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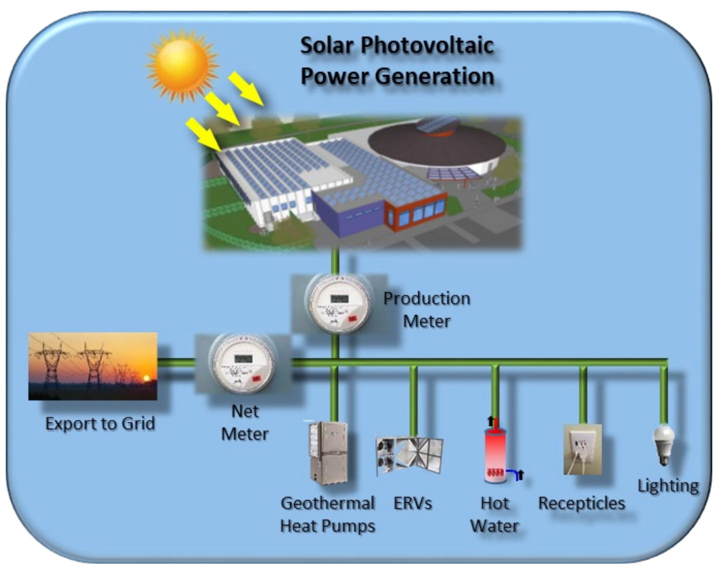
First Universalist Church Denver

Sustainable Energy System

Performance Report for First Two Years of Operation

2019, 2020



March 2021

Green First Task Force

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Preface

This story picks up where an earlier story entitled "**From the Ground Up: Transitioning a Faith-Based Facility to Sustainable Energy Using Solar Electric and Ground-Source Heating & Cooling**" left off. Hidden between the lines of this story – between the lines of these nerdy STEM[1] details - is an attempt to share experiences of First Universalist Church of Denver along their path toward a simple goal: Learning to live sustainably on a finite planet – trying to be in right relationship with all life.

Too often our built environments are still not designed, and constructed to be in right relations; as a result, the operation of these facilities causes harm to present and future life. Sharing experiences allows our collective consciousness to evolve – one small step at a time. We hope that the Lessons Learned at First Universalist can help others on their journey toward zero GHG emissions and Right Relationships to all forms of Life.

Within the blink of a geological eye, the human species walked out of Africa, trekked over (and populated) the entire planet, augmented their feet with hooves, extended hooves with wheels, enhanced wheels with wings and developed alternative forms of transportation,[2] learned to travel into space and left footprints on the Moon in the late 1960s.[3] What an astonishing journey this has been in the history of evolving awareness! So far. Each of these steps in evolving consciousness has been enabled by an increased expenditure in physical energy. The discovery of vast stores of ancient sunlight in Earth's mantle as concentrated forms of carbon & hydrogen allowed homo sapiens to move in the industrial age. And then motivated by the fear of losing the race to tap into subatomic weak and strong nuclear forces, multiple nations developed nuclear energy technology – a terrible responsibility toi be handed to such infants in dealing with diversity / differences / mass destruction It is simply mind-boggling what humans can accomplish when they collaborate.

STOP

And the converse is also true. Collectively we can cause enormous destruction. Although there have been numerous unheeded warnings of danger ahead, we continue our unsustainable behavior and today we are at the brink of an ecocidal precipice – about to slip over the edge and plunge into extinction.

and seemingly establish a form of dominion over most other living systems (species)

Climate scientists around the globe are telling us about this imminent danger using various dialects of the STEM language. There is no serious "debate" among real climate scientist that the behavior of humans, particularly over the past half century has initiated a change in the global climate. The quest for "truth" has been and hopefully

Democracy of interest parties

always will be the guide rails of science. "The whole truth and nothing but the truth" is a well-known mantra that reflects the innate tendency of the most living systems to explore and experience what is possible. Not all explorers return home safely, but those who don't usually leave valuable lessons learned. primary There is no question that dominated the what maybe most important human global issues facing humankind – actual all complex lie on Earth – since the last (5th) mass extinction.

[1] The acronym STEM stands for the disciplines of science, technology, engineering, and mathematics.

[2] Including wind powered sailing vessels, steam powered ships, early lead battery powered electric vehicles, internal combustion engine powered land vehicles and airplanes, and recently developed electric vehicles.

[3] Solar cell technology

Coronavirus Pandemic – a portal to imagining a better world

"And in the midst of this terrible despair, the pandemic offers us a chance to rethink the doomsday machine we have built for ourselves. Nothing could be worse than a return to normality.

Historically, pandemics have forced humans to break with the past and imagine their world anew. This one is no different. It is a portal, a gateway between one world and the next.

We can choose to walk through it, dragging the carcasses of our prejudice and hatred, our avarice, our data banks and dead ideas, our dead rivers and smoky skies behind us.

Or we can walk through lightly, with little luggage, ready to imagine another world… ready to fight for it."

--- Arundhati Roy

On the national scale, the appearance of the novel coronavirus in the US was met with a tepid response, a staggered state-by-state startup, and denial of a problem at the Federal level (as well as some state levels)

On the state level, public health officials reported the first two cases of coronavirus in Colorado on March 5, 2020. On March 10, Governor Jared Polis declared a state of emergency. A March 14 executive order closed ski areas. On March 22, Governor Polis ordered non-essential businesses to reduce the number of people physically present in the workplace by 50 percent. On March 25, Governor Polis put the state of Colorado in complete lock-down, with a stay-at-home order.

On the local scale, fortunately, the First Universalist Staff and Board of Trustees' responded to the corona virus in a timely, decisive manner that was consistent with medical science and the CDC guidelines. The staff and congregation immediately began practicing social distancing that minimized the probability of spreading the COVID-19 disease from one member to another. The staff immediately began using today's social media and virtual technology to continue the work of the church. In summary, the First Universalist response to this pandemic was exemplary.

So on Earth Day 50 (April 22, 2020), First Universalist Church was operating in a manner that was consistent with medical science. The facility was used on a limited basis until further notice for safety reasons. The parking lot remained nearly empty. The few staff members inside the facility practiced physical distancing. Sunday services were conducted virtually so members could remain at home as they sheltered-in-place and wait to receive their COVID-19 vaccinations.

We are at a portal … and opportunity to imagine another world

Pre-pandemic Background

In 2015, the Green First Task Force of First Universalist Church Denver (FUCD) proposed a new sustainable energy system be included in the Building for the Future (BFF) church renovation project. The goals were simple. Out of respect and reverence for the interdependent web of all life, the Green First Task orce proposed incorporating the current understanding of green building design practices into the renovation project. These green building practices included a transition to inexhaustible non-carbon energy sources (often referred to as renewable energy.) By installing a solar photovoltaic system to generate all the electrical power and a ground-source heat pump HVAC system to provide heating and cooling, the proposed energy system would stop dumping greenhouse gases into the atmosphere. If successful, FUCD could stop buying electric from Xcel Energy (generated by burning ancient hydrocarbons – fossil fuel) and operate the church using 100% solar electric. If successful, FUCD could stop buying natural gas from Xcel to heat the church building and instead heat and cool the renovated facility using thermal energy in the Earth below us. If successful, the renovated facility would be **fully powered by on-site renewable energy and be considered a Net Zero Energy building.** [4]

With the support of several Board Members, the Green First Team constructed a 'revenue neutral' funding model that provided the needed capital to purchase and install the new energy system without increasing the church operating budget. The Green First Team then secured the necessary capital in the form of member donations and low interest member loans. On November 6, 2016, the First Universalist congregation voted unanimously to incorporate a sustainable energy system in the ongoing BFF renovation project. The new energy system was installed and became operational in June of 2018.

After the first full year of operation, one member of the Green First Task Force suggested that a report be written documenting the performance of the new energy system. This seemed like an excellent suggestion because there was an early indication that the FUCD goal of Net Zero Energy was not being met. After the first six months of operation, there appeared to be a 5% shortfall in electrical energy production based on information from the FUCD installed eGauge monitoring system. So after a full year of operation, it was appropriate for someone to collect the annual data, evaluate the observations, and document the findings.

Two members of the Green First Task Force, who were involved in the BFF Renovation Project during the construction phase, set out to complete this task. What they found was unexpected. And they had no idea of how difficult this "year-end" report would be to compile and where their investigation was going to take them. The Green First Task Force was not involved in the operations of the renovated facility. Their role was limited to collecting operational data, evaluating the new energy system's performance relative to UU values and sustainable living goals and then documenting their findings.

Unfortunately, there was insufficient quantitative data available after the first year to recommend a specific path forward. There was still uncertainty about how much energy (kWh) the renovated church used/consumed during the previous 12 months (2019). There was some uncertainty about the accuracy of the Xcel Net Meter; it did not agree with the FUCD eGauge Metering system. There was even uncertainty about how to use the Xcel monthly bill to determine how much energy the building was using each month.

The investigative team identified what additional information (and monitoring instrumentation) was needed to understand and address the energy shortfall observed in 2019. The Green First Task Force then funded and installed nearly two dozen sensors at the subarray level to obtain additional performance data required to develop a specific Roadmap to achieve the Net Zero Energy / Zero GHG emissions goals.

But the Universe threw another curve ball. The Green First team was hoping to replicate the 2019 operations in 2020 with additional instrumentation that measured daily performance of the solar PV system at a more detailed level. Instead, the operation of facility and energy usage were dramatically reduced in response to the COVID-19 pandemic.

After the second year of operation, (albeit at a reduced level of activity and energy usage), they discovered that in 2020 FUCD had achieved all of the sustainable operational goals – albeit fortuitously:

1) Zero Net Energy (the facility produced more energy than it consumed),
2) Zero GHG Emissions (emissions had been reduced to nearly zero),
3) "Revenue Neutral" operation (i.e. the new renewable energy system was operating at a lower cost than the old fossil-fuel based system.)

