

PLUG-IN HYBRID CHARGING IN LOS ANGELES: Analysis of the Load-leveling Capacity for Charging Plug-in Hybrids in the Los Angeles Department of Water and Power Transmission Area

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Abstract

In January of 2007, Kintner-Meyer et al. from the Pacific Northwest National Laboratory released a study assessing the impact of Plug-in Hybrid Electric Vehicles (PHEVs) on electric utilities and regional power grids. The study used 2002 North American Electric Reliability Corporation data paired with U.S. Department of Transportation data to quantify the excess capacity potential of regional power production for the purpose of charging PHEVs. This report examines a more detailed case-study of the excess capacity potential in the Los Angeles Department of Water and Power (LADWP) transmission area using Velocity Suite® software modeling capabilities. A much higher degree of resolution in the information presented is attainable through the use of the Velocity Suite® load, capacity, and emissions data paired with recent PHEV energy storage data. Timely and detailed data will be presented to further identify the impacts and benefits of a PHEV charging system in Los Angeles.

Keywords: Plug-in Hybrid Electric Vehicle, Capacity, Load-leveling, Distributed Energy, Utility.

Introduction

In January of 2007, Kintner-Meyer et al. from the Pacific Northwest National Laboratory released a study assessing the utility and grid impacts caused by the projected addition of large numbers of Plug-in Hybrid Electric Vehicles (PHEVs) on a national scale. This paper will zoom in on a 24 hour period at the Los Angeles Department of Water and Power – the nation’s largest municipal utility – to examine the availability of power for use by PHEVs in the area on the day of the highest hour in electricity demand during 2006. Information on the load, capacity, PHEV charging potential, and resultant emissions will be presented.

Research Methods

The following research was conducted using Velocity Suite® software to determine the available capacity for charging PHEVs in the Los Angeles Department of Water and Power transmission area.

Load

The hourly load data used in the study was derived from the 2006 Federal Energy Regulatory Commission (FERC) Form-714, specified to the Los Angeles Department of Water and Power transmission area. The ‘peak day’ or day with the highest daily load in the area was determined by sorting the data by load in units of megawatt-hours (MWh). This peak day in LADWP was determined to be July 24th, 2006 with a maximum load between 3 p.m. and 4 p.m. of 6,102 MWh. The minimum load for the area in 2006 was 2,041 MWh, and the mean was 3,136 MWh [3]. The peak day was selected for the study to demonstrate a worst-case scenario of increasing loads with limited capacity resources.

Capacity

Total capacity in the Los Angeles Department of Water and Power transmission area was determined through Velocity Suite® software based upon FERC Form-906 data and Energy Information Administration (EIA) Form-860 data. Imported energy for the area was determined by referencing the LADWP Draft 2006 Integrated Resource Plan (IRP) [2] and applying ownership and purchased power percentages to the corresponding power plants in the Form-906 and Form-860 data. The data is classified by plant fuel, prime-mover, nameplate and summer capacities, online date, and dispatch. The total gross capacity available to the LADWP transmission area was determined to be 7,335 MW [3]. According to the LADWP Draft 2006 IRP, the utility is required to maintain a reserve capacity of 1,121 MW [2] leaving a total net capacity of 6,214 MW.

PHEV Charging

Available capacity for the charging of PHEVs was then calculated by subtracting the hourly load from the total net capacity. This available capacity was modeled for use to charge 10 kWh batteries over 4 hour “charging blocks”. According to ‘An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles’ [4], a 10 kWh battery is fairly typical of what one might expect for a commuter PHEV traveling approximately 30 miles per day at an energy rate of 0.25 to 0.34 kWh/mile [4]. The 4 hour “charging blocks” were used based on the projected delivery of approximately 2500 watts per hour. The total number of PHEVs able to utilize these “charging blocks” is arrived at by dividing the available capacity during this 4 hour period by 10 kWh per vehicle.

