Becoming a Net Zero Carbon Congregation

A Church Community’s Decarbonization Journey

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April 18, 2021

Outline

- Introduction
  - Net Zero Carbon
  - Solar Electricity
- Steps to Net Zero Carbon for a Non-Profit Organization
  - Changes
  - Experience and Lessons
  - Energy Costs
- Net Zero Carbon Homes – experience and lessons
- Comments and Questions

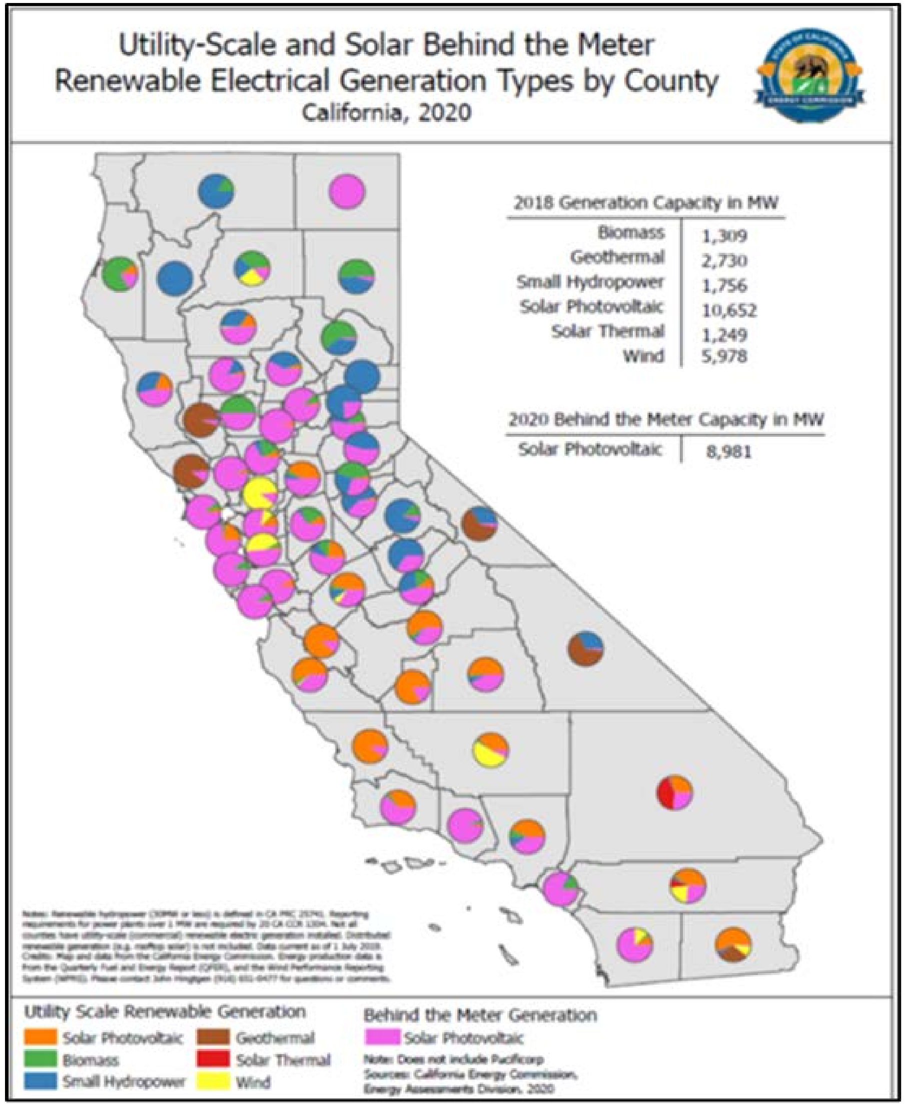
Net Zero Carbon

- For more than a decade, net zero carbon has been feasible and affordable standard for new buildings and new communities, as UCD’s West Village Energy Initiative demonstrated.
- US developers and builders include energy features that are mandated by local building codes. California now mandates net zero electricity, but not net zero carbon.
- Construction of new buildings causes building energy use and global greenhouse emissions to increase by two percent per year.
- Plus, 11% of global CO2 emissions are “embedded” emissions from building materials and construction.

