Electrification Feasibility Report and Plan for Trinity Church of Menlo Park

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Targets for Electrification

Trinity Hall Electrification Targets

Existing Gas Appliances	Recommended Electric Appliance
• Range with 6 burners	• One electric range with 4 to 6 induction burners.
• Range with grill top	• One electric commercial combination resistance grill and oven
• Double oven	• One double oven unit
• 80-gallon conventional water heater, 80 to 90 EF (efficiency factor)	• One Heat Pump Water Heater (HPWH) unit with at least an 80-Gallon tank, 3.4 COP or higher
• 40-gallon conventional water heater, 80 to 90 EF	• One 40-gallon HPWH for non-kitchen sinks and dishwasher in Wyatt room, 3.4 COP or higher
• Existing gas boiler, 80 to 90 EF, with cold make up water bringing the temperature to safe radiant floor ranges	• Hydronic System sized for 120,000 BTU to 150,000 BTU ○ Two to Three 5-ton inverter driven units, depending on design

Church Electrification Targets

Existing Gas Appliances	Recommended Electric Appliance
• 40-gallon water heater with 80 to 90 EF	• One 40-gallon Heat Pump Water Heater, 3.4 COP or higher
• Existing gas boiler (shared with Trinity), 80 to 90 EF, with cold make up water bringing the temperature to safe radiant floor ranges	• Hydronic System sized for 150,000 BTU to 180,000 BTU ○ Three Spacepak SIM 5-ton units, depending on design

Montgomery House Electrification Targets

Existing Gas Appliances	Recommended Electric Appliance
• 40-gallon water heater, 80 to 90 EF	• One 40-gallon (or larger) Heat Pump Water Heater
• Conventional gas ranges, four burners, one per apartment	• Two Four-burner Induction cooking ranges.
• Ducted furnaces in attic and basement, each serving one floor with heat. No air conditioning	• Heat Pump system for each floor sized between 40,000 BTU and 50,000 BTU, 14 SEER or higher ○ These can be housed on the ground floor and indoor ducted units can make use of the existing ductwork to deliver heat.

Angus Hall Electrification Targets

Existing Gas Appliances	Recommended Electric Appliance
• Gas boiler that feeds sinks in 1st and 2nd floors and the radiant floor, controls temperature of floor with make-up cold water	• One 80-gallon Heat Pump Water Heater similar to an Eco2 system that supplies 1st and 2nd floor sinks and the radiant floor
• 4-ton Air conditioning and ducted furnace with 80 to 90 EF	• Swap out existing air conditioning units (both are 4-ton units), with heat pump units of equivalent size, 14 SEER or higher (48,000 BTUh)

Rectory Electrification Targets

Existing Gas Appliances	Recommended Electric Appliance
• Ducted furnace in crawlspace, 80 to 90 EF	• One 3-ton Heat Pump unit
• Conventional gas dryer	• One 120V Electric Combination Condensing washer/dryer unit
• Conventional range	• One Electric induction stovetop/range if needed
• 50-gallon water heater, 80 to 90 EF	• One 40-50 Gallon Heat Pump Water Heater, 3.4 COP or greater

Background

Figure 1: Trinity Hall has high potential for photovoltaics.

Redwood Energy was contracted by Trinity Church in Menlo Park to deliver a feasibility report and plan for reducing natural gas use on its campus and adding a resilient microgrid so that the campus could be used as a shelter during grid outages. This document includes budget estimates for needed equipment and specific equipment recommendations to replace each gas appliance. This document is not a substitute for the specific design work of a mechanical contractor, but rather will serve to inform decision makers at Trinity and future contractors that the church may hire about some of the considerations involved in selecting appropriate electric equipment.

Redwood Energy Founder, Sean Armstrong, began teaching net-zero design in 1992 and before founding Redwood Energy completed 12,000+ hours as a Project Manager with affordable housing developers Pacific West Communities, Danco Communities, and the Redevelopment Agency of the City of Arcata. Sean developed the first 50% Net Zero Energy (NZE) apartment complex in California in 2005-2006, and the first three 80-100% NZE apartment complexes in California in 2012.

Addressing Climate Change with Building Electrification

Building electrification is an essential strategy for reducing human impact on Earth's climate and has the added benefits of improving energy efficiency, reducing operational costs as gas prices increase, reducing exposure to combustion gases and pollution that are linked to health concerns such as asthma, and avoiding the inherent explosive danger of piping a flammable gas into a closed space. Methane, which is the main ingredient in natural gas, is a potent greenhouse gas. By some scientific estimates, methane has a global warming potential 86 times greater than

carbon dioxide. Compounding the problem, methane leaks at fracking well heads and in gas pipelines have been found to be so common that natural gas is now believed by many to be as serious a contributor to climate change as burning coal. That means ridding our buildings of natural gas appliances must become an urgent priority if we are to address climate change.

The good news is that we can convert our buildings to all-electric with technology available off the shelf today and not give up on comfort or affordability. In fact, Trinity is not the first Episcopal Church in California to make this switch. The following is a quote from the Episcopal Church of St. Martin in Davis, CA, which recently completed its own full electrification project: *"By 2018, we reduced the church's carbon footprint by about 60%, annual natural gas bill by 50%, grid electricity bills by 75%, and overall energy costs by nearly 20%. This successful experience encouraged the church to consider additional steps to achieve complete carbon neutrality."*

Utility costs are often lower with modern electric appliances versus gas appliances. This is especially true of systems that take advantage of the "magic" of heat pumps. An electric heat pump will be 3 to 5 times as efficient as an existing gas boiler or furnace. Gas technology itself cannot be improved to match this. Since gas costs at Trinity represent a significant expense, almost $7,000 per year, converting to electric heat pumps for space heating has the potential to insulate Trinity against natural gas price increases and help the church avoid stranding assets once California ends the delivery of natural gas to buildings in order to meet the upcoming Paris climate goals.

Presented here are our findings and recommendations for four distinct but complimentary decarbonization projects the Church may wish to undertake: 1) building electrification, 2) installation of rooftop solar, 3) installation of a battery storage system for back-up power in outages and 4) installation of electric vehicle chargers for use by apartment residents, employees, and church members. You will see that bundling solar together with building electrification makes the latter quite affordable, with modest net investment.

Utility Expenses at Trinity Today

Table 1: Trinity's Average Annual Energy Cost taken from PG&E bill data.

Annual Energy Costs (average of years 2017-2020)			
	Gas Use	*Electricity*	*Totals*
Trinity Hall and Sanctuary	$ 3,972	$ 9,284	$ 13,256
Montgomery	$ 1,103	$ 3,058	$ 4,161
Angus	$ 1,234	$ 8,774	$ 10,008
Rectory	$ 552	$ 2,496	$ 3,048
Subtotal	**$ 6,860**	**$ 23,612**	**$ 30,472**

Adding new electric appliances and removing gas appliances will reduce Trinity's gas bill but will increase the electricity bill. The increase in electricity consumption can be offset by on-site solar

power. In residential applications cost parity is often seen because solar is so affordable and the electric replacements for gas appliances are so much more efficient.

Important Considerations

Figure 2: A 200-amp electrical panel, also called a breaker box.

