet a mandate) of 12,000 MW of distributed generation by 2020. Proportionally, that would allocate 1,200 MW to LA. In the subsequent section, we discuss LA's support for distributed generation, especially PV, which leverages existing infrastructure and serves the local economy. Altogether, LA anticipates that between LADWP-sponsored programs and voluntary efforts by utility customers, around 500 MW of distributed solar will be installed in LA. Higher levels are being evaluated, subject to better understanding of the effect on local system reliability. Recognizing local needs and constraints is essential, and the state target, at over a third of average peak load, could overburden LADWP's infrastructure and delay progress toward the RPS.

On the technical side, LADWP is learning along the way about integration of intermittent renewable resources. At present, solar and wind come laden with hidden costs, fundamentally because of the variability of production and inability to confidently predict generation output from these resources—resulting in a lack of dependable capacity.[10] This refers to the percentage of power generation of a renewable generator, under optimal conditions, that the utility can reliably count on during peak load times. Table 2 illustrates this point—for example, while typical wind turbines under contract to LA have a 24% to perhaps 37% capacity factor, their dependable capacity is only on the order of 10%, after averaging geographically diverse wind energy resources. The difference implies that LADWP needs to acquire expensive single cycle gas turbines to provide contingent reserve and quickly ramp up and back down to "firm" the wind energy production. This is an expensive proposition, so LADWP is now working to improve its wind energy production forecasting capabilities, for example by placing meteorological equipment along known upwind corridors, to improve dependable capacity value of its renewable generators.

Generation Source	Levelized Cost ($/MWh)	Capacity Factor (%)	Dependable Capacity (%)
Wind	105	24-37	10
Solar PV—PPA	116	25-32	27
Solar PV—FiT	152	19	27
Geothermal	109	91-95	90
Combined Cycle Gas	80	59	100
Simple Cycle Gas	225	9	100

Table 1*: LADWP Estimates of renewable energy costs and generation characteristics. "Solar PV—FiT" refers to the Feed-in Tariff program for distributed solar described in the next section. To compute levelized costs over the 2012-2032 timeframe, the net present value of fixed and variable costs as well as interconnection to LADWP's transmission system was determined for each source. The capacity factor is defined as the ratio of actual output to potential output based on nameplate power rating. The dependable capacity fraction refers to the proportion of nameplate power rating that the utility can count on achieving during peak power periods.*[4]

Finally, LA is extremely wary of the possibility of "curtailment," under which LADWP would be forced to sell excess peak power or even pay to offload that power. This occurs when customer loads are low (especially late at night), and the combination of wind energy and minimum operating levels of gas-fired generation result in excess supply absent curtailing some part of the utility's production. Elsewhere in the world, for example in Australia,[11] curtailment has increased the cost of renewable energy, because at high levels of renewable penetration, weather and demand can conspire toward excess supply. As LA advances toward higher renewable targets, its intermittent resources will produce unexpected consequences, rain or shine.

Focus on Distributed Solar

Throughout this piece we have argued that cities can implement state and federal guidelines to suit local needs. With utility scale solar, it is easy to leverage federal tax credits to meet California's RPS target, but that singular approach misses valuable opportunities for improving the local economy.[12] In February, 2013, LA introduced the largest urban Feed-in Tariff (FiT) in the nation, which will deliver 150MW of distributed solar PV within the city of LA.

Distributed generation can benefit the grid—through lower line losses, more robust protection against cascading failure, and reactive power support—as well as the local economy by creating jobs within LA.[13,14] LA has supported distributed solar for 15 years, but until recently did so through up front installation rebates for "net-metered solar," installed by utility customers to offset their purchases of energy from LADWP. By switching to a FiT and paying a fixed price per kWh of energy delivered to LADWP under a PPA, LA can spread out its incentive payments over twenty years, enabling it to accelerate the pace of local installations fourfold.[15] Moreover, while net-metered solar has effectively increased market exposure and demand for rooftop PV, its implementation creates some serious inequities; the offset energy use of the customer only accounts for about half the total cost of service, which includes costs like electric distribution, customer service, risk management, and storm response. These costs are borne by customers not participating in net-metered solar, so LADWP is moving forward quickly with a FiT model that avoids such cost-shifting. The first 20MW offered in 2013 were fully subscribed in a week, attesting to the success of the program.

