V2G and G2V smart grid optimization study in a Renewable-Fossil Based Energy System for Southern California

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Research Question

- What economic and environmental value may be created by the timely charging of electric vehicles in California when electric grids are powered predominantly by intermittent, renewable generation?
- Which electric vehicle charging strategies realize the most of that potential economic and environmental value?
- Under what policy and technical conditions would EVs and/or electrolysis technology become economically viable in California's energy system to enable optimized demand response?
- How much is the net grid impact effect for these technologies to solve intermittent and duck curve issues in California?
- What are the hourly operational behavior and demand response effects of these technologies in California grid network if to be implemented on a massive scale.

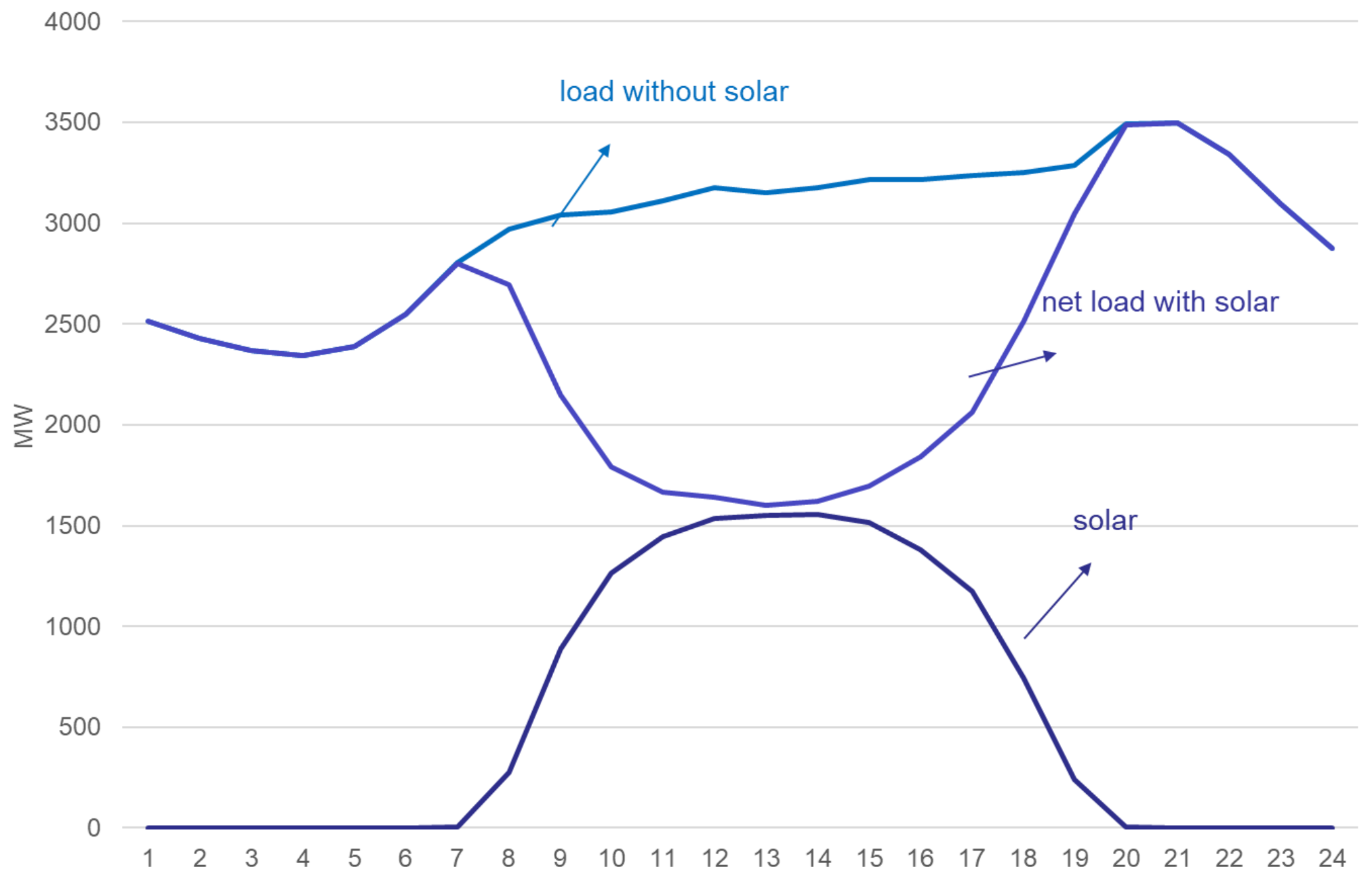


Fig. 1: Actual duck curve (prior to simulation (no G2V or V2G) resulting from solar Generation during daytime on March 27, 2017 in LADWP territory