Electrical Panel Capacity Availability

This constraint is common to almost any electrification retrofit project, and it boils down to one simple issue – we are asking the building's electrical system to provide us more power than it did before.

It is sometimes necessary for buildings to have their electrical panels upgraded to support full electrification. Our amperage analysis examined the extent to which such improvements would be needed. In Trinity's case, we determined that all but one building, Angus Hall, should be able to fully electrify without any increase to the building's electrical panel. For Angus Hall, the use of smart subpanels and other electrical load management systems may be sufficient to increase the available amperage to the system by reducing load coincidence. Following is an assessment of the amperage available on each building's electrical panel:

- Trinity Hall and the Church have a combined 473 available amps
- Montgomery Hall has 148 amps available
- Angus Hall has 96 amps available
- The Rectory's electrical panel was not available for evaluation

Our assessment is that Trinity Hall and the Church are unlikely to experience a power constraint issue, but Angus Hall may be power constrained and need a panel upgrade.

Heat Pump Technology

Remarkably similar in appearance and engineering to an air conditioner, a heat pump system contains one or more additional devices that allow it to reverse the flow of refrigerants inside. Reversing this flow has the effect of also reversing the flow of heat between the building and the outside world. This means that the same device can cool a building in summer and heat a building all winter long.

Figure 2: Example 5-ton Heat Pump Outdoor Unit

Figure 3: Example Hydronic System

Hydronic Heating Systems

Hydronic means heating with hot water. The term "hydronic", applies both to pipes in the floor and to fan coils that use hot water. Hydronic systems currently deliver heat through water in pipes to the heated radiant floors beneath Trinity Hall, the Sanctuary, and the labyrinth in the Chapel. These systems will be designed to utilize water temperatures between 85- and 100-degrees Fahrenheit.

Hydronic systems that use heat pumps to heat water take advantage of the high efficiency of heat pump technology. These systems have a low risk of refrigerant leaks because all refrigerant is located within the outdoor unit and water is used to transmit heat throughout the system.

The Hydronic Heat Pump products we recommend for replacing the gas boilers that currently feed the radiant floors throughout the campus do come with an option to cool spaces as well. The church could consider incorporating a radiant floor design that allows for hydronic cooling in the future. Although presently not common in homes, new commercial buildings often make use of hydronic cooling.

That said, the way Trinity's radiant flooring system is currently designed, major changes may be necessary to deliver cooling. That could include removing concrete floors in the Sanctuary and Trinity Hall and so may not be desired. Given the potential for significant disruption to church operations, radiant cooling was not included in this analysis.

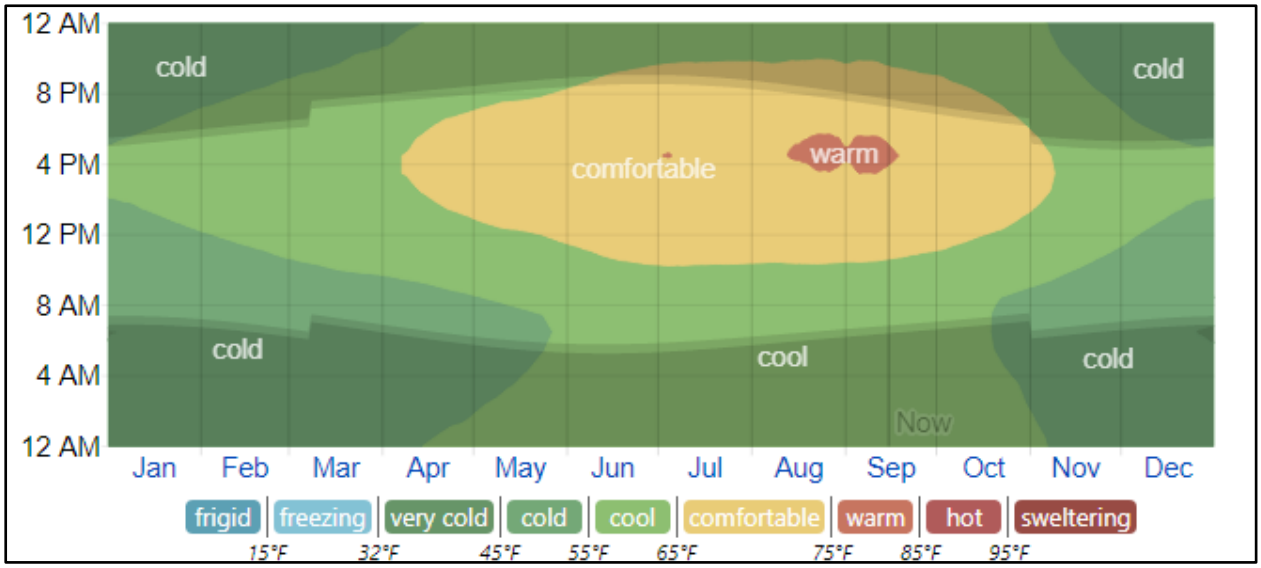

Figure 4: Historical Average hourly Temperature in Menlo Parkas of September 2020, courtesy of weatherspark.com

Climate Change

Menlo Park has a cool, dry Mediterranean climate and is likely to experience at least minor heat pattern changes due to climate change in the coming years. Changes to our local climate will be mitigated due to the persistent offshore effect of the California Current[1] which brings cool water from the bottom of the ocean to the surface. This cooling effect of the coastal waters of California means that coastal areas are less likely to experience extremely hot full summer seasons due to climate change.

However, due to increased climate variability, heat waves may be more likely and more intense[2], as has already been witnessed in early September of 2020 when temperatures reached 107 degrees Fahrenheit in Menlo Park. This suggests cooling may be desired as a resiliency strategy for supporting disadvantaged members of the community, who may not always have access to air conditioning at home, or during Public Safety Power Shutoff (PSPS) events. The State of California provides funding through its Self-Generation Incentive Program (SGIP) for battery storage projects that benefit the energy resiliency of disadvantaged communities. However, it is important to be aware that space cooling is energy intensive compared to the energy used for short term tasks such as cooking food, and so if battery storage is desired for resiliency during power outages, space cooling during PSPS events will increase the battery system size needed.

Products to Consider

[1] https://www.sandiegouniontribune.com/news/environment/sdut-taking-stock-california-current-2011jun18-htmlstory.html

[2] http://onlinepubs.trb.org/onlinepubs/sr/sr290many.pdf

General Electrification Products

Products have been selected as examples based on the needs of the Church and the list of gas appliances targeted for replacement on page two of this report. These represent the products that are best suited to the climate of Menlo Park and are available for purchase in the region as of Summer 2020. Many of these products are eligible for rebates and incentives in the Menlo Park area. Prices reflect those found on online stores and websites such as Home Depot and may be subject to change or differences between in-store and online purchase. Availability may also change as manufacturers deal with COVID-19 supply chain constraints. However, these products will be representative of the market in Fall/Winter 2020.

Induction Ranges

Induction ranges have been used for decades, with the very first introduction occurring at the Chicago World's Fair in 1933. More efficient and faster than their coil-based counterparts, cooks can use stainless steel or other magnetic cookware to cook a meal even faster than with gas. Cooking on electric or induction stoves also brings a significant reduction in the indoor air pollution associated with natural gas stoves.

