Net Positive Electricity:
Insights from Home, Church and City Projects

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Net zero building retrofits were identified in a Cal-IRES report as a key element of a renewable energy roadmap for Davis, California. In the past year I've had opportunities to smoke the devil out of the details of this vision. I purchased a PV system for our home, negotiated a solar electricity power purchase agreement for our church, and worked with a few like-minded colleagues to advocate for applying net zero as a standard for a new residential development in the city. In parallel, in the 2013 legislative session our state senator, Lois Wolk, successfully carried legislation that carved out 20MW for the city in a bill that mandates 600MW of "solar gardens" state-wide.

It's important to start this article with a bit of philosophy. For the lessons from my projects to be worth sharing, the projects needed to save money. Projects that don't save money simply don't provide broadly replicable experience. My premise, validated by the projects, is that it is easily possible, at least where I live, to make investments that have a good economic return and also add up to a strategy for carbon neutrality. "Add up to" is an important term, as I'll explain. There are no convenient silver bullets. Decisions need to be technically and economically informed, and most importantly, integrated. Fortunately, this is not as difficult as it sounds. Common sense is a reliable ally.

I took the time last year to analyze energy consumption and related carbon footprints of both our home and our church. My immediate purpose was to quantify the cost saving and carbon saving benefits of solar electricity. In both cases the numbers indicated comparatively good energy efficiency. So, solar electricity would be a logical next step, but only another part of a good start.

Studies to determine how our city could get to carbon neutrality had shown that 50% of our community carbon footprint was a result of personal vehicle use. So, efficiency and solar electricity might at least take care of the other half. Not so easily, though. I was surprised that so much of my home's and church's carbon footprints (75% and 60%) resulted from natural gas usage. Even so, we decided to go ahead with solar electricity as the next relatively easy and clearly cost-effective step in both cases, while starting to contemplate the further steps that would be needed on a path to carbon neutrality. The motivation for these further steps would shift from cost saving to carbon, but it would be important that they also pay for themselves over the life of any purchased equipment.

Driving an existing home's carbon footprint toward zero

As if to validate the importance of integrated thinking about a solar array for our home, I learned that our utility, PG&E, will not connect arrays that produce more annual electricity than historical usage. This is defensible in the context of concerns about "solarizing" inefficiency, to borrow a thought from my friend, Jan McFarland. But it may work against economically optimum grass roots climate action. Let me explain.

In our household, the batteries of our two hybrid cars were approaching the end of an impressive ten year lifespan. Our plan was to purchase one electric vehicle to replace one of the hybrids.

We would use the EV around town and on regular trips where recharging would be convenient. If we went ahead and purchased an EV, the utility's array sizing limit could be adjusted upward to account for estimated increased usage. So, we purchased an EV, and as a result we were able to "over-size" our array by about 20% to account for its expected annual electricity use. If our vehicles were newer, we'd have been faced with a choice of either a premature new vehicle purchase or an unnecessarily expensive two phase solar electricity investment. We avoided a personal need for a second phase. But hopefully, a second phase will be possible at some point anyway. As the photo suggests, the array covers only a portion of our south facing roof. You'll notice there is a lot more roof area available that could be used to produce net positive electricity.

What we are currently aiming for is net zero carbon, not just net zero electricity. It turns out that switching to solar electricity was just a good start. The electricity component of our household carbon footprint was only 40% of the total, with the other 60% attributable to the natural gas we use for water and space heating and cooking. Solar water heating is cost effective in many cases; it requires much less roof space per unity of energy delivered than solar PV, and there is a fair chance of finding a qualified local installer. (Makes me sort of wish we used more hot water, but as empty nesters we don't, so the economics are less attractive for us than for families with teenagers taking frequent, long showers.)

Space heating and cooking are more problematic. We like cooking with gas. Northern Europeans rely on hydronic space heating, making combined solar space and water heating a good retrofit option, but most US space heating is "forced air", meaning air is heated directly and then distributed around the home to heat its rooms. If bio-gas or hydrogen were distributed to homes, it would enable us to back out natural gas with more climate friendly fuels. This option is not on the horizon in our area.

The immediate option is to back out the gas we use for space heating using electricity, and to generate the electricity on our roof. It turns out we have enough south facing roof area for this. But the first step is to switch to electric heating before expanding our solar electricity system to cover the additional usage. We may or may not need additional panels.

This approach turns out to be a good idea for other reasons as well. Our heating, ventilation and air conditioning system was about 14 years old, has lost some efficiency over the years, and was a candidate for replacement. So, we just replaced it with a heat pump unit. The photo shows the outdoor heat exchanger. This should go a long way toward driving our everyday total carbon footprint closer to zero. Newer HVAC equipment is more efficient, plus duct leakage can eat away as much as 20-30% of heating and cooling energy inputs.

