STORING THE SUN

ASSESSING THE ENVIRONMENTAL IMPACTS OF UTILITY-SCALE BATTERY STORAGE IN CALIFORNIA

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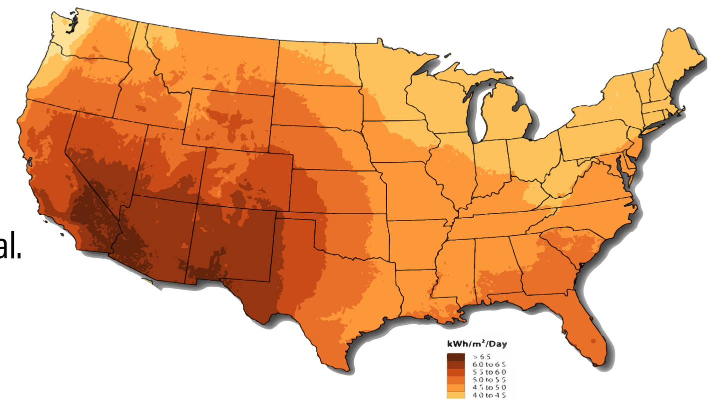
THE PROBLEM

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, which has a large production potential.

While solar energy can provide many environmental and economic benefits, we can't always take full advantage of its potential.



California has one of the highest solar energy generation profiles in the U.S. (National Renewable Energy Laboratory)

TWO OF THE BIGGEST ISSUES WITH SOLAR ENERGY ARE:

THE SUN ISN'T ALWAYS AVAILABLE TO PRODUCE SOLAR ENERGY WHEN WE NEED IT (E.G., CLOUDY DAYS OR AFTER SUNSET). BECAUSE OF THIS, WE RELY ON FOSSIL FUEL ENERGY, SUCH AS NATURAL GAS, TO MEET ENERGY DEMAND WHEN THE SUN IS UNAVAILABLE.

SOME PLACES, SUCH AS CALIFORNIA, GENERATE MORE SOLAR ENERGY (OVERGENERATION) THAN CAN BE USED DURING THE DAY, CAUSING ISSUES FOR THE ELECTRICITY GRID.

These issues will continue to get worse as California continues to add more solar energy to its grid.

OUR SOLUTION

Large or utility-scale battery storage can be used to 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

WHY LITHIUM-ION BATTERIES?

Li-ion batteries are currently considered to be the frontrunner technology for future utility-scale storage projects due to its high energy density, relatively large production capacity, and dramatically falling costs.

CONCEPTUAL FRAMEWORK

To determine whether the benefits of long-term battery storage use outweigh its environmental impacts, we compared two different scenarios for meeting California's energy demand:

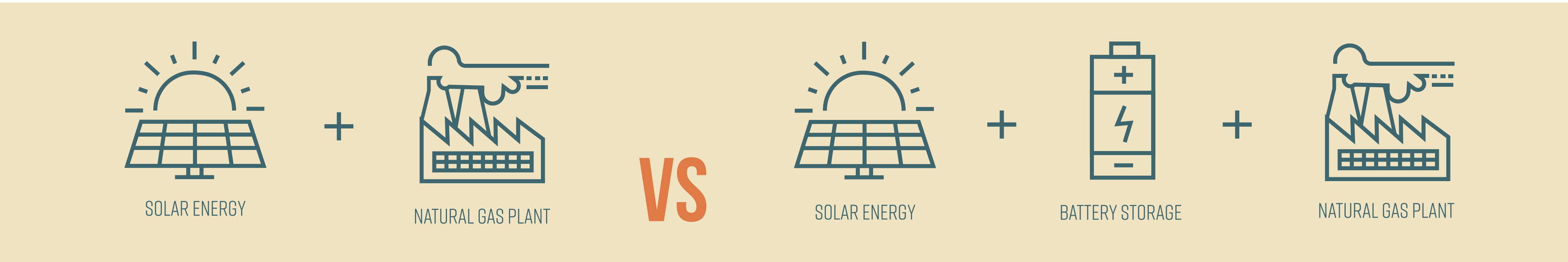
Business as usual (BAU) scenario is our current scenario with no battery storage. Solar energy is generated during the day to meet energy demand, excess solar energy is curtailed to prevent damage to the grid, and then natural gas power plants are deployed to meet peak energy demand in the evening when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