The appliances chosen for the Trinity Hall kitchen are commercial-grade and professional and provide all the normal services needed for a high volume commercial kitchen. The range hood in the kitchen was not considered for replacement, because it is already electric. If a new range hood needs to be installed in the future, a leading manufacturer is Broan, which makes range hoods as quiet as one sone.

Commercial-Grade and Professional Induction Ranges and Resistance Grills

Make/Model	**Royal** RRE-GT36 	**Bertazzoni** MAST365INMXE 	**Verona** VDFSIE65SS 	**Viking** VIR5301 
Description	36" electric resistance range with 4 French plates, 36" griddle-top, and oven	36", 5-burner freestanding induction range with 5.9 cu. ft. Oven	36", 5-burner induction range with Oven 5.0 cu. ft	Commercial 30" 4-Burner induction range with 4.7 cu. ft. Oven
Breaker Amps	50A – 3 Phase	40A	50A	60A
Max Power	16,000W	15,000W	12,000W	13,200W

Voltage	240/208V	240/208V	240V	240/208V
Price	$7100	$4900	$5000	$7500
Selected in Budget	Yes, Trinity Hall Kitchen	Yes, Trinity Hall Kitchen	No	No

Commercial Double Convection Ovens

Make/Model	**Blodgett** ZEPHAIRE-200-E 	**Vulcan** VC44ED-208/1 
Description	Standing Double Oven Unit, 10 Pans, 500F	Standing Double Oven Unit, 10 Pans, 500F
Breaker Amps	60A	120A
Max Power	22,000W	25,000W
Voltage	208/240V	208/240V
Price	$9090	$8340
Selected	Yes, Trinity Hall Kitchen	No

Free-standing Home Kitchen Induction Ranges

Make/Model	**Frigidaire** GCRI3058AF 	**KitchenAid** KFID500ESS 
Description	30” Four Burner Induction Range, one Convection oven, Air Fryer setting	30” Four Burner Induction Range, Two Separate Ovens
Breaker Amps	40A	40A
Max Power	9,600W	9,600W
Voltage	240V	240V

Price	$1,300	$2,600
Selected in Budget	Yes, Montgomery House	No

The following cooktops can be utilized in a variety of ways because they are portable and make use of standard wall outlets. They also use less power than a traditional range cooktop and so would be especially useful during a power outage if the Church chooses to install back-up batteries, as they will drain batteries more slowly than a large range.

Induction Cooktops, 1800W Rated, 120-Volt

Make/Model	**Inducto** 	**Avantco** IC18DB 	**Eurodib** S2F1 	**NuWave** PIC Double 
Temp. Range	176°F -460°F	140°F -460°F	150°F -450°F	100°F – 575°F
Price	$150	$150	$200	$200
Location	These countertop products can use standard outlets to provide cooking area.			

Energy Storage and Resilience Ready Cooking – Optional Improvements

Make/Model	**Instant Pot** Duo Nova 	**Galanz** GL76S1E 
Description	6-quart Pressure Cooker	7.5 cubic foot compact refrigerator
Rated Power (Watts)	600-1000W	85W
Energy Use	0.021 kWh/day	0.95 kWh/day
Price	$89	$350
Location	Trinity Hall (for power outages)	

The above products have been selected because they will enable the church to significantly reduce energy use during power outages when compared to conventional appliances. Because they are much more efficient, they will reduce the discharge rate on a potential battery system, increasing the amount of time that can be spent off-grid. The refrigerator is smaller than most refrigerators but uses approximately one-third as much energy. Using efficient products with a battery system will extend the time that medications or food can be stored during an outage, while simultaneously freeing up more energy for cooking meals and keeping the lights on at night.

Heat Pump Dryers (240V) and one Condensing Washer+Dryer Combo (120V)

	LG WM3998HBA 	**Whirlpool** WHD560CHW 	**Whirlpool** WHD862CHC 
Type	Condensing	Heat Pump	Heat Pump
Energy Use (kWh/year)	120	460	Energy Star
Drum Capacity (cu. ft.)	4.5	7.3	7.4
Volts/Amps	120V/10A	240V/30A	240V/30A
Price	$2,000	$1,300	$1,200
Selected in Cost Analysis	Yes, Rectory	No	No

Above are two heat pump laundry dryer options that are energy-efficient and can handle large loads of laundry. Selected above is a good option for a condensing washer/dryer units that could be used in the Rectory. Washer/dryer combination units let you put your laundry in to be washed and dried all in one motion. Rather than having to movedamp laundry over to the dryer, users add dirty laundry to the machine and remove clean dry laundry at cycle completion, with no intermediate steps. This saves time and in apartments, tenants do not have to move each others wet laundry.

80-85 Gallon Heat Pump Water Heater Options

Make/Model	**ECO2** 	**Rheem** Performance Platinum 	**AO Smith** 
Description	Split Heat Pump Water Heater	Hybrid Heat Pump	Hybrid Heat Pump
Max Power (W)	2,990W	4,500W	4,500W

Voltage	208/230	208/240V	208V
Max Temp	145F	150F	150 F
Max Amps (A)	13	20.8	20.8
Breaker Amps (A)	15	30	30
Price	$ 3,400-3,500	$1,900	$1,850
Selected in Cost Analysis	Angus Hall	Trinity, Montgomery	No

Heat pump water heater systems are a highly efficient option to replace gas water heaters, and they also make use of heat pump technology to deliver hot water with less energy. The ECO2 model above uses a low global warming potential (GWP) refrigerant and employs a split system for greater efficiency. This system would be an appropriate choice to replace a water heater that feeds a small hydronic radiant floor and hot water to sinks.

In the 40-gallon size (shown in the following table), these appliances will deliver more than enough hot water to serve a single-family house or, at the Church, the hot water needs in bathroomsneeds. The Steibel Eltron unit above is a mini-tank electric resistance water heater that stores hot water at the point of use and uses electric resistance to help keep hot water flowing as long as is needed. The Rheem heat pump water heater tank is commonly deployed in affordable housing and multifamily buildings to deliver hot water for as many as three residents.