Net Zero Carbon Village on the UC Davis Campus, Circa 2013

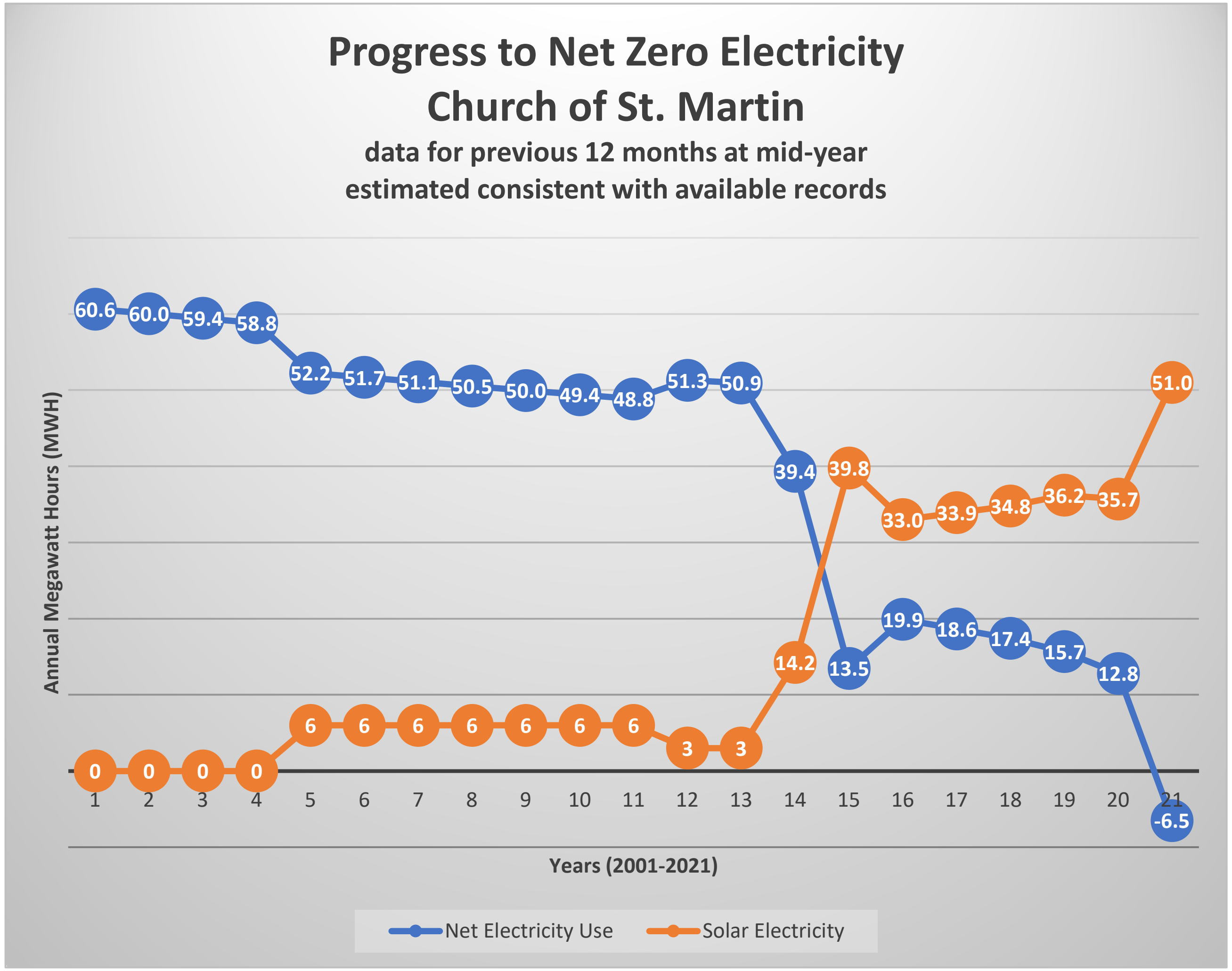
California Solar Electricity

- Bulk Power (> 20,000 kW) - Lower electricity production cost, high electricity transport cost, and project-specific environmental impact.
- On-site Power:
  - Residential (< 10 kW) – Higher electricity production cost, minimal environmental impact.
  - Non-residential (>10kW) – Medium electricity production costs, minimal environmental impact.
- The sum of residential and non-residential solar power capacity in California nearly equals the sum of bulk solar power capacity.



Net Zero Electricity is Key to Net Zero Carbon

- Three on-site solar arrays:
  - **Church Office Roof – 2004**
  - **Solar Carport – 2014**
  - **Classroom Building Roof – 2020**
- Church purchases the solar electricity from the carport - nearly 60% of total on-site production.
- Replaced gas appliances with heat pump appliances (2011, 2015, 2016, 2017, 2019, and 2021).
- COVID related usage reductions resulted in greater annual solar electricity production than electricity usage in 2020.



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Step 1 - Getting Started – Rooftop PV on Office Roof - 2002

Project experience highlights:
During bidder inspections in 2014, discovered that one of two inverters for the solar array had failed. Replaced both with one new inverter.

