

# COST ESTIMATION TOOL (CHIP) AND OPTIMIZATION OF ELECTRIC VEHICLE DC FAST CHARGING STATIONS

Charlotte Wertz, Shuchismita Biswas, Christine Holland, Roshan Kini, Siddarth Sridhar, Alexander Vlachokostas



## INTRODUCTION

In 2021, The Bipartisan Infrastructure Law invested in electric vehicle charging stations called the National Electric Vehicle Infrastructure Program (NEVI) [1], managed by the Joint Office of Energy and Transportation. As part of this investment, NEVI relieves up to 80% of capital costs incurred by Direct-Current Fast Charging stations (DCFC's) that lie on heavy-traffic highways in the United States. Because of the novelty of DCFC charging technology, costs of building a DCFC station are highly variable and difficult to predict. There is demand for a well-researched tool that can provide a cost estimate associated with DCFC's. As electric vehicle adoption accelerates, this will only be of increasing importance. Figure 1 shows an Annual EV Sales Forecast [2].

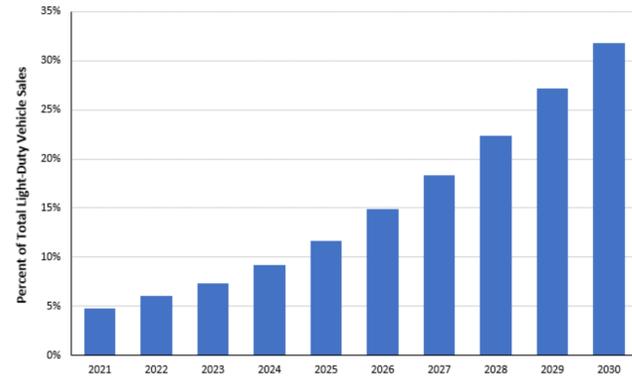


Figure 1: Annual EV Sales Forecast, Percent Of Total Light-duty Vehicles

PNNL aims to alleviate this problem by developing the Charging Hub Investment Potential (CHIP), a web-based interactive tool that can estimate costs and revenues of an EV charging station over its system lifetime. The CHIP tool will be fully flexible, allowing the user to edit all inputted assumptions that have been made with in-depth research and industry discussion. The CHIP tool will be open-source and is hoping to receive feedback in coming months.

Because of the increased electrical load in coming years largely due to electric vehicle adoption, the CHIP tool integrates battery-energy storage systems and photovoltaic solar on-site. These distributed energy resources are optimized to minimize demand and energy costs accumulated by the station.

The CHIP tool is under development and open to industry feedback. Currently, this project is focused on an example use case in Garden City, Kansas.

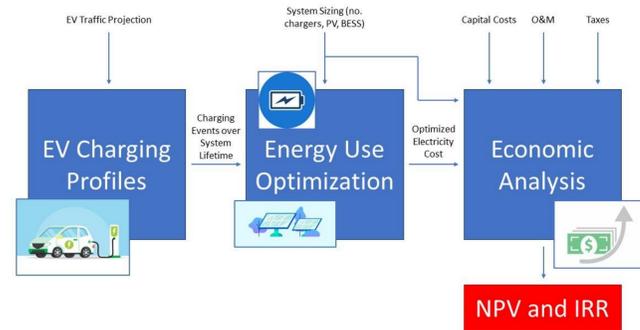


Figure 2: CHIP Tool Block Diagram

## ELECTRIC VEHICLE CHARGING PROFILE ESTIMATION

Before estimating and thus optimizing the electricity costs of a DCFC station, it is necessary to estimate the electric vehicle charging behavior. Factors that may influence this electricity profile are included but not limited to location, EV traffic projection, sizing of EV batteries, popular charging times, and typical length of charging sessions.

To simulate EV charging behavior, CHIP uses the Caldera tool developed by Idaho National Laboratories [3]. Caldera provides samples of EV's entering and leaving a charging station based on real observed behavior, then outputs the energy consumption from this vehicle in kWh.

We observe regional traffic estimates provided by the Department of Transportation on Alternative Fuels Corridors [4]. This is then compounded with the percentage of electric vehicles out of this total traffic, in addition to a low percentage that would stop to charge at said station. Figure 3 shows an example of the projected utilization of a DCFC station in Garden City, Kansas.