While the first 100MW offering of the FiT was designed to incorporate best practices from around the world, such as a declining rate structure over time, the final 50MW exhibit the kind of policy innovation that cities must deploy to leverage their particular strengths. As previously discussed, LA has attracted hundreds of developers keen to secure contracts to develop large utility-scale solar installations outside city limits and the LADWP distribution system. Under a new and innovative program, LADWP is requesting bids to develop four parcels within a 200MW site in the Mojave desert, northeast of LA, and committing winning developers to collectively install 50MW of distributed solar within the LA Basin as a condition of the utility scale award. By creating economies of scale for developers to bundle local projects along with utility-scale installations, LA is supporting local economic development and a healthier electricity grid in an affordable manner. This new bundled model for the FiT's second phase will provide valuable insight into the relative economics and ease of implementation of solar in LA, as compared to the "local-only" FiT. LA will learn from these different models to determine the best paths for distributed solar implementation for LADWP in the future.

LA offers a unique window into the construction of a robust renewable energy portfolio to power a megacity. Cooperation between the City and LADWP has allowed a dramatic ramp in renewable penetration despite political and technical obstacles; if LA can successfully implement its 33% target, it will provide insight into sustainably powering cities around the world.

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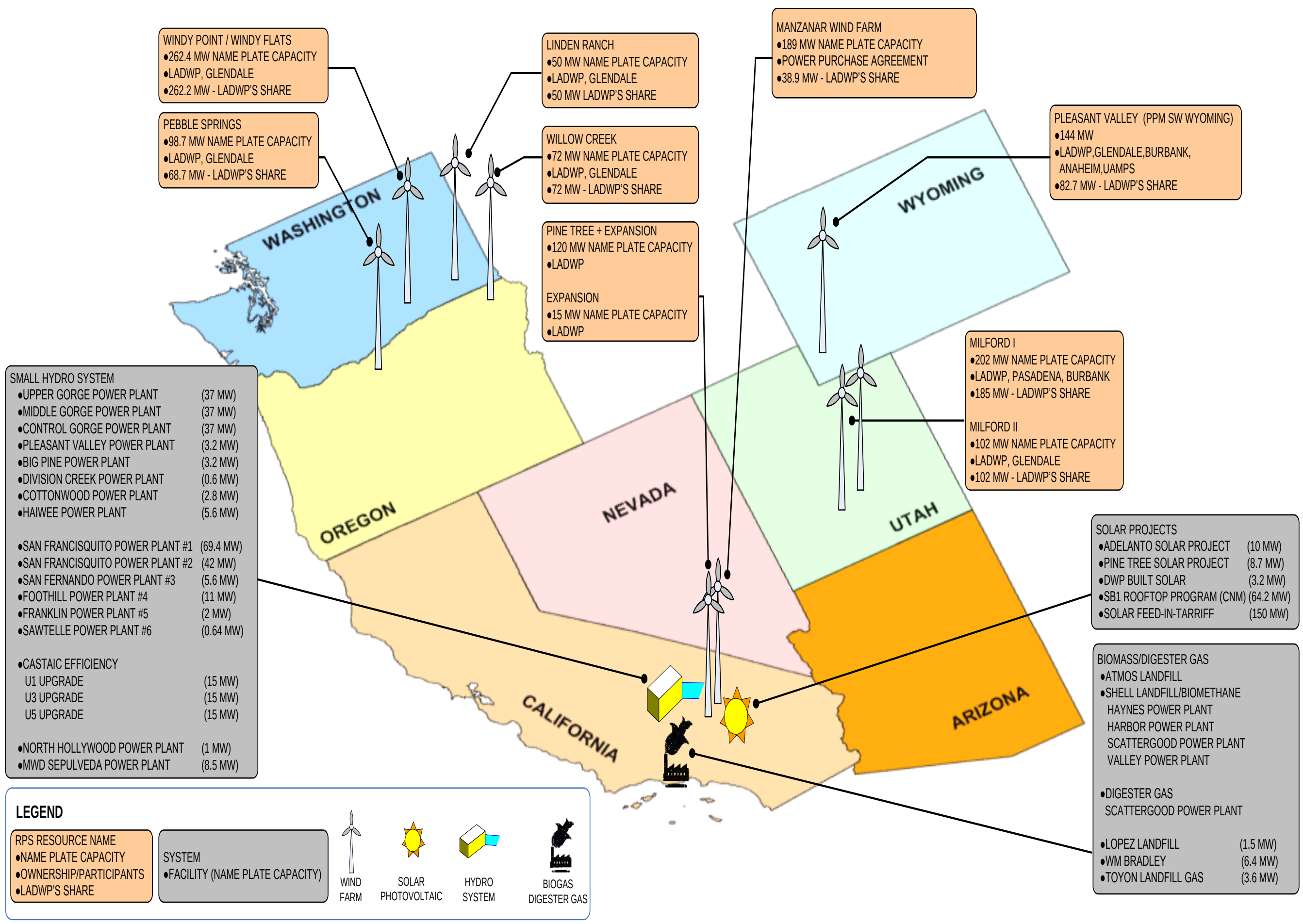

Figure S1*: Map of existing LADWP Renewable Generation Sources*