40 Gallon Heat Pump Water Heaters and Mini-tank Resistance Water Heaters

Make/Model	**Rheem** ProTerra 40 Gal.	**Hubbel** PBX	**Stiebel Eltron** SHC Series
			
Description	Hybrid High Efficiency	Hybrid High Efficiency	Mini tank, Point of use
Gallons	40	40-119	6, 4, 2.7
Voltage (V)	208/240	208/240	110/120
Dimension (in)	63H x 20.25W x 20.25D	49H x 28W x 28D	20H x 15W x 15D
Power (W)	4,500	4,400	1,300
In-Use Max Amps (A)	20.83	18.4	11.3
Breaker Amps (A)	30	25	15
Max Temperature	150F	160F	140F

Price ($)	$1350	Hydronic Specialties[3]	$ 230
Selected in Cost Analysis	Trinity, Rectory, Church	No	No

Ducted Heat Pumps (outdoor units shown)

Make/Model	**Bryant** Legacy Series	**York** YZH02412C	**Goodman** GSZC180481C	**Pioneer** DYC036GMFI18RT
				
Power (W)	1,800 – 5,000	2,500 – 3,412	4,840	2,200
Heating Capacity (BTUh)	18,000 – 60,000	18,000 - 59,000	22,000 – 59,500	33,600
Cooling Capacity (BTUh)	18,000 – 60,000	19,000 – 58,000	23,000 – 56,500	34,600
Price ($)	$2,000 - $4,300	$ 2,000 – 5,000	$ 2,500 – 5,600	$ 3,000
Selected in Cost Analysis	Angus and Montgomery Halls	No	No	No

The units above are examples of some of the most efficient and cost-effective ducted split heat pump systems on the market. The York product is particularly efficient and may be preferred over the Bryant because it has a variable speed compressor and does not make use of a crankcase heater. The Bryant system was selected for analysis because cost information had been provided by a local HVAC contractor, and it will deliver cost-effective efficiency based on the quote. Angus hall currently has a York branded air conditioning system and a switch to a York heat pump there could save installation costs. We recommend that you bring up these points with an HVAC contractor to get themost efficient system for your site at a competitive price.

Example Hydronic Heat Pumps

	Spacepak – SIM Inverter SIM036, SIM060	**Steibel Eltron** - WPL 57	**Aermec** - ANK030/045/050	**Transom** - HAP124W
				

[3] http://www.2hsc.com/residential-1/hubbell-1/

Heating Capacity (BTUh)	39,000; 56,300	101,000	38,000; 52,000; 58,000	124,000 – 259,000
Heating COP	<5.01, <4.67	3.3	3.6, 3.8, 3.9	1.84 – 3.53
Water Rate (gpm)	7, 13	-	8, 10, 12	36
Max Set Point (F)	130	149	140	180
Current (amps)	18, 21	37	14, 17, 18	30
Location	Trinity Hall and Sanctuary	Not Selected	Not Selected	Not Selected, useful for hi-water temperature heating

Companies like Spacepak and Aermec have developed Hydronic Heat Pump units that can be combined to provide hot water for radiant floor systems using more efficient, more powerful or higher temperature systems. Systems with inverter-driven compressors allow for water to be heated to a specific temperature without the use of make-up cold water.

Hydronic Heat Pumps may use one or more storage tanks that store the heated water so that there is a buffer between when the water is heated to when it is used. Mechanical design contractors will be able to determine whether these storage tanks are ultimately necessary. In some cases, the heating element inside the tank can be removed or taken off the circuit in order to reduce current draw, thereby relieving amperage constraints on the electrical panel. These supplemental heating elements can use a 15-amp circuit or a 30-amp circuit. Designers should be able to size the system with high accuracy in order to avoid the need for heating elements in the buffer tanks. Tanks generally come in a range between 40 and 80 gallons.

Figure 5: Spacepak brand, 80-gallon Buffer Tank

System design is a vital component of installing a hydronic system. The gas hydronic system in Angus Hall currently uses more energy than it needs to by raising water to a higher temperature than it is delivering, and adding cold supply water to reduce the temperature. An advantage of installing a hydronic heat pump system is that temperature control is generally more precise than with gas. System design may also consider the potential to increase overall system efficiency by placing the Hydronic Heat Pump Water Heaters closer to the recirculation loops or closing loops that are currently open loop systems.

Cost Analysis for Hydronic Systems

Table 2: Selected Hydronic-only system cost estimates.

Unit	***Tons***	***Manufacturer Unit Price***	***Distributor Price***	***Unit and Parts (subtotal)***	***Unit, Parts, Design, Labor (Final Cost)***
Spacepak Solstice Extreme	4	$7,000	$9,100	$9,900-$12,000	$15,800 - $18,700

Spacepak SIM Inverter 5-ton	5	$5,500-$6,500	$7,100-$8,500	$10,000-$11,400	$14,300- $18,200
Aermec 045	4	$5,000- $6,500	$9,800	$12,700	$17,575 - $18,575

These cost estimates have been developed in conjunction with manufacturers and suppliers, and informed by our experience working with partners in the field. Distributors generally charge a higher price than manufacturers, which means that working directly with a manufacturer and a willing contractor may be a way to save on cost.

Solar Photovoltaic Systems - Payback Potential

Rooftop solar power has gone from an expensive luxury reserved for eco-minded building owners to simply one of the best ways to save money on a building's utilities. Assuming the Church decides to electrify its buildings, adding affordable rooftop solar to the project will save the Church so much money that the savings can almost entirely underwrite the cost of the electrification. Inexpensive solar power will then offset the added electricity needs generated by the new electric equipment.

In order to determine the optimal size for the solar system, an analysis was performed using historical energy bill data to calculate the electrical demand of the Church's existing appliances. Existing gas appliances were modeled in comparison to their electric counterparts on an energy cost basis to determine what the new electrical demand would be. This wholistic approach captures both the avoided cost of natural gas and estimates the additional cost of electricity generated by new appliances.

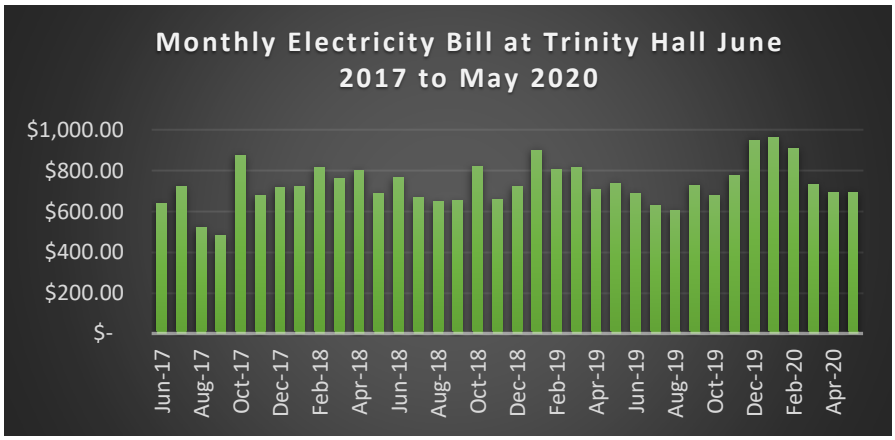

Figure 3: Historical Electricity bills for Trinity Hall alone. Because Solar Power is metered at the electrical panel by the utility, it is better to analyze cost at the building level.

This analysis did not consider the potential for rebates, tax credits or incentives that may be available for solar. We used cost information generateds from the System Advisor Model calculator from the National Renewable Energy Lab (NREL), an advanced version of the PVWatts

standard calculator used to set affordable housing project utility rates with solar panel offsets. All building solar analyses do not include the cost of a loan but use standard industry assumptions including a cost of $2.50 per watt installed for the solar system and a permitting cost proportional to the size of the system. While a 25-year lifespan is used for the system, photovoltaic systems are known to last decades beyond 25 years.