Our experience argues for more flexibility to at least temporarily generate more electricity than historical usage would require. Otherwise, climate conscious homeowners face the need for two

sequential solar installation projects, resulting in significant duplicative “soft” costs in cases where electricity usage needs to increase in order to achieve greater “decarbonization”.

Driving a commercial building’s carbon footprint toward zero

It turns out that our church faces the same sizing flexibility issues “in spades”. First, as an artifact of utility tariff design, the economically optimum solar array size does not result in net zero electricity. Our church is on a time of use tariff. This means that, with net metered solar arrays, we will get credit for electricity our solar arrays produce at prices we would have paid for the equivalent amounts of grid electricity. Our usage is weighted to daytime, so it is well matched to solar production profiles. As a result, we can reduce our grid electricity bill to near zero by sizing our solar capacity to generate only about 80% of our annual consumption.

Over-sizing our church’s solar arrays would result in being credited for "over-production" at PG&E's marginal generation cost, i.e. about 20% of the average price we pay them for what they sell us. Not a good deal. Sounds complicated, and it is, but it is how things work out with electricity tariffs that were designed before solar electricity became a cost saving option.

Our church’s new solar electricity array will reduce our church’s carbon footprint by about 25%, with most of the remainder attributable to our natural gas usage. So, it becomes clear, as with our home, that our church will have to take further steps to shrink its carbon footprint. We will need to consider retrofitting our multiple HVAC systems (different sizes, different designs, different ages). We’ll need a five year plan for the transition.

The good news is that our church, like our home, has plenty of roof space for additional solar. Its new solar array will be on a carport in the church parking lot, leaving most of our south-and west-facing roof space for additional solar arrays. The carport is a perfect site for an electric vehicle charging station or two. It is worth noting that the choice to build a carport for the solar array was actually economically and otherwise preferable to roof mounting. This adds to the weight of comparable experience from the UC Davis West Village net zero solar community.

Democratizing solar electricity

The question of our city's solar electricity portfolio is becoming more important as we work to determine how much of our electricity can come from solar and how much solar electricity must come from community "solar gardens" rather than systems behind electricity customer meters. In settled communities like Davis that have healthy “urban forests”, most existing residential buildings are not suitable for rooftop solar because of shading and limited roof space having the right orientation, etc. The good news is that commercial buildings require parking lots for their customers. Our church project demonstrates that mounting solar PV on shade structures is now cost-competitive with roof mounting. It is economically preferable in many cases even without considering the bonus of shaded parking, including energy saved by avoiding the need to cool hot vehicle interiors.

We are fortunate, thanks to the work of Mitch Sears, Mark Braly, and Richard Flood, to be in the early stages

of the DavisFREE project, which will, thanks to cost sharing with the California Energy Commission, generate a detailed renewable energy build-out roadmap for our city. As we seriously plan the best strategies to achieve our city's carbon neutrality goals, rules of thumb, untested intuition and expert advice all need to be validated by independent analysis.

Energy users are on a learning curve, and so it appears are our utilities and policy makers. It is becoming important for electric utilities to know their own costs, specifically which of their customers are getting a good deal at the expense of the others. There is quite a bit of misinformation in circulation on this point. I was surprised in a recent meeting to hear a state legislative aide assert matter-of-factly that the state's rooftop solar electricity customers are being subsidized at the expense of non-solar customers.

As noted in a previous IRESN article, this particular bit of conventional wisdom doesn't square with direct experience. In Davis the opposite appears to be true. Our utility's cost of wires connecting net metered customers is small in comparison to the value of solar electricity flowing into the grid from net metered customers rooftops during peak usage periods. As residential customers, we are credited by our utility for the electricity our solar array feeds into the local grid during peak periods at about $.013/kWh; meanwhile our church is charged $.045/kWh for its simultaneous use of electricity, including the electricity that spills into the grid from our rooftop.

As we enter a period of energy infrastructure transformation and policy re-alignment, we need to consider the source of our "facts". Some become "facts" through repetition and are not facts at all. We should be especially careful not to use them as a foundation for energy policy and market regulation. Do bad facts underlie bad policy? Would energy policy experts agree that the (fictitious?) cross-subsidization that so worries some electric utilities must be curtailed in due course? Rather, I hope that they will come to recognize that electricity service costs vary according to location and be wary of generalizations that are valid only in hypothetical situations, not in real life.

A dose of reality regarding local climate neutrality goals

Speaking of real life, our city has a nice piece of land that developers have been lusting after for quite a while. This year a proposal came forward to make it the site of a new neighborhood for about 500 residents.

Our city has a long term carbon neutrality goal. Naturally, some of us saw the new development as an opportunity to apply and build on the net zero residential development lessons of UC Davis' West Village. The developer apparently did, too, and hired a local energy efficiency consultant to scope the energy packages for the new homes.