Emissions

The resultant emissions associated with the burning of fossil fuels to meet the hourly load and projected PHEV load were determined through the Velocity Suite® emissions data based on the Environmental Protection Agency's Quarter 3, 2006 Hourly Continuous Emissions Monitoring Systems (CEMS) reporting. Hourly generation and the aggregate emissions of carbon dioxide (CO₂), sulfur dioxide (SO₂), and Nitrogen Oxides (NO_x) are presented as reported in CEMS [3]. Modeling for the emissions associated with the charging of PHEVs was conducted by applying the hourly rate of emissions from the fossil fuel power plant to the total capacity available for the plant – not being utilized to meet the hourly load. Based on the LADWP Draft 2006 IRP supply stack, it is reasonable to conclude that fossil fuel fired plants would be utilized primarily, along with available renewable and nuclear capacity, to meet the increased demand of PHEV charging. Hydroelectric facilities would be used only above the 3,900 MW load level, and to meet reserve capacity requirements [2].

Results

In this section, the findings from the analysis of the load-leveling capacity for PHEV charging in the LADWP transmission area are presented.

Load

The Los Angeles Department of Water and Power provides electrical service for approximately 3.9 million people in an area of approximately 465 square miles. Annual electricity sales at the LADWP are in excess of 23 Terrawatt-hours (TWh) [2] with an average hourly load of 3,136 MWh and a minimum hourly load of 2,041 MWh in 2006 [3].

A typical 24-hour load model for the LADWP looks like a wave, with low-points in the night-time hours when electricity usage is at a minimum, and high-points in the afternoons when consumers are returning home from work and utilizing air conditioning units and other consumer electronics. Figure 1 depicts the load model for July 24th, 2006, when the LADWP reached its maximum demand between 3 p.m. and 4 p.m.

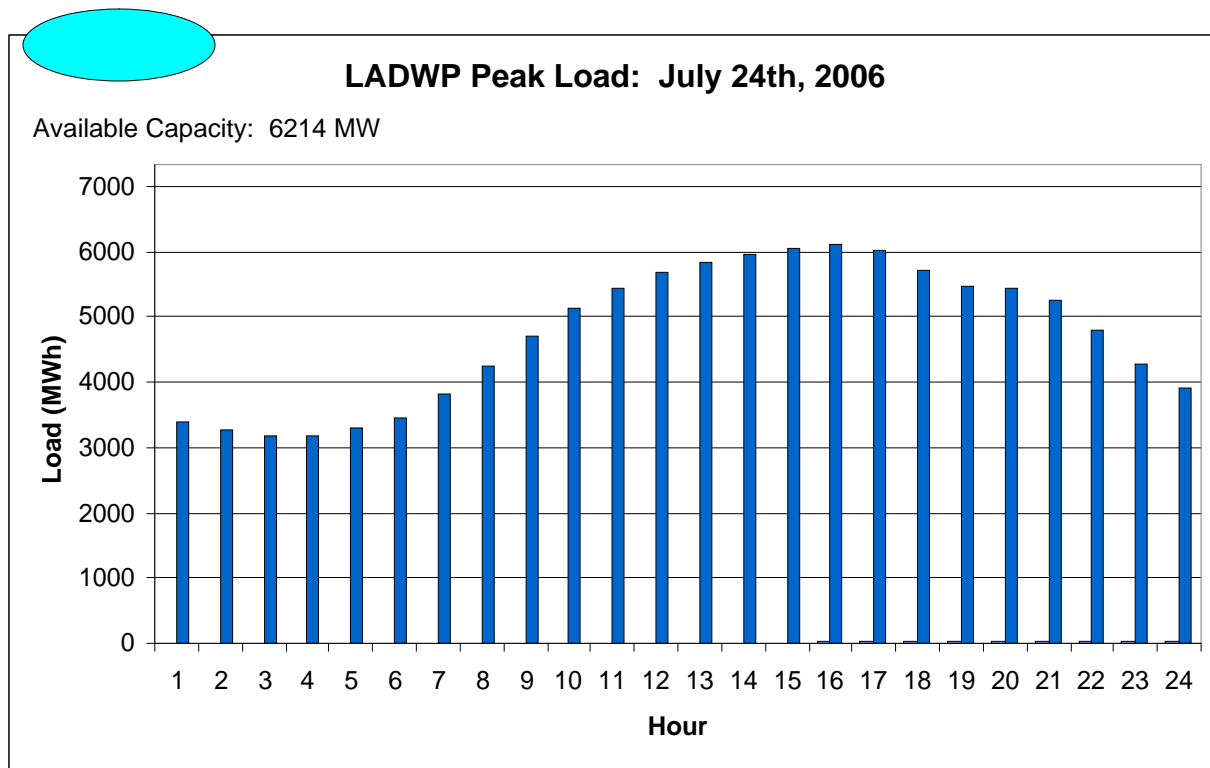


Figure 1: Hourly demand in megawatt-hours for the LADWP service area at peak load in 2006.