Step 2a - Restarting – Carbon Footprint Analysis – July 2013

- Three important uses:
  - Site electricity
  - Site natural gas
  - Water supply/delivery
- Energy use (gas and electric) determines a site’s carbon footprint
- Church campus carbon footprint:
  - Equivalent to 6-8 efficient Davis homes
  - 55.6% from site NG, 41.4% from site electricity

	lb/mo.	
Site Electricity	26195	41.4%
Water	1886	3.0%
Natural Gas	35174	55.6%
Total	63255	100.0%

Step 2b - Energy Usage and Cost -July 2013

Church administrator provided access to utility bills for analysis of energy usage and cost

- Whereas natural gas usage accounted for most of the campus carbon footprint, electricity accounted for nearly 80 percent of annual utility bills.
- Time of electricity usage determined its cost.
- Decarbonization was likely to shift peak net electricity usage more to winter months.

Diagnostic Data – Total Use (est.)

Aug 2011 through Jul 2011	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	**Year**		Aug
Net Energy Consumption		Summer				Winter					Summer				
Natural Gas	58	59	28	361	571	481	406	289	163	72	62	61	**2611**		62
Peak Electricity	940	1340	560	80	0	0	0	0	300	540	940	1180	**5880**		1580
Partial Peak Electricity	1180	1580	920	1720	2120	2120	1480	1480	1340	1100	1420	1500	**17960**		1820
Off Peak Electricity	1600	1760	1520	2960	3440	2880	2480	2080	2000	2080	2480	2560	**27840**		3040
Total Net Electricity	3778	4739	3028	5121	6131	5481	4366	3849	3803	3792	4902	5301	**54291**		6440
Net Cost															
Natural Gas	$80	$80	$51	$339	$524	$450	$185	$253	$135	$77	$73	$75	**$2,322**		$76
Electricity	$659	$938	$581	$666	$754	$663	$512	$463	$416	$566	$878	$1,012	**$8,108**		$1,327
Total Net Cost	$739	$1,018	$632	$1,005	$1,278	$1,113	$697	$716	$551	$643	$951	$1,087	**$10,430**		$1,403
Average price per unit															
Natural Gas	$1.38	$1.36	$1.82	$0.94	$0.92	$0.94	$0.46	$0.88	$0.83	$1.07	$1.18	$1.23	**$0.89**		$1.23
Electricity	$0.17	$0.20	$0.19	$0.13	$0.12	$0.12	$0.12	$0.12	$0.11	$0.15	$0.18	$0.19	**$0.15**		$0.21

Notes:
1. Energy units are therms and kWh
2. Summer peak is noon to 6 pm @ $0.445/kWk
3. Summer partial peak is 8:30am to noon and 6 pm to 9:30 pm @ $0.225/kWh
4. Summer off peak is 9:30 pm to 8:30 am @ $0.136/kWh
5. Winter partial peak is 8:30 am to 9:30 pm @ $0.151/kWh
6. Winter off peak is 9:30 pm to 8:30 am @ $0.127/kWh
7. Estimated cumulative solar generation to date is 40,000 kWh which would offset approx. $12,000 of electricity charges at current tariffs
8. Winter month solar generation assumed to be 25% of annual total, i.e. 1200 kWh based on 4 kW of peak AC generation at 1200 kWh/kW
9. Summer month solar generation assumed therefore to be 3600 kWh

Step 3 – 1st Solar Capacity Upgrade - 2014

- Non-profit organizations are not eligible for tax credits. Asked bidders to assist financing. Only one bidder offered power purchase and leasing options.
- Negotiated 25-year power purchase agreement (PPA) starting at $0.18/kWh with 2% annual escalation. PPA included penalties for annual underperformance.

Experience highlights:

- Successful bidder's finance model enabled choices. Economic benefits were highly sensitive to system performance.
- Equipment failures in early years impacted production. 2019 review of production data revealed consistent annual under-performance vs. PPA forecast.

Lessons:

- Closely monitor performance and equipment status in early years and later at least annually.
- Contractor estimates of annual performance may be inaccurate if contractor lacks solar technology training and certifications.

Note: Dry season array cleaning can boost annual production by 10% in dusty CA Central Valley.

Step 4 – Solar Electrified Space Heating

Electrifying multiple buildings required numerous space heating. Most heating upgrades relied on highly efficient mini-split units – see photo

- 2011: Heat pump HVAC installed in new gathering space foyer and replaced gas/electric HVAC with heat pump HVAC unit in one existing classroom building
- 2015: Replaced gas furnaces serving office area with heat pump HVAC unit
- 2016: Replaced gas/electric HVAC in three classrooms with mini-split heat pump HVAC units
- 2017: Replaced gas/electric HVAC serving gathering space with mini-split electric heat pump units

Lighting upgrades proceeded in parallel.

Experience highlights:

- Replacing gas furnaces with heat pumps did not increase annual electricity usage, probably because:
  - Efficiency of old units had likely degraded by as much as 30%
  - Reduced electricity consumption for cooling off-set increased electricity use for heating.
- Small but highly competent Sacramento company won all the bids and became a trusted partner.