OBJECTIVES

The purpose of our project is to help our client, First Solar Inc. quantify the environmental impacts of using battery storage from now to 2030, when California is required to meet 50% of its electricity sales with renewables. We then compared the environmental impacts of battery storage with the impacts of natural gas electricity generation to determine if battery storage can help California mitigate its greenhouse gas emissions while meeting the 50% RPS goal. Our project had two primary objectives:

- CONDUCT A **LIFE CYCLE ASSESSMENT** TO QUANTIFY THE ENVIRONMENTAL IMPACTS ASSOCIATED WITH USING BATTERY STORAGE VERSUS NATURAL GAS TO PROVIDE 1 MEGAWATT-HOUR (MWH) OF ENERGY TO THE GRID.
- PROJECT THE ENVIRONMENTAL IMPACTS FROM NOW UNTIL 2030 OF USING BATTERY STORAGE VERSUS NATURAL GAS TO MEET CALIFORNIA'S ENERGY DEMAND

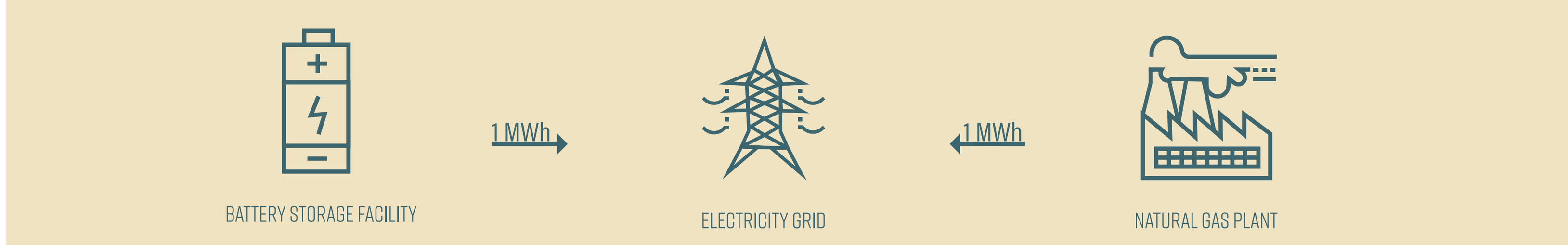


BUSINESS AS USUAL SCENARIO (CURRENT) | BATTERY STORAGE SCENARIO (PROPOSED)

OUR APPROACH

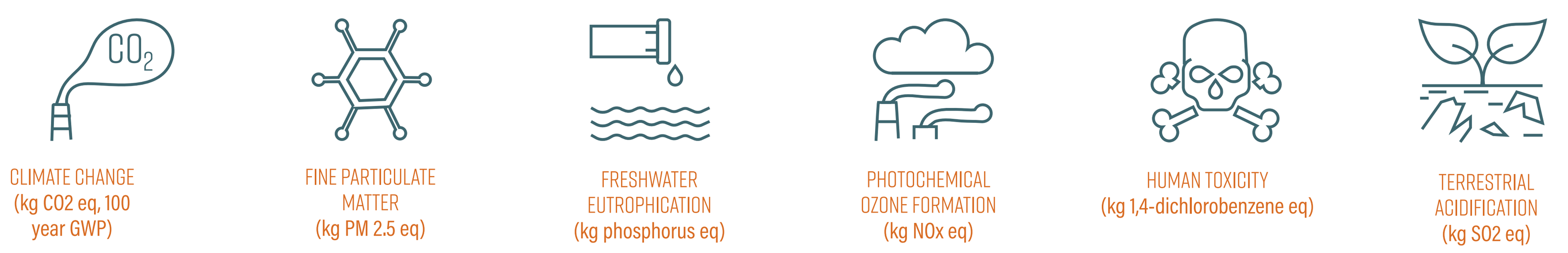
LIFE CYCLE ASSESSMENT

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.