[4] "Net Zero Energy" is discussed further in the Glossary. FUCD was not concerned about any industry awards or certifications. Our goal was to generate solar electric from the Sun's energy and harvest the Earth's thermal energy available on-site as the congregation needed to operate the facility.

But there was even more good news. The Congregational Carbon Footprint had been reduced to near zero in 2020. This report explains how that happened.

Perhaps the most important sections of this report are the "Recommendations" and the "Roadmap / Plans to Go Forward." The work is not done. But, the FUCD roadmap to zero GHG emissions confirms they are headed in the right direction. And they have a plan that completes the needed adjustments without increasing the church operating budget.

Milt Hetrick
Green First Task Force Reporter

...there is always light if only we're brave enough to see it,

if only we're brave enough to be it.

---Amanda Gorman,
Biden Inaugural Ceremony,
January 20, 2021

Executive Summary

The Building for the Future (BFF) renovation project of First Universalist Church Denver (FUCD) successfully accomplished its primary goals.[5] The Green First Task Force assisted the BFF building committee in identifying sustainability considerations for the renovation project.[6] It is estimated that about 10% of the BFF project's budget was dedicated to making significant changes in the energy usage of the facility including the installation of a sustainable energy system that uses solar electric and ground-source thermal energy for heating and cooling. The BFF design team (Barrett Studio Architects and DMA mechanical design) performed an energy analysis and predicted the new energy requirements for operating the renovated facility. The predicted energy requirements were then used to size the rooftop solar PV system and the ground-source heat pump HVAC system.

First Two Years of Operation the Renovated Facility with a New Energy System.

After the first full year of "normal" operation of the renovated facility (2019), it was possible to assess the energy usage and the performance of the new sustainable energy system. The new energy system appeared to be working properly, but the year-end summary was unexpected because the new system did not achieve the Net Zero Energy goal. At the end of the first year of operation, there were more questions than answers.

Nevertheless, the investigative team was able to answer several questions at the end of the first year of operation:

In this report, we ask and answer several questions:

1) ***Are we on the right path?***
2) ***Are we there yet?***
3) ***Where is "There?"***
4) ***When will we be there?***

Are we on the right path?

Yes.

Are we there yet?

No. But we have a Roadmap to get there.

Where is "There"?

From a global perspective, "There" is a global awareness that humans must stop adding greenhouse gases (e.g. CO_2, Methane,…) to the atmosphere.

"There" is a time when global human behavior no longer burns hydrocarbons as a source of energy and dump combustion products (aka greenhouse gases) into the atmosphere.

"There" is a point in human history when civil societies reward "negative carbon emissions" – behavior that **extract** carbon from the atmosphere and sequesters it for centuries even millennia.

Only when humans stop emitting greenhouse gases will the Keeling Curve[7] begin to flatten out and the laws of nature curtail further global warming/climate change. Only when humans begin extracting carbon from the atmosphere and the Keeling Curve starts downward toward the pre-industrial level (i.e. 280 ppm) will further extinction of living species be prevented.

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[5] Renovation Goals included: Fix a leaky roof, enlarge the sanctuary, replace all windows, add insulation to walls and roof, install LED lighting, and install a sustainable energy system. The new energy system utilizes a solar PV system intended to generate all electrical power needs, and a ground-source (geothermal) heat pump system replaced 10 natural gas burning furnaces for heating and cooling needs.

[6] Details of the renovation project were documented in **"From the Ground Up: Transitioning a Faith-Based Facility to Sustainable Energy Using Solar Electric and Ground-Source Heating and Cooling,"** by The Green First Task Force, First Universalist Church Denver. 2019. ISBN-13:978-1-0866-0744-4

[7] The Keeling Curve is merely a record of the amount of CO_2 that is in the atmosphere measures as part per million (ppm). As of 2020, if you have 100 molecules of "air," and separate out the CO_2, there would be around 415 CO_2 molecules (I.e. 415 ppm.) Further discussion of the Keeling Curve can be found in Appendix A.

From a local perspective, "There" is when FUCD acknowledges its own Keeling Curve and takes responsibility for it. "There" is when our individual and group behavior as a faith-based organization is in right relationship with our planet's life support system.

The renovated facility and increased awareness of environmental injustices has brought FUCD much closer to "There."

When will we be "There?"

That depends on our congregation.

According to the IPCC (global climate scientists), to limit global warming to less than 2 deg C, the Laws of the Universe indicate the global community must be 50% of the way to zero GHG emissions by 2030; then arrive at zero emissions around 2040. FUCD has chosen IPCC Path P1. See Appendix B for a detailed description.

Hopefully, FUCD can continue to serve as a positive example in the local community and be at Zero GHG Emissions well before 2040.

The proposed FUCD Roadmap to zero GHG emissions is in compliance with the IPCC global guidelines.

The reputation and goodwill of an organization is a function of the behavior of the individual members of the organization. So the FUCD Roadmap to zero emissions is in part dependent on the plans of individual church members. The Green First team is urging all members to acknowledge that their life style reflects on the church.

> **Example:** Personal plans to reduce GHG emissions influence/ affect the church plan to reduce its carbon footprint. If members plan to drive a gasoline car to attend church services and other church related events, then those GHG emissions are assigned to the church carbon footprint. If the church did not exist or was not having services, then those GHG emissions would go to zero and the church carbon footprint would be reduced as well.

Ironically, the COVID-19 pandemic in 2020 has shown us one path to Net Zero Energy / Zero GHG Emissions.

Summary after Two Years of Operation.

After the first year of operation, the following observations were made:

- **The new Energy System (i.e., solar electric; ground-source heat pump heating & cooling) does not emit greenhouse gases and operates successfully without doing harm to the interdependent web of Life.**
- Operating First Universalist Church Denver in 2019 resulted in a significant carbon footprint because:
  - **FUCD missed the Net Zero Energy goal for the Energy System by 43%. *The reasons are understood and can be remedied***
    - The renovated facility consumed 98,019 kWh in 2019
    - The solar PV generated 68,630 kWh
    - There was a 29,389 kWh energy shortfall, so FUCD purchased 29,389 kWh from Xcel at a cost of $6,450.
    - Xcel burned fossil fuels to generate 72% of the power sold to FUCD and dumped 20 metric tonnes of GHG into the atmosphere
    - The renovated facility did reduce the FUCD GHG emissions by over 85 metric tonnes, but missed the Zero GHG emission goal by 20 tonnes. *The reason is linked to the energy shortfall and will be remedied.*
  - Most FUCD members, staff & renters travel to church using vehicles that burn gasoline – a carbon based energy source. **These transportation GHG emissions become part of the FUCD carbon footprint and are estimated to dump 35 metric tonnes / year into the atmosphere.** This document proposes a plan to eliminate transportation-related carbon emissions over the next decade.

- FUCD prepares ethical food onsite unethically by using a stove/oven that burns natural gas. **In 2019, the eight burners and their pilot lights used 470 therms of natural gas that cost $720 and dumped 5 tonnes of GHG into the atmosphere.** This document proposes an electrification plan to eliminate the food preparation carbon emissions within the next decade.

- **FUCD missed the Revenue Neutral goal by a mere 0.2%. *This will be reduced when the energy shortfall is eliminated***
  - The goal was to make this transition without significantly changing the church operating budget.
  - The church annual operating budget of $770,000 was increased by $1820 by transitioning to sustainable renewable energy. (0.2% of the total budget; 9% of the "Utility" budget).
  - Reasons for the slight increase in operating expenses are understood and suggested remedies are found in Appendix C.

After the second year of operation, the following observations were made:

- **The new Energy System continued to operate successfully without doing harm to the interdependent web of Life.**
- Additional eGauge monitoring equipment was purchased and installed by the Green First Task Force. It is now possible to measure/monitor the production of the solar PV system at the subarray level.
- The additional performance data quantified how much shading and weather reduce the FUCD solar PV system output from theoretical predictions.
  - Tree shading reduces system output by 4%
  - Structural shading reduces output by 2%
  - Using the PVWATTS default weather model (as the Green First team did) over predicted production by 10-12%.
- Operating First Universalist Church Denver in 2020 resulted in a near zero carbon footprint because:
  1. **FUCD achieved the Net Zero Energy goal in 2020**
     a. The renovated facility consumed 66,731 kWh
     b. The solar PV system generated 68,958 kWh
     c. There was a 2,227 kWh energy surplus.
     d. Xcel did not burn fossil fuels to generate power for FUCD. There were no GHG emissions linked to electric power or heating and cooling
  2. The parking lot contained only a few gasoline powered vehicles so the transportation related carbon footprint was reduced to near zero
  3. FUCD did not prepare food onsite in 2020. However, the eight pilot lights on the gas stove flames burned the entire year, used 470 therms of natural gas, cost $720 and dumped 5 tonnes of GHG into the atmosphere.
  4. FUCD reduced its GHG emissions by over 135 metric tonnes compared to 2016 emissions,
  5. FUCD achieved the Revenue Neutral goal. The renewable energy system cost $412 less to operate in 2020, than the fossil fuel energy system in 2016.
     a. The goal was to make this transition without significantly changing the church operating budget.
     b. The church annual operating budget of $770,000 decreased by $ 412 due to less energy usage (-2% of the "Utility" budget, -0.05% of the total operating budget.

Has the BFF Renovation Project Reduced the FUCD Carbon Footprint?

Yes. Dramatically. As discussed in a separate chapter of this report, the carbon footprint of FUCD has been reduced to an all-time low (as of early 2021). The FUCD carbon footprint is currently around 10% of what it was before the BFF renovation. A part of that reduction is permanent (e.g. the 10 natural gas burning furnaces were replaced by 10 ground-source (geothermal) heat pump furnaces; a 57 kW solar PV system has been installed on the roof). A part of the reduction is temporary because the church is being used less in response to the COVID-19 pandemic. Temporarily, the energy usage of the church is less than normal and the parking lot is nearly empty of gasoline powered cars. As a result, FUCD is not importing/buying energy from Xcel and therefore Xcel is not burning any carbon to produce the energy needed to operate the church. However, this is only a temporary situation. As the community becomes vaccinated for COVID-19 and church operations return safely to a new normal, it is expected that energy use will trend back to the 2019 level.