The peak load in the area reached 6,102 MWh – 112 megawatts below the available capacity, and 1,233 megawatts below the total capacity. The minimum during the 24-hour period occurred between 2 a.m. and 3 a.m., at a low 3,190 MWh.

During these morning hours, the LADWP diverts a portion of the power it produces to the Castaic Pumped Storage facility. The pumped storage facility works by using inexpensive electricity during off-peak hours to pump water uphill to a reservoir where the water is stored. During peak hours when

electricity is more expensive, the water is released to flow downhill to turn hydroelectric turbines which produce power. The Castaic Pumped Storage facility uses approximately 1500 MWh for pumping between the hours of 1 a.m. and 6 a.m. [2]. During the day when the water is released, the facility produces between 1322 MW and 1495 MW of power [3].

The Castaic Pumped Storage facility provides a good example of the load-leveling method: energy not being utilized during the night-time hours can be stored via a water reservoir or a PHEV battery, and then released during the day when the demand for energy is greater. During the hour of minimum demand on July 24th, 2006 between 2 a.m. and 3 a.m., 3,024 megawatts of capacity was available for the pumping of Castaic waters, and for the charging of PHEVs [3].

By aggregating all available capacity not being utilized to meet the load of the consumer and the Castaic water pumps, the total available capacity for charging PHEVs may be found in a similar manner. The result is an inversion of the data from Figure 1; when the total load and available capacity are combined, the load is referred to as leveled. By employing the load-leveling method, the utility will thus be increasing the energy demand to the level of the supply. In this case, the total energy available over the 24-hour peak day is 33.938 Gigawatt-hours (GWh) [3].

Next, the available capacity is grouped into 4 hour “charging blocks” assuming a power transfer of 2500 watts per hour. A PHEV would be assigned to one of six charging blocks, and would pay the current electricity rate for charging during that time period. Peak charging hours between noon and 4 p.m. could be reserved for emergency vehicles or those willing to pay a higher rate. Figure 2 provides a graphical representation of the charging blocks.