It probably shouldn't have come as a surprise that, rather than designing to a net zero standard, the developer chose to make net zero an option at significant additional cost to the home buyer. The fact that, on a life cycle basis, net zero would be the best deal for all of the new homeowners, did not fit the developer's business model. Thanks to the conversation the Valley Climate Action Center (VCAC) initiated with the developer, at least some of the homes will have net metered solar PV arrays, albeit small ones in relation to average annual energy usage. In the context of the city's climate action plan, the outcome feels like an unfortunate missed opportunity.

Buildings hang around more or less unchanged for many decades. New ones that aren't the best they can be become a part of an overhang of excessive greenhouse gas emissions that is much more expensive to whittle down through retrofits than it would be to just avoid in the first place. The

unshaded roofs in the new development could have generated clean electricity, not just for residents in the new neighborhood but perhaps even a net amount to distribute to other electricity users in the city.

Net positive energy. We need to change our electricity systems so that net positive electricity production is encouraged, not prohibited.

Reality is that negotiations between cities and land developers typically revolve around concessions having nothing to do with a development's carbon footprint. Getting to carbon neutrality will be a heavy lift for a settled, low growth community where the overhang of existing buildings includes a high percentage of rentals. We obviously need a plan. Hopefully VCAC's DavisFREE Project will inform it, and community solar gardens will provide the low carbon electricity needed by new net negative buildings as well as existing net negative buildings.

This outcome is far from guaranteed. In our case the incumbent utility has proposed an alternative implementation of Senator Wolk's bill that would rely on "green tariffs" rather than enable community solar gardens as Senator Wolk envisioned. The green tariff model would essentially decouple solar electricity production from the communities whose residents purchase it. It would essentially set aside a portion of the solar electricity purchased anywhere in very large region for resale by the incumbent utility at a premium to electricity users that lack other access to solar electricity. Fortunately, the Sierra Club and some of our local energy policy stalwarts (Gene Wilson, Matt Cheney, and Richard McCann) have intervened on behalf of the legislation's intent. Their briefs and testimony on behalf of the Sierra Club make interesting reading, the disturbing implications of which are that some utilities will choose to defend the 20th century electric utility business model at all costs. This is somehow reminiscent of the US auto industry right before overseas competitors began selling us better cars at lower prices.

The importance of standards

In Davis we almost lucked out. Last year our Natural Resources Commission developed and sent to our City Council a proposed ordinance that would have flexibly mandated on-site renewable energy for new buildings and buildings undergoing major renovation. Had the ordinance been in place while the city was negotiating concessions with the land developer, negotiating positions would have been reversed, and the city would have been in a position to consider how best to apply its standard. Instead, the usual horse trading between local government and land developers used the usual bargaining chips.

So, one thing we learned the hard way is the importance of standards. Not just for Davis, but for all communities facing the need to account for energy in an economic and environmental sustainability context. It seems doubtful that eventual state net zero standards will do more than codify the energy efficiency metrics of new net zero buildings. New building energy usage profiles depend as much on occupant numbers and behavior as design. Specifying the sizes of solar arrays for "net zero" will be a long and contentious process. It may be better to de-emphasize net zero standards and focus more on standards for net positive and net negative buildings, both new and retrofit. In the trade-offs and balancing between net positive and net negative lies much of the potential to accelerate progress toward overall carbon neutrality.

This suggest an urgent need for a more comprehensive and pragmatic approach to net metering. Net zero is a standard that needs to be achieved on the average, not building by building. Some buildings can be net negative if others are sufficiently net positive. Our experience sizing a solar array for our home suggests that a lot of homes and commercial buildings can easily be highly net positive. This should not be news. Even in Germany where annual solar resources are less productive, "feed in tariffs"

have been very effective in capturing net positive electricity. The only thing standing in the way in the US is the lack of tariffs for net positive buildings. Let's get to work on this!

A community's unshaded roofs and parking areas are not just an energy resource but a sustainability resource that in most cases is vastly underutilized. Even in Davis where local solar installations already account for 3% of our electricity usage, we are just getting started. But we probably won't get far without standards.

Our city is taking first steps toward owning its own electricity distribution infrastructure. This may be the key to making maximum economic use of our unshaded roofs parking areas and brownfield sites. The ability to feed net positive electricity into the local grid will accelerate the rate at which we can deploy cost effective solar and shrink our carbon footprint. By a lot. Every roof or unshaded area that is fully used will mean a comparable area of agricultural or undisturbed land that won't be needed for energy generation.

20th century US electric utility models are a big stumbling block. In Davis our hopes for net positive electricity and virtual net metering standards may be dimmer than for other communities that are already being served by publicly owned utilities. There is growing interest in new utility business models. Publicly owned municipal utilities are in a position to take the lead in creating new business models. When they do, "integrated resources enabling sustainable communities" will be a reality, not just IRESN's tag line.