Lessons: Always request competitive bids and keep warranty documents on file.

Step 4 – Goal Setting - 2016

- Net zero project proponents proposed that the church vestry (financial oversight committee) adopt a goal to reduce the campus carbon footprint to zero in roughly equal yearly increments over five years, by replacing remaining natural gas heating appliances and adding solar capacity or purchasing 100% zero carbon electricity from PG&E or the local CCA (Valley Clean Energy).
- The vestry objected to replacing "currently working/reasonably functional appliances". No goal was set.
- Within a year, a gas leak was detected in an and underground gas line on campus. Then, the large (20 ton) HVAC unit for the gathering space stopped working and needed to be replaced, causing considerable disruption to routine parish activity.

Experience:

- Some progress toward zero carbon continued while the church focused on bringing a new rector aboard.

Lessons:

- Political views regarding climate change were probably a factor in the vestry's response. It became clear that a more economically compelling case would need to be made before lay leaders could embrace a net zero carbon goal. (Many other northern California building occupied by non-profits are in rural areas where cost-savings and energy resilience may be stronger motivations for investment than decarbonization.

Step 5 - Restarting Again – Energy Usage and Emissions Review - 2019

A 2019 review of solar carport data indicated chronic annual underperformance, requiring determination of penalties and model updates. This led to a full update of energy usage, costs and emissions. GHG emissions had been reduced by more than 60% since 2012 resulting in $2000 annual energy bill savings.

Experience: Surprisingly, replacing gas furnaces with heat pumps did not increase annual electricity usage, probably because:

- Efficiency of old units had degraded
- More efficient electricity consumption for cooling off-set increased electricity use for heating.

Lessons:

- Contrary to “if it ain’t broke, don’t fix it” theory, it can make economic sense to replace aging gas appliances with solar powered appliances.
- Do the arithmetic. Sanity check energy billing and enforce PPA terms.

The Episcopal Church of St. Martin's Annual Energy Usage, Cost and Carbon Emissions			
	Initial (1)	Current (2)	Change
Usage			
Natural Gas (Therms)	2611	1002	-62%
Peak Grid Electricity (kWh)	4080		-100%
Partial Peak Grid Electricity (kWh)	14960		-100%
Off Peak Grid Electricity (kWh)	27840		-100%
Grid Electricity (kWh)	49491	19370	-61%
Solar Electricity (kWh) (est.) (4)	3000	32500	983%
Electricity Total (kWh)	52491	51870	-1%
Purchases and Self-Generation			
Natural Gas	$2,322	$1,121	-52%
Grid Electricity			
Purchases	$8,108	$4,060	N/A
Credits	$0	-$1,783	N/A
Net	$8,108	$2,277	-72%
Solar Electricity (24 kW Hooked on Solar Carport)	$0	$5,163	N/A
Solar Electricity (4kW Array over Office)	$0	$0	N/A
Electricity Cost	$8,108	$7,440	-8%
Energy Total	$10,430	$8,561	-18%
Average price per unit			
Natural Gas ($/therm)	$0.89	$1.12	26%
Grid Electricity ($/kWh)	$0.16	$0.20	25%
Solar Electricity Purchases ($/kWh) (3)	$0.18	$0.19	8%
GHG Emissions (lbsCO2)			
Natural Gas	35174	13493	-62%
Grid Electricity	26195	10150	-61%
Emissions Total	61369	23643	-61%
Notes:			
1. August 2011 through July 2012			
2. March 2018 through February 2019			
3. 2% per year price escalation after year 1 (July 2014 through June 2015)			
4. One of two inverters found to be inoperable in 2014			

Step 6. A Briefing, then a Way Forward

Following the progress review, interested community members attended a briefing:

- How much had investments to date reduced our annual energy bill?
- How close had we come to a net zero carbon finish line?
- What would it take to get the rest of the way?

The church's finance committee chair proposed a way to finance remaining steps. The leadership team got behind it.

Experience:

Remaining steps included:

- Replacing gas/electric HVAC for three classrooms and the church hall with mini-split heat pump HVAC units
- Installing an additional solar array on the classroom building
- Replacing the gas water heater in the kitchen area with a heat pump water heater

Lessons: The progress review stimulated fresh, pro-active thinking...especially about the opportunity to create a replicable model for other northern California churches in the same diocese.

Step 7 – 2nd Solar Capacity Upgrade – 2020

Second On-site Solar Production Upgrade

- Estimated system size to get to net zero, budgeted accordingly and requested bids.
- Selected low bidder (local area residential solar retailer.)

Experience highlights:

- 2019 installation required for system donor to capture maximum tax credits.
- High year-end business volume resulted in permitting delays
- Contractor inexperience with commercial system permitting and projects caused additional delays - for mounting system redesign and correction of documentation errors.