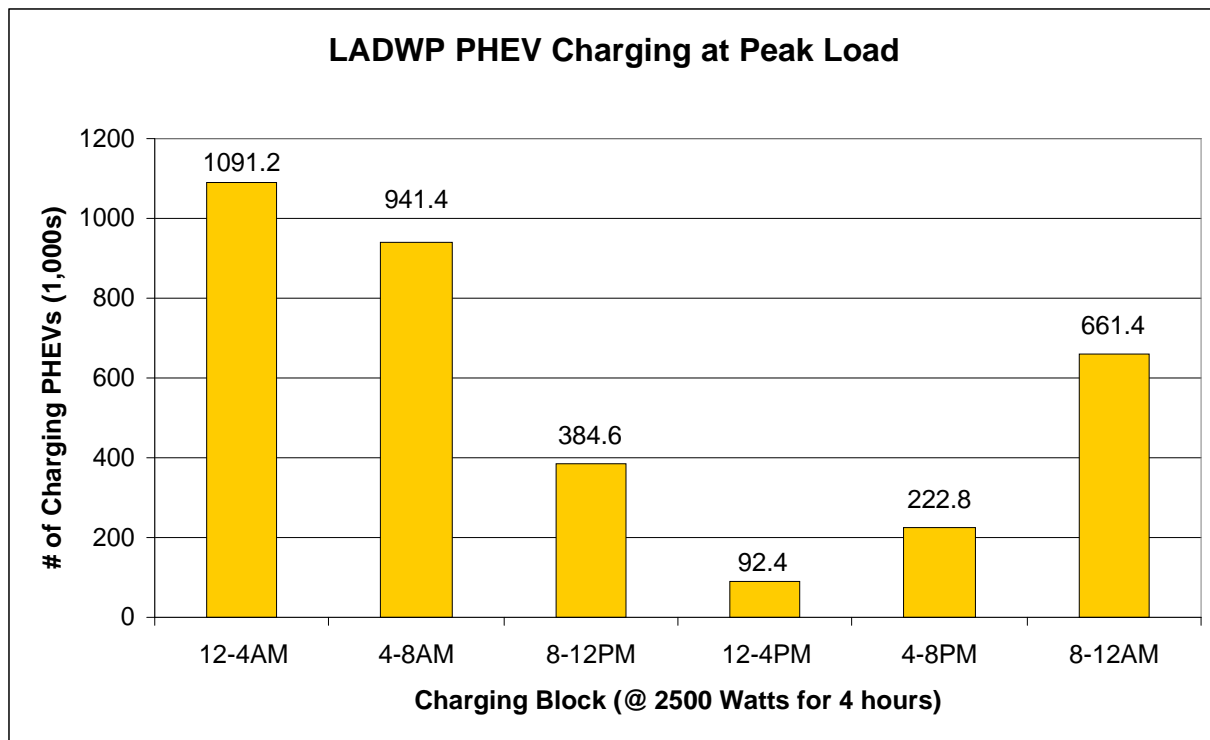


Figure 2: PHEV charging blocks – potential to supply 10 kWh per vehicle on July 24th, 2006.

Between midnight and 4 a.m., 1,091,200 PHEVs could be charged using available capacity in the LADWP transmission area. From 4 a.m. to 8 a.m. another 941,400 PHEVs could be charged. 384,600

PHEVs could be charged between 8 a.m. and noon, 92,400 between noon and 4 p.m., 222,800 between 4 p.m. and 8 p.m., and 661,400 PHEVs could be charged from 8 p.m. to midnight [3]. In this way, a total of 3.39 million PHEVs could be charged during the LADWP peak 24-hour period – accounting for 87% of all LADWP electric service customers.

Capacity

Having examined the demand and PHEV charging potential of the LADWP transmission area, a closer look at the supply of energy in the area is warranted.

The LADWP has an installed power plant capacity consisting of 48% natural gas, 28% hydroelectric (including pumped storage and eligible renewable ‘micro-hydros’), 18% coal, 5% nuclear, and less than 1% other renewable energy sources (photovoltaic and landfill gas facilities) [3]. The LADWP supply stack utilizes available renewable energy, nuclear energy, and coal-fired energy to the maximum extent possible, meeting ‘baseload’ capacity or the primary load with these sources. Capacity requirements above this baseload level are met first through the use of natural-gas fired power plants, followed by hydroelectric power sources for peaking purposes [2].

It is important to note that not all the energy utilized in the LADWP transmission area is produced locally – approximately 30% of the capacity is from imported power. The LADWP owns 44.6% of the capacity from the coal-fired Intermountain Power Project in Utah and 21.2% of the coal-fired Navajo power plant in Arizona. The LADWP also has power contracts for 9.7% of the capacity from the Palo Verde Nuclear power plant in Arizona, and 25.15% of contingent capacity available from the Hoover Dam hydroelectric power plant [2]. Furthermore, the LADWP will be increasing its renewable energy usage upon the completion of the 120 MW Pine Tree Wind Farm in 2009, and will be required by state law to drop all power contracts for coal-fired capacity upon the expiration of those contracts over the next 10 to 20 years [2].

Due to the fact that the current LADWP power supply stack utilizes fossil-fuel fired power for the majority of its baseload and intermediate power needs, an increase in emissions will be a likely result of the utilization of existing capacity to supply energy to PHEVs under this scenario. It is likely that the emissions associated with the charging of a PHEV will be lower than the emissions per unit energy from a petroleum-fired internal combustion engine vehicle; due to the localized nature of the power plant, more stringent environmental regulations, and more advanced emission control technology. A side-by-side comparison of PHEV ‘emissions’ versus those of a combustion engine vehicle however, is beyond the scope of this writing.

To arrive at the emissions associated with the PHEV in the LADWP transmission area, the Velocity Suite® software was used to establish the emissions associated with meeting the load over the 24 hour period being studied. Continuous Emissions Monitoring Systems (CEMS) data for carbon dioxide (CO₂), sulfur dioxide (SO₂), and nitrogen oxides (NO_x), is presented in Figures 3, 4, and 5 respectively. To deduce the emissions caused by increased load from PHEVs, the hourly rate of emissions per power plant was taken and applied to the maximum capacity of the power plant as these facilities will be used to their highest availability. These emissions estimates are therefore subject to the operating conditions during the hour examined, and are subject to variations in ambient air temperature and humidity, fuel quality, the usage of emissions controls, and the acceleration or deceleration of the turbine-generator units themselves.