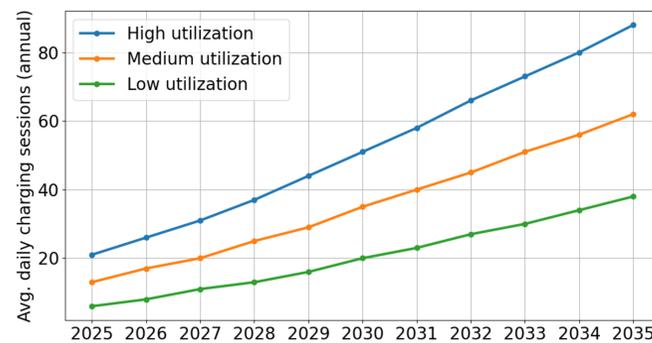


Figure 3: Projected Utilization Of DCFC Station

With these EV charging events compounded with station usage estimates, we project the number of electric vehicles that will charge at a given DCFC at a given time, thus outputting a charging load profile. An example of this algorithm can be seen in figure 4.

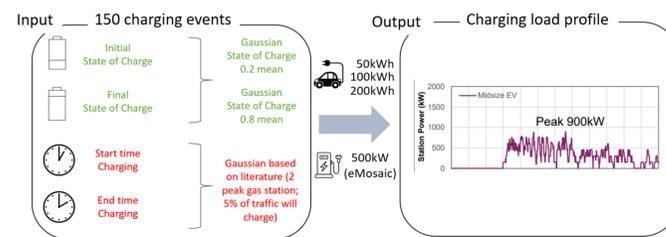


Figure 4: Charging Load Profile Algorithm

**References:** [1] US Department of Transportation, Federal Highway Administration, National Electric Vehicle Infrastructure (NEVI) Formula Program <https://www.fhwa.dot.gov/environment/nevi/> [2] Cooper, Adam, Scheffer, Kellen, Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030, Edison Electric Institute, Nov. 2018, Web. [3] J. Smart, D. R. Scofield, Z. Yi, Caldera Change - Electric Vehicle Charging Infrastructure Simulation Platform. Computer software. Vers.00. USDOE Office of Energy Efficiency and Renewable Energy (EERE), 8 Jan. 2020. Web. [4] Office Of Energy Efficiency & Renewable Energy, (n.d.). Developing infrastructure to charge electric vehicles. Alternative Fuels Data Center: Developing Infrastructure to Charge Electric Vehicles. [5] M. Sengupta, Y. Xie, A. Lopez, A. Habte, G. Maclaurin, J. Shelby The National Solar Radiation Data Base (NSRDB), Renewable and Sustainable Energy Reviews, 89, 2018, 51-60 <https://doi.org/10.1016/j.rser.2018.03.003>. [6] National Electric Vehicle Infrastructure Formula Program; Annual Report; Plan Year 2022-2023 <https://driveelectric.gov/files/nevi-annual-report-2022-2023.pdf>. [7] V. Ramasamy, D. Feldman, J. Desai, R. Margolis. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, National Renewable Energy Laboratory, 2021. [www.nrel.gov/publications](http://www.nrel.gov/publications). [8] K. Mongird, V. Viswanathan, J. Alam, C. Vartanian, V. Sprengle. 2020 Grid Energy Storage Technology Cost and Performance Assessment, Pacific Northwest National Laboratory, 2020. Web.

## OPTIMIZATION OF DISTRIBUTED ENERGY USE

DCFC stations are evaluated using distributed energy resources (DERs) including photovoltaic solar (PV) and a battery-energy storage system (BESS). The sizing evaluated for PV is 40 kW, 70 kW, and 100 kW. The sizing evaluated for BESS is 50%, 70%, and 100% of 4 hours of the peak DCFC load. Any combination of these can be used in the CHIP tool. After receiving the monthly charging sessions from the EV projected utilization, the DERs are factored in to calculate the total monthly electricity cost. The National Solar Radiation Database (NSRDB) provides solar radiation data for various locations across the United States; the CHIP tool evaluates PV output based on this data [5]. The BESS charge/discharge cycle is based on the hourly electricity price and the load; during high electricity tariff hours and/or high load, the battery discharges; during low electricity tariff hours and/or low load, the battery is charged from either the grid or the PV. Ultimately this outputs an average optimized electricity cost, aggregated over 1 month.

Figure 5 illustrates how electricity cost changes for a given DCFC station and utilization, under flat or time-of-use tariffs, in addition to how it varies given no PV/BESS optimization and fully rated PV/BESS optimization.

