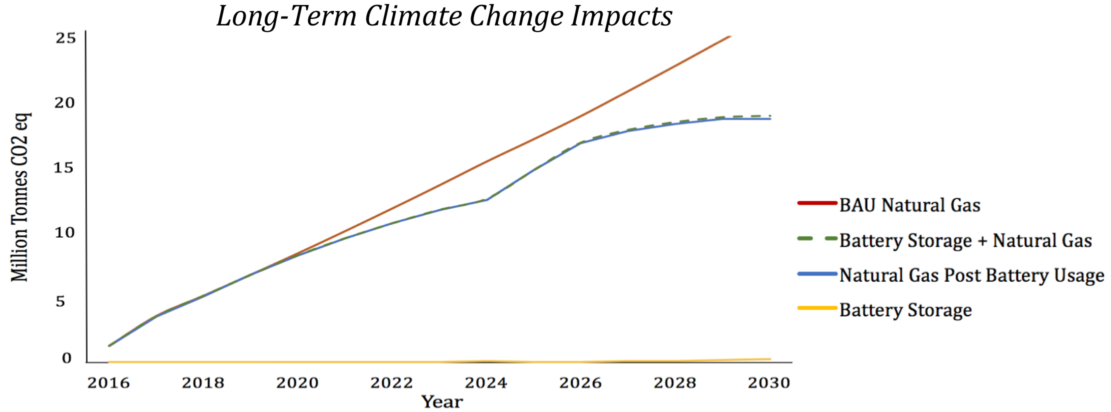
3 Long-Term Environmental Impacts

Switching from the BAU/no storage scenario to the storage scenario from now until 2030 decreased the climate change impact of energy generation by 8%. This was due to the displacement of natural gas to meet California's energy demand.

Long-Term Climate Change Impacts



CONCLUSION & SIGNIFICANCE

Overall, we found that implementing battery storage can reduce the climate change, photochemical ozone formation, terrestrial acidification, and fine particulate matter impacts of energy generation. In addition, using battery storage from now until 2030 could result in an 8% reduction in the climate change impact associated with meeting California's energy demand. In 2030 alone, battery storage could reduce the climate change impact by 14% and displace 15% of the natural gas used to generate California's electricity.

The projection model we developed for our client, First Solar, allows users to incorporate and adjust different scenarios of energy demand and generation that could affect overgeneration levels. This can subsequently influence the amount of battery storage needed to store overgeneration and affect the resulting environmental impacts.

Decarbonizing the energy grid is a major priority for California and First Solar. Due to this priority and our results, we find that battery storage provides a promising solution to help California achieve its stringent greenhouse gas reduction target while improving grid flexibility and increasing renewable penetration on the grid.

ACKNOWLEDGEMENTS

We would like to thank all those who supported and guided our team throughout this project. In particular, we would like to thank our client First Solar Inc., especially Parikhit (Ricky) Sinha and Mahesh Morjaria, as well as our external advisor, Jim Baak. We would also like to thank our faculty advisor, Dr. Roland Geyer; without whom this project would not have been possible. Lastly, we would like to extend our gratitude to Yardi Inc. for their funding support.

Assessing the Environmental Impacts of Utility-Scale Battery Storage in California

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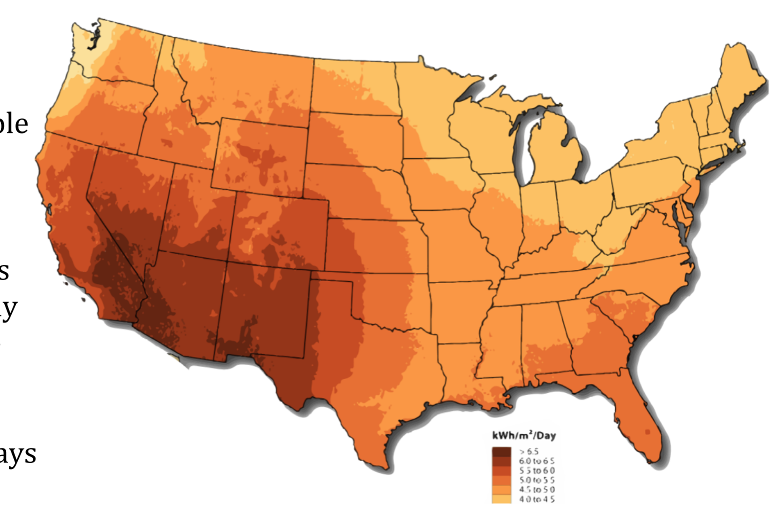
THE PROBLEM

