CO_2 and Cost Impacts of a Transportation-microgrid with Electric Vehicle Charging Infrastructure: a case study in Southern California

Luis Fernando Enriquez-Contreras, Matthew Barth, Sadrul Ula

Department of Electrical and Computer Engineering
University of California, Riverside

Purpose

- This research holds significant implications for the advancement of intelligent transportation systems, as it aims to address the economic needs of EV charging infrastructure owners and determine the optimal configuration that benefits both EV owners and the environment by minimizing greenhouse gas emissions
- This paper delves into the impacts of transportation-micrografids equipped with Level 2 and Level 3 charging on the behavior of microgrids, associated electricity costs, and CO_2 emissions within the context of southern California
- The simulations are conducted using OpenModelica, a dynamic modeling and simulation environment
- This study distinguishes itself from previous research in many ways, including employing a higher time resolution for calculating CO_2 emissions that is measured every 15 minutes

Abstract

As an important part of Intelligent Transportation Systems (ITS), this paper presents a case study at the University of California, Riverside (UCR) that evaluates the effectiveness of different transportation-based microgrid configurations in reducing both carbon dioxide (CO_2) emissions and electricity costs. CO_2 emissions are calculated using high-resolution California Independent System Operator (CAISO) CO_2 emissions data to accurately assess the environmental impact of each setup. Electric costs were also compared to determine the financial savings potential for the consumer. The results demonstrate that a peak-shaving transportation-microgrid strategy can effectively reduce CO_2 emissions in the range of 24% to 38% and costs from $27,000 to $29,000 per year, even when considering the additional demand from 12 vehicles charging daily at the building. However, careful consideration should be given to battery sizing, as peak-shaving has diminishing returns. Doubling the battery size may only provide an additional savings of $2,000 per year with a negligible reduction in emissions. This highlights the importance of optimizing battery capacity to maximize cost-effectiveness and environmental impact.

Microgrid Architecture

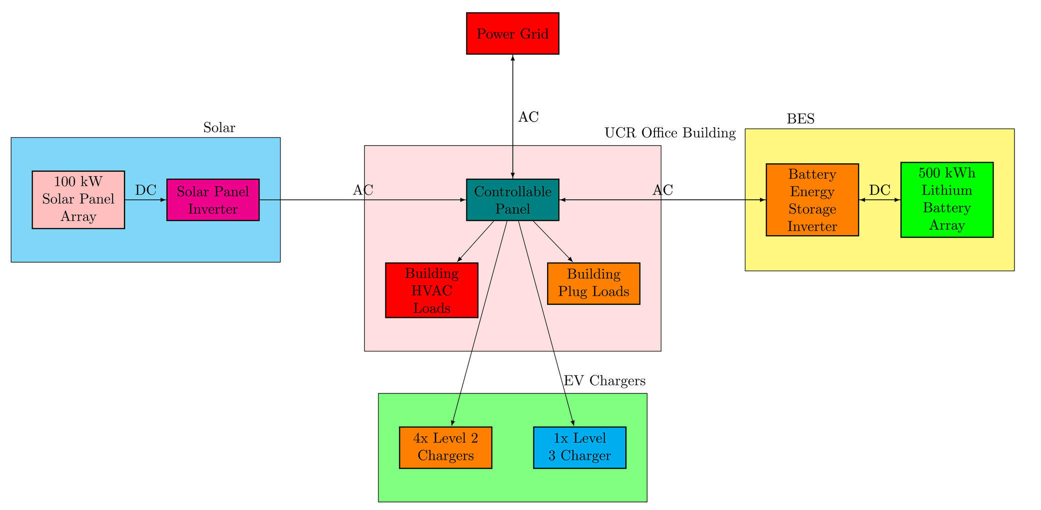

Figure: Microgrid Architecture of our Case Study Example BESS: Battery Energy Storage System

