GreenPeaks: Employing renewables to cut load in electric grids

In this project we investigate integrating renewable energy in electric grids to cut energy demand- and peak demands on the grids. We devised GreenPeaks, an online algorithm for integrating solar energy and energy storage devices at homes to cut their electricity bills, cut their power draw (especially peak draw) from the grid, and make their electricity consumption profile grid friendly. (GreenPeaks builds upon PeakCharge, our previous work on scaling distributed energy storage, published in ACM eEnergy-2013.) We evaluate the efficacy of GreenPeaks using real power consumption traces from ~200 homes, and existing time-of-use (ToU) and day-ahead real-time electricity pricing plans.

Summary of findings

Our experiments show that naïve renewable integration methods (such as the common Net Metering approach) don't effectively cut peak electricity demands; this is mainly because solar energy harvest peaks earlier in the day, but residential peak demands typically occur around dinner times. To address these limitations of the Net Metering approach, we propose GreenPeaks, a system that intelligently integrates renewables & onsite energy storage. GreenPeaks---under ToU pricing---can reduce an individual home's electricity bills by up to 20%, can cut aggregate peaks by 18%, and (on average) save generation costs up to 21%. Further, GreenPeaks---given day-ahead electricity pricing---can cut aggregate peaks by around 35%, which is around 75% improvement over PeakCharge (the previous approach). Besides, it results in an average daily cost savings of more than $1 for a typical home. Our initial analysis shows this can result in a positive return on investment (RoI) for homes already possessing the necessary infrastructure for GreenPeaks---such as homes with EVs. Further, with the advent of more efficient, long lasting batteries, and an (expected) decrease in cost of solar panels, GreenPeak's RoI may become positive for an average home in the near future.

Completed Tasks

We presented our algorithm, and results at CEJS brown bag presentation in fall-2016 and submitted the midterm report in February-2017. We have completed the following tasks in the project, as outlined in the proposal (tasks in green were completed after midterm report submission):

- Literature survey for existing approaches to integrate renewable energy in grid.
- Coding for baseline renewable integration approaches to experiment and compare with GreenPeaks (to be devised as part of this work).
- Design of GreenPeaks---online battery charging-discharging algorithm to cut peaks and bills using renewables.

- Design of GreenPeaks system architecture to enable homes and buildings deploy GreenPeaks.
- Simulation code for GreenPeaks.
- Initial experiments with GreenPeaks, mostly for sanity check and bug fixes. (Some more functionality needs to be added and tested before final evaluation can be done.)
- Initial cost saving and peak reduction evaluation of GreenPeaks for individual homes.
- Extensive cost saving and peak reduction evaluation for individual homes for time-of-use and day-ahead real time prices.
- Extensive cost saving and peak reduction evaluation of GreenPeaks across the grid for time-of-use and day-ahead real time prices.
- Cost benefit analysis of GreenPeaks.
- Prepare manuscript for journal/conference publication. (This is underway. We hope to be able to share a link of manuscript later this summer.)
- Final report for year-end submission.

Future Directions

GreenPeaks developed techniques for integrating renewable energy sources (such as solar panels) along with energy storage devices at homes (or buildings) to make the overall consumption profile of the grid more sustainable. However, energy storage can also be deployed higher in the grid hierarchy such as at the transformers and substations (not just at customer premises). In the future, we would like to study the challenges and opportunities these choices offer and devise techniques to harness their potential.

Recently, we started working on GreenDraw. In this project we analyze electricity consumption traces of an anonymous building in Seattle University (SU), and investigate techniques to cut the building's electricity bill, cut the building's energy consumption, and make its consumption profile more grid-friendly, eco-friendly. We will develop a set of techniques to achieve these goals by integrating energy storage, and solar energy in the building's consumption---especially by cutting the building's peak electricity demand. In addition to devising energy and cost saving techniques, we hope that findings from this study can provide recommendations for rooftop solar panel integration in the new science building that is coming up in next few years.