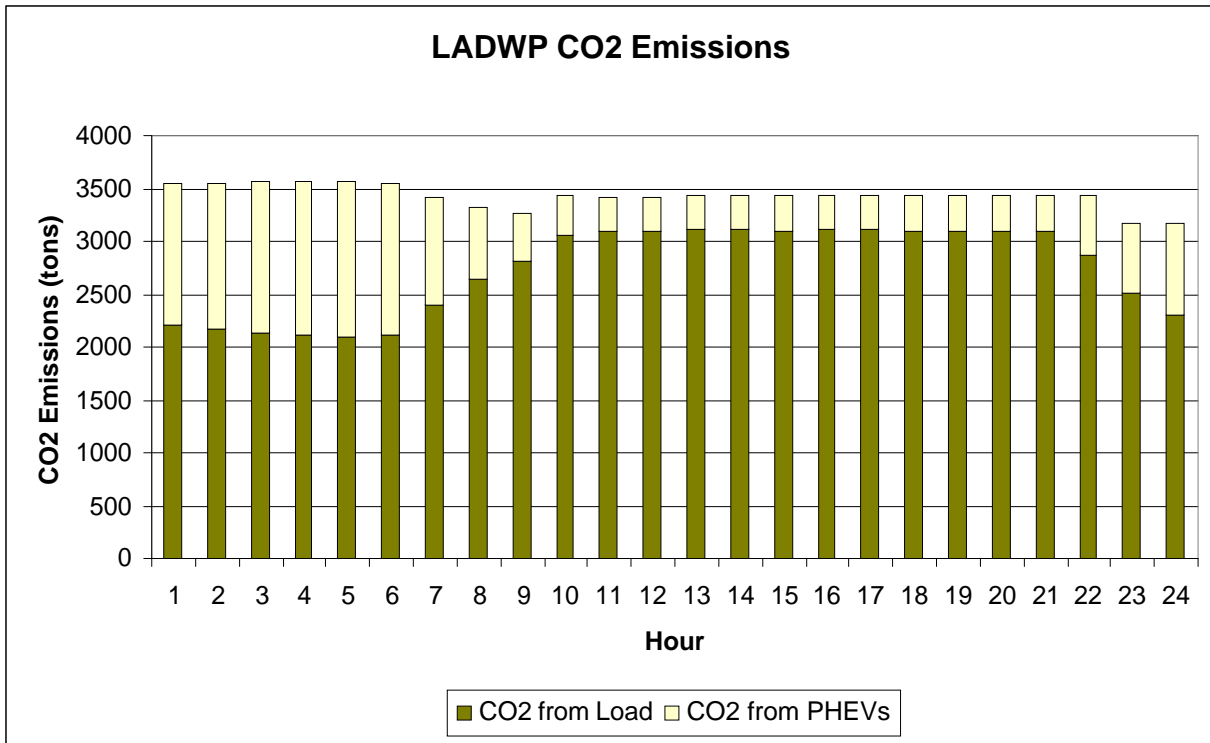


Figure 3: CO2 emissions (tons) and PHEV 'Potential to Emit' on July 24th, 2006.

Over the 24 hour period, 65,506 *tons* of CO2 were emitted into the atmosphere. The average rate of CO2 emissions from power plants servicing the LADWP was 1,298.79 tons per MWh. Of the total CO2 emissions over the 24 hour period analyzed, 52% came from coal-fired power plants producing 34.7% of fossil-fuel based power (the remainder was generated by natural-gas fired facilities). The addition of 3.39 million PHEVs to the LADWP power grid would contribute a total of approximately 16,786 tons of CO2 emissions to the atmosphere, an increase of approximately 25.6% [3].