EV Charging Simulations

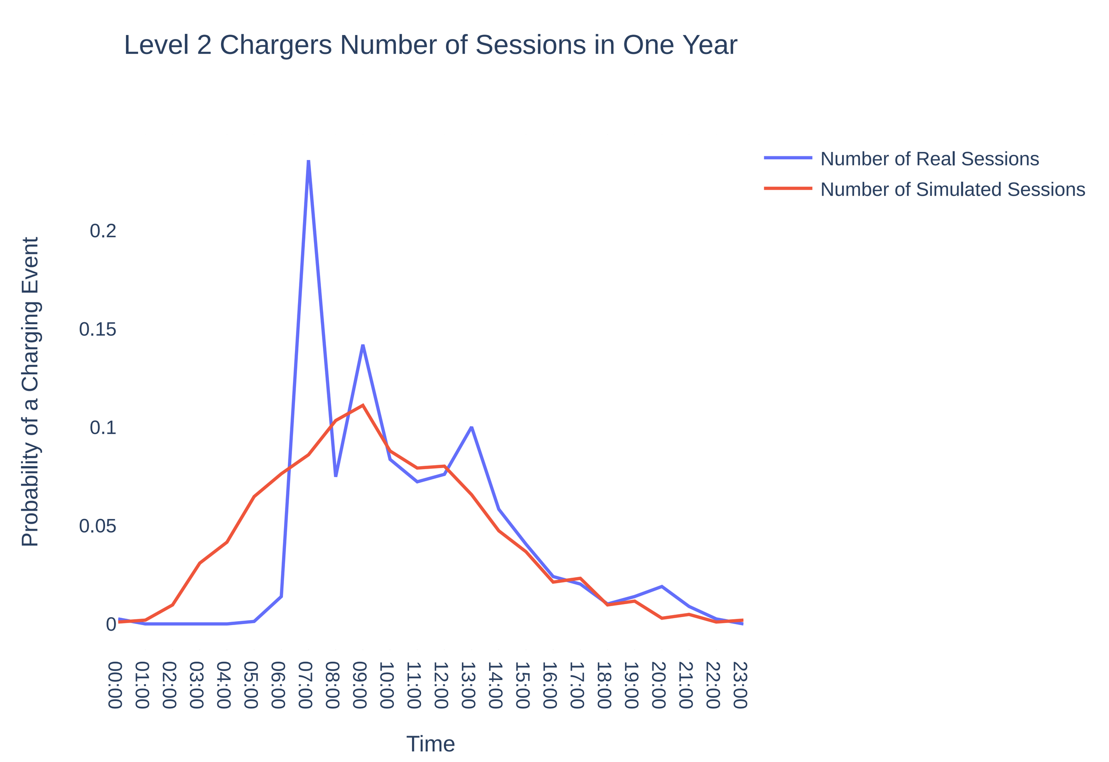

Figure: Validation of the Level 2 EV Charger Stochastic Process that Compares the Probability Density Function of Actual Charging Data to the Poisson Process

Simulated Scenarios of the UCR Microgrid using Different Layouts

Table: Simulated Scenarios of the UCR Microgrid using Different Layouts

Scenario	
1	Standard Building with no EV Chargers
2	Standard Building with Level 2 and Level 3 Charging
3	Microgrid Building with 100 kW Solar, 500 kWh BESS, No EV Charging
4	Microgrid Building with 100 kW Solar, 100 kWh BESS, Level 2, and Level 3 Charging
5	Microgrid Building with 100 kW Solar, 250 kWh BESS, Level 2, and Level 3 Charging
6	Microgrid Building with 100 kW Solar, 500 kWh BESS, Level 2, and Level 3 Charging
7	Microgrid Building with 100 kW Solar, 1 MWh BESS, Level 2, and Level 3 Charging
8	Microgrid Building with 100 kW Solar, 1 MWh BESS, Level 2, and Level 3 Charging