As a world leader in environmental policy, California has implemented a renewable portfolio standard (RPS) with the goal of meeting 50% of the state's electricity sales with renewable energy by 2030. This objective was designed to reduce the state's greenhouse gas emissions. To meet these goals, California has built up its renewable energy capacity, especially photovoltaic (PV) solar, of which the state has a large production potential. While solar energy can provide many benefits, we can't always take full advantage of its potential.

U.S. Solar Energy Generation Potential



Two of the biggest challenges with solar energy are:

1. The sun isn't always available to produce solar energy when we need it.
2. Some places, generate more solar energy (overgeneration) than can be used.

OUR SOLUTION

Utility-scale battery storage can store excess solar energy generated during the day when demand is low and return this energy to the grid during the evening when demand is high. Combining solar energy with battery storage could prevent the waste of excess solar energy (curtailment), increase the amount of energy demand met by renewables, reduce the environmental impacts associated with electricity generation, and improve the flexibility and responsiveness of the energy grid. Though battery storage can provide many benefits to the grid, we don't know the environmental impacts of using battery storage over the long term.

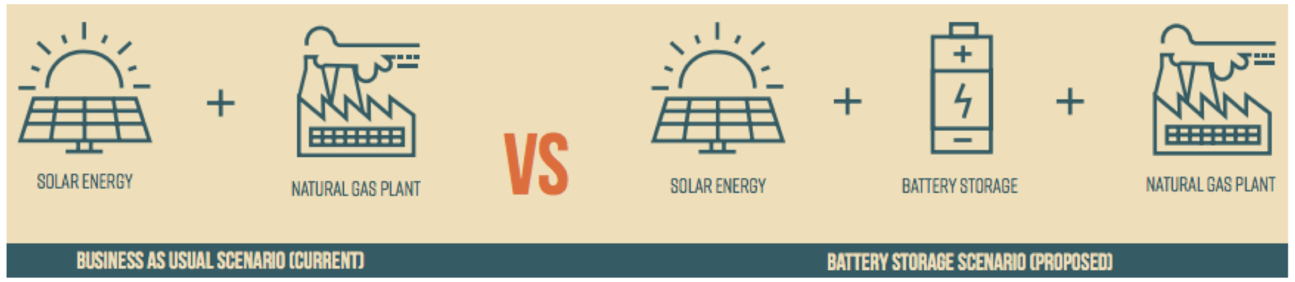
PROJECT OBJECTIVES

Our goal was to understand the long-term impacts of using lithium-ion (li-ion) battery storage vs natural gas to meet California's energy demand. Our two primary objectives were to:

1. Conduct a life cycle assessment to quantify the environmental impacts of using battery storage vs natural gas to provide 1 megawatt-hour (MWh) of energy to the grid.
2. Project the environmental impacts from now until 2030 of using battery storage vs natural gas to meet California's energy demand.

OUR APPROACH

We compared two different scenarios for meeting California's energy demand:

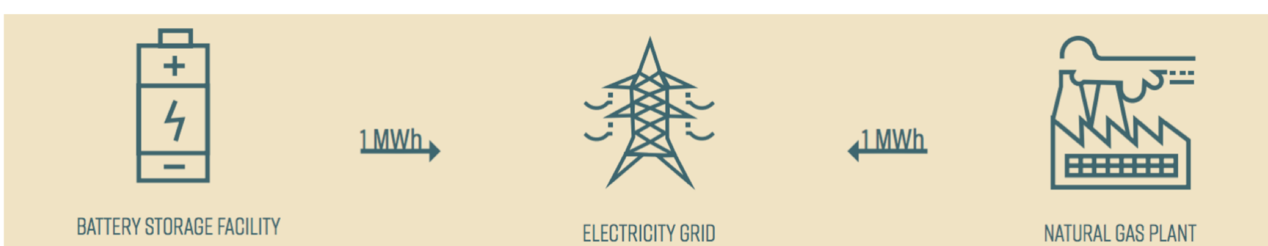


Business as usual (BAU) scenario is our current scenario with no battery storage. Solar energy is generated during the day to meet energy demand, excess solar energy is curtailed to prevent damage to the grid, and then natural gas power plants are deployed to meet peak energy demand in the evening when solar is no longer available.

