

## Introduction

The current grid system is antiquated and inefficient, essentially having grown out of the same systems originally developed with the spread of electrification through regions which are not always compatible with each other. The grid is nonuniform and unintelligent in which the demand side cannot communicate with the supply side. Its incommunicability and incompatibility hinders energy efficiency and increased utility of electrical services. A smart grid, which includes communication and interconnectivity of utilities, would reduce the frequency and severity of blackouts improving the quality of electrical service in the country. Smart grids have the potential of reducing CO<sub>2</sub> emissions by eliminating excessive standby power, which can account for 40-50% of a utility's electricity output. The current grid system requires the large standby power to accommodate the difference between peak and off-peak power demands. The final issue is that the current business model only rewards the utilities for expanding their sales of power and building more generators. There is no incentive to make improvements in terms of efficiency or to work with consumers to achieve energy demand reductions. These issues create the opportunity for dramatic efficiency increases through the development of smart grid technology leading to decreases in carbon dioxide emissions.

## Smart Grid Solution

The ability for electricity users and suppliers to communicate would enable centralized control over individual appliances in which standby power could be minimized and non-critical tasks could be performed automatically during off-peak hours. In cases of extreme demand the grid could shut off non-essential loads in order to prevent blackouts. This communication would enable easier metering of overall power consumption as well as individual appliance usage and power generation of installed renewable energy systems. Communication between electricity users and producers would allow the consumer to have a larger amount of information at their fingertips in order to manage their own energy demands. A smart grid, solely operating in a residential area, would save 586 billion kWh by minimizing vampire loads [1]. If we use the EPRI's estimate of 617,000 tons of CO<sub>2</sub> per billion kWh sold then the minimization of vampire loads could yield a 358 million ton reduction of CO<sub>2</sub> emission per year [2,3].

The majority of CO<sub>2</sub> emission savings stem from the smart grid acting as a catalyst for clean technologies. Advanced metering and compatibility for distributed power supplies would bring down costs for connecting solar panels and wind turbines to the grid. The smart grid would encourage consumers to buy smart and energy efficient appliances so they may save money on electricity bills by purchasing cheap and renewable energy from solar and wind sources. Furthermore, plug in hybrids or all electric cars could use vehicle to grid (V2G) technology and serve as energy storage sites for the grid. V2G also encourages solar and wind power by storing electricity generated during off peak hours. If all vehicles in the United States could store 25 kWh (hybrid-electric), that would amount to a maximum of 6.25 billion kWh in backup power [5,6]. Even a fraction of the backup power would be sufficient to satisfy spikes in electricity demand thus negating the need to run standby CO<sub>2</sub> emitting power plants. Also plug in electric hybrid vehicles (PHEV) emit about 70% less CO<sub>2</sub> than internal combustion engines therefore if we phased in PHEVs we would cut our transportation emission by 1.3 billion metric tons a year [16, 17].

## Feasibility

There are a number of technological requirements that must be met in order for a smart grid to be a viable option. The first requirement, the need for two way communication between the utility and the consumer, is essential. This system must be dependable, regularly updated, and, most importantly, be able to interconnect with any consumer or utility system. The next requirement, smart appliances, is also of critical importance. In order for the grid to be utilized to its full potential, appliances must be able to make "decisions" based on the current cost of power at any given time, which the appliance must be able to monitor. The last objective is the ability of the grid to be able to decentralize power storage, most

likely be fulfilled by the large scale use of hybrid vehicles where power can be stored and drawn upon through the car's battery. Fortunately, almost all of the tools necessary for the smart grids implementation already exist. The two way communication system is already available through the preexisting internet infrastructure in the form of wireless mesh networks (WMNs) which are used by the City of Burbank, CA [14]. Also available is "broadband over power lines" (BPL) which can transmit the data right over the existing power line infrastructure. Both of these communication systems can and have been implemented to serve as two-way energy information portals. The communications chips are available from several manufacturers including the Ember Corporation in Boston [13]. There are a number of plug-in hybrid vehicles with smart grid compatibility already on the road (the Ford Escape PHEV 25 and Toyota Prius PHEV 15 for example [12]) and many more on the way. Though it may take some time for there to be enough of them to produce sufficient backup power on a large scale, the rising cost of oil and greater socio-political emphasis on conservation and energy efficiency will likely drive consumers to purchase hybrid vehicles in the numbers required in the near future.

In order to integrate a smart grid into society, government regulation is required to create economic incentives for utility companies and consumers to adopt to this system. This could be done by creating subsidies for home projects which promote energy efficiency and implementing a carbon tax, setting renewable energy standards, or creating a cap and trade system which would set limits to the overall consumption of energy in a given region. Ontario, Canada is a current example of a tiered carbon tax system in which the Ontario Energy Board increases electricity price rates if a certain threshold consumption is passed. In 2007, this threshold was set at 250,000 kilowatt hours per year for residential customers and 750 kWh per year for non-residential customers [11].

The economic choice to implement a smart grid in a region depends on the current use, projected growth, and cost of retrofitting the existing infrastructure. On the consumer side, the front-end costs associated with a smart grid are entailed in retrofitting current appliances with smart chips. Sources estimate that the average household could spend \$400 to \$500 to retrofit their current appliances with smart chips [7]. Assuming a 10% reduction in electricity consumption, achieved in Seattle pilot study caused by the smart chips, the payback period for the consumer is between 40 and 50 months [8,9]. On the supply side, a study in San Diego estimated that the total cost to build and maintain a smart grid would be approximately \$970 million per utility for twenty years. In the same time period, the utility company could realize \$1.4 billion in revenues [10]. Similar analyses have shown economic benefits from implementing smart grid technologies in Seattle, Burbank, and Boulder. These analyses do not include subsidies provided by the government to incentivize consumers and utilities companies. In general, current technologies allow for payback periods shorter than the lifespans of the smart grid infrastructure components on the supply and demand side.

