FOUR GOOD DEEDS
For Residential Building Decarbonization

Residential Building Decarbonization - Blog

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After 40+ years working in industry on commercial and industrial energy efficiency and decarbonization, I recently had the opportunity to apply that knowledge while renovating our 20-year-old single family residence in Fort Myers, Florida. The objective was to achieve significant increases in performance – energy, emissions, indoor environmental quality, and resilience – while achieving an attractive return on investment.

The World Resources Institute recently published research which ranked activities that individuals and households can take to reduce their greenhouse gas emissions. Sourcing renewable energy, electrical vehicle use, and energy efficiency retrofits - which were cited among the most impactful actions - were key elements of our home renovation project. These measures are also important considerations when decarbonizing commercial buildings.

In a 2020 article for the World Economic Forum, I described "four good DEEDs" for achieving zero-carbon buildings. DEEDs refers to Decarbonization, Electrification, Efficiency, and Digitalization. This article, along with a subsequent article, included a number of case studies from the US, Europe, Middle East, and Asia. A key question was whether the same general approach used in decarbonizing these larger buildings and campuses could be applied in a single-family residential building.

From an **Efficiency** and **Electrification** standpoint, our home was already performing well. It was well insulated across both the living space and garage and equipped with ENERGY STAR appliances throughout. We were also fully electric, with a high-efficiency air conditioner (paired with a smart thermostat) and a heat pump pool water heater.

Using the "four good DEEDS" framework, our home retrofit project started with **Decarbonization** and the installation of 10.1 kW of solar PV panels.[1] This represented about two-thirds of our pre-retrofit electrical use on an annual basis. The pay-back period was estimated to be about ten years, helped by the 26% tax credit at the time and utility net-metering.

Shortly after our solar PV installation, Hurricane Ian passed directly over our house causing days of power outages. Luckily, there was no damage to our solar panels which actually fared better than our non-covered roof area. This experience taught us first-hand the importance of resilience and we prioritized battery storage as our next renewable energy improvement. We opted for a 10-kWh battery system with microgrid control serving critical circuits within the home.

The microgrid controller has built-in strategies for managing battery charging and discharging based on cost, site-level carbon emissions, or reliability. In order to minimize system-level carbon emissions, I created a fictitious real-time price tariff based on average grid emission factors for the local utility grid. This tricked the microgrid controller into "thinking" it was minimizing costs while actually minimizing carbon impact on the grid.

[1] The ASHRAE Position Document on Energy Efficiency in Buildings states that "Energy efficiency is the first priority in reducing building GHG emissions." This case study focuses on GHG reductions in an all-electric home that has already implemented many energy efficiency measures.

Our next efficiency improvements included installing an induction range and smart heat pump domestic hot water heater (after donating our perfectly good resistance electric hot water heater to hurricane relief efforts). The smart heat pump hot water heater also provides resilience benefits as we can remotely increase the water temperature prior to a storm to increase backup hot water heating capacity. It also helps condition our garage with its cool exhaust air. We schedule our air conditioning, heat pump water heater, pool pump, filter and heater, EV charging, and laundry tasks based on our solar generation, further reducing peak load and grid emissions.

To further decarbonize our home (and life), we decided to purchase an electric vehicle and chose one of the few with vehicle-to-load (V2L) capabilities. The EV can power up to two 16-amp, 120v circuits from its 78 kWh battery. In order to further increase our thermal resilience during hot weather severe weather events, we purchased a portable air conditioner to cool a few critical areas of our home.

The large battery capacity of our EV provides the same power capacity as eight 20-pound canisters of propane powering a small backup generator. Saving the cost of installing a small (or large) propane back-up generator provided additional cost justification for the battery storage system and the EV with V2L capabilities.

Our battery storage/microgrid supplier plans to offer Vehicle-to-Grid capability in the future but this will require collaboration between the EV manufacturer (for V2H) and the local utility (for V2G) capabilities. We're not holding our breath for either of these things, but we have offered to be a pilot or early adopter of both capabilities just in case they become reality.

Digitalization is a key element of our retrofit strategy but is far less automated and integrated than we had originally intended. Despite almost every device in our home having smart controls and communications, I have 16 different web apps to monitor and control them. Even our induction range, convection oven, and EV have web interfaces but there is precious little digital integration and control between systems and devices. One of our improvements was adding digital IAQ sensing, but we are left with manually controlling windows, sliding doors, and exhaust fans to reduce high concentrations of pollutants.

Given the number of smart controls, devices, equipment, and appliances we have, we originally planned on leveraging demand response and real-time pricing to generate additional cost savings. Our attempts were foiled, however, as our local utility only allowed direct load control with remote-controlled hardwire interfaces. Time-of-use tariffs and solar net metering unfortunately require different mechanical meters (so much for digital Advanced Meter Interfaces). Net metering is currently more valuable for solar installation although this is being challenged by the local utility. Providing valuable energy services to the utility, using our distributed energy resources, feels more like being "behind enemy lines" than "behind the meter."

Well, so much for digitalization, an area of tremendous innovation and opportunity in residential and utility applications. We need standard protocols, open interfaces, integration platforms, and device certification nationwide if we are ever going to achieve the potential of virtual power plants (VPPs) to address utility load growth and reduce energy consumer bills. Utilities also need to implement Distributed Energy Resource Management Systems (DERMS) to take full advantage of their many customers implementing building decarbonization measures.

So, what about our home's energy performance? Implementing the four DEEDs resulted in solar PV providing 57% of our electricity supply with only 4.6 metric tons CO_2e energy-related emissions remaining. This carbon footprint is 42% below average according to residential carbon calculator estimates. HVAC energy use was 37% less than similar homes in our area based on vendor analyzed thermostat data. We are also able to deliver demand flexibility of 3.3 kW for two hours, which is equal to our base load without HVAC, pool heating/pumping, or EV charging. We are just waiting for a local VPP program to monetize those reductions.

ASHRAE has a unique opportunity to advance decarbonization, electrification, efficiency, and digitalization in residential buildings while simultaneously improving indoor health, resilience, and affordability. Encouraging and supporting our ASHRAE members around the world in proactively retrofitting their own personal residences and sharing their experiences within their communities is a great way to lead by example!