A plan to Reduce the FUCD Carbon Footprint to Near Zero

Is there a Roadmap or plan or reducing the FUCD Carbon Footprint to Near Zero? Yes. A summary is provided below. Details are provided in a separate section of this report.

The FUCD 'Carbon Footprint' before and after the BFF renovation is illustrated in Figure 1.

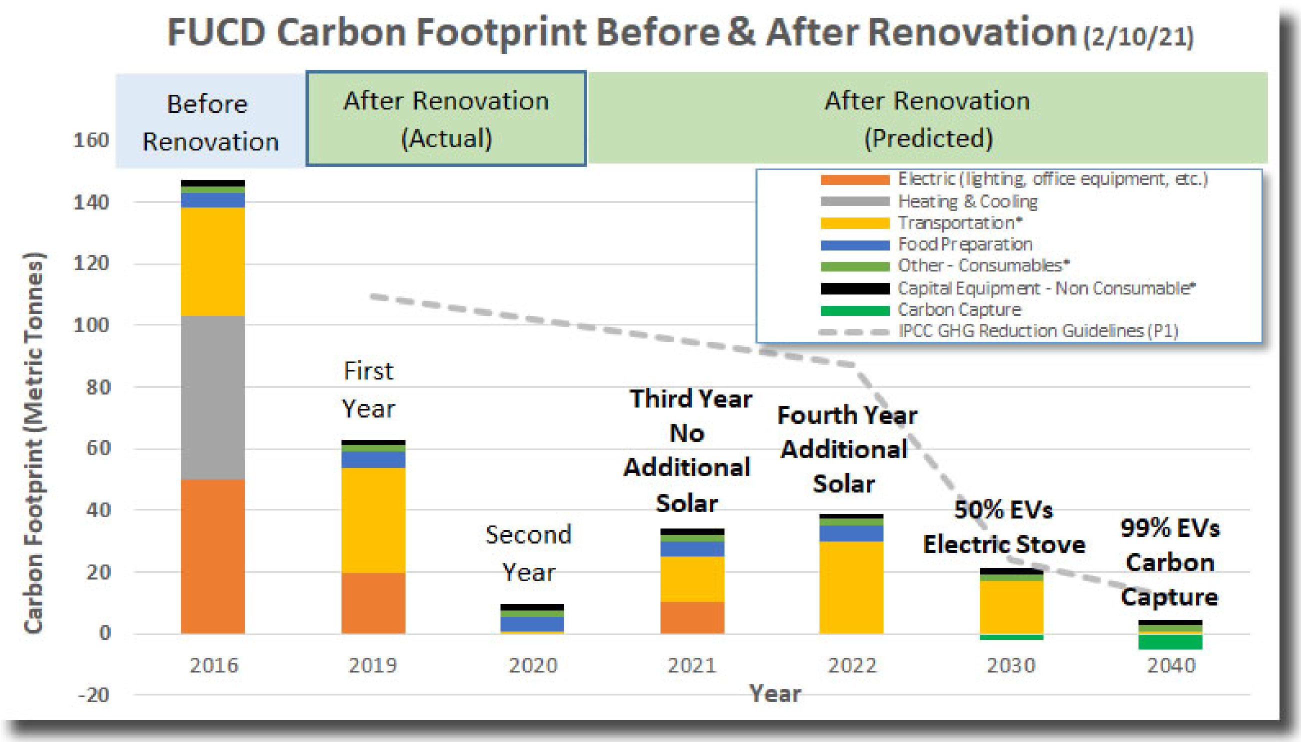

Figure 1 First Universalist Annual Carbon Footprint – Stepping Stones to Sustainable Operation in the Future

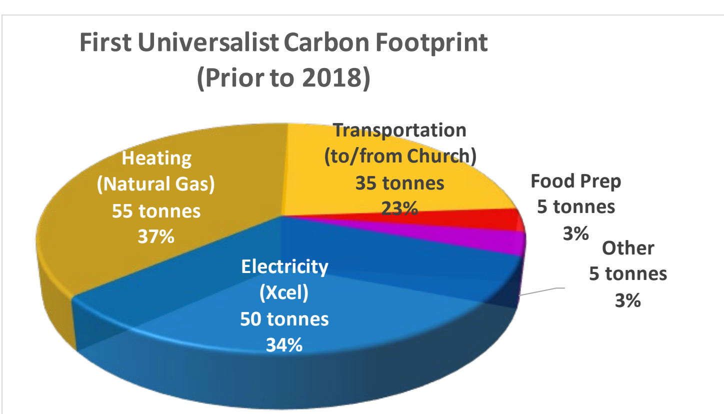

Figure 2 First Universalist Carbon Footprint Prior to Renovation (2018)

Carbon Footprint Before Renovation.

As indicated in Figure 1, prior to the BFF renovation, the FUCD carbon footprint was around 150 metric tonnes of CO_2 annually (See bar labelled 2016). At that point in time, the facility operated using energy derived from burning fossil fuel.

There were five significant FUCD sources of the harmful greenhouse gases before the renovation. The recent BFF renovation project addressed the two largest contributors to the FUCD carbon footprint: 1) generating electric power for the operating the facility, and 2) heating the building.

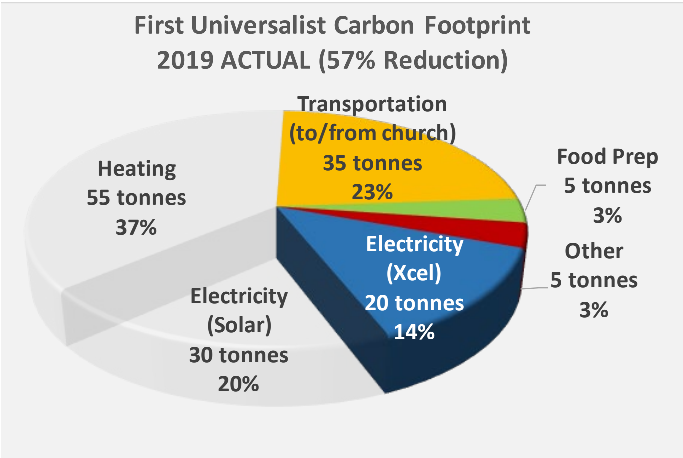

Figure 3 Carbon Footprint was Reduced 57% as of 2019

Carbon Footprint After Renovation – First Year.

By adding a new sustainable energy system (solar electric and geothermal heating and cooling), FUCD reduced GHG emissions significantly as illustrated in **Error! Reference source not found.**. The goal for the BFF renovation project was to eliminate emissions linked to heating and cooling the facility as well as emissions associated with generating electrical power. The first part of the goal was achieved, but there were more activities at the church and use of the renovated facility than predicted – hence more energy was used than predicted. As a result, the solar PV system was not sized properly to provide all the energy needed to operate the building sustainably.

After the first full calendar year of operation (2019), the carbon footprint had been reduced to around 65 tonnes – a 57 % reduction. It should be noted that one major source of GHG emissions was eliminated completely – i.e. burning natural gas to heat the facility. The renovation project replaced 10 gas-burning furnaces with 10 ground-source (geothermal) heat pump furnaces powered by solar electric. There are no GHG emissions associated with heating and cooling the renovated facility. The harm associated with electric power was also reduced significantly because FUCD generates its power using a rooftop solar PV system.

The third major contribution to the FUCD carbon footprint is associated with transportation to and from the church using gasoline-powered vehicles as illustrated in **Error! Reference source not found.**. Simple observation of the church parking lots during a Sunday Service indicates 90-95% of FUCD members and staff have not yet transitioned to emission free vehicles (e.g. electric vehicles).[8] This source of GHG emissions was unchanged by the renovation.

Carbon Footprint After Renovation – Second Year.

During the second year of operation (2020), most activities of the church were put on hold as a response to the COVID-19 pandemic. Sunday services were suspended and FUCD did not host any conferences; energy use dropped. As expected, the solar PV system produced about the same amount of energy in 2020 as it did in 2019. However, in 2020, the energy generated exceeded the usage in this limited mode of operation. As a result, FUCD met its Net Zero Energy goal – in fact there was a small surplus of energy generated (3%) during 2020. Althe so, casual observation of the church parking lots indicated very few cars except those of the staff; therefore the transportation related GHG emissions were minimal. A back-of-the-envelope calculation indicated the transportation emissions associated with the staff were similar to the GHG emissions avoided by the surplus of energy generated by the solar system. Albeit fortuitous, FUCD had a near zero carbon footprint for the year 2020 as indicated in Figure 1.

[8] The Green First Task Force is exploring a program to help staff purchase EVs (not lease) with a zero interest loans to purchase an EV. (plus the agreement they would recycle/repurpose the vehicle responsibly when they no longer need it.) Members could create a capital fund for this purpose as an incentive for staff.

Carbon Footprint After Renovation - Third Year Projection.

A projection of the carbon footprint for 2021 is illustrated in Figure 1. It was assumed most members will be vaccinated for COVID-19 before the end of the year, allowing the facility to re-open appropriately, and start to return to a new normal usage by the end of 2021 – possibly approaching that of 2019.

Carbon Footprint After Renovation - Fourth Year Projection.

By 2022, it was assumed that additional solar modules would be installed on-site or in a community solar garden. It was not expected that there will be significantly more members driving electric vehicles to church functions, so in 2022, the major source of GHG emissions for FUCD will likely be associated with transportation to / from the church as illustrated in Figure 1.

Carbon Footprint One Decade from Now.

By 2030, to comply with the IPCC GHG emission reduction guidelines, FUCD will be challenged. 50% of the vehicles in the parking lot will need to be emission free (e.g. electric or hydrogen powered) vehicles.[9] Also by 2030, it was expected that the natural gas stove/oven in the church kitchen would be replaced by an electric induction stovetop / electric convection oven so food could be prepared sustainably. As illustrated in Figure 1, the major source of GHG emission will be associated with church members who continue to drive gasoline powered vehicle to church events.