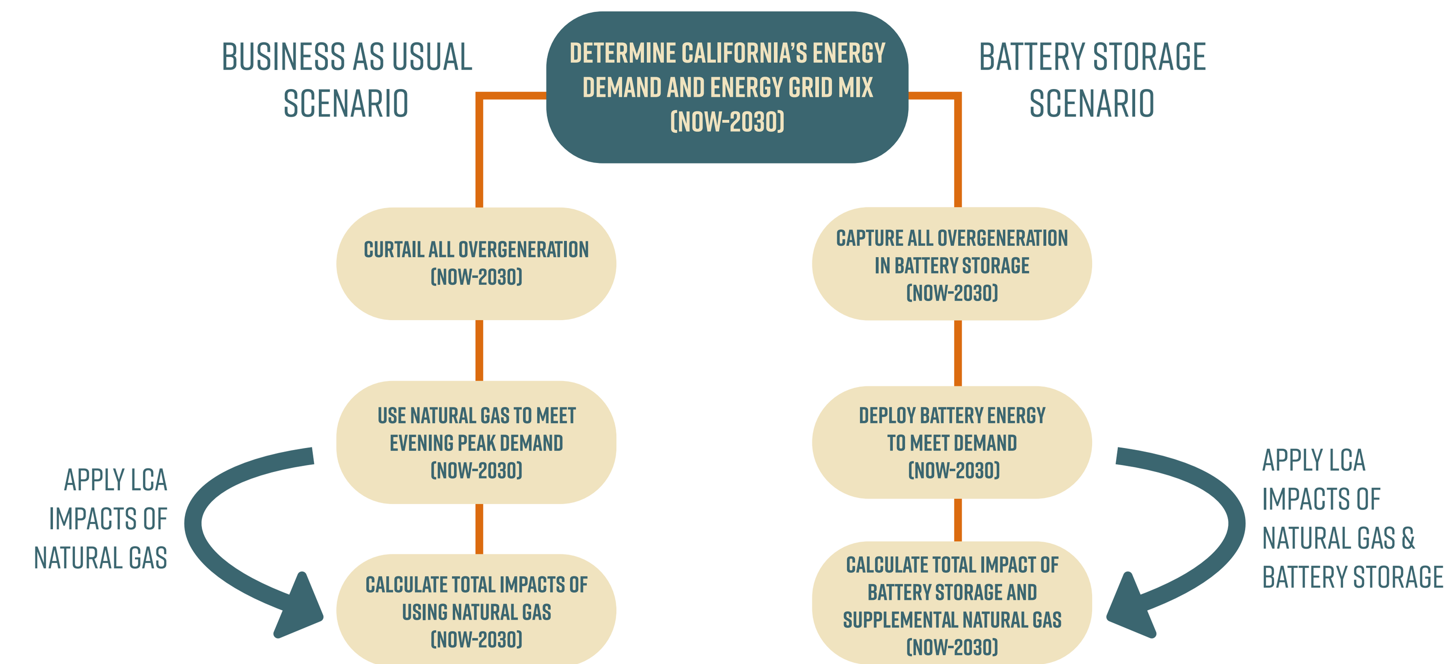
We compared the impacts of using a battery storage facility and a natural gas power plant to produce 1 MWh of energy to the grid.