The solar analysis found that the building with the best overall potential net payback from solar power was Trinity Hall. Trinity Hall's solar sizing is limited as all grid-tied PV systems are by the National Electric Code (705.12(D)(2)). The 120% rule calculation from that code section yields a maximum sizing of 28.8 kWDC for Trinity Hall based on a panel size of 600 amps. This includes the Sanctuary because they share the same main electrical panel. The NEC calculation for the other three buildings yields a maximum system sizing of 9.6 kWDC each. A larger solar system that takes advantage of the large flat roof at Trinity Hall will require other interconnection methods such as a line-side-tap. A line-side-tap allows some or all of the solar to be interconnected on the utility side of the electrical panel, bypassing the busbar, and avoiding any possibility of of tripping the main breaker.

PV Cost, Production, and Payback Estimates

Table 3: $2.50/Watt Market Rate Solar Production Estimates

Building	System Energy per year (kWh)	System Capacity (kWDC)	Estimated System Cost at Market Rate	Estimated Utility Bill SavingsPotential in Year 1 ($/Year)
Trinity Hall *Option 1 (NEC Limit)*	41,000	27	-$68,000	$9,000
Trinity Hall *Option 2 (Past the panel)*	64,000	43	-$107,000	$10,100
Montgomery Hall	14,200	9.6	-$24,000	$3,000
Angus Hall	14,200	9.6	-$24,000	$3,700
Rectory	14,200	9.6	-$24,000	$2,600

Option 2 above for Trinity Hall offers financial benefits in utility bill reduction. However, as mentioned above, this larger system would require a line side tap, electrical work costing on the order of $2,000. Another option is to utilize some or all the solar capacity in conjunction with a smart Lithium-Ion battery system such as a Tesla Powerwall, so that the electrical panel only sees 27 kW of power, at most.

Table 4: Solar Potential Value Projections ($2.50/W)

Building	Average Yearly Power Bill by Building	Simple Payback Time	Power Bill Avoided Cost (Year 1)	Net Present Value in 25 Years (Net Savings)

	(2017-20 data projected at 5% rate of increase)			
Trinity Hall Option 1	-$9,000	8 Years	$8,900	$71,000
Trinity Hall Option 2	-$9,000	6 Years	$17,000	$160,000
Montgomery Hall	-$3,000	9 Years	$3,200	$26,000
Angus Hall	-$8,500	7 Years	$3,700	$34,000
Rectory	-$2,500	11 Years	$2,500	$17,000

Table 5: Solar System Net Present Value Payback Totals

Building	Total Net Present Value in 25 years with Trinity Hall Option 1	Total Net Present Value in 25 years with Trinity Hall Option 2
Trinity Hall	$71,000	$160,000
Montgomery Hall	$26,000	$26,000
Angus Hall	$34,000	$34,000
Rectory	$17,000	$17,000
Total Capital Cost	*-$140,000*	*-$179,000*
Total Net Present Value after 25 years	*$147,000*	*$236,000*

The Net Present Value of a PV system represents the bill savings and expected reimbursement at 25 years from a 4% discount rate, and a year-one electricity rate of $0.26. This is a conservative assessment that does not consider increases in electricity rates or Time-of-Use rates, which would improve the net present value of the system. This conservative assessment allows us to compare the cost of an electrification project at the campus to the most certain bill savings from the PV system.

Electricity rates have historically increased by 5 to 10% in PG&E territory, and if the church campus falls under a Time-of-Use rate in the future that may improve the cost effectiveness of a PV or PV+Battery system. Another method of improving cost is to seek bids with entities with tax liability to enter into a Power Purchase Agreement, which is something St. Martin's Episcopal in Davis chose to do[4].

Electrification Project Budget Estimate

The budget estimates on the following page are based on product information available online and from aggregated data from Sacramento Municipal Utility District (SMUD) and from our experience with advising development of Zero Net Energy apartments and homes. Kitchen appliance cost info came from retailers such as Home Depot and East Bay Restaurant Supply. Heat pump system cost estimates are built from SMUD data and quotes from local contractors. Hydronic system cost information comes from business relationships with hydronic installers and building developers.

[4] https://churchofstmartin.org/2020/07/16/st-martins-zero-carbon-achievement-lauded-by-ipl/

Location/Type	Description	Product Selection	Quantity	Equipment Cost	Wiring Cost	Installation Cost	Cost Total
Electrification Project Budget Estimate				**$109,010**	**$13,850**	**$105,560**	**$232,170**
Trinity Hall and Sanctuary				**$74,170**	**$5,750**	**$64,500**	**$147,170**
Kitchen	45-Burner Induction Range	Bertazzoni MAST365INMXE	1	$4,900	$500	N/A	$5,400
	Oven/Grill Combo	Royal RRE-GT36	1	$7,000	$500	N/A	$7,500
	Double Oven	Blodgett ZEPHAIRE-200-E	1	$9,090	$500	N/A	$9,590
Resilient Cooking Improvements	Induction Cooktops	Inducto	2	$300	N/A	N/A	$300
	Pressure Cookers	Instant Pot Duo Nova	2	$180	N/A	N/A	$180
Water Heating	80-Gal Heat Pump Water Heater	Rheem Performance Platinum	1	$1,900	$500	$2,100	$4,500
	40-Gal Heat Pump Water Heater	Rheem ProTerra	2	$2,700	$1,000	$4,200	$7,900
Trinity Hall Hydronic Heating	Hydronic Heat Pump Water Heater	Spacepak SIM-060	3	$23,100	$2,250	$29,100	$54,450
	80-gal Hydronic Buffer Tank	Spacepak AC-BT80-H	1	$950	$500	N/A	$1,450
Sanctuary Hydronic Heating	Hydronic Heat Pump Water Heater	Spacepak SIM-060	3	$23,100	$2,250	$29,100	$54,450
	80-gal Hydronic Buffer Tank	Spacepak AC-BT80-H	1	$950	$500	N/A	$1,450
Montgomery Hall				**$15,700**	**$3,000**	**$13,500**	**$33,200**
Apartment Kitchens	4-Burner Induction Range	Frigidaire GCRI3058AF	2	$2,600	$1,000	N/A	$3,600
Basement	80-Gal Heat Pump Water Heater	Rheem Performance Platinum	1	$1,900	$500	$2,100	$4,500
	5-ton Ducted Heat Pump	York YZH Series or similar	1	$5,600	$1,100	$4,900	$11,600
Attic	5-ton Ducted Heat Pump	York YZH Series or similar	1	$5,600	$1,400	$6,500	$13,500
Angus Hall				**$12,720**	**$3,000**	**$22,120**	**$37,840**
1st Floor	4-ton Ducted Heat Pump	York YZH Series or similar	1	$4,460	$1,100	$4,120	$9,680
2nd Floor	4-ton Ducted Heat Pump	York YZH Series or similar	1	$4,460	$1,400	$4,800	$10,660
Mechanical Room	83-Gal Heat Pump Water Heater	Eco2 System	1	$3,800	$500	$13,200	$17,500
Rectory				**$6,420**	**$2,100**	**$5,440**	**$13,960**
Water Heater Closet	40-Gal Heat Pump Water Heater	Rheem ProTerra	1	$1,350	$500	$2,100	$3,950
Crawlspace	3-ton Ducted Heat Pump	York YZH Series or similar	1	$4,070	$1,100	$3,340	$8,510
Laundry Area	Condensing Washer/Dryer	LG WM3998HBA	1	$1,000	$500	N/A	$1,500
Electrification Project Budget Estimate				**$109,010**	**$13,850**	**$105,560**	**$232,170**