*Carbon Footprint Two Decades from Now***.**

By 2040, it was assumed that nearly all church members will be driving a vehicle with zero emissions (e.g. an electric vehicle with a hydrogen fuel cell or battery charged from renewable energy.) It was also assumed the church grounds will include sustainable vegetation intended to capture and sequestration carbon (i.e. negative carbon emissions). If so, FUCD will be in complete compliance with the IPCC P1 pathway[10] that will limit global warming of the planet to 1.5 deg C as depicted by the dashed gray line in Figure 1.

Using the trajectory of the IPCC P1 pathway (described in Appendix B) as guidelines, (see dashed gray line in Figure 1), the FUCD Carbon Footprint Roadmap stays within the IPCC guidelines. FUCD can claim they are “still in the Paris Agreement.”

Climate science tells that ALL human activities that search for, drill, dig, and extract, transport, refine, and burning carbon-based fuels of any kind (especially the tar sands product being reined at Suncor) is ecocidal - meaning it contributes to an impending global mass extinction of complex living beings. The sooner we transition to solar, wind, hydro, hydrogen and other non-carbon fuels, the more lives of human and non-human species we can save. (Suncor must be shut down.) Medical science tells us that the discharge of carcinogenic substances (including benzene by Suncor) into our common air, water and soil is a structural form of violence that is killing and debilitating humans and other forms of life. (Suncor must be shut down **now.** Their products are obsolete; there are safe, plentiful and healthy alternative sources of energy. We don't need to refine more tar sands oil. Based on Suncor’s inability to be a lawful citizen, their insistence on violating the ethics of a civil society, Suncor must stop operations immediately and be denied a permit to proceed.)

First Universalist should also be held to the same standards of a civil society and stop buying and burning carbon-based materials as a source of energy. The proposed Roadmap shows the replacement of the natural gas stove in the church kitchen within this decade. The Roadmap shows that 50% of church members will need to transition to electric vehicle (charged from renewable energy sources) by 2030.

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[9] The electrical energy for these EVs must be derived from renewable energy sources – not by burning carbon.

[10] Further discussion of the IPCC pathways can be found in Appendix B IPCC Pathways to 1.5 deg C.

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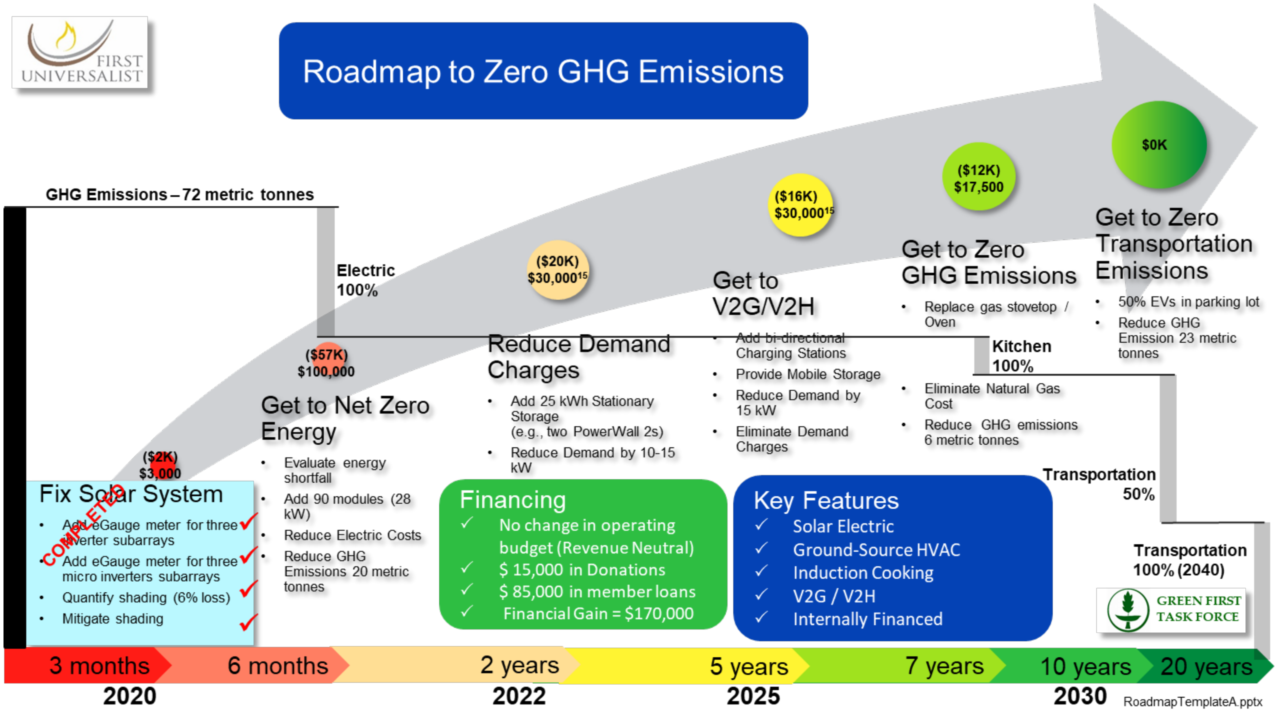

Figure 4 Roadmap to Zero GHG Emissions by 2040

This performance report for the first two years of operating the renovated facility identifies several possible reasons why there was a shortfall in energy production in 2019 and what can be done about it to meet the sustainability goals. Although the solar PV system and ground-source (geothermal) heat pump HVAC system are functioning properly (as designed), some other adjustments to the energy system are suggested, in addition to installing more solar PV modules to make up the shortfall in energy production.

Unfortunately, there was insufficient quantitative data available after the first year to recommend a specific path forward. In general, it became obvious that the size of the solar PV system would need to be increased to meet the Net Zero Energy goal if the new "normal" operations trended back to 2019 operations.

At the end of the first year, it became apparent that additional information (and monitoring instrumentation) was needed to develop a specific roadmap / path to reach our Net Zero Energy / Zero GHG emissions goals. The Green First Task Force funded and installed nearly two dozen sensors at the subarray level to obtain performance data needed to understand and address the energy shortfall observed in 2019.

After a second year of observation with the additional monitoring equipment and performance data, it was possible to better understand how the system works and how much additional solar equipment was needed to be at Net Zero Energy.

During the second year of operation, the Green First team also developed a Revenue Neutral funding model that is simply an extension of the successful funding approach used to purchase and install the initial solar system. The proposed funding approach does not require a change in the church budget. The needed capital to extend the current system can be obtained from member donations and low interest member loans. An implementation plan along with a proposed funding approach is provided in this report for Staff, Board and Congregational approval.

1. Introduction / Background

Goals and Objectives.

During the recent "Building for the Future" (BFF) church renovation project of 2016-2018, First Universalist Church of Denver installed new 21st-century energy-related equipment that does not produce any GHG emissions. The rooftop solar PV system is shown in Figure 5. What is not visible is the heat exchanger for the ground-source heat pump heating and cooling system located under the north parking lot. The ground loop heat exchanger is a network of black plastic HDPE pipe installed in 12 five inch diameter boreholes that were drilled 400 deep to circulate water and exchange thermal energy with the Earth. There are 10 heat pump furnaces in six different mechanical rooms throughout the facility that are connected to the common ground loop heat exchanger.

Figure 5 The Sustainable Energy System utilizes a 57 kW solar PV system to generate electric power and a 45 Ton ground-source heat pump system for heating and cooling.

Instead of buying and importing energy from the local utility company (Xcel Energy), 21st century technology allows First Universalist to operate **using energy that is already available on the property as illustrated in** Figure 6**.** (incident solar energy and thermal energy in the ground). There is no need to import energy and no need to burn hydrocarbons.

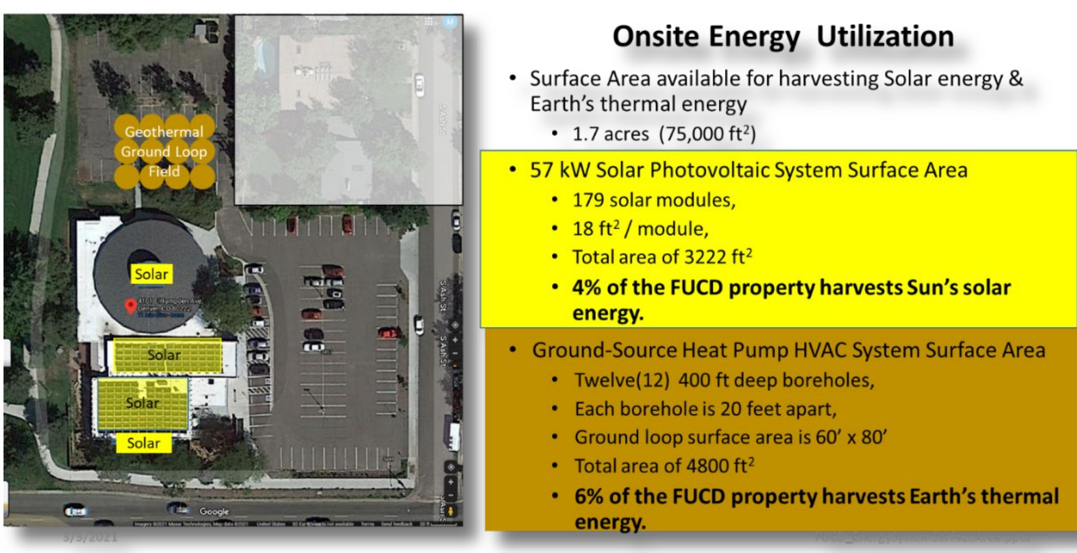

Figure 6 First Universalist Renewable Energy System - 2018

The new Sustainable Energy System was designed to provide all the electrical power as well as heating & cooling for the facility without burning hydrocarbons and dumping greenhouse gas (GHG) into the atmosphere.

