How much electricity can we save by using direct current circuits in homes?

Brock Glasgo, Inês Azevedo, and Chris Hendrickson

Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh PA

Background information

In recent years, a discussion has emerged as to whether we should power buildings with DC circuits instead of AC. This strategy is particularly interesting when considering buildings with a source of DC generated electricity such as solar photovoltaics (PV).

Previous studies have quantified several variations of the energy savings associated with supplying DC power to commercial and residential building loads by applying efficiency gains to energy consumption profiles obtained from large top-down studies or generated by simulation. But the cost-effectiveness of these savings are highly uncertain given the lack of previous research.

Why DC?

Advantages:

- Much of the energy consumed in US homes is already transmitted as direct current at some point between the grid and the end load. Substantial electricity savings can be realized in a large number of buildings by eliminating the losses that occur when converting from one form of current to the other
- The only major loads in an average US home that do not presently have direct current in their power supply are those utilizing constant-speed induction motors or resistance heating elements. These same technologies present the greatest savings opportunities if converted to an equivalent, already available DC device
- DC circuits have the potential to improve the reliability and reduce the cost of consumer electronics by centralizing AC-to-DC rectification duties from distributed, failure-prone power supplies to central, home-level rectifiers.

Disadvantages:

- DC circuits increase the capital wiring cost of a home
- DC circuits at the residential level rely on wiring, circuit breakers, and switches which are not currently manufactured at a scale needed to supply broad adoption
- Engineers and technicians are not trained in DC systems, resulting in inflated design and installation costs of these systems
- Existing building codes and standards are specific to AC power and would require amendment for wider application of DC
- DC power poses different safety requirements in insulation and arc-quenching due to the nature of DC power

Cost-benefit analysis using levelized annual cost

In this work, we assess the energy and economic potential of a transition to DC circuits in homes using appliance-level monitored data of (24) homes supplied by the Pecan Street Research Institute. Levelized annual cost (LAC) of electricity was used to evaluate the economic feasibility of each of the proposed scenarios. LAC takes into account varying lifetimes of system components as well as the time value of money.

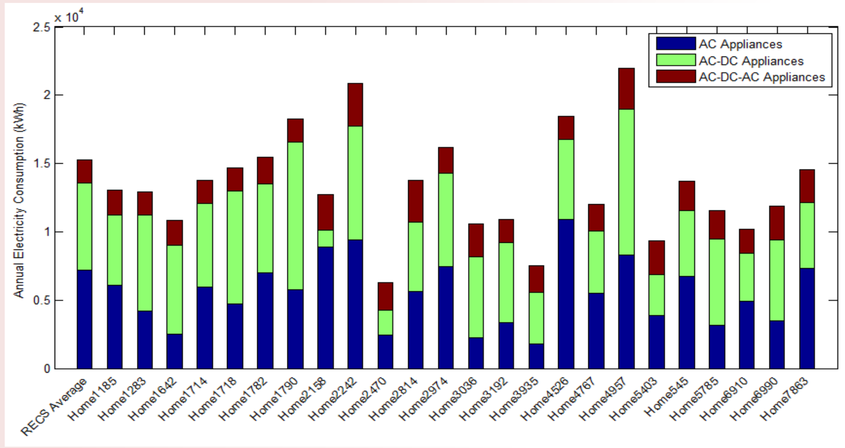
Monte Carlo simulations are used to quantify the effect of direct current circuits on sample homes' energy use using ranges for uncertain equipment efficiencies and costs. Uniform distributions were chosen to represent inputs, generating a range of output values for each simulation. Summary statistics are presented from these output distributions.

This study investigates a transition approach where appliances easily supplied by DC are, while those which would require a complete equipment replacement continue to be serviced by AC. Changes in appliance costs due to changes in power supplies are ignored at this stage as these values are thought to be minor.