Lessons:

- Permitting of commercial and residential solar projects differ.
- Site surveys require engineering attention.

Steps 8 & 9 – More Solar Electrified Heating

- Step 7 - replacement of remaining gas furnaces in 2019.

- Step 8 - replacement of gas water heater with an electric heat pump unit in early 2021.

Project experience highlights:

- Expected gas usage to be near zero after furnace and water heater retrofits.
- Instead, we were still using nearly the same amount as before in non-winter months.
- Was there a gas leak? No, the commercial kitchen stove has pilot lights burn a $40 worth of gas every month, even if the stove is never used to cook anything.

Lessons:

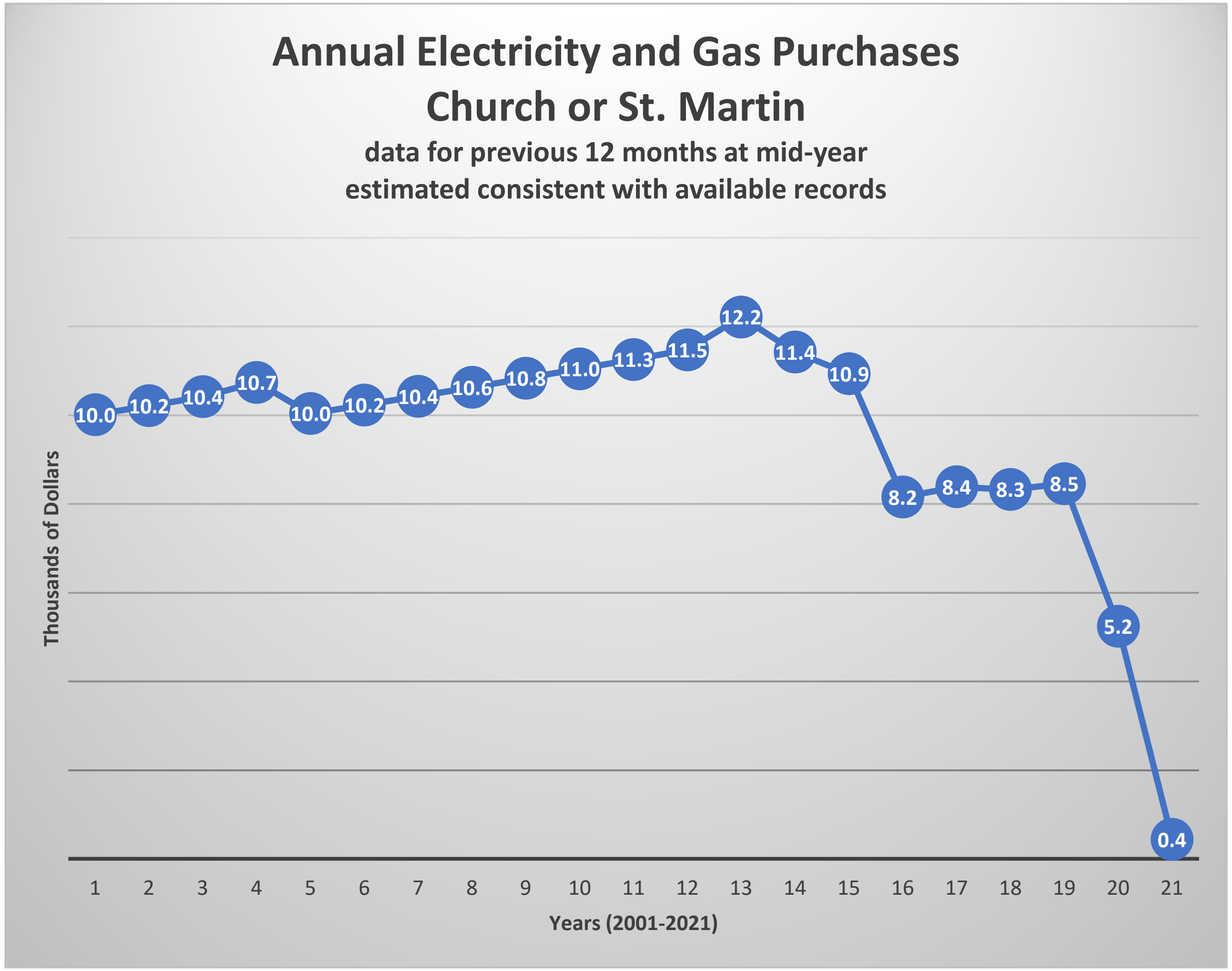
- Commercial stove pilot lights consume significant quantities of gas.