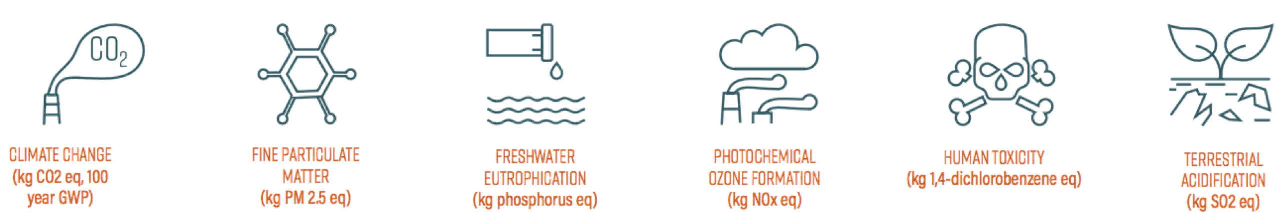
Battery storage scenario is a potential scenario where battery storage is installed at solar PV plants. Solar energy is generated to meet energy demand during the day and excess solar energy is stored in battery storage instead of being curtailed. Evening peak demand is met by deploying stored energy onto the grid first, and if there is remaining energy demand, it is met with natural gas-generated electricity.

1 Life Cycle Assessment

We conducted a life cycle assessment (LCA) to determine the environmental impacts of using a utility-scale li-ion battery storage facility versus a natural gas power plant to deliver electricity to California's grid. LCA is an analysis for quantifying the environmental impacts of a product across all phases of its life, from resource extraction to end of life. The environmental impacts were calculated for 1 MWh of electricity delivered from each energy source to the grid.



We choose to evaluate the battery storage facility and natural gas power plant using six environmental impact categories:



2 Projected Environmental Impact

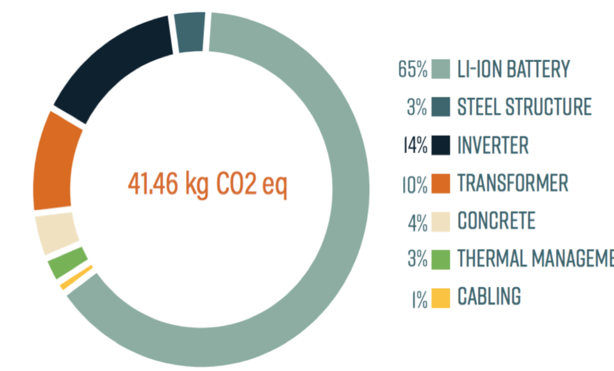
To project the long term environmental impacts of using a battery storage facility vs a natural gas power plant to meet energy demand, we created a model of California's energy demand and generation (by source) for every year between now and 2030. The energy demand and generation projections were used to predict how much overgeneration could occur between now and 2030, and how much battery storage would be needed to store that overgeneration.

RESULTS

1 Life Cycle Assessment Impacts of Battery Storage Facility

The results of our LCA on the battery storage facility show that the li-ion battery and inverter account for the largest impacts in the climate change impact category. There was a similar trend in all six impact categories.

Daily climate change impact of battery storage facility per MWh



2 Life Cycle Assessment Impacts of Battery Storage Facility vs Natural Gas Plant

When we compared the LCA impacts of the battery storage facility to the natural gas plant, the battery storage scenario resulted in a significant reduction in climate change, photochemical ozone formation, terrestrial acidification, and fine particulate matter impacts of energy generation. However, this scenario caused a significant increase in freshwater eutrophication and a minimal increase in human toxicity.