## Conclusion

A smart grid that enables communication between suppliers and consumers and improves compatibility between utility companies would be an ideal replacement for the outdated traditional grid. A smart grid minimizes necessary backup power, reduces frequency of blackouts, and allows consumers to choose when to power their appliances. Current technology supports the implementation of a smart grid as evidenced by pilot studies. The benefits of a smart grid creates payback periods that are shorter than the lifetime of the hardware and infrastructure even without potential added incentives from the government. Government policies are necessary to encourage utility companies and consumers to use energy more efficiently. Though its effect varies in terms of CO<sub>2</sub> emissions, the immediate reduction is approximately 358 million tons of CO<sub>2</sub>. Reductions in emissions of 1.3 billion can be realized with a whole fleet of PHEVs. If PHEVs make up the whole market by 2030 and a smart grid was implemented nationwide by 2020 the prevented emissions would be 36 billion metric tons of CO<sub>2</sub>. This is a modest estimate since we are assuming no rise in energy demand. Also further benefit from the large scale storage of PHEVs is the ability to make possible larger market penetration of distributed generation such as wind and solar power for an even greater savings in CO<sub>2</sub> emissions.

## Works Cited

1. "Diagram 1: Energy Flow 2007", Annual Energy Review **2007**: *Energy Information Administration* <<http://www.eia.doe.gov/emeu/aer/diagram1.html>>. Accessed 26 Jan 2009
2. "Carbon Dioxide From the Generation of Electric Power in the United States", **July 2000**: *Department of Energy & Environmental Protection Agency* <[http://www.eia.doe.gov/cneaf/electricity/page/co2\\_report/co2report.html](http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html)>. Accessed 26 Jan 2009.
3. Siddiqui, O. "The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid", **June 2008**: *Electric Power Research Institute*, Palo Alto, CA.
4. "Standby Power", **25 Jan 2009**: *Wikipedia* <[http://en.wikipedia.org/wiki/Standby\\_power](http://en.wikipedia.org/wiki/Standby_power)>. Accessed 26 Jan 2009.
5. "New Battery Technology for Hybrid Vehicles", **26 Oct 2006**: *Alternative Energy* <<http://www.alternative-energy-news.info/new-battery-technology-for-hybrid-vehicles/>>. Accessed 26 Jan 2009.
6. "Passenger vehicles in the United States", **23 Jan 2009**: *Wikipedia* <[http://en.wikipedia.org/wiki/Passenger\\_vehicles\\_in\\_the\\_United\\_States](http://en.wikipedia.org/wiki/Passenger_vehicles_in_the_United_States)>. Accessed 26 Jan 2009.
7. Nelson, B. "Smart appliances learning to save power grid: Washers, dryers, refrigerators grow savvier, adjust to demand", **26 Nov 2007**: *MSNBC: Business* <<http://www.msnbc.msn.com/id/21760974/>>. Accessed 26 Jan 2009.
8. Kiesling, L. "Smart Savings", **21 Sep 2008**: *Science in Society* <<http://scienceinsociety.northwestern.edu/content/articles/2008/kiesling/smart-savings>>. Accessed 26 Jan 2009.
9. Bluejay, M. "How much electricity costs, and how they charge you", **April 2008**: *Saving Electricity* <<http://michaelbluejay.com/electricity/cost.html>>. Accessed 26 Jan 2009.
10. Pullins, S.; Westerman, J. *San Diego Smart Grid Study Final Report*, SAIC: **2006**.
11. The Ontario Energy Board regulates the province's electricity and natural gas sectors in the public interest. <http://www.oeb.gov.on.ca/OEB>
12. Riddell, L. "Stimulus package may spark local smart grid projects", **23 Jan 2009**: *Puget Sound Business Journal* <<http://seattle.bizjournals.com/seattle/othercities/sanfrancisco/stories/2009/01/26/story14.html?b=1232946000^1766364>>. Accessed 26 Jan 2009.
13. Anderson, M. "Hybrids Plus makes vehicles capable of use in Boulder's Smart Grid City pilot", **1 Dec 2008**: *Parts and People*, <<http://www.partsandpeople.com/Mountain/article/3459>>
14. Roush, W. "Ember's Wireless Chips Power Smart-Energy Efforts", **22 Jan 2009**: *Xconomy: Boston*, <<http://www.xconomy.com/boston/2009/01/22/embers-wireless-chips-power-smart-energy-efforts/>>
15. Bane P. "Growing Use of Sensors...BPL or WiFi for the Smart Grid...GIS maps the Smart Grid", **5 Dec 2007**: *Smart Grid Newsletter*: <[http://www.smartgridnews.com/artman/publish/grid\\_research/Growing\\_Use\\_of\\_Sensors\\_BPL\\_or\\_WiFi\\_for\\_the\\_Smart\\_G\\_325.html](http://www.smartgridnews.com/artman/publish/grid_research/Growing_Use_of_Sensors_BPL_or_WiFi_for_the_Smart_G_325.html)>
16. Google.org. "RechargeIt.org", **2008**: <<http://www.google.org/recharge/experiment/CO2.html>>
17. "US Emissions Inventory." **2006**: <<http://www.google.org/recharge/experiment/CO2.html>>