The environmental goals were:

- to operate the facility in a manner that is consistent with the Unitarian Universalist Association principles and several recent UUA General Assembly Resolutions.[11] In other words, to stop doing harm to the interdependent web of life and its future generations.
- to be responsible global citizens and operate the facility consistent with the 2015 Paris Agreement.

> By coming together in mind and spirit, and held together by common values, the congregation found a way to renovate its facility so it operates sustainably.

By coming together in mind and spirit, and held together by common values, the congregation was able to find a way to renovate its facility so it operates sustainably and reduces GHG emissions to comply with the most recent scientific guidelines that will limit global warming to 1.5 deg C.[12]

By constructing a 'Revenue Neutral" funding approach, the Green First Task Force found a way to make this transition to renewable energy without a significant impact on the church operating budget. On 6 Nov 2016, the congregation voted unanimously to install a 21st century energy system using this funding approach. As a result, "energy" costs continue to be around 2.5% of the annual operating budget, but now the facility carbon footprint has been reduced significantly.

This transition required a group effort. The Green First Task Force is grateful for all who helped make this physical change happen.[13] The new integrated solar electric / ground-source heat pump heating & cooling system began full operation in June of 2018. Xcel monitoring equipment and rate schedules were being modified for the first several months of operation. "Billing Adjustments" were occurring until mid-October 2018, so the data before then is not consistent and cannot be used as a part of the baseline operation. By November 2019, there were 12 full months of operational data for the renovated facility. So, it is then possible to assess and document the annual performance of the new energy system in this report.

Prior to the renovation project, operation of the First Universalist facility was dumped approximately 120 metric tonnes of GHG emissions into the atmosphere per year. The new energy system (solar electric & ground-source heat pumps) has zero GHG emissions so the congregation has reason to conclude they reduced their GHG emissions sufficiently to say, "*We are still in* (the Paris Agreement)."[14]

Questions and Answers addressed in this report

[11] Specifically the 7th Principle: "Respect for the interdependent web of all existence of which we are a part." See GA Resolutions for 2006, 2013, 2014, and 2015.

[12] See IPCC 1.5 C Report of October 2018.

[13] The project to transition to renewable energy is summarized in "*From the Ground Up: Transitioning a Faith-Based Facility to Sustainable Energy Using Solar Electric and Ground-Source Heating & Cooling.*" Green First Case Study: First Universalist Church Denver, 2019. ISBN 978-1-0866-0744-4. Abridged Version, pg 13.

[14] The COP21 Paris Agreement of December 2015, signed by over 190 countries including the United States of America is intended to reduce GHG emissions in a manner that limits global warming to less than 2 deg C. The Trump Administration decided to "drop out" of the Paris Agreement in 2020; however many states, cities, and organizations continue to individually adhere to the Paris Agreement and indicate their intent by declaring, "We are still in."

Table 1 List of Questions & Answers discussed in this report.

Question	Short Answer	Source of Detailed Discussion
General		
Is the New Energy System Performing Properly?	Yes. It is working as designed.	See Section 2.0 of this report There are some areas where adjustments are recommended
Is the New Energy System Operating as a Net-Zero Energy building as Intended?	No, in 2019. Yes, in 2020 In the future, No, unless solar production is increased	See Section 3.0 of this report The renovated facility is more energy efficient than before The renovated facility uses more electrical energy as expected – more than predicted. Renovated facility is being used more – energy use has increased Energy required for heating and cooling has decreased plus thermal energy cost is now zero
Is the New Energy System Operating with Zero GHG Emissions as Intended?	Yes	See Section 4.0 of this report
Is the New Energy System Operating as a Revenue Neutral Renovation?	No, in 2019. Yes, in 2020 In the future, No, unless solar production is increased	See Section 5.0 of this report
Energy Production/ Power Generation		
Is the Xcel Production Meter that measures energy generation accurate?	Yes	Resolved. For details see: ***Appendix D Energy System Monitoring Meters (Renovated Facility) in 2019.*** ***Appendix E Energy Generation / Production***
Is the FUCD eGauge meter that measures solar production accurate?	Yes	Resolved. For details see: ***Appendix D Energy System Monitoring Meters (Renovated Facility) in 2019.*** ***Appendix E Energy Generation / Production*** ***Appendix F Solar PV System Field Test Results - 7 May 2020***

Is there enough instrumentation to obtain the data needed to troubleshoot the output performance of the solar system?	No, as of the end of 2019.	
	Yes, as of March 2020. The additional eGauge sensors allow measurement of the power output of the six(6) subarrays. This allows quantification of the shading effects.	Resolved. The Green First team purchased and installed additional sensors to continuously monitor the output of the 6 subarrays. For details see: ***Appendix G Monitoring Three Inverters – 15 strings of 10 modules*** ***Appendix H Open Items Related to Adding Instrumentation to the Energy System,*** ***Appendix I Awning Solar Subarray Performance,*** ***Appendix J Structural Shading due to Walls & Circuit Panels,*** ***Appendix K Monitoring Micro Inverters - AP System Installation***,
Why was the energy production less than predicted?	1) The PVWATTS' weather model did not use as many "cloudy/snowy" days as actually experienced in 2019 – as a result, the computer model over predicted output performance by about 9% 2) Shading by the two deciduous trees on the south of the building was not factored into the initial output prediction. Tree shading reduced output by 4% 3) Some structural shading was discovered due to shadows from the three inverter boxes, the combiner panel, the mid parapet wall and the kitchen's exhaust make-up air heater unit. Structural shading reduced output by 2%	1) Resolved. See ***Appendix L*** for details. 2) Resolved. See **Appendix M Shading** for details. 3) Resolved. See ***Appendix N Shading Assessment*** for details.
Energy Usage / Consumption		
Is the Xcel Net Meter that measures energy usage accurate?	Yes	Resolved. For details see ***Appendix O Energy Use/Consumption*** ***Appendix P Comparison of Xcel 15-minute interval data with eGauge performance data*** for details
Is the FUCD eGauge meter that measures total building usage accurate?	No. It appears to be 20% low. The Xcel Net Meter reading will be used instead.	Resolved. See ***Appendix Q Basis for the unexpected increase in operating cost*** for details.

Is there enough instrumentation to trouble shoot the energy usage of renovated facility	Yes	See ***Appendix R Xcel Response to Billing Questions*** for details about Xcel meters
Why was the energy consumption more than predicted?	Multiple reasons. 1) The architect's energy usage model under estimated the level of activity in the renovated facility 2) There was significant rental use of the facility during the weekdays 3) The renovated facility became a showcase for sustainability. FUCD hosted a number of new multi-day events and provided numerous tours of the facility in 2019 4) LED lighting may be excessive both in intensity and duration	Resolved.
Plans and Roadmap to Achieve our Sustainable Living Goals		
There was an energy shortfall in 2019 and a small energy surplus in 2020. Can the energy usage for 2021 be estimated?	Yes. Only rough estimates can be made. Energy usage in 2021 will dependent on how long it will take to vaccinate enough of our local population so the church is able to return to "normal" operations safely.	There will be an energy shortfall as the church resumes operations in the latter half of the year - unless the solar PV production capability is rextended to meet the increasing usage.
In 2020, FUCD generated all the energy needed to operate the facility. The annual Xcel utility bill was still over $4,000 due to "Peak Demand" and Xcel administrative fees. Can these charges be reduced?	Yes. By investing in stationary and mobile energy storage (V2G), the demand charges can be reduced significantly. Some ideas are explored in this report.	See A***ppendix Q Basis for the unexpected increase in operating cost*** and ***Appendix S Storage and Vehicle-to-Grid (V2G) Capability*** for details. See ***Appendix T Demand Control System Proposal by Brayden Automation Corp.*** for an approach used successfully by Mountain View Methodist in Boulder, but is not applicable for FUCD.
What about our sustainability goals: Zero Net Energy, Zero GHG Emissions, Revenue Neutral operations and Near Zero Carbon Footprint?	In the reduced operational mode in response to the coronavirus, these goals will be meet unintentionally until the church "re-opens."	See Section 6.0 of this report As the church re-opens and operations trend back to the 2019 "normal", solar electric production must increase (e.g. add more modules to the current array and harvest more energy already on-site; or invest in a community solar garden.) Getting to Near Zero Emissions & Carbon Footprint will require replacing the natural gas stove and members transitioning to zero emission vehicles

		(e.g. Electric or hydrogen fueled vehicles)
Is there a path forward to Zero GHG emissions?	Yes. This report provides a Draft Roadmap and funding approach.	See Section 9.0 in this report. See **Appendix U Remaining Space on the Flat Roof,** and ***Appendix V Steps to get to zero net energy*** for details
What about the FUCD Carbon Footprint?	In 2020, the FUCD congregation carbon footprint was nearly zero – illustrating it is possible.	This report addresses the FUCD carbon footprint and a identifies a path to zero GHG emissions that is consistent with the IPCC guidelines that will limit global warming to 1.5 degree C.

- **FUCD remains dedicated to the UU Seventh Principle: "Respect / Reverence for the Interdependent web of Life" and wishes to do no harm to future generations.**
- **The renovated facility has allowed FUCD to make significant progress along the path to sustainable operations.**
- **Lessons Learned have been documented and communicated to other faith-based organizations.**
- **There is still work remaining to fully implement our Roadmap and achieve our sustainable operational goals:**
    - ***Zero Net Energy,***
    - ***Zero GHG Emissions,***
    - ***Near Zero Carbon Footprint, and***
    - ***Revenue Neutral operations***

2. Is the New Energy System Performing Properly?

Introduction

There are many features to this energy system, some are obvious, but most of the new energy-related equipment is functioning passively, quietly, as designed, out-of-sight while contributing to the total system performance.

New windows, added insulation, and additional air sealing were included in the renovation project to reduce the heating and cooling requirement of the facility significantly. New LED lighting and increased use of natural lighting (e.g. oculus in the Sanctuary) were included to reduce the amount of electricity required for operation. Installation of beetle-kill pine paneling in the ceiling of the Sanctuary was a subtle indication of our effort to strive for zero waste and 100% recycling/reuse as the congregation proceeds into this pivotal century of human existence. The Solstice/Equinox light portal in the Sanctuary provides a seasonal reminder of the life-sustaining energy received from the Sun.