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



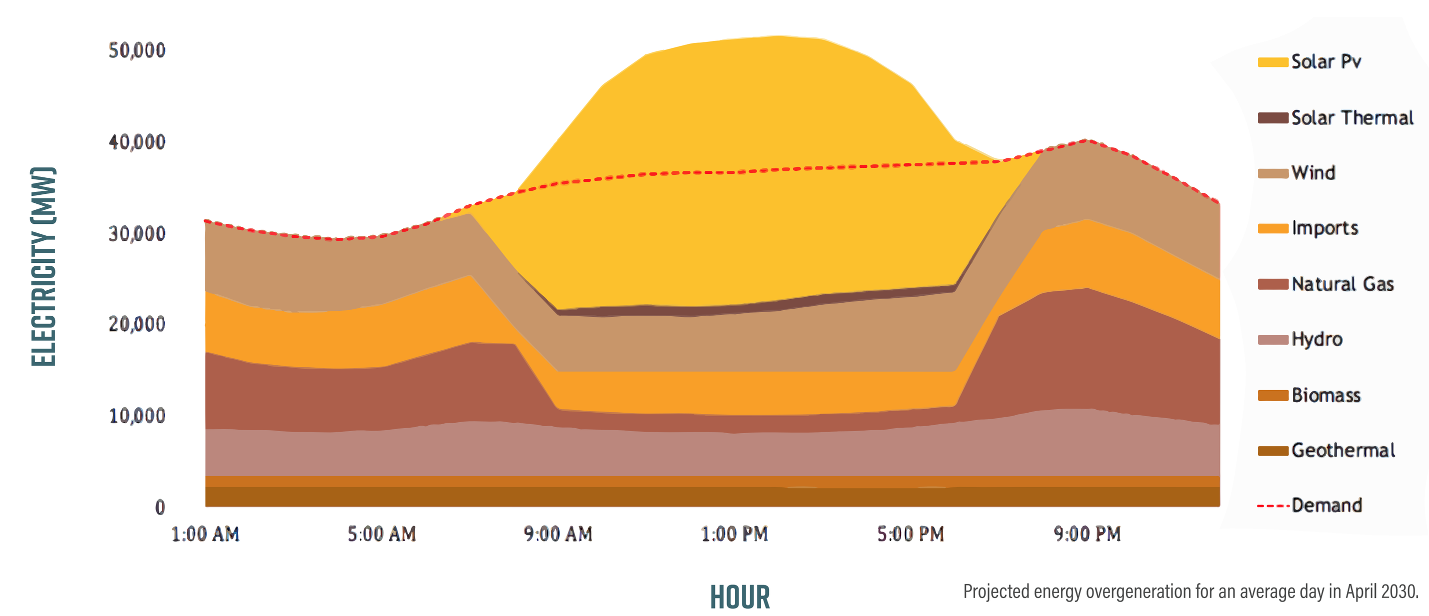
PROJECTED ENVIRONMENTAL IMPACT IN 2030

To calculate the projected environmental impact of using a battery storage facility versus a natural power plant to meet energy demand from now until 2030, 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.



Our step-by-step process for determining the long-term environmental impacts of using battery storage and natural gas from now until 2030

SO HOW MUCH OVERGENERATION IS EXPECTED IN 2030?

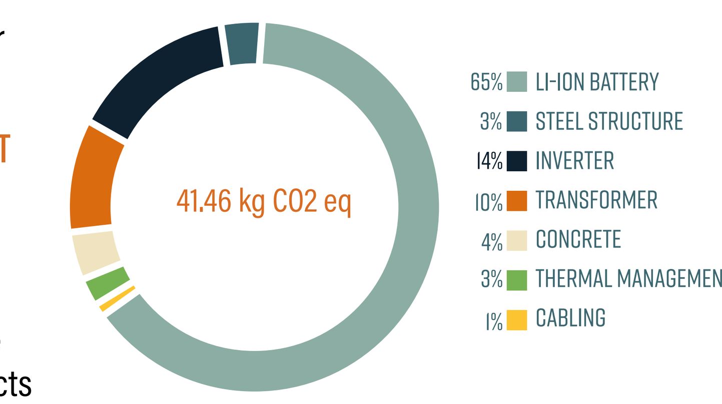


Projected energy overgeneration for an average day in April 2030.