Table 6: Utility Cost Comparison

Utility Cost Calculations for Fuel Switching for Trinity Church						
Building	*2017-2020 Average Annual Natural Gas Use ($/therms)*	*Average Annual Natural Gas Bill*	*Annual Energy Delivered to Buildings via Natural Gas (BTUh/yr)*	*Equivalent Annual Electricity Used (kWh/year)*	*What would it cost to operate Electric Appliances yearly?*	*Difference Electric vs Gas in Year 1*
Trinity Hall	**4,023**	**$3,972**	**260,712,000**	**27,289**	**$7,095**	**$3,123**
Angus Hall	**943**	**$1,234**	**61,106,400**	**6,396**	**$1,663**	**$429**
Montgomery	**1,026**	**$1,103**	**66,484,800**	**6,959**	**$1,809**	**$706**
Rectory*	**513**	**$552**	**33,242,400**	**3,480**	**$905**	**$353**
Totals	**6,505**	**$6,860**	**421,545,600**	**44,124**	**$11,472**	**$4,612**

The net increase in future utility bills from the electrification project is approximately $4,600 per year, which has the opportunity to be offset by solar power and is dependent upon the future of electricity rates and natural gas rates.

Table 7: Projected 25-year revenue changes from proposed projects.

	Business as Usual	Electrification Alone	Electrification + Solar	Electrification + Solar + Batteries	All Projects + EV Chargers
Capital Investment	$0	($232,170)	($411,170)	($599,870)	($646,510)
Annual Utility Energy Expenses	$30,472	$35,084	$8,509	$8,509	$7,283
Annual Utility Energy Savings vs. Business as Usual	$0	($4,612)	$21,963	$21,963	$23,189
Present Value of 25-yr Utility Energy Expenses	($476,036)	($548,084)	($132,931)	($132,931)	($122,984)
Present Value of 25-yr Utility Energy Savings vs. Business as Usual	$0	($72,048)	$343,105	$343,105	$353,052
Net Present Value of the Project vs. Business as Usual	$0	($304,218)	($68,065)	($256,765)	($293,458)

The above table describes the Net Present Value of each potential project option. The second column from the left describes the business-as-usual scenario for the Church projected 25 years. The Electrification Alone column describes the capital cost of the full electrification project in today's dollars, and projects the increase in the electricity bill out by 25 years as a present value. The Solar column adds the offset utility costs from installing the PV system outlaid in Option 2, which is the larger of the two systems, and the capital cost to install the system to project a present value of the project. The Battery column includes both previous projects and may be able to reduce costs further than we project above by taking advantage of Time-of-Use rates and powering the grid when energy is more costly. The EV charger project may be able to reduce electricity prices at the church if EV rates are extended to Small Commercial ratepayers, and the EV charger project may be able to offset some or all of its cost if a pay-to-charge service similar to Chargepoint is used as a passthrough for cost-recovery.

Trinity Hall and Sanctuary

Appliance	Estimated Investment	Location	Description	Replaces
80-gallon heat pump water heater	$4,500	Kitchen	Supplies Kitchen and Trinity Hall	80-gallon gas water heater
40-Gal Heat Pump Water Heaters	$7,900	Sanctuary and Trinity hall	One Supplies Side rooms at Trinity Hall, another Supplies Sanctuary Bathrooms	Replaces 50-gallon gas water heaters
Hydronic Heat Pump Water Heater Systems	$111,800	Sanctuary and Trinity Hall	Two Systems, one for Trinity hall and one for the Sanctuary, heats the buildings by distributing hot water	Replaces gas boiler, install outdoor units

4-Burner Induction Range	$5,400	Kitchen	Induction range with 4 to 6 burners that runs off a standard oven outlet	Replaces gas product in use
Oven/Grill Combo	$7,500	Kitchen	Grill top with oven beneath, runs off standard oven outlet	Replaces gas product in use
Double Oven/Warmer	$9,590	Kitchen	Double convection oven for baking for large groups, runs off standard oven outlet	Replaces gas product in use
Induction Cooktop	$300	Kitchen	Low-power cooktop that can be used with a battery back up in power shutoffs or for cooking demonstrations	New use case
Pressure Cooker	$180	Kitchen	Lowest power cooking device available, stretches battery life	New use case
TOTAL	$147,170			

Montgomery Hall

Appliance	Estimated Investment	Location	Description	Replaces
4 Burner Induction Ranges	$3,600	Laundry Room	Large Heat Pump Dryer to serve tenants at Montgomery house Apartments, may require wiring	Existing gas dryer
80-Gal Heat Pump Water Heater	$4,500	Supplies whole building	Supplies Kitchen and Trinity Hall	80-gallon gas water heater
5-ton Ducted Heat Pump	$11,600	Attic	Ducted split heat pump system that uses existing ductwork to deliver heat, refrigerant lines go from outdoor unit to units in the ducts	Gas Furnace
5-ton Ducted Heat Pump	$13,500	Basement		Gas Furnace
TOTAL	$33,200			

Angus Hall

Appliance	Estimated Investment	Location	Description	Replaces

83-gallon ECO2 heat pump water heater	$17,500	Angus Hall	Supplies 1st and 2nd floor sinks, and the radiant floor labyrinth	83-gallon gas water heater
Two Ducted Heat pump systems	$20,340	Outdoor units will replace existing A/C	Heat pump units that deliver heating and cooling to the building	Outdoor units will replace existing A/C, heat pump function replaces furnace. Refrigerant piped to units indoors will deliver heat and cooling
TOTAL	$37,840			

Rectory

Appliance	Estimated Investment	Location	Description	Replaces
40-Gal Heat Pump Water Heater	$3,950	Water heater closet	Small heat pump water heater for single-family home	Existing Gas Furnace
3-ton Ducted Heat Pump	$8,510	Crawlspace	Heat pump system sized for a home	Replaces furnace, adds A/C
Condensing Washer/Dryer	$1,500	Laundry room	Combined Washer and Dryer saves space	Gas Dryer
TOTAL	**$13,960**			

Power Storage and Estimates

Power storage sizing deeply depends on why the system is being installed. If you want to maximize grid power savings, you want to be able to deliver your whole electrical load to the buildings. That means a larger system that may often not utilize its full capacity. These systems generally last longer due to their size but come with higher capital cost. If you just want resiliency against power outages, a smaller system can be designed.

Because the solar resources happen to be the best at Trinity Hall, and there are several use cases possible if a storage system is housed there, our models were built around the storage being located at Trinity Hall. This location also enables the installed battery system to improve the size of the photovoltaic system installed at Trinity Hall, allowing electrical work necessary for both projects to be done at the same time and according to one design, reducing design and labor costs. The NEC 120 rule also applies to Battery systems, so a line-side-tap should be considered.

Power Storage

With the rise in Public Safety Power Shutoff events as well as unplanned outages, the appeal of resiliency is greater than ever. When an onsite battery system is paired with a Photovoltaic (PV) system, there can be potential for onsite generation of power during the day with use overnight. This would allow the Trinity community to continue to gather and utilize the facilities even during power outages, and the ability to provide shelter for those whose health and safety relies on access to electricity in daily life.