Results

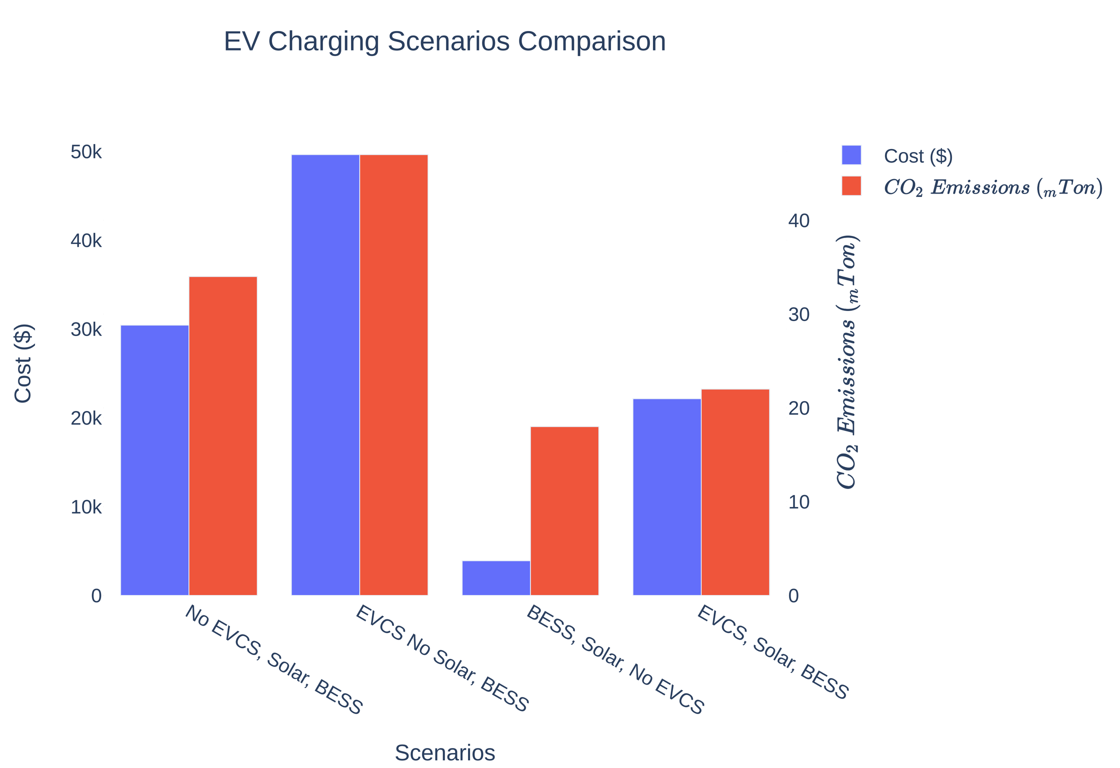

Figure: EV Charging Scenarios Comparison

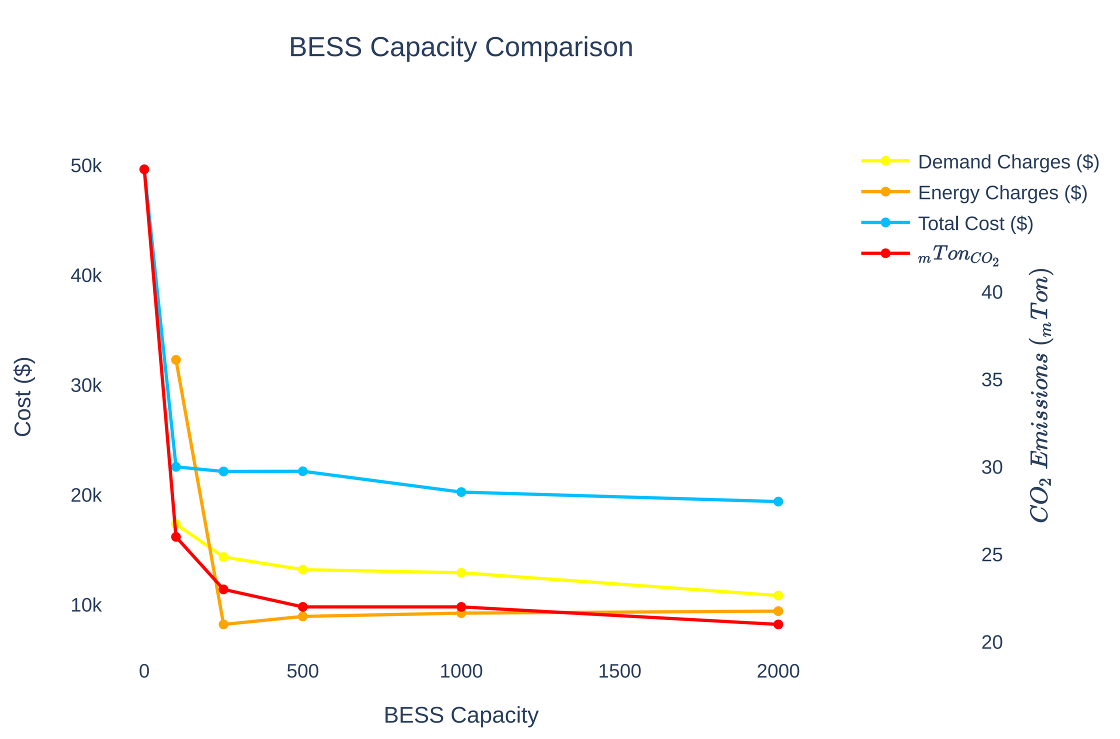

Figure: Cost and CO_2 Emissions for Different Battery Capacities

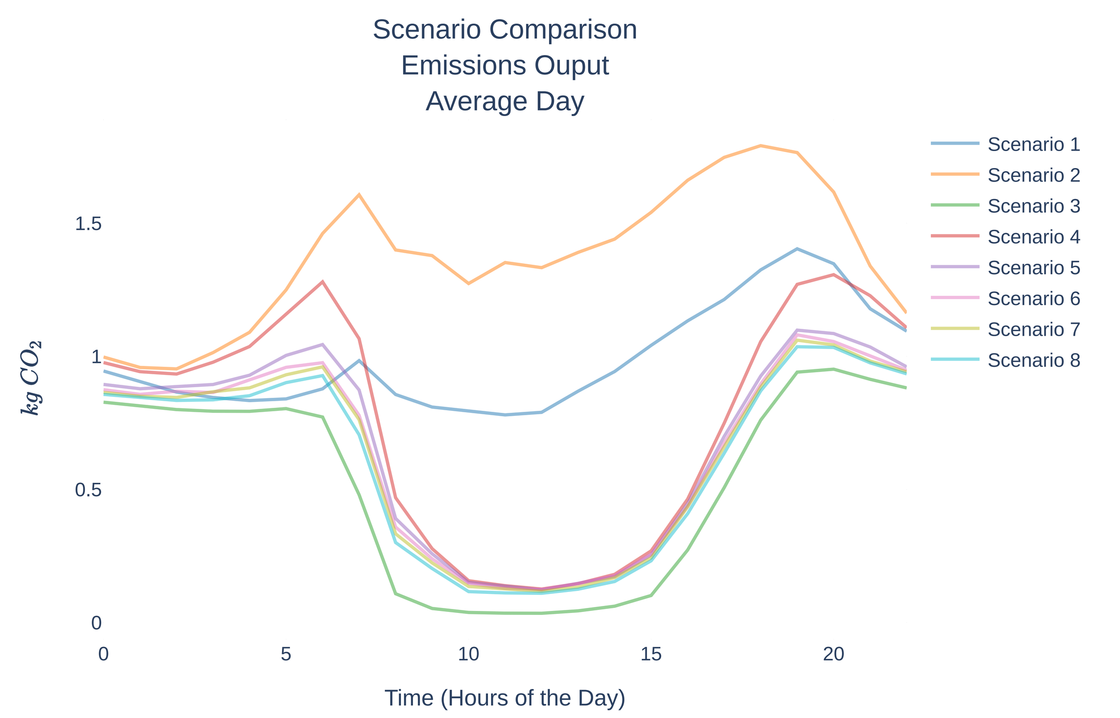

Figure: Microgrid CO_2 Emissions Outputs Averages During Times of Day

Table: Microgrid Utility Prices and CO_2 Emissions Output under Different Scenarios

Scenario	Demand Charges ($)	Energy Charges ($)	Total Cost ($)	CO_2 Emissions ($_m$Tons)
1	7695	22736	30431	34
2	17343	32289	49632	47
3	3904	0	3904	18
4	14341	8209	22550	26
5	13193	8937	22130	23
6	12909	9239	22148	22
7	10835	9418	20253	22
8	9811	9577	19388	21

Conclusion

- Transportation-microgrids offer significant economic and environmental benefits
  - Estimated annual savings of $8,000-$10,000 compared to conventional systems
  - Annual savings of $27,000-$29,000 compared to buildings with EV chargers but no microgrid
  - 24% - 38% reduction in CO_2 emissions compared to conventional buildings
  - 45% - 55% reduction in CO_2 emissions compared to buildings with EV chargers and no microgrid
- Increased battery capacity does not guarantee improved performance
  - Increased capacity improves performance but not proportionally to the cost
  - Large capacity needed for challenging situations may not be cost-effective
- 15 kW demand price floor discourages zero net load
  - Discourages zero net load in peak shaving setups, increasing CO_2 emissions
- Future Work
  - Optimizing electric costs and CO_2 emissions through throttling charging, maximizing solar energy use, and minimizing grid draw during peak CO_2 emissions times
  - Assessing the impact of California's new net energy metering policy

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Contact Information

- Researcher: Luis Fernando Enriquez-Contreras
- Web: https://www.cert.ucr.edu/transportation-systems-vehicle-infrastructure-interaction
- Email: lenri001@ucr.edu
- Phone: +1 (909) 763 1899