RESULTS

LCA RESULTS

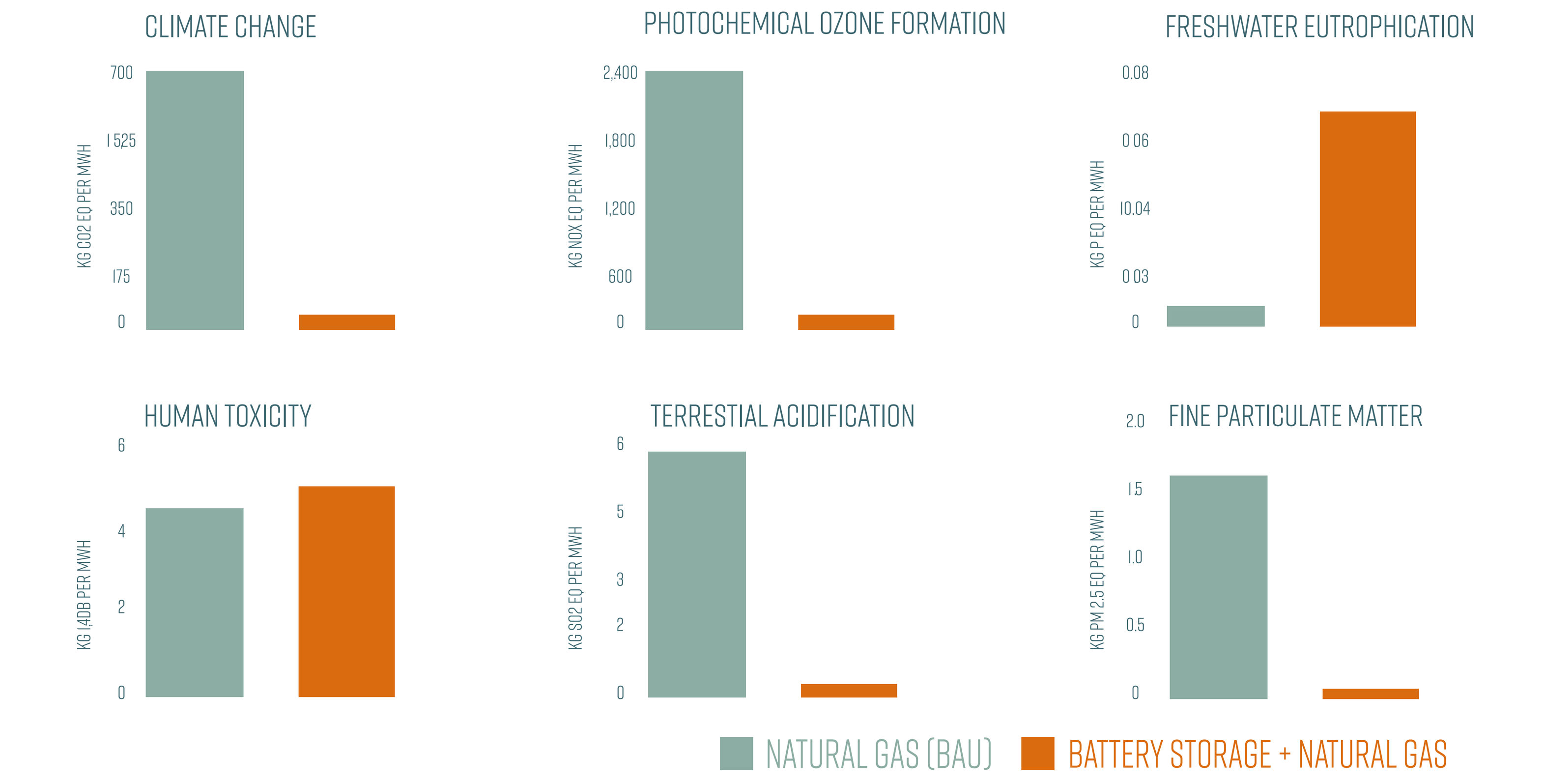
The results of our LCA on the battery storage facility show that the li-ion battery, inverter, and transformer account for the largest impacts in the climate change impact category. There was a similar trend in all six impact categories.