There are climate benefits in addition to the amenities provided by a battery system. Because solar panels only power the grid during the hours of sunlight, when the sun goes down, many utilities switch on natural gas powerplants. By being able to spread the energy generated by the solar panels over the course of the night, the owner can avoid purchasing electricity during highly carbon intensive (and more expensive) periods of the day. This cost saving measure can improve battery costs to such an extent that depending on Time-Of-Use (TOU) power rates, it is possible to offset some or all of the cost of a battery system. The Church is not currently on a TOU rate schedule, but this is likely to change in the future according to future state policy.

Storing energy also means having a contingency for when the grid goes down and sizing the system appropriately to what you need to accomplish when that happens is key. A large system allowed the Blue Lake Rancheria in Humboldt County.[5] to reduce the members' emissions by 175 tons and lower energy costs by $195,000, as well as saving at least 4 community members lives during Public Safety Power Shutoffs in 2019.

Battery systems need to include more than just a battery. All batteries store energy as DC power so batteries need to be installed with or include an inverter to convert the power to AC at 240 Volts, which is the type of power buildings and homes use. Installing a separate battery, inverter, solar connection, and power panel connection can increase permitting costs and installation costs when using outside installers.

Battery Market Leaders

	Tesla Powerwall 2	**Panasonic** EVDC-105	**Sonnen** Eco Gen 3.1
			
Power Output (kW-Continuous)	5	4.6, 5.5	3 to 8
Capacity (kWh)	13.5	11.4, 17.1	5 – 20 kWh
Round Trip Eff.	90%	89%	95%

[5] https://microgridknowledge.com/blue-lake-rancheria-microgrid-outages/

Inverter	DC-DC, AC-Coupling	DC-DC, AC-Coupling	DC-DC, AC-Coupling
Chemistry	Lithium Nickel Manganese Cobalt[6]	Lithium-ion	Lithium Iron Phosphate
Price	$7,600 (+ $3,500 install)	$15,300, $18,500	$24,870 (10 kWh system)
Location	Selected, For Trinity Hall	Not Selected for Analysis	Not Selected for Analysis

Connection Methods of Battery Systems

Although all the batteries shown above include an inverter that converts power from the battery to power that the building can use, there are other costs beyond the nameplate to consider. First is the consideration of using a subpanel versus not using a subpanel. A subpanel is a secondary electrical panel that runs only the circuits you want the battery to be able to power. A backup gateway will take those circuits on and off the grid as needed. This method often saves energy while using only battery power – but it comes at an increased installation and parts cost.

The other method is to connect the battery to the whole electrical panel. This could be a good strategy if there are personnel onsite who are trained to shut unwanted circuits off at the panel when the outage occurs, which would be a simple method of choosing which circuits receive power. This process would need to be done for the 400-Amp Kitchen subpanel and the two 100-amp subpanels and undone at the end of the Public Safety Power Shutoff or outage.

Controls and Grid Savings

Battery systems should include some form of time-based controls which automatically or manually allow the system to take advantage of lower power rates by supplying power back to the grid or to the building during high-rate periods. Energy storage is considered a generator under CPUC Electric Rule 21 and is subject to standard interconnection procedures. If Trinity Church decides to enter a Net Energy Monitoring Agreement, and the photovoltaic system is also under a Net Energy Monitoring Agreement, the Church as a customer will be subject to the Net Energy Metering Multiple Tariff.

Chemistry and Safety

Lithium iron phosphate (LiFePo) have a cycle life of upwards of 3,000 full discharges and can be expected to last between 12 and 15 years from installation. Warranties on systems generally last 10 years, and payback time often occurs well before the warranty is up on a Lithium iron phosphate system.

A common concern with batteries is fire risk. Lithium iron phosphate battery chemistry is by far the safest. Because it does not contain cobalt, lithium iron phosphate has low reactivity with

[6] Tesla may be working on new battery systems, TBA September 22, 2020: https://electrek.co/2020/06/24/tesla-reveals-status-roadrunner-secret-project-battery-production/

oxygen. If punctured, such as from an earthquake or sheer bad luck, the battery will not catch fire.[7]

Power Storage Estimates by Use Case

Storage System Option 1:

Resilient Kitchen, Minimal Plug Loads	Quantity	Product	Installation	Cost Total
Tesla Powerwall 2.0 13.5 kWh	**2**	**$15,200**	**$7,000**	**$22,200**

System sized to power at night off-grid at least 5 CPAP units, a resilient kitchen with Instant Pots and small refrigerators, and code standard for lights and plugs at 1000 square feet. Lights and plugs were modeled for being in use 5 hours a day, CPAP units for 10 hours a day, and cooking was modeled at 4 hours per day. No cooling or heating use. Two Tesla Powerwall 2.0 systems, and a total of 27 kWh would be installed.

Storage System Option 2:

Resilient Kitchen, CPAP units, Lights, Plugs	Quantity	Product	Installation	Cost Total
Tesla Powerwall 2.0 13.5 kWh	**8**	**$60,800**	**$28,000**	**$88,800**

Storage System 1 sized to power at night off-grid at least 5 CPAP units, a resilient kitchen with 5 Instant Pots and 2 small refrigerators, and code standard for lights and plugs at 6800 square feet, which is the full area of the Trinity Hall building. Lights and plugs were modeled for being on 5 hours a day, CPAP units for 10 hours a day, and cooking was modeled at 4 hours per day. Eight Tesla Powerwall 2.0 systems, a total of 108 kWh installed.

Storage System Option 3:

Resilient Kitchen, Lights, Plugs, CPAP, Cooling	Quantity	Product	Installation	Cost Total
Tesla Powerwall 2.0 13.5 kWh	17	**$129,200**	**$59,500**	**$188,700**

System sized to power at night off-grid at least 5 CPAP units, a resilient kitchen with Instant Pots and small refrigerators, and code standard for lights and plugs at 6800 square feet as above. Lights and plugs were modeled for being on 5 hours a day, CPAP units for 10 hours a day, HVAC at 16 hours/day and cooking was modeled at 4 hours per day. Seventeen Tesla Powerwall 2.0 systems, a total of 230 kWh would be installed.

Grant Potential

The Self Generation Incentive Program was developed by the State of California to support new and emerging clean energy resources, including storage. Storage provides utilities with added

[7] https://www.intellipower.com/images/Batteries/Advantages_of_Lithium_Iron_Phosphate_Batteries.pdf

flexibility and helps them keep rates lower, especially during times of high use. There are often grants that can be applied for through SGIP depending on the programs offered at the facility. These grants are separate from tax rebates. Depending upon qualifications, the grant could cover up to the full cost of the system.

Electrification Timeline Considerations

Included here are some considerations for the order in which the building electrification process can occur.

General Timeline for Process

Start with getting all the electrical work done first. If a given appliance fails before its expected lifespan, it will be important to have the electrical outlets needed available when that happens. Otherwise, a conflict between delivering needed heat, laundry, or hot water and reducing natural gas use could arise. If the hot water heater that serves the preschool were to fail before electrical work was done, the church would be left with the tough decision of whether to quickly bring warm water to the preschoolers or to wait a few weeks until electrical work is complete.