The more obvious features of the new energy system are of course the rooftop solar photovoltaic system now used to generate electric power and the ground-source heat pump system used for heating and cooling. Early on, it was realized that all the energy needed to operate the facility is already available on-site. Plus, it is free and inexhaustible.[15] First Universalist Church no longer needs to buy and import energy from a utility company.[16]

A primary goal was to install new 21st-century equipment that could honorably harvest some of the inexhaustible sustainable energy already onsite to operate the church with zero GHG emissions.

So, the first question to ask, "Is this new equipment performing properly?"

Qualitative Conclusions.

The renovated facility is now sustainably harvesting energy from the Sun incident on the roof and converting **solar energy** into electrical power with zero GHG emissions using today's photovoltaic technology.

The facility is successfully exchanging **thermal energy** with Earth for cooling in the summer and heating in the winter with zero GHG emissions using solar-electric to power today's ground-source heat pump technology.

> From an overall **qualitative** perspective, the performance of the new sustainable energy system exceeds that of the old fossil fuel system.

Yes, all the passive elements of the new energy system including the solar and geothermal systems appear to be functioning as designed. From an overall **qualitative** perspective, the performance of the new sustainable energy system dramatically exceeds that of the old fossil fuel system. By incorporating 21st century technology in the BFF renovation project, FUCD has made giant strides along the path to Zero GHG Emissions. Most importantly, the carbon footprint of FUCD has been reduced significantly as discussed in this report.

Quantitative Conclusions.

[15] The new energy system harvests solar energy incident on about 4% of the surface area of the FUCD property and exchanges thermal energy with the Earth under about 6% of the surface area of the property.

[16] Fossil Fuel generated Electric and Natural Gas are provided by a for-profit regulated monopoly, Xcel Energy, a corporation based in Minnesota.

Electric Energy. During 2019, the FUCD solar PV system generated 68,630 kWh[17] of energy[18] (18% less than originally predicted) thereby avoiding 48 metric tonnes of GHG emissions.

In 2019, the renovated facility was used extensively and hosted a wide range of activities. As a result, a new standard of "normal usage and energy consumption" was established. The amount of energy consumed that first year was 98,019 kWh[19] (30% significantly more than the architect predicted.) As result, the new energy system did not achieve the Net Zero Energy goal in 2019. From a quantitative perspective, the solar PV system generated 71% of the energy used to operate the renovated facility based on a "new normal" operating year (2019). Because there was a **production shortfall, First Universalist purchased 29,389 kWh[20] of energy from Xcel in 2019.**

*From a **quantitative** perspective, the solar PV system generated 71% of the energy used to operate the facility for a "new normal" operating year (2019).*

These results were unexpected and prompted an extensive investigation by the Green First Team. At the end of 2019, there were more questions than answers. So in 2020, the Green First team purchased and installed more instrumentation and monitoring equipment to answer these questions. The Green First team also contacted Xcel Energy and requested that Xcel verify the calibration of the Xcel production meter and net meter (which they did. See Appendix P)

During 2020, the second year of operation, the FUCD solar PV system produced 68,958 kWh[21] of energy (0.5% more than in 2019) and the renovated facility consumed 66,731 kWh[22] of energy (32% less than in 2019) because operations had been reduced in response to the COVID-19 pandemic. **As a result, First Universalist ended the 2020 calendar year with a small annual surplus of 2,227 kWh.[23]**

Thermal Energy. The renovation project successfully replaced 10 natural gas burning furnaces with zero emission ground-source (geothermal) heat pump furnaces, thereby avoiding 50 metric tonnes of GHG emissions annually.

GHG Emissions. The GHG Emissions have been reduced by nearly 100 metric tonnes of $CO_{2\,eq}$ annually.

GHG Emissions have been reduced by nearly 100 metric tonnes of $CO_{2\,eq}$ annually.

By the end of 2020, the new monitoring equipment recorded additional performance data that enabled the investigative team to answer most of the questions from the previous year (See Table 1). The new energy system does appear to be operating as it was designed to operate. However, the renovated facility is being used more than expected. As a result, in 2019, it consumed more energy than predicted by the architectural team.

ADD CARBON FOOTPRINT HERE

The good news is:

1) Reasons for the energy shortfall on this first attempt to operate the church facility sustainably have now been identified and can be easily corrected (e.g. by increasing the solar PV system production.)

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[17] See Table 2 Xcel Production Meter Billing Data for a 12-month period from 11/17/2018 to 11/18/2019.

[18] The 57 kW rated solar PV system installed on the roof was predicted to produce 84,281 kWh / year by the PVWATTS computer model using the default weather model.

[19] See Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version), Row 21 Col D.

[20] See Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version), Row 23 Col D.

[21] See Table .

[22] See Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version).

[23] See Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version).

2) The path forward to reach the finish line of Net Zero Energy can be defined. A plan to finance additional solar modules and increase solar electric production is being developed by the Green First Task Force and evaluated by Independent Reviewers. The plan will then be made available to the Board of Trustees for review and approval. The Board will determine if Congregational approval is necessary.

In addition to installing more solar modules and other small modifications to increase the solar electric production and eliminate the energy shortfall, some other final adjustments in the energy system design were identified and recommended in this report.

Heating & Cooling System Adjustments - Considerations

1) **Comfort.** The forced-air circulation patterns within the round space of the Sanctuary are complex and some temperature variations have been found in this room. The airflow patterns need some adjustment, particularly for the last row of the choir section at the back of the dais. The addition of a return air duct to alter the current airflow has been suggested to resolve this issue. **A poll of the choir members affected indicates this adjustment has a low priority.** Precise Mechanical has submitted proposals for a new return air duct.

2) **Comfort & Care of Equipment.** The small 2-ton rated heat pump furnace that controls the temperature within the office space appears to be undersized. The heating and cooling capability of this furnace needs to be augmented to maintain a more comfortable working environment for the office staff in extreme weather (below 30 °F and above 90 °F). The 2-ton heat pump runs constantly in extreme weather; such use will shorten the furnace's service life.
Note: The current 2–ton rated furnace could be augmented with an additional 2-ton rated heat pump furnace as a "second stage" or replaced with a 4-ton unit. Precise Mechanical has submitted proposals for a 4-ton unit.

   Note: This adjustment in the HVAC system was put on hold. Plans were being evaluated to modify the office space by adding walls to create separate offices and eliminate the "bullpen" style working area. The new walls will require a re-examination of the heating and cooling ducting requirements including an upgraded heat pump furnace.

3) **Comfort.** The renovation design added a new "music office area." However, air ducts for heating and cooling this new office space were overlooked in the renovation design. Two possible solutions have been suggested:
   a) add new air ducts in the crawl space under this office area (difficult), or
   b) add a small external air-source heat pump (mini-split) to service this office space.

   Note: This adjustment in the HVAC system was put on hold and will be addressed in the redesign of the entire office area. The HVAC open items are associated with the general BFF renovation project and are not linked to the use of solar or ground-source heat pumps. As a result, they were not a part of the funding for the new "Energy System."

4) **Preventive Maintenance.** The new geothermal heat pump HVAC system will need routine preventive maintenance just as a fossil fuel based HVAC system. Air filters will need to be changed periodically (annually) in the 10 heat pump furnaces as well as the 5 Energy Recovery Ventilator (ERV) units. Incoming and outgoing air & water temperatures will need to be checked periodically to identify any issues with air blower motors and water circulation pumps.[24] Water circulates in a closed loop between the building and the Earth under the north parking lot to exchange thermal energy for heating and cooling. The water contains a non-toxic antifreeze (food grade polypropylene glycol) and the level needs to be checked every year or so.

[24] The Green First Team installed a temperature monitoring system for the HVAC system consisting of 70 temperature sensors that record air and water temperatures every minute. The system is referred to as the Web Energy Logger (WEL) and can be viewed via the internet at URL, http://www.welserver.com/WEL1022/ . No one is assigned to periodically monitor these temperatures – ideally someone on the staff or the Building & Grounds Committee should be assigned that responsibility.

Ideally, the accumulated run time of the two Wilo water circulation pumps should be recorded and compared to the design life of the pumps.

Solar PV System Adjustments - Considerations

More solar modules will be installed to get to Net Zero Energy during normal operating conditions

In addition to installing more solar modules, there are a number of small adjustments that can be made to the solar PV system to increase its energy production.

1) **Shade Mitigation.** During the first year of operation, there was a concern that a portion of the rooftop array was being partially shaded by two deciduous trees on the south side of the facility. At that time, it was not possible to quantify how much energy production was being lost due to tree shading because there was no monitoring capability of the solar PV system at the string or module level. As installed, the only monitoring instrumentation was the Xcel production meter; Xcel provided a read-out of the monthly production at the end of each billing period. The Green First team recognized this limitation, purchased and installed additional eGauge monitoring equipment capable of continuously recording the total solar system output 24/7. Still this single piece of information (total system power output) was insufficient to identify what portions of the array were being shaded and to what extent partial shading was having on the power output of the solar PV system. To resolve the shading issue, the Green First team installed additional instrumentation during the second year of operation (March 2020) as described in Appendix M.

   The solar array on the flat roof was not designed to accommodate partial shading. To mitigate (but not eliminate) the effects of partial shading, the system could be modified by adding "power optimizers" or micro inverters to the modules that are partially shaded. BriteStreet has submitted a proposal for some shade mitigation that will cost just under $3000. Or trees can be trimmed.

   It should be made clear that shade mitigation or even cutting down the deciduous trees on the south side of the facility is not going to increase solar electric production by 40% and eliminate the production shortfall experienced in 2019. A larger solar PV system is still required to operate the renovated facility in a Net Zero Energy operation.

2) **Monitoring / Trouble Shooting / Maintenance.** The solar PV system was installed with no means of monitoring any of the subarrays or individual modules.

