Driving Down CO_2 Emissions and Electricity Costs: Unveiling the Power of Transportation-Based Microgrids

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Outline

Introduction I

- **Electrification of Transportation**
  - Electric vehicle (EV) adoption is increasing rapidly, with 25.4% of Q2 2023 vehicle sales being EVs in California
  - California aims to ban the sale of internal combustion engine vehicles by 2035
  - The state is expanding its EV charging infrastructure, with over 13,844 Level 2 and 1,924 Level 3 stations as of November 2023
  - Technological advances allow new EVs to charge up to 80% in 20-60 minutes, making EVs more appealing
  - This rapid charging capability poses challenges for grid operators due to the high electricity demand it creates
- **Challenges**
  - Two key challenges exist:
    - Providing enough electricity capacity for the growing number of EVs
    - Minimizing the CO_2 emissions associated with battery electric vehicles by ensuring a clean grid

- **Solution**
  - Microgrids offer a potential solution to both challenges
  - Microgrids can integrate renewable energy sources and EV charging stations, reducing the burden on the main grid and minimizing CO_2 emissions
- **Research Focus**
  - Further research is needed to understand the economic and environmental impacts of EV charging, especially fast charging, and how microgrids can be effectively utilized to manage EV demand and promote a sustainable transportation future

Purpose and Contributions

- 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-microgrids 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 and updated net energy metering rates for Riverside Public Utility

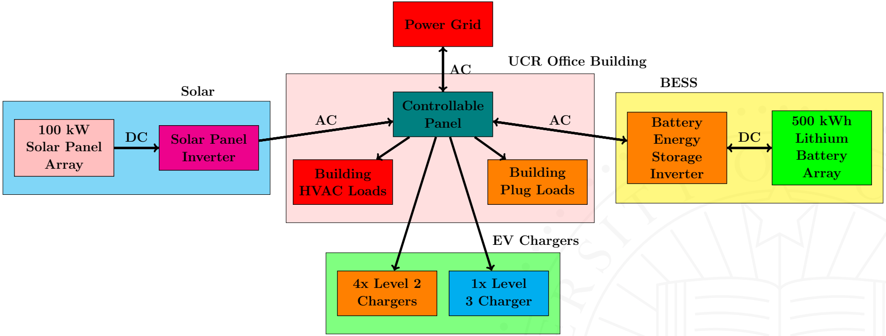

Figure: Microgrid Architecture of our Case Study Example BESS: Battery Energy Storage System

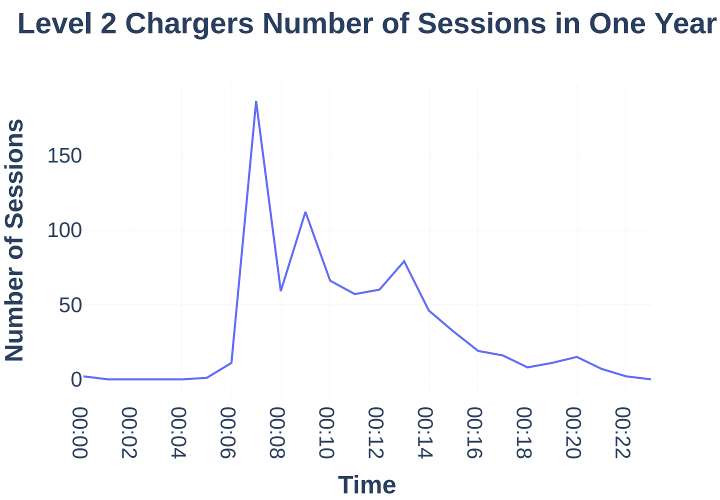

Figure: Level 2 EV Charger Probability Density Function Created by Using Actual Charging Data Obtained from a SCADA System

- The charging setup is modified in OpenModelica for different layouts and scenarios
- The scenarios are described in Table 1

Table: Simulated Scenarios of the UCR Microgrid using Different Layouts and Electric Pricing Structures

