Consequential Life Cycle Assessment of Combining Solar PV with Utility-Scale Battery Storage to Improve Renewable Penetration and Grid Reliability

Proposers
Parikhit (Ricky) Sinha, Sr. Scientist, Global Sustainability, First Solar Inc., (602) 427-3361; parikhit.sinha@firstsolar.com
Alexandra Jamis, MESM Student, Bren School, (301) 448-0173; ajamis@bren.ucsb.edu
Roland Geyer, Bren Faculty Sponsor, Bren School, (805) 893-7234; geyer@bren.ucsb.edu

Client
Parikhit (Ricky) Sinha, Sr. Scientist, Global Sustainability, First Solar Inc., (602) 427-3361; parikhit.sinha@firstsolar.com
Andreas Wade, Director, Global Sustainability, First Solar Inc., +49(0)173-5798423, andreas.wade@firstsolar.com

Objectives
The overall objective of this project is to conduct a consequential life cycle assessment (CLCA) of the environmental impacts and benefits of combining solar photovoltaic (PV) systems with utility-scale battery storage in California. Specifically, this project aims to:

1. Assess the environmental consequences of integrating utility-scale battery storage systems into the existing electricity grid.
2. Develop realistic grid development scenarios in California with and without utility-scale battery storage systems.
3. Compare the environmental impacts of increasing solar PV and utility-scale battery storage capacity to alternative grid development scenarios.
4. Discuss the policy implications of the CLCA findings regarding grid development goals, such as the 50% renewable integration by 2030 target of California’s Senate Bill 350.

Problem and Significance
Currently, power grids are structured so that electricity supply must match demand at all times. This means that there is currently no system for storing surplus energy for later use. When overgenerating occurs, it can result in electricity producers having to pay utilities to buy their surplus (negative pricing) and cause damaging effects to the power grid. To prevent overgeneration, system operators can curtail energy output from power plants. However, this action is more feasible for conventional power sources and less favorable for renewables, such as solar. As the amount of solar energy curtailed increases, the overall benefit of solar declines to levels where more solar installations are no longer worth the cost.1 The lack of dispatchable electricity from renewable generation increases the likelihood of price volatility and over- and under-generation issues.

Including energy storage into the grid is thought to help improve grid stability, allow more renewable energy generation, and improve grid efficiency.1 As the California power grid moves towards 50% renewable power generation, it will require increasing amounts energy storage.1 This project seeks to understand the environmental impacts and benefits of increasing large-scale battery storage systems to facilitate further increases in solar PV capacity. Last year’s group project with First Solar has shown that, in micro-grids, the environmental impacts of batteries far outweigh those of PV installations.2 It is thus very important to assess the environmental trade-offs and consequences of deploying utility-scale battery storage systems to facilitate increases in PV solar generation capacity. This proposed second group project with First Solar will therefore generate findings and insights with important implications for ambitious renewable grid content policies such as California’s SB350.
Background
Under our current power grid, system operators have to carefully balance energy output with real-time demand for electricity. Electric demand is easy to forecast and conventional power sources, such as nuclear and natural gas, are able to adjust their power outputs according to changes in demand. Although utility-scale solar PV systems can have grid-friendly features, they cannot as easily adjust their power output as conventional sources. Because of the variable nature of solar PV energy production, concerns about grid stability have been raised by electric utilities and energy policymakers. Solar energy is well positioned to meet energy demand during daylight hours, but declines during the evening hours when the sun goes down, while there is a rapid increase in customer energy demand. This is a particular challenge in the winter when the sun sets well before the evening peak load. Additionally, at certain times of year and in locations such as Germany or California where market penetration of solar energy is relatively high, solar energy production can exceed demand in some cases, resulting in negative pricing and/or a need to curtail production. In a 2016 presentation at the IEEE Photovoltaic Specialists Conference, First Solar’s Chief Technology Officer identified improving electric grid flexibility as the “number one impediment to long term industry sustainability”. In addition, the Department of Energy’s SunShot program recently evaluated a series of topics that need to be addressed to enable significant penetration of solar energy in the U.S. electricity grid, including grid integration.

Combining PV systems with storage allows solar power to be more dispatchable as produced energy can be stored until it is needed. Some commercial solutions for small-scale solar storage have been discussed by entrepreneur Elon Musk with regards to Tesla’s Powerwall technology. In 2016, GreenCharge issued a white paper on solar storage for commercial and industrial scale systems. There has been relatively little analysis of solar storage for utility-scale PV systems, even though California has recently adopted bulk storage mandates aimed at promoting grid integration of renewable energy (AB 2514 and associated AB 2861, AB 2868, AB 33, and AB 1637).

This project aims to evaluate the impacts and benefits of combining utility-scale solar PV systems with large-scale storage by examining a reference case without storage systems and comparing the material and energy requirements with the addition of storage and the subsequent benefits from grid integration and displacement of conventional energy. Life cycle inventory data will be obtained from First Solar and from publicly available sources.