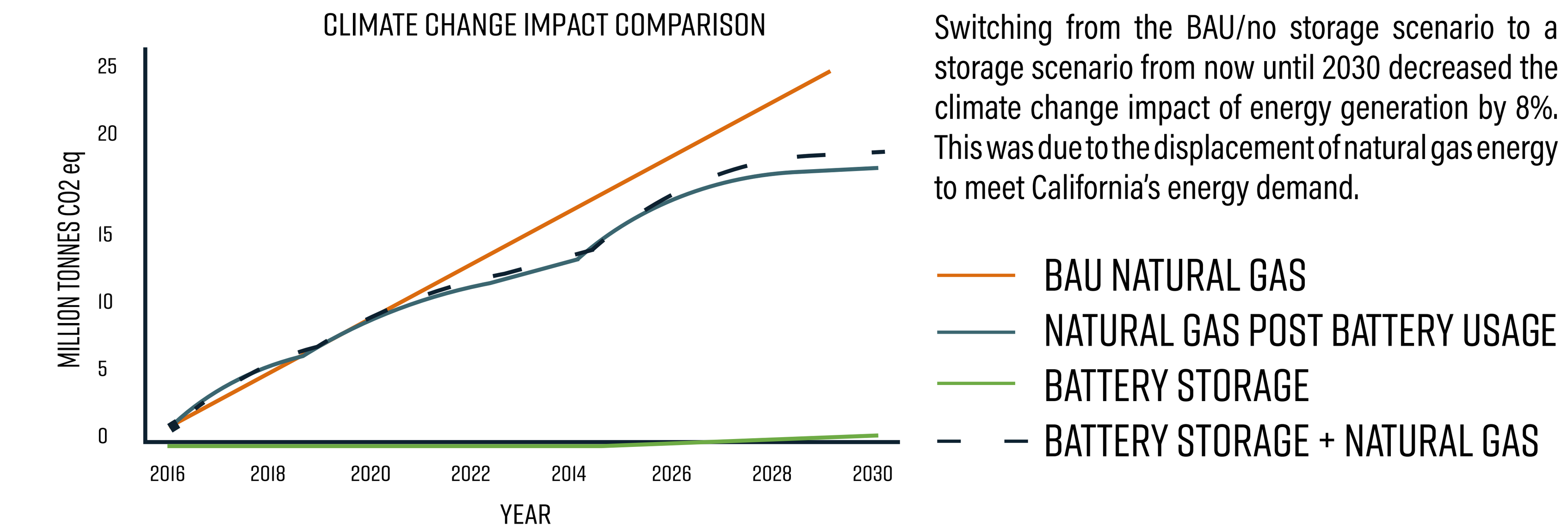
Climate change impact of the battery storage facility per 1 MWh of electricity discharged to the

LCA 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, we found that switching from the BAU/no battery storage scenario to the battery storage scenario resulted in a significant reduction in the climate change, photochemical ozone formation, terrestrial acidification, and fine particulate matter impacts of energy generation. However, switching to battery storage caused a significant increase in freshwater eutrophication and a minimal increase in human toxicity.



LONG-TERM ENVIRONMENTAL IMPACTS



Switching from the BAU/no storage scenario to a 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 energy to meet California's energy demand.

CONCLUSION & SIGNIFICANCE

Overall, our results show that using battery storage can reduce the impacts of climate change, photochemical ozone formation, terrestrial acidification, and fine particulate matter. In addition, using battery storage from now until 2030 could result in an 8% reduction in the climate change impact of meeting California's energy demand. In 2030 alone, battery storage could reduce the climate change impact by 14% and displace natural gas use by 15%.

Reducing the climate change impacts of energy production is a major priority of California and our client, First Solar. Based on this objective and our results, we find that battery storage provides a promising solution to help California meet its GHG reduction targets while increasing grid flexibility, and renewable penetration on the grid.

OUR TEAM WOULD LIKE TO THANK THE FOLLOWING INDIVIDUALS, WITHOUT WHOM THIS PROJECT WOULD NOT HAVE BEEN POSSIBLE: DR. ROLAND GEYER, FACULTY ADVISOR; JIM BAAK; EXTERNAL ADVISOR, RICKY SINHA, MAHESH MARJARIA, ROB VANHAAREN, AND SCOTT RACKEY, CLIENT; ALLISON HORST; DAVID SPENCE; DAVID ERHART; RICHARD JENSEN; AND ANGELA TANGHETTI

FOR MORE INFORMATION, PLEASE VISIT OUR WEBSITE: HTTPS://SOLARSTASH.WEEBLY.COM // YOU CAN ALSO CONTACT US DIRECTLY AT GP-SOLARSTASH@BREN.UCSB.EDU