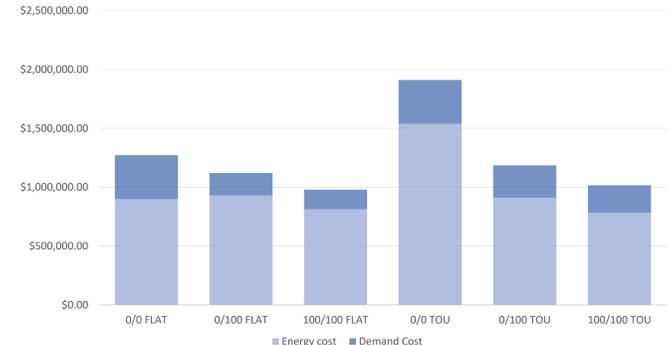


Figure 5: Electricity Cost For Charging Station With Distributed Energy Resources

## ECONOMIC ANALYSIS

DCFC stations have capital costs, accumulated costs, and revenues. Capital costs include the hardware (i.e. the charging station itself and the pedestal), installation costs, fixed station costs (i.e. electrical wiring, transformer, or other make-ready costs), and maintenance costs. For capital costs, the CHIP tool uses default values outlined by the Joint Office [6]. They are inflated to match dollars in 2025, the starting year of NEVI projects, assuming a 2% climb per year. Costs associated with photovoltaic are assumed to be in line with NREL [7], and costs associated with the battery-energy storage system are from PNNL's Grid Energy Storage Cost Assessment [8].

Accumulated costs include electricity costs, which comes from the output of optimization, operations & maintenance costs - which are obtained from industry experts - and any taxes associated with the station's revenue.

Finally, it is assumed that the cost passed onto customers will include a fixed charge per car charging at the station, on top of a variable charge in dollars per kilowatt-hour. Table 1 outlines all cost assumptions which are fully editable by the user of the CHIP tool. The costs and revenues are compared using the net present value over the charging station's lifetime, assumed to be a 10-year horizon.

Table 1: Capital Cost Assumptions [6, 7, 8]

Equipment	Cost
Station Hardware	87,000
Installation	33,000
PV	1,284
BESS	448
Fixed Station Costs	103,000

## EXAMPLE USE CASE IN GARDEN CITY, KANSAS

For an example use-case, Garden City, Kansas was selected as a demonstration of the CHIP tool. This location was chosen due to it being outlined as a priority region by NEVI. Additionally, Garden City provides a good example of the complications a rural DCFC charging station may experience with regards to low utilization in beginning years.

Below is a breakdown of all system costs divided into rent/land costs, taxes, capital construction costs, O&M, DERs (if applicable), energy cost, demand cost, and interest buildup. In addition, the cumulative cash flow charts are included that demonstrate system revenues compared to costs over time. The comparison is done between the base case (4 charging stations with no DERs) and a fully rated station with 100kW PV and a battery rated at 100% of the load.

Current results indicate that a station without PV/BESS at maximum rating is more profitable; however, both systems have a positive net present value (NPV) at the end of the assumed system lifetime. Limitations of this analysis include lack of clarity regarding the prices of new technology (i.e DCFC and BESS costs), and unknown actual DCFC station utilization rates.

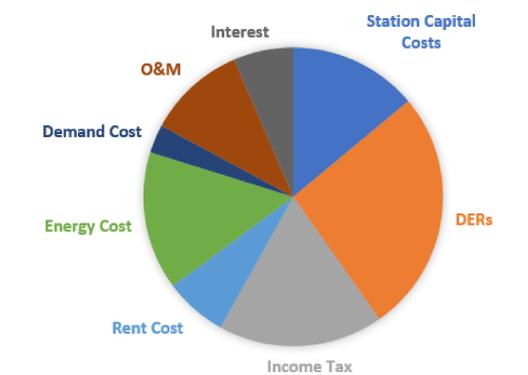
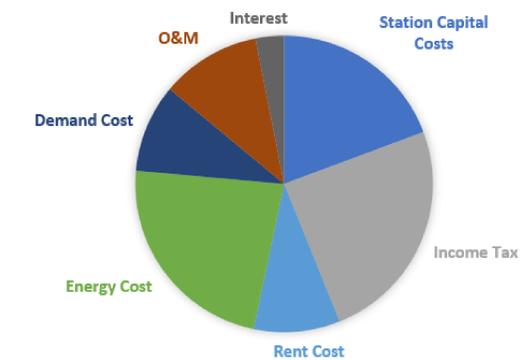


Figure 6: Cost Breakdown: Base Case (Top) And BESS 100%/PV 100KW (Bottom)

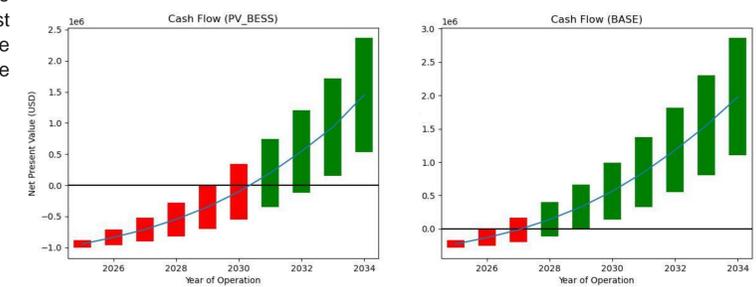


Figure 7: Cash Flow Chart: Base Case (Left) And BESS 100%/PV 100KW (Right)