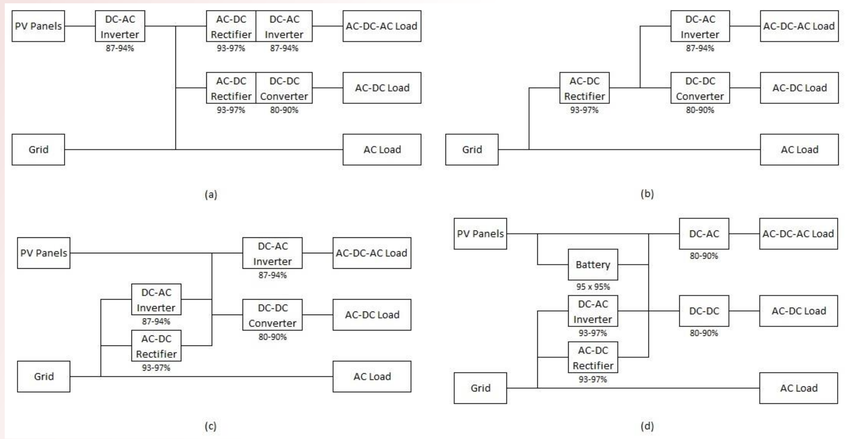
DC load disaggregation and simulated scenarios

We allocate the loads of (24) monitored homes into three appliance types based on their existing power supply. The same allocation was applied to the most recent RECS data and plotted for comparison.

AC Appliances	AC-DC Appliances	AC-DC-AC Appliances
AC condensing unit, furnace fan, garbage disposal, oven, range, refrigerator	TV, computer, stereo, LED lighting, most consumer electronics	Clotheswasher, dryer, dishwasher, fluorescent lighting

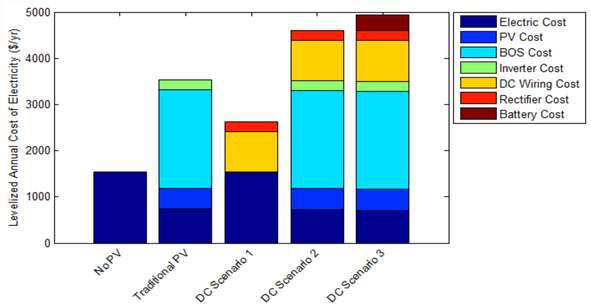


Four scenarios were assumed for simulating conversion to DC circuits in homes.



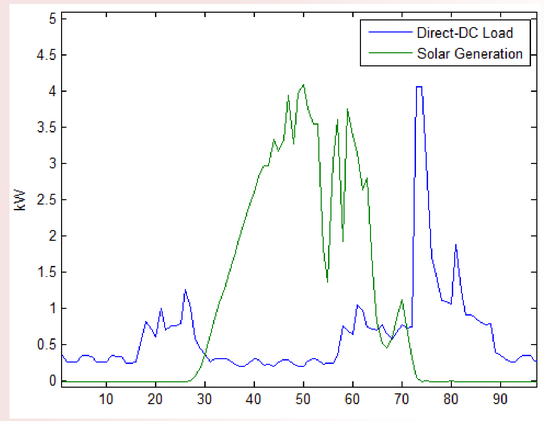
Simulation results: levelized annual cost of electricity

In the scenarios simulated, the energy cost savings of DC circuits average less than $100/yr in all simulated scenarios. This is outweighed by the added cost of DC wiring retrofits, central rectifier costs, and battery storage costs. Note that costs shown are an average of the homes included in the study.



Non-coincident loads

These low savings numbers are primarily due to non-coincident load profiles between solar PV generation and DC acceptant loads.



During the day when solar power is being generated, DC load is low. This results in most generated power being inverted and sold to the grid, generating no savings compared to a traditional PV array.

Future Work

Additional work will continue to investigate scenarios which have either been proven economically viable in commercial settings or show promise in the residential sector. These include:

- Investigating key technologies which serve as the most eligible candidates for a transition to DC circuits. LED lighting systems have been proven to reduce LAC in commercial buildings when connected to a direct-DC photovoltaic array. Many of the same benefits shown in these applications exist in homes and will be included in future analysis.
- Investigating the possibility of decreasing the size of a home's solar array to serve only a base DC demand. This allows the capital cost of the system to be decreased, while optimizing the benefits of direct-DC distribution
- Estimating the reduction in cost of consumer electronics associated with centralizing rectification duties to the home level. This will have the effect of reducing the amount of electronics in power supplies, but additional research is required to determine the overall impact on retail price.

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We thank Carnegie Mellon University's Center for Climate and Energy Decision Making, and the Pecan Street Research Institute for their support of this work.