In the past, First Solar has undertaken several LCA projects to gauge the impact of their solar projects. Specifically, in 2016 they completed a project with the Bren School to assess the benefits and impacts of solar PV microgrid systems in off-grid communities, such as Kenya. However, there have been no comprehensive LCA studies done on utility-scale solar PV with storage systems to quantify the environmental benefits to regions in which they are installed.

Available Data
First Solar has publicly available data on utility-scale solar PV systems. Additionally, last year’s group project with First Solar developed life cycle inventories for all balance of system components and several battery chemistries. Complementary to this earlier work, data on utility-scale battery storage systems are publicly available.

The Bren School also has several licenses for the professional version of PE International’s LCA software, GaBi, and a variety of PE’s proprietary life cycle inventory databases. Software and databases get updated on a regular basis. In addition, the Bren School owns a license to a version of the EcoInvent database, which can be used with GaBi, and GaBi compatible versions of many publicly available data bases, such as ELCD, USLCI, and data from industry associations. GaBi also contains the environmental impact characterization factors necessary to conduct impact assessment.
Taken together, the data resources of the Bren School, the data from First Solar, and the data from all publicly available studies make this a group project proposal with outstanding data availability.

Possible Approaches
LCA typically distinguishes between consequential and attributional studies (ALCA and CLCA). CLCA is a method to study the environmental consequences of changes in product systems. We propose to apply CLCA to study increases in solar PV and utility-scale battery storage capacity. ALCA methodology has largely been canonized through ISO standards (14040-14049), but CLCA has not reached that point yet.\textsuperscript{11} This creates an opportunity for this group project to contribute to methodology development. Having said that, CLCA methodology is mature enough so that it is an appropriate approach for a Bren group project.

In taking a CLCA approach, future grid development scenarios will need to be considered. The U.S. National Renewable Energy Lab (NREL) has used the Regional Energy Deployment System (ReEDS) model to forecast future U.S. grid mixes through 2050 under renewable energy capacity expansion scenarios, as documented in their Renewable Electricity Futures Study.\textsuperscript{8} The forecast includes both geographic and temporal resolution, including consideration of time of day of energy delivery and consequent displacement of peaking or baseload generation. Renewable generation when combined with storage can have environmental benefits both directly due to the displacement of fossil-fuel generation and indirectly due to the displacement of spinning reserves.

Shorter term forecasts for California through 2020 are available from CAISO, which recommends a broader perspective on addressing grid integration challenges in a low carbon grid.\textsuperscript{9} For example, a future low carbon grid will need to integrate both larger capacities of renewable energy and larger demand for electricity from electrification of the transportation system, with possible synergies if the surplus generation from renewable generation is used to charge electric vehicles. Although not the primary focus of this study, the consideration of this co-emerging trend of transportation electrification may help inform the grid development scenarios.

Deliverables
The primary deliverables from this project will be the group project report on the CLCA methods, data, and results, and the CLCA model that will be created in the GaBi software.\textsuperscript{10} The report will also contain a discussion of the policy implications of the CLCA results and findings. A likely additional deliverable is a spreadsheet containing detailed descriptions of the grid development scenarios.

Internships
Due to a significant industry downturn First Solar is unable to offer a paid internship. However, First Solar is excited to offer office space, supervision, and mentoring through an unpaid internship. The intern would work in the sustainability and storage divisions. At least 50% of the time would be spent on projects other than the group project.

Supporting Materials
a) References

b) Budget and Justification
No additional budget costs above the $1300 provided by the Bren School are anticipated to be required for our project at this point. Current funding will be utilized to cover presentation costs including poster production and printing fees.

c) Client Letter of Support
Please see attachment for letter of support.
Dear Group Project Committee,

I am writing to express my support for the 2017 Bren School Group Project Proposal on “Consequential Life Cycle Assessment of Combining Solar PV with Utility-Scale Battery Storage to Improve Renewable Penetration and Grid Reliability.”

To date the solar PV industry has largely focused on providing renewable energy in the form of stand-alone grid-connected systems. However, the long-term potential for substantial grid penetration by renewables is dependent on improving electric grid flexibility. In combining utility-scale PV systems with large-scale stationary battery storage, a PV plant can be operated as a dispatchable resource.

The objective of the group project is to help assess whether large scale deployment of utility-scale solar PV and battery storage systems can be sustainable from an environmental and socioeconomic point of view, in relation to stand-alone PV systems under future grid development scenarios.

First Solar will provide public data in the form of life cycle inventories of First Solar PV systems, battery systems, and grid-development forecasts. No additional funding above the $1,300 provided by the Bren School is anticipated to be required for the Group Project at this point.

Due to a significant industry downturn First Solar is unfortunately unable to offer a paid internship. However, First Solar is excited to offer office space, supervision, and mentoring through an unpaid internship. The intern would work in the sustainability and storage divisions. At least 50% of the time would be spent on projects other than the group project.

I look forward to working with the Bren School Group Project team on this engaging and important study.

Sincerely,

Parikhit Sinha, Ph.D.
Sr. Scientist, Global Sustainability