   There are 150 solar modules (aka panels) divided into three subarrays of 50 modules each. Each group of 50 is further divided into 5 strings of 10 modules that are connected to an Inverter to transform the DC output of the modules into AC for input into the grid. Each string could be monitored individually if the three inverters are upgraded with the proper monitoring equipment.

   There are 29 modules that use micro inverters and they are divided into three (3) subarrays;. Each of these modules could be monitored individually if the system is upgraded with additional monitoring electronics. However, only 11 of the 29 modules are affected by shading representing around 6% of the system power output. Six (6) of the 11 are "Awning" subarray mounted on the south wall of the church at a 87 degree tilt primarily as a visual indication the facility is solar powered rather than function for maximum productivity. The cost to add equipment to record the output from the remaining 5 modules with micro inverters to quantify shading effects may not be worth the benefit.

If and when this lack of monitoring is remedied, it will be possible to quantify how much production is being lost due to partial shading, snow coverage, or equipment malfunction (should it occur in the future.)

Conclusion

So is the New Energy System Performing Properly? With unreserved enthusiasm, the Green First team says YES! It is operating as designed. But it was underestimated how much the congregation was going to be using the renovated facility. Assuming the congregation wishes to get back to the level of activity prior to the pandemic, the Green Team would like to finish the job and extend the solar PV equipment to accommodate the new activity level of the facility.

The renovated facility is now sustainably harvesting energy from the Sun incident on the roof and converting solar energy into electrical power with zero GHG emissions using today's photovoltaic technology.

The renovated facility is successfully exchanging thermal energy with Earth for cooling in the summer and heating in the winter with zero GHG emissions using solar-electric to power today's ground-source heat pump technology.

Qualitatively, the performance of the new sustainable energy system exceeds that of the old fossil fuel based system from a technical perspective, from an economic perspective and most importantly from an ethical/moral/spiritual perspective.

Quantitatively, the energy system performance did not achieve 100% of the sustainability goals the first year of operation, for reasons were clarified during the second year of operation. Fortuitously, all the primary goals were met the second year of operation, 2020, including a near zero carbon footprint for FUCD.

The detailed investigation by the Green First team explains why the goals were not met the first year, and identify the adjustments that need to be made to the system.

3. Is the Facility Operating as a Net-Zero Energy building as Intended?

No, if the activity level (and therefore energy usage) of 2019 is the new “normal operation” of the renovated facility. The new “normal operations” consume 98,016 kWh annually. This is 25% more electrical energy than the 72,630 kWh before the renovation.

But, the renovated facility can be made a Net-Zero Energy building easily by installing additional solar modules. The Green First team stands ready with a Roadmap, installation plan, and proposed funding model that does not affect the church operating budget. The team simply needs the approval of the Board to finish carrying out the BFF goal of a sustainable energy system authorized in 2016.

Intended Goals & Objectives

The 2016 goal was to install new 21st-century energy equipment that stopped doing harm to future generations of our interdependent web of life. During the first year of operation (2019), the facility operated as intended and sustainably harvested energy and producing electrical power; however, energy usage exceeded energy production.

To answer the question “Is the system properly sized to be a net-zero-energy system?” it is necessary to compare the amount of energy generated by the solar PV system to the amount of energy consumed by the renovated facility over the course of a year. If the energy produced from sustainable sources is equal to or exceeds the energy consumed on an annual basis, the facility can be considered to be Net-Zero Energy.

Consequences of a Shortfall in Energy Production.

If the church does not sustainably harvest all of the energy it uses to operate, then it must buy electric power from Xcel Energy.

> *Note: The fuel mix that Xcel Energy uses to generate electricity is available on their website. In 2019, Xcel generated nearly 72% of its electrical power for Colorado customers by burning ancient hydrocarbons (fossil fuel). See Appendix W for details. As a result, Xcel Energy continues to dump around 1.55 pounds of greenhouse gases into the atmosphere for every 1 kWh of power they generate.*

In 2019, FUCD had an energy production shortfall and purchased 29,389 kWh from Xcel Energy. The hydrocarbons Xcel burned to generate this electrical energy dumped around 21 metric tonnes of GHG into the atmosphere. FUCD must assume responsibility for the harm perpetrated by Xcel Energy.

Conclusion

So, is the Facility operating as a Net-Zero Energy building as Intended? The response is “No.” The renovated facility is being used more than predicted and the energy usage is more than predicted. The sustainable source of energy to operate the building not large enough to generate all the electric power used. This is a simple issue to resolve.

4. Is the Facility Operating with Zero GHG Emissions as Intended?

By inspection, the church can confidently affirm its new sustainable energy System (solar PV / geothermal heat pumps) does not burn any hydrocarbons and does not generate CO_2 or other greenhouse gases. The new sustainable energy system harvests energy for operating the church facility that is already onsite – sunlight incident on the roof and thermal energy in the Earth (below the north parking lot.) The energy generated by the solar PV system and then consumed by FUCD resulted in zero GHG emissions.

However, in 2019, there was a 29,389 kWh shortfall in the annual power production. The consequences of the shortfall were: 1) it was necessary to buy 29,389 kWh of energy from Xcel Energy, 2) Xcel burned hydrocarbons (coal and natural gas) to generate that energy and created 45,553 pounds (**20.7 metric tonnes)** of GHG emissions.[25]

At this point, **because of the shortfall in production**, the facility is not operating with Zero GHG Emissions as intended.

Although food preparation at the church is not considered a part of the Sustainable Energy System, the natural gas stove/oven pilot lights continues to carbon 24/7. Gas usage related to food preparation was around 720 therms/year for 2019 and 2020; as a result 6 metric tonnes of CO_2 are dumped into the atmosphere from the FUCD kitchen each year.

Operating the renovated facility in 2019 was still doing some harm to future generations.

Conclusion

There are zero GHG emissions from the new energy system. However the energy purchased from Xcel produced 21 metric tonnes of $CO_{2\,eq}$ in 2019. Food preparation at FUCD produces an additional 6 metric tonnes of $CO_{2\,eq}$ each year.

[25] Prior to 2018 the church was causing over 100 metric tonnes of GHG to be dumped into the atmosphere. The new Energy System eliminated 10 natural gas furnaces and reduced emissions by 55 metric tonnes of $CO_{2\,eq}$ / year. In addition, FUCD reduced the emissions associated with electric generation from 50 metric tonnes to under 20 tonnes associated with the production shortfall of 29,389 kWh.

5. Is the New Energy System Operating as a Revenue Neutral Renovation?

History – Cost of Xcel Energy Prior to Church Renovation.

Annual utility payments in 2015-2016 were $16,625 plus around $3000 for annualized equipment replacement. There was a total of around **$20,000 allocated for electric and heating & cooling**. The annual cost of electric was $12,795; the annual use was 72,040 kWh. The cost of natural gas was $3830; annual use was 5196 therms (152,243 kWh.) This information is summarized in Table 2. Notice that the "Unit Cost" of electric before adding solar was a typical commercial rate of $0.178 / kWh (See Row 3:Col 4 in Table 2.)

Table 2 Energy Usage and Costs- Pre-Renovation (2015-2016): Ground Rules for Developing a "Revenue Neutral" Funding Model

Energy Usage and Costs Pre-Renovation (2015-2016) Ground Rules for Developing a "Revenue Neutral" Funding Model				
	Annual Cost	Annual Energy Use	Unit Cost	Ignored Social Costs (GHG Emissions)
Electric	**$12,795**	**72,040 kWh**	**$0.178 / kWh**	**50 tonnes / year**
Natural Gas	**$3,830**	**5196 therms (152,243 kWh)**	**$0.737 / therm**	**55 tonnes / year**
Annualized Equipment Replacement & Maintenance	**$3000**			
Total Cost	**$19,625**[26] (2.3% of operating budget)			**105 tonnes / year** **$10,500 / year**[27]

History – Cost of Utilities after Church Renovation.

The financial aspects of the new energy system are complex. The Xcel rate schedule changed January 2017, two months after the funding model was finalized and approved by the congregation. The "Revenue Neutral" financing model tried to anticipate the impending Xcel SPVTOU rate schedule, but the Xcel rate schedule is so complex that only an experienced specialist with an Excel spreadsheet could begin to predict the SPVTOU rate for a given customer for a yet-to-be-build facility with a yet-to-be-determine usage profile.

Over a 12 month period of operation (2019) of the new solar / geothermal system, First Universalist paid Xcel Energy $6,450 for electric services (See Table 6.) All-natural gas costs are now associated with food preparation, not the facility or hot water heating; Food preparation was not considered in the Energy System budget/fundraising. In addition, the church paid $17,505 to the Seventh Principle Partnership, the member lender group that provided the capital for purchasing and installing the new energy-related equipment. The church also paid an HVAC contractor $750 for maintenance (changing furnace filters, etc.)

On 11 Jan 2017, First Universalist submitted an application for the Xcel REC payment program (called Solar ® Rewards.) These REC payments are awarded on a first-come-first-served basis. To be conservative, the "Revenue Neutral" funding model did not assume there would be any REC rebates. Over the past 12 months, Xcel paid the church a "Renewable Energy Credit" rebate of $0.0475 / kWh. As indicated in Table 22, **Xcel paid FUCD $3260 in**

[26] By internalizing Externalities, the True Cost was $30,125

[27] This cost is deferred to future generations who will have to capture & sequester this carbon for a habitable planet. Assumes the cost of carbon capture and sequestration (CCS) to remove the GHG (the process has yet to be demonstrated on a large scale) is about $100 / ton.

REC rebates, so the net cost of electricity was $3,190. The REC rebate reduced the Unit Cost of electric to $0.11 / kWh.

The total energy-related "utility" cost was $21,445. (~2.4% of the annual church budget) compared to the 2015-2016 "utility" cost of $19,625 – **a difference of $1820.** The cost perspective with the new energy system is summarized in Table 3.