Do Solar as soon as possible – cost savings are immediate with or without financing. Although Trinity cannot take advantage of tax credits due to non-profit status, a business organization that does have tax liability or otherwise provides Power Purchase Agreements can take advantage of the tax credits, and this may be a good option to investigate to reduce capital costs for the system further in compliance with non-profit tax law. Redwood Energy does not provide legal advice.

Trinity Hall and Church Sanctuary

Due to their location, solar panels can essentially be installed regardless of other building updates. That said, it would simplify the design process and reduce potential conflicts if the solar and storage are installed at the same time. This is because of the potential to use shared inverter equipment between the solar and storage.

The biggest users of natural gas are the two large hydronic boilers systems for Trinity Hall and the Sanctuary. In terms of reducing impact on climate change, these would be a good first target. In terms of reducing pollutant impact on the health of people who use the Hall, replacing the gas appliances from the kitchen is another great step.

The radiant flooring and hydronic system design work will be a crucial first step and should occur before electrical work is done on this portion of the project. This design stage being done well will improve efficiency of the system and potentially avoid the need for cold supply water if possible.

Angus Hall

While Angus Hall does have a natural gas furnace that is more on the efficient side, it would be a quite simple installation for an HVAC contractor to replace that furnace with a ducted heat pump because there are already two air conditioning units installed that share ductwork with the furnace. This means far less ductwork and it makes much of the wiring and refrigerant piping easier.

Due to the remaining electrical panel capacity in Angus Hall, the panel will be able to include all products recommended, but the panel will be close to full capacity. This does not mean the panel will be fully loaded all the time, rather, the electrical code calculations estimate the load that may occur if all equipment happened to be running at once. The two air conditioning units are going to be replaced by heat pumps which will have a similar power usage to an air conditioning unit of the same size, and it is quite likely that everything will fit onto the existing panel with some room to spare. Because of the National Electrical Code load study methodology used to determine existing space on the electrical panels, we are unable to subtract out the existing air conditioning units from the data, but the panel math works out such that all the equipment we recommended will fit.

The ECO2 unit recommended to heat the radiant floor is a heat pump water heater that has a unit that sits outdoors to improve efficiency, similar in appearance to a mini-split system outdoor unit. This system can be used to run domestic hot water as well as a radiant flooring system. Designing a system that uses recirculation loops with the Sanden would improve efficiency, but in Angus Hall a designer may determine that a cold-water mixing system is better suited.

Montgomery Hall

Montgomery Hall has two natural gas furnaces that are polluters, but not on the order of the carbon emissions from the hydronic boilers in Trinity Hall and the Sanctuary. That said, if there is room to replace the one 40-gallon natural gas water heater with the 80-gallon Rheem product recommended, it will certainly be an upgrade to the tenants without much additional cost, and still help protect our natural resources. Timing the heat pump HVAC upgrades after or alongside any upgrades to insulation will help prevent oversizing the heat pump system. If the heat pumps are installed after or alongside insulation upgrades, the cost and size of the system can decrease, as well as its energy use.

Rectory

While a load study was not performed at the Rectory it likely has ample electrical panel space for the products recommended. While it only has a 120-Volt outlet in the laundry area, the 120V condensing washer/dryer combination unit recommended are more convenient and two can potentially share the same outlet depending on the outlet's rating and the house wiring. One is suggested for this project based on the understanding of the Rectory's laundry usage. This part

of the project is a typical single-family home retrofit that has the advantage of already having an electric stove. As with all parts of the project, competitive bids will be key to reducing costs.

EV Charging and Electrical Panels

Electric vehicles are here to stay, and they are rapidly appearing in the Bay Area. It was brought to our attention that Electric Vehicle charging was of interest, but not at an elevated level of detail. Below we provide quotes for installation in Menlo Park from Chargepoint, a service that installs EV chargers connected to an app and a network that would allow visitors to find the Church on a map and come for a visit.

Estimate for Installation of Three, Dual-Port Pedestal Chargepoint Level 2 EV Chargers*	
Design	$7,800
Permitting	$1,500
Load Study	$1,290
Labor	$15,500
Construction	$11,200
Electrical materials	$4,230
Asphalt Overlay	$4,200
Striping	$920
TOTAL BUDGET	$46,640

*Total of three chargers installed. Combined, they can charge six total vehicles.

The above estimate is for three EV charger systems which are dual port, allowing up to six vehicles to charge at one time. This is a lot of power, and the only panel that will have space for this after electrification is the Trinity Kitchen panel. The above estimate was delivered as part of conversations with an EV Charger installer who works closely with Chargepoint. This quote is considered a high estimate and includes specific requirements for updating parking lots like ADA requirements and other markings. Rebates for EV charging systems are available from local and state government entities.

EV Chargers and Fast Chargers

Make/Model	**Chargepoint** CT4025-GW1 	**Ossiaco** Dcbel 	**Bosch** PowerExpress 
Description	Dual Port Bollard Mount	Solar Inverter and Home-style wall EV Charger	Dual Port Bollard Mount
Power	7200W Dual Charging	22,000W between EV Charging, Vehicle-to-home, and PV Inverter	7200W Total Dual Charging
EVSE Level	Level 2	Level 2	Level 2
Price	$7,210 + Installation	$7,500 + Installation	$3,200+Installation

Another option is the dcbel by Ossiaco, coming to market in the US soon. This charger is both a solar inverter and an EV charger, taking the power from the photovoltaic system and converting it into either grid power or EV charging power. This would provide advantages such as combining some of the capital cost of a photovoltaic system with the capital cost of an EV charger system. It would also allow EV owners to provide backup power to Trinity Hall or another building in the event of a power outage, by taking power from the car and converting it to power that the building can use.

Subpanels and Smart Circuit Splitters

Make/Model	**Span** 	**Lumin** Smart Panel 	**Eaton** Pow-R-Command 

Price	$2,500 including installation costs	$2500 - $4500	$4000
Max Current (A)	200A Main Breaker 225A Bus	6 Circuits up to 60A	480V up to two poles
Description	• Replaces traditional electrical panel in the home • Can monitor and control electrical usage at the circuit level • Puts control into the hands of the homeowner with intuitive smartphone app • Plug in play solution for rooftop solar, battery storage and EV charging	• Real time balancing of battery use and charging • Manages renewable generation, energy use and storage • Dynamic switching of loads based on time of use rates • Off-grid mode sheds non-critical loads and islands • Can pair with batteries to create an integrated energy management system, removes requirement of a subpanel or protected loads panel • Programmable schedules to automatically control loads	• Control lighting and plug loads with time and space occupancy schedules to maximize energy savings • 15 A, 20 A and 30 A configurations in single- and two-pole models suitable for voltage systems up to 480V • Can add expansion panels up to 168 controllable circuit breakers

These are examples of products that can be deployed in the event of a need for a panel upgrade. A variety of capacities are shown. The lumin brand smart sub-panel pairs well with battery systems to make off-grid power management easier. A smart sub panel allows building managers to select which loads turn on and off depending on the building manager's preference.