Still More To Do

- First, replacing the kitchen stove with a new gas stove having electronic ignition and switching to renewable gas when it is offered by PG&E.
- Longer term:
  - Aim to maximize economic benefits of zero carbon infrastructure.
  - Future consideration of energy storage and electric vehicle charging.
  - Thoughtfully monitor on-site energy usage and production.
  - Decide on participation in programs offered by PG&E and Valley Clean Energy
  - Clean dirt off solar arrays and thereby increase annual production by 10% and cost savings even more!

Net Zero Carbon Investments are Recovered in Roughly Ten Years

- Without on-site solar investment and purchase agreements since 2004, annual energy bill would have been roughly $15K in 2020 vs. a little over $5K.
- Outlays for HVAC electrification and solar retrofits over time, including parishioner donations, total more than $100K.
- Payback periods for new solar systems are typically less than a decade. Savings continue to accumulate after up-front costs are recovered.
- PG&E electricity rates have escalated moderately over two decades, but an 8% increase is expected in 2021, and further increases are likely. The situation is not stable.
- Increased solar electricity production and low usage in the past 12 months resulted in bill credits that will off-set 2021 solar power purchase costs. But resumption of normal parish operations will significantly reduce bill credits.



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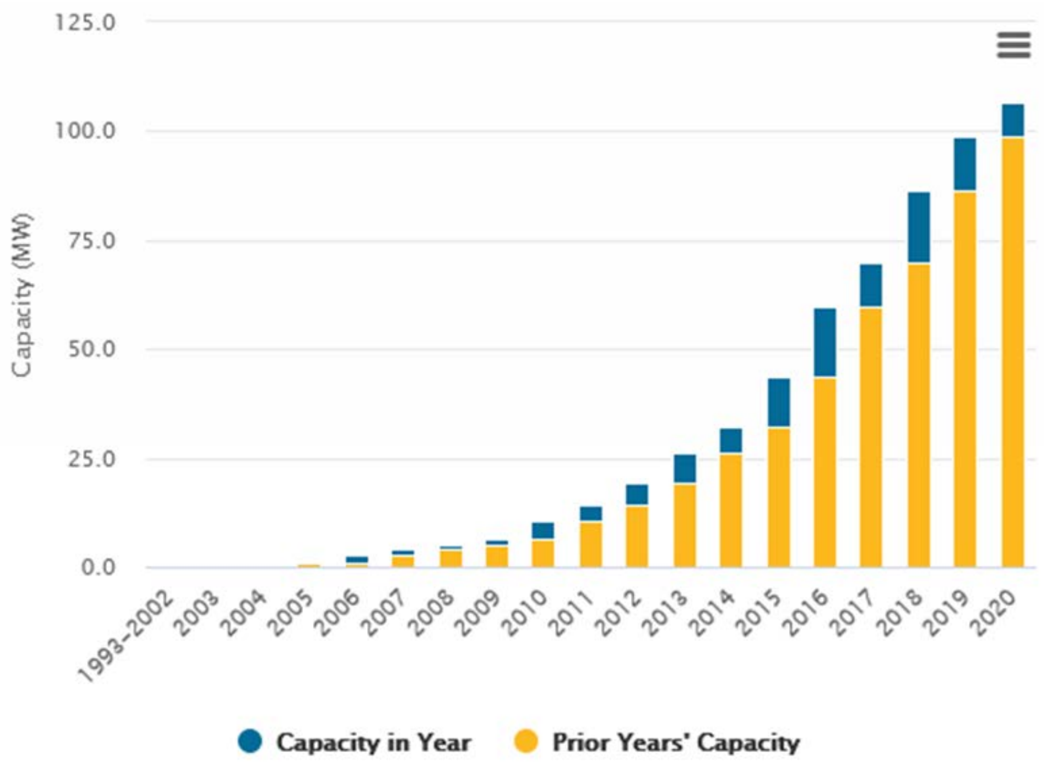
Motivation