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

Results

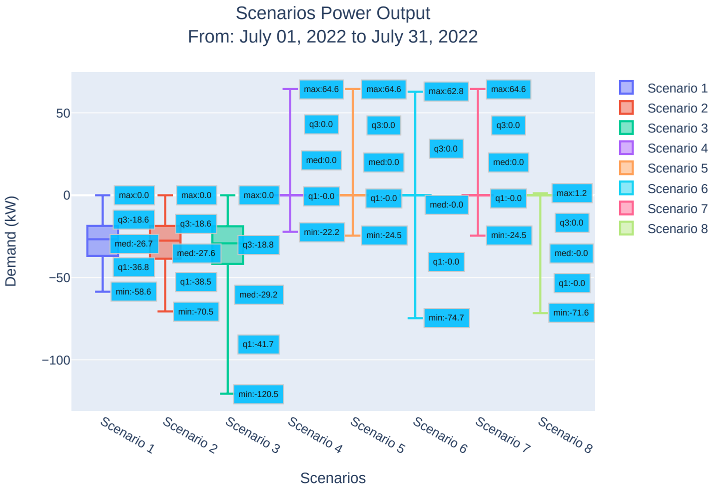

Figure: Power Measured from the Meter for the Month of July

Results

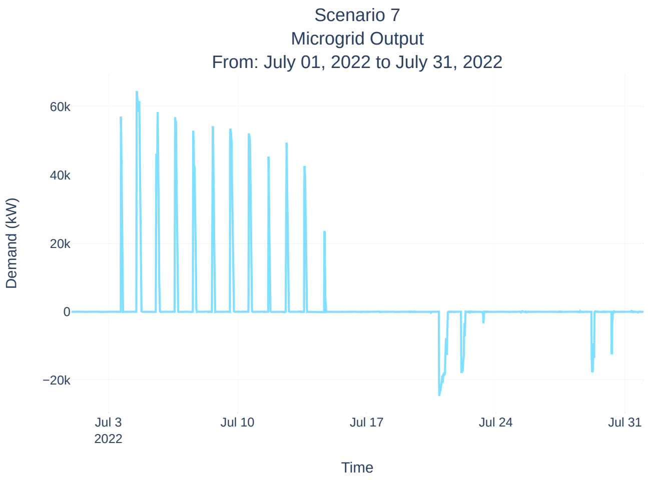

Figure: Peak Shaving Failure after Battery Depletion (Level 2 Charging, 500 kWh BESS)

Results

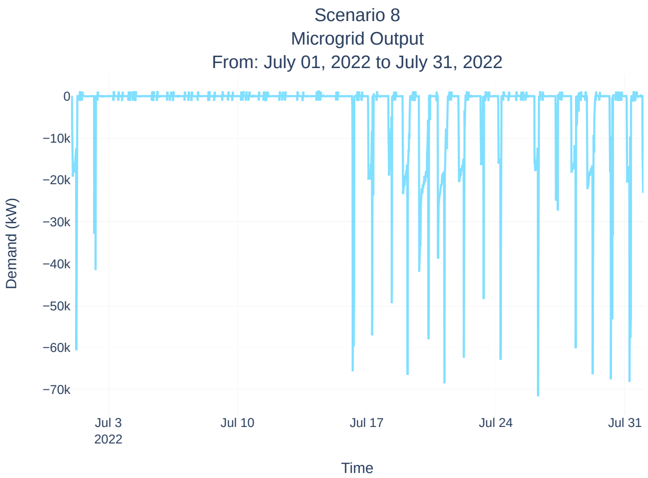

Figure: Peak Shaving Failure after Battery Depletion (Level 2 and Level 3 Charging, 500 kWh BESS)

Results

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

Scenario	Demand Charges ($)	Energy Charges ($)	Total Cost ($)	Emissions
1	6616	22736	29352	34
2	8196	24607	32803	37
3	14235	29693	43928	43
4	3887	2387	6274	5
5	5133	3853	8986	7
6	11329	8238	19567	14
7	5022	3814	8836	7
8	11400	8133	19533	14

Results

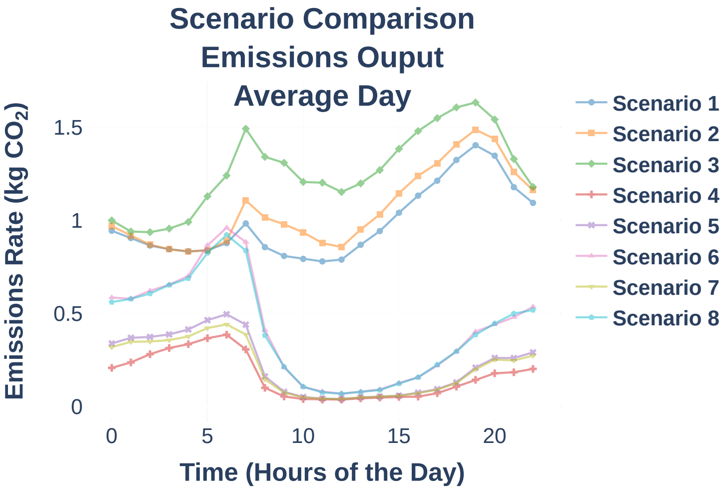

Figure: Microgrid CO_2 Emissions Outputs Averages During Times of Day: Adding a microgrid significantly reduces CO_2 Emissions compared to the non-microgrid scenarios of 1, 2, and 3.

Conclusions and Future Work I

- **Transportation Micrgrids Benefits:**
  - Reduced Electricity Costs:
    - Load-Following Algorithm: \$23,000 - \$24,000 annual savings
    - Cost of Demand Saved: Follows total cost trend (around \$3,000)
    - Cost of Energy Saved: Follows total cost trend (around \$21,000)
  - Reduced CO_2 Emissions:
    - Load-Following Algorithm: 67% - 85% reduction (30 tons CO_2/year)
- **Key Considerations for Optimization:**
  - Balance Clean Energy Sources (Solar/Wind) with Load:
    - Level 2 chargers: manageable for office buildings
    - Level 3 fast chargers: require additional clean energy sources
  - Net Energy Metering Policy:
    - Incentivizes low CO_2 load-following operation of a microgrid instead of peak-shaving
  - Battery Capacity (BESS):
    - Increased capacity for extreme solar outages is expensive with diminishing returns on CO_2/cost savings
    - Requires additional solar power for full battery charge during daylight

Conclusions and Future Work II

- **Effective Microgrid Planning:**
  - Requires all three aspects:
    - Clean Energy Generation
    - Energy Storage
    - Load Management
- **Future Work**
  - Explore advanced control strategies for optimizing electric costs and CO_2 emissions in transportation-microgrid.
  - Assess effects of new net energy metering policy in California on BESS system value.
  - Analyze impact of different time-of-use (TOU) rates in California on electric costs and CO_2 emissions.
  - Investigate methods to maximize clean energy utilization and minimize grid power during high CO_2 times.

Questions?

Thank You

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