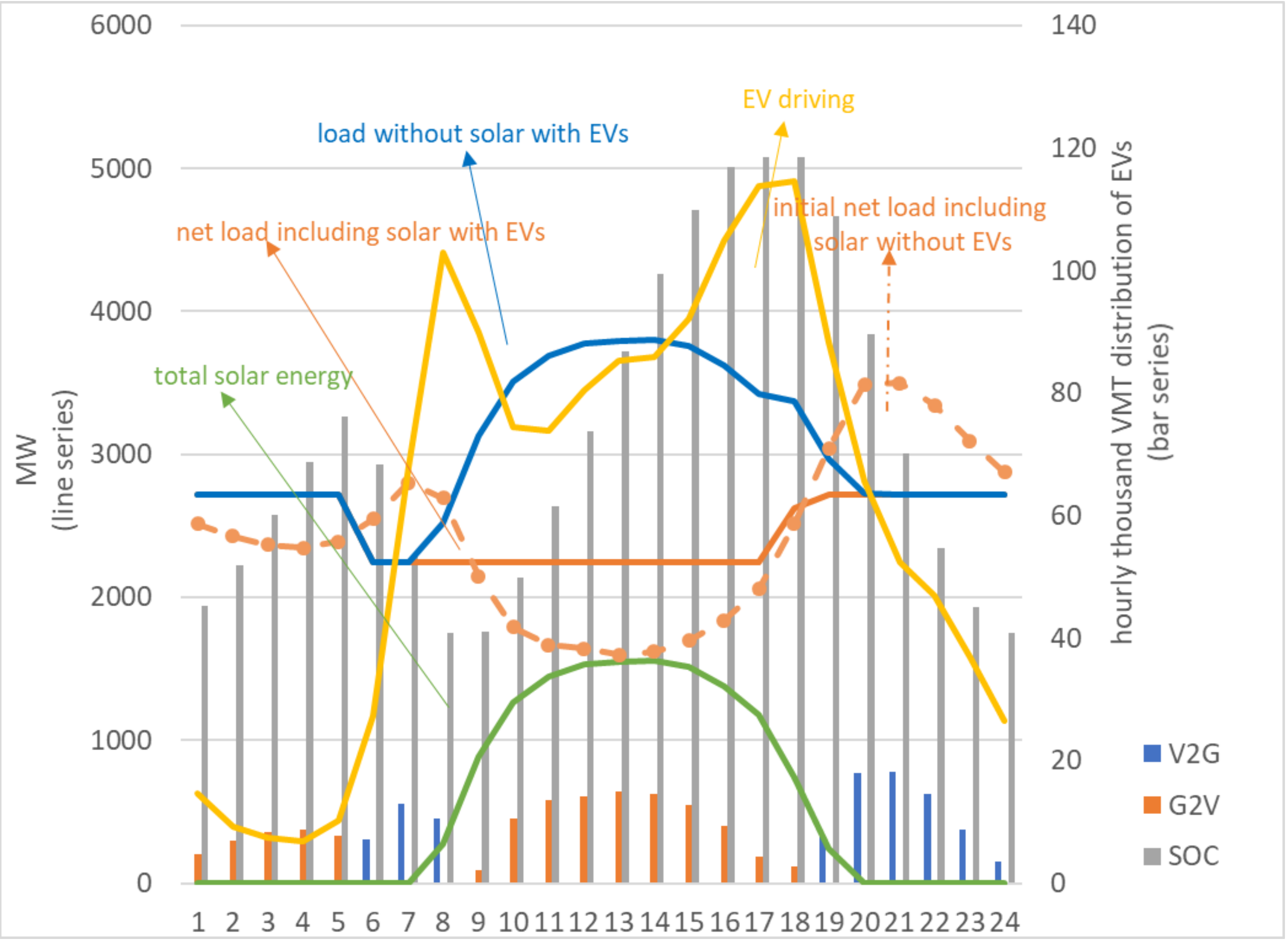
Methods and Data

- We created a techno-economic optimization model, called CalEV, using the MESSAGE (Model for Energy Supply Strategies and their General Environmental Impacts) platform
- CalEV optimizes the system as a mixed-integer mathematical model. Our system simulates a smart grid, where the interaction between EVs and grid is optimized based on different technoeconomic factors, such as pricing, travel demand, and electricity supply, etc.
- According to the LADWP Transportation Electrification Plan, 127,000 EVs are forecasted to be in Los Angeles in its base case scenario for the year 2020.
- Based on our assumption of 35 mile/day average vehicle travel in LA, we would have an average of 4,551,657 eVMT in any single day. According to NREL report, a BEV100 consumes 0.325kWh/mi, which results in 1,479,288 kWh energy required for all EVs in Los Angeles for March 27. Average BEV battery capacity is assumed to be 50kWh for year 2020.

Results

- Optimization for an actual hourly supply and demand in LA for March 27, 2017, shows that a smart grid V2G and G2V system, can reduce the difference between minimum and maximum net load for any given day, from 1.9GW without EVs (Figure 1) to only 500kW with EVs (Figure 2), and reduce the duck curve significantly.
- Optimization reduces the peak load from 3500MW to 2700MW (about 800MW), which is a considerable amount that can reduce the need for expensive capacity expansion and can contribute to stability of electricity prices or helps justifying the expenses associated with V2G uptake incentives.

Figure 2. Optimized results for a smart grid V2G and G2V connection to the grid showing how duck curve changes by utilizing the EV battery capacity throughout the day. The yellow line refers to the right hand y-axis in 1000 VMT, the other curves and bar graphs to the left hand y-axis in MW and SOC in MWh



Conclusions

This grid simulation indicates that although there might be additional constraints that can affect the vehicle availability to the grid, such as availability of charging stations, willingness of EV owners to participate in grid interaction program, costs associated with V2G investments and charging infrastructure, the potential impact of EV storage on the grid warrants continued development and investigation of this option. Over time, the potential should continue to improve as more EVs are added to the roads.

Future Work: CA Study

- Add hydrogen vehicles and hydrogen infrastructure (electrolysis only, as SMR does not affect the grid), and consider scenarios on combined EV/FCEV fleets on the grid. Hydrogen vehicles could also be considered as a storage technology, with H2 generated during off peak times, andto work as load shifting for our smart grid dispatch model.
- Simulate other regions, within and beyond California. Any added region will need a database for hourly load, generation plants, transmission lines and their capacity constraints. A first step would be to cover the five major electricity regions in California. Transmission capacities between the five regions were calculated to be incorporated into the regional model.
- Add other types of storage such as pumped hydro and distributed storage from other economic sectors and conduct a cost minimization across these storage types in terms of capacity and utilization.
- Ass the potential effects of different policies on system development and generation, including LCFS and other carbon tax policies, emissions constraints, and a representation of the societal costs of pollution.

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