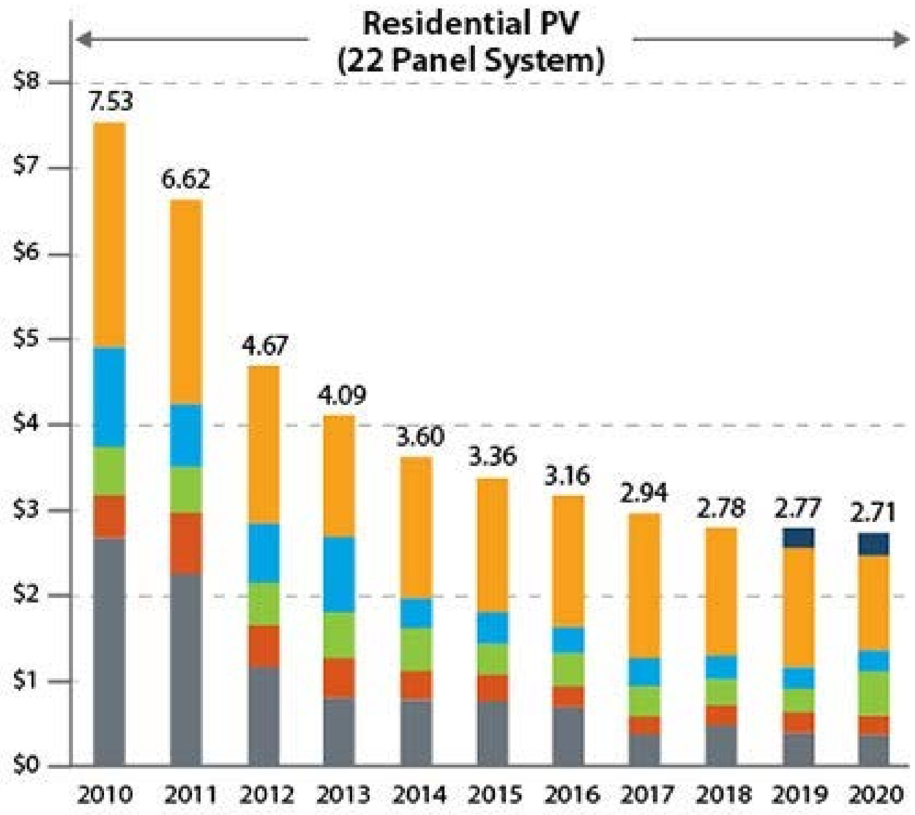
- Hoped to inform and inspire community members...and “catch the wave”.
- Some members did ask about solar for their homes.
- None asked about GHGs or electrification.
- Most who asked followed through (with solar) and are happy they did.
- Basic solar guidance offered:
  - Get three bids
  - Ask questions
  - Support local businesses that provide credible answers and competitive prices.

On-site Solar Capacity Build-up – Yolo County
55% Residential



Solar on Homes

- Retrofitting solar on existing homes costs more than including it during initial construction.
- However, thanks to cost reductions over the past decade, plus Federal tax credits, simple payback periods for solar retrofits in northern California can be as little as six to seven years.
- In California, annual housing unit additions are less than one percent of its current 14 million housing unit total. So, solar retrofits are key to timely building and facility decarbonization. They already cover 12% of current Yolo County electricity use.



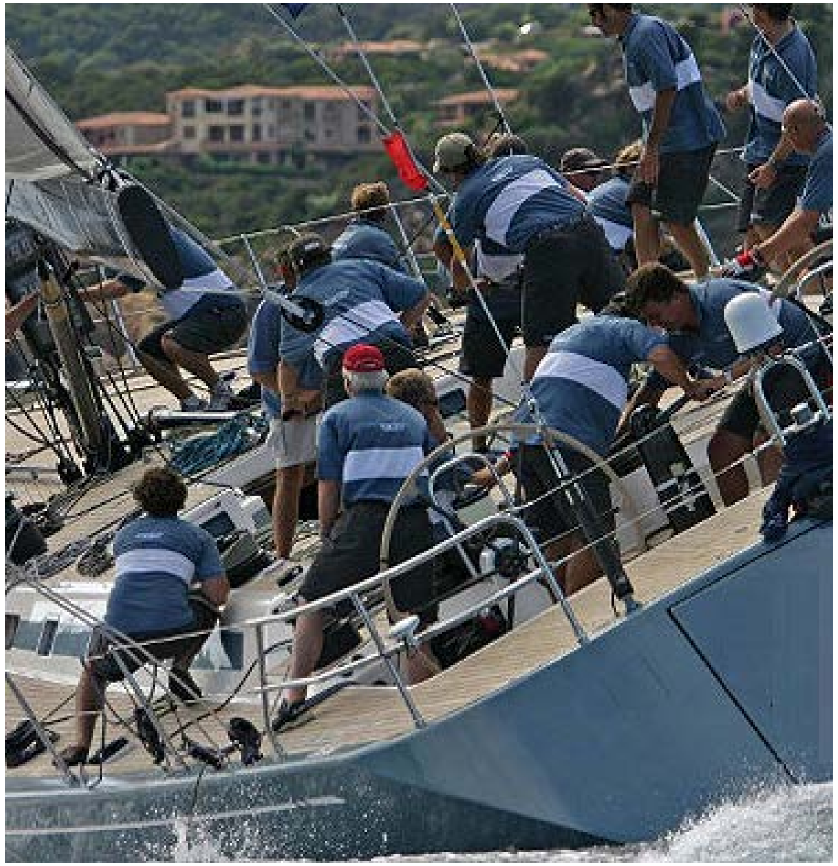
Installed Costs (per kW) of Residential Solar PV Systems in the US