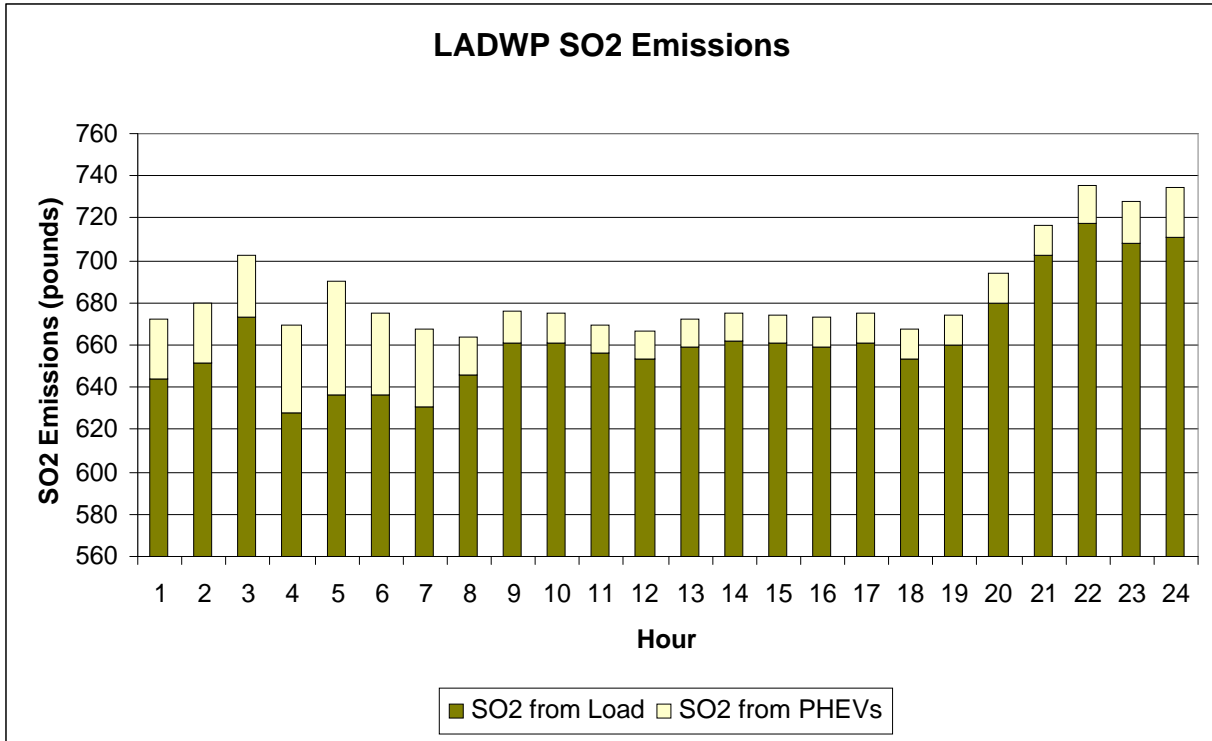


Figure 4: SO2 emissions (pounds) and PHEV 'Potential to Emit' on July 24th, 2006.

During the 24 hour period examined, 15,910 pounds of SO2 were emitted into the atmosphere. The average rate of SO2 emissions from facilities servicing the area was 0.1183 pounds per MWh. Of the total SO2 emissions, 97.75% were caused by coal-fired power plants producing 34.7% of fossil-fuel based power. The PHEV fleet of this scenario would add approximately 517 pounds of SO2 to the atmosphere, an increase of approximately 3.2% [3].