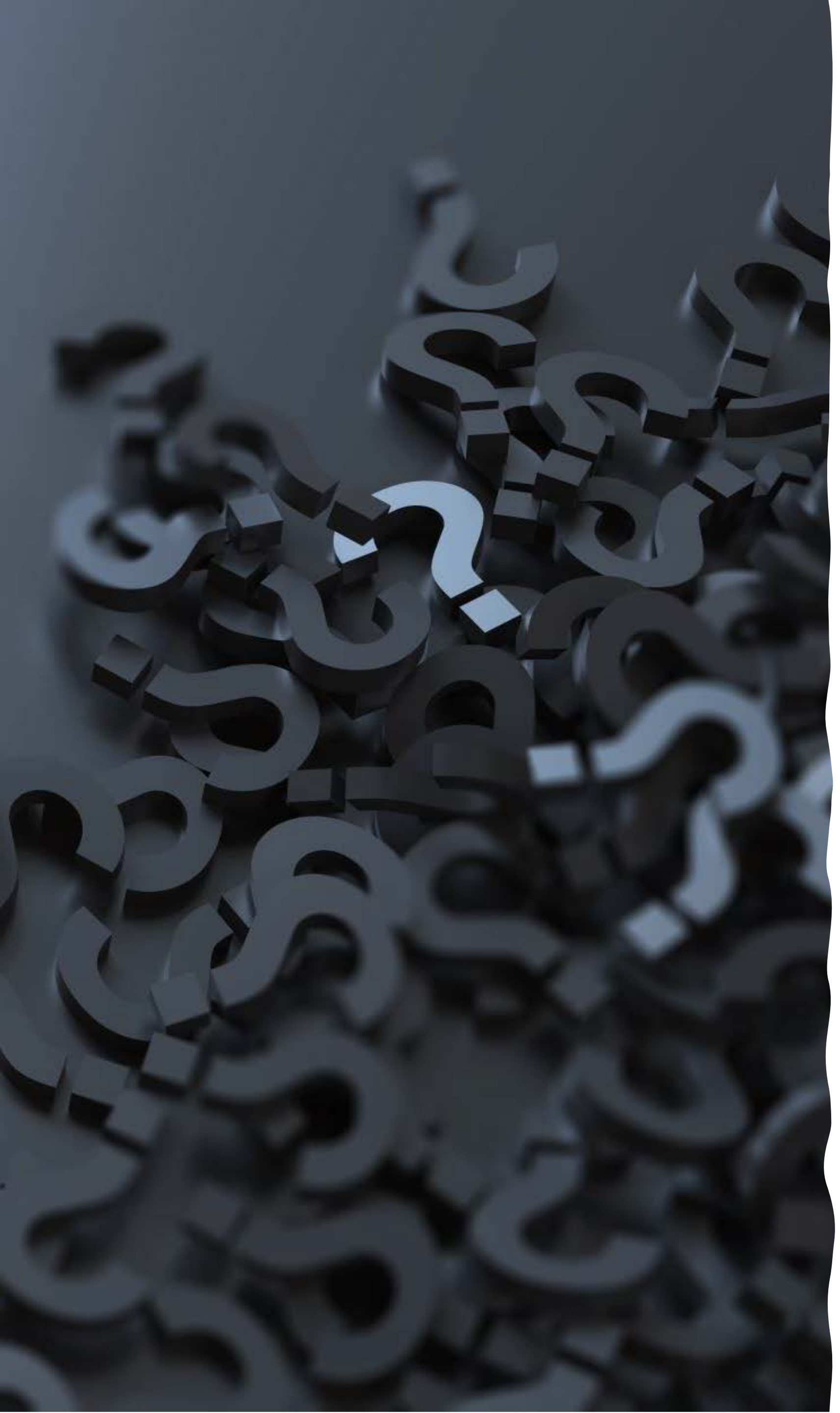
Solar Home Electrification

- Solar electrification of homes involves fewer steps than the church project did.
- Substituting solar electricity for heating and transportation fuels increases overall home electricity usage by about a factor of two.
- By rule, rooftop solar electric arrays are sized to match historical annual usage, not future usage. Two sequential small projects cost a more than one larger project. Under current rules it's best to retrofit space and water heating, then add solar a year later.
- In Davis, solar arrays on home roofs use one third to one half of unshaded roof space. They also provide shading that reduces heat gain and reduces electricity usage for cooling.

Community and Policy Context

- Total unshaded and code compliant roof area in most small to medium California cities suffices to produce more solar electricity than existing buildings require.
- 100% city or county decarbonization is technically feasible and affordable, would cost local governments almost nothing, while strengthening local economies, increasing property tax revenues and buffering communities from grid power cut-offs.
- The most hopeful response to climate change is “all hands on-deck”.
- Save money by saving creation. Save creation by saving money. Same message.





Thank You!

Comments?

Questions?

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