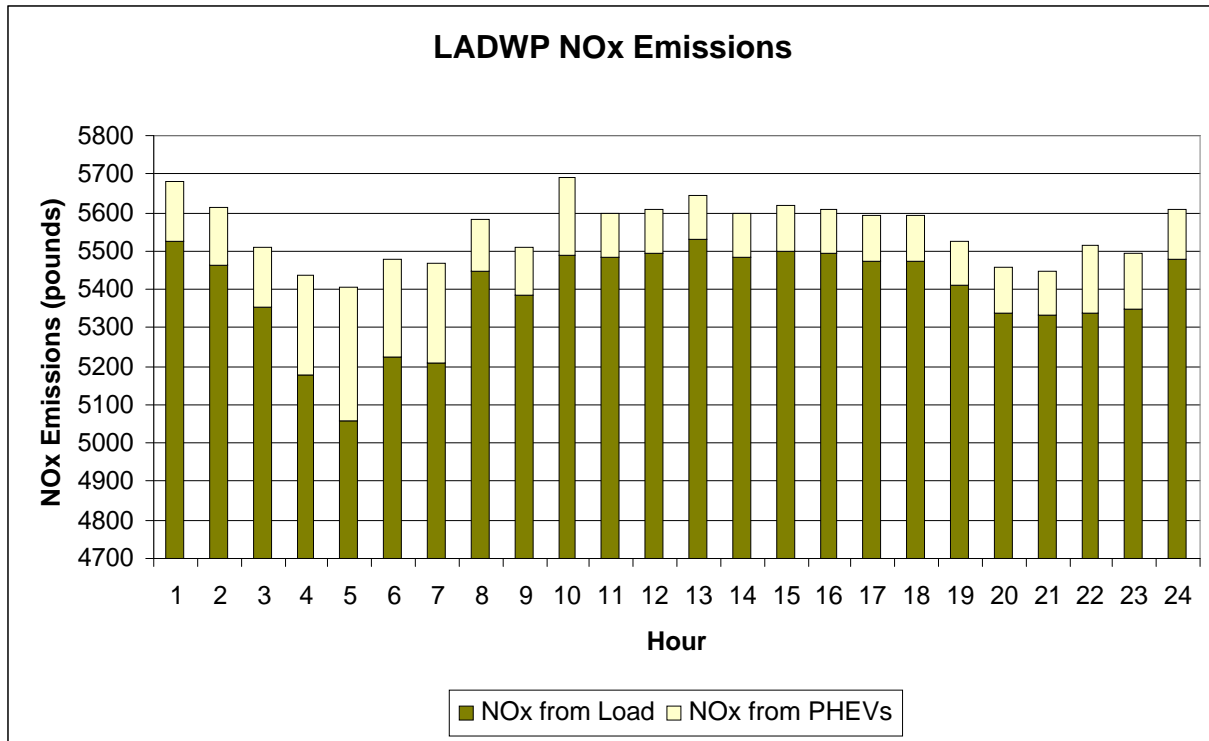


Figure 5: NOx emissions (pounds) and PHEV ‘Potential to Emit’ on July 24th, 2006.

Finally, the 24 hour period yielded 129,504 pounds of NOx to the atmosphere. The average rate of NOx emissions from power plants servicing the area during this time was 1.02 pounds per MWh. Of the total NOx emissions, 97.55% were caused by coal-fired power plants. The PHEV fleet in the LADWP transmission area would contribute 3,778 pounds of NOx to the atmosphere, an increase of approximately 2.9% [3].

Conclusions

The Los Angeles Department of Water and Power had an excess energy capacity of 33,938 MWh available over the 24 hour period of July 24th, 2006 – its peak demand day. During this worst-case scenario of maximum load, the LADWP had enough spare capacity to fully power a PHEV fleet of 3.39 million vehicles using 10 kWh batteries. The charging of the PHEVs would be best organized in 4 hour “charging blocks”, with the hours between 8 p.m. and 8 a.m. being best suited for maximum available capacity. While baseload power in the area is derived primarily from coal and nuclear sources, the bulk of the capacity available to a PHEV fleet in this scenario would be from intermediate and peaking power plants in the LADWP supply stack, making PHEV charging particularly vulnerable to water levels available to hydroelectric power plants, and fluctuations in the natural gas market (including abuse by unscrupulous energy companies). An increased reliance on renewable energy sources and a decreased reliance on coal-fired energy will lighten the emissions impact of a PHEV fleet. The load-leveling energy storage capability of PHEVs may also serve to foster the growth of intermittent renewable energy sources. Under the scenario examined, the PHEV fleet would lead to increases in CO2 emissions of 25.6%, SO2 emissions by 3.2%, and NOx emissions by 2.9%. As coal-fired power plants are phased out of the LADWP capacity over the next 10 to 20 years, NOx and SO2 emissions associated with PHEVs will be negligible, while CO2 emissions will remain a major issue, necessitating the use of renewable energy and/or carbon capture and sequestration. Overall the introduction of the PHEV in the LADWP transmission area would benefit the utility through the increased sales of energy otherwise untapped, and

would benefit the PHEV driver through a decreased reliance on imported oil, and the potential for greater stability in energy prices through the leveling of the LADWP load.

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