Table 3 2019 Actual Operating Costs for the New Sustainable Energy System after Church Renovation

2018-2019 Actual Costs for the "Revenue Neutral" Funding Model						
	Annual Cost	**Annual Energy Used**	**Annual Energy Generated (Solar Electric)**	**Annual Energy Purchased**	Unit Cost	Ignored Social Costs (GHG Emissions)
Electric (Purchased 29,389 kWh)	**$6,450**	**98,019 kWh**	**68,630 kWh**	**29,389 kWh**	$0.23 / kWh	19 tonnes / year
Utility Repayment of Low-interest Member Loan[28]	$17,505	N/A				
Maintenance (Filters,…)	$750	N/A				
~~Natural Gas~~		**No Natural Gas used for space heating or hot water**				
Xcel Solar Awards Rebate @$0.0475 / kWh	($3,260) [See Energy Use/Consumption]	N/A				
Net Electric Cost	$3,190				$0.11 / kWh	
Total Net Annual Cost of New Energy System	**$ 21,445 (~2.4% of operating budget)**					
Cost Difference Compared to Fossil Fuel System ($19,625 in 2016)	**$1820**	• **FUCD Investment will save future generations $10,000 in Carbon Sequestration costs** • **Missed Revenue Neutral Goal by 9%** • **Increased Church Total Operating Budget by 0.2%**				

Table 4 2020 Actual Operating Costs for the New Sustainable Energy System (Reduced Operations for COVID-19)

2020 Actual Costs for the "Revenue Neutral" Funding Model						
	Annual Cost	Annual Energy Used	Annual Energy Generated (Solar Electric)	Annual Energy Purchased/Banked	Unit Cost	Social Costs (GHG Emissions)
Electric (Surplus of 2,227 kWh)	**$4,228**	**66,731** kWh	**68,958** kWh	**2,227 (Banked)** kWh	N/A	**-1.0 tonnes / year**
Utility Repayment of Low-interest Member Loan[29]	$17,505	N/A				
Maintenance (Filters,…)	$750	N/A				
~~Natural Gas~~		**No Natural Gas used for space heating or hot water**				
Xcel Solar Awards Rebate @$0.0475 / kWh	($3,276) [See Energy Use/Consumption]	N/A				
Net Electric Cost	$953				N/A	
Total Net Annual Cost of New Energy System	**$19,207 (~2.4% of operating budget)**					
Cost Difference Compared to Fossil Fuel System ($19,625 in 2016)	**$-418 Savings**	• **Met 'Net Zero Energy' Goal in 2020** • **Met 'Revenue Neutral' Goal in 2020**				

[28] Paid to member lenders who formed a legal entity called "Seventh Principle Partnership." The 12 members loaned different amounts but the terms were for 15-years @ 1.5% interest.
[29] Paid to member lenders who formed a legal entity called "Seventh Principle Partnership." The 12 members loaned different amounts but the terms were for 15-years @ 1.5% interest.

		• **FUCD Investment will save future generations $10,000 in Carbon Sequestration costs** • **Decreased Church Total Operating Budget by 0.2%**

Cost Perspective

Direct Cost. Table 6 illustrates the Xcel cost information provided to the commercial customer. Of the 40 some columns in the complete Xcel billing table, approximately 20 provide cost information. **The Total Electric Charges for the past 12 months were $6,450** as indicated in Row 28 Col U.

The total cost is comprised of the cost of generating the electric (including numerous administrative costs) plus several "Demand" related charges. By attempting to identify the "Demand" charges, and subtracting them from the Total Electric Charges, the annual cost of the 29,389 kWh purchased from Xcel comes to $3578. That equates to around $0.12 / kW. Consequently, the annual "demand" charges would then be $2872.

Table 5 Illustration of Xcel "Demand" Charges for the SPVTOU-B Rate Schedule (2019)

	A	B	F	G	K	L	S	U	X	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
3	Customer Name	**FIRST UNIVERSALIST CHURCH**																		
4	Account Number	53-2125618-2																		
5	Account Address																			
6	Premises Number	3E+08																		
7	Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262																		
8	Premises Status	CURRENT																		
9	Service	ELECTRIC-1																		
10																				
11																				
12	Last Read Date	Billing Days	Demand (kW)	Total Delivered by Customer (kWh)	Generation& Transmission Demand (kW)	Total Delivered by Xcel (kWh)	Billable Demand (kW)	Total Electric Charges	Dem Side Mgmt Cost	Distribution on Dmd	Purch Cap CostAdj	RESA FS	GRSA	Gen & Transm Dmd	Srv & Facility	CACJA	ECA On-Peak	SPVTOU B OffPk	Renew. Energy Std Adj	Trans Cost Adj
13	11/18/2019	29	32	1099	24	5886	32	$514.14	$16.32	$180.16	$39.68	$2.88	($11.33)	$55.92	$34.40	$29.76	$46.61	$0.00	$9.73	$20.16
14	10/20/2019	31	18	3065	11	3160	22	$286.45	$9.18	$123.86	$22.32	$7.02	($8.09)	$16.03	$34.40	$16.74	$0.00	$0.00	$5.32	$11.34
15	9/19/2019	30	19	3458	12	3240	22	$318.86	$9.69	$123.86	$23.56	$11.87	($8.80)	$49.32	$34.40	$17.67	$0.00	$0.00	$5.84	$11.97
16	8/20/2019	29	41	3309	41	3671	41	$632.48	$20.91	$230.83	$50.84	$13.14	($18.39)	$168.51	$34.40	$38.13	$0.00	$0.00	$11.80	$25.83
17	7/22/2019	32	16	5024	10	2223	22	$270.42	$2.50	$123.86	$19.84	$14.10	($8.72)	$41.10	$34.40	$14.88	$0.00	$0.00	$4.89	$10.08
18	6/20/2019	30	18	5498	5	1951	22	$250.24	$9.00	$123.86	$22.32	$11.39	($8.23)	$3.89	$34.40	$16.74	$0.00	$0.00	$4.56	$11.34
19	5/21/2019	29	20	3772	12	2777	22	$269.00	$10.00	$123.86	$24.80	$6.69	($8.70)	$27.96	$34.40	$18.60	$0.00	$0.00	$5.01	$12.60
20	4/22/2019	29	28	3077	13	3854	28	$394.53	$14.00	$157.64	$34.72	$6.57	($10.83)	$30.29	$34.40	$26.04	$0.00	$14.17	$7.38	$17.64
21	3/24/2019	31	43	1948	28	7653	43	$804.10	$21.50	$242.09	$53.32	$6.12	($18.89)	$65.24	$34.40	$39.99	$63.05	$104.06	$15.19	$27.09
22	2/21/2019	30	43	535	43	9214	43	$1,016.18	$21.50	$242.09	$53.32	$3.92	($22.68)	$100.19	$34.40	$39.99	$160.00	$158.30	$19.28	$27.09
23	1/22/2019	34	37	287	26	9780	37	$957.11	$8.10	$208.31	$17.50	$3.00	($20.20)	$60.58	$34.40	$11.88	$94.20	$173.15	$18.16	$6.27
24	12/19/2018	33	29	557	21	7609	29	$736.96	$17.98	$163.27	$38.86	$4.00	($15.90)	$48.93	$34.40	$26.39	$97.64	$128.63	$13.96	$13.92
25		**367**	***29***		***21***		***30***	**$6,450**	**$161**	**$2,044**				**$668**						
26			Average		Average		Demand	**$2,872**	Total	Total				Total						
27							Other	**$3,578**												

By incorporating shade mitigation and adding more solar modules, production would increase and FUCD could stop buying electric from Xcel and reduce some of the $3578 charges that are not fixed charges. Adding more production will reduce demand charges slightly. Adding some behind-the-meter (BTM) storage, and a control system that draws energy from on-site storage during peak demand, FUCD can also reduce some of the $2872 in "demand" charges. Adding a Power Control system (e.g. Brayden Control System described in Appendix T) may help somewhat, but it is difficult to find items that can be commanded off during Sunday services when the weekly Peak Demand occurs.

Indirect Cost- Lost Revenue. In addition to the direct cost of having to buy energy from Xcel, there is the lost revenue from the production shortfall (REC payments). Had FUCD produced the 29,389 kWh there would have been a rebate of $0.0475 x 29,389 = $1395.98

Cost Summary. As indicated in Row 28 Col U of Table 6, the annual cost for electric was $6,450. So the effective net cost associated with the shortfall was $7846.

DRAFT

Table 6 Xcel Cost Data for 2019 - a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version)

11		C	G	L	F	K	S	U	X	Z	AD	Y	AG	AA	AB	AE	AF	AH	AI	AJ	AK
12	Last Read Date	Electrical Usage (kWh)	Total Delivered by Customer (kWh)	Total Delivered by Xcel (kWh)	Demand (kW)	Generation & Transmission Demand (kW)	Billable Demand (kW)	Total Electric Charges	Dem Side Mgmt Cost	Distribution Dmd	Gen & Transm Dmd	**ECA Off-Peak**	**ECA On-Peak**	Purch Cap CostAdj	RESA FS	Srv & Facility	CACJA	SPVTOUB OffPk	Renew. Energy Std Adj	Trans Cost Adj	Average Temperature (° F)
13	11/18/2019	-3511	1099	5886	32	24	32	$514.14	$16.32	$180.16	$55.92	$74.87	$46.61	$39.68	$2.88	$34.40	$29.76	$0.00	$9.73	$20.16	40
14	10/20/2019	-8298	3065	3160	18	11	22	$286.45	$9.18	$123.86	$16.03	$8.98	$0.00	$22.32	$7.02	$34.40	$16.74	$0.00	$5.32	$11.34	56
15	9/19/2019	-8393	3458	3240	19	12	22	$318.86	$9.69	$123.86	$49.32	$30.19	$0.00	$23.56	$11.87	$34.40	$17.67	$0.00	$5.84	$11.97	72
16	8/20/2019	-5175	3309	3671	41	41	41	$632.48	$20.91	$230.83	$168.51	$38.05	$0.00	$50.84	$13.14	$34.40	$38.13	$0.00	$11.80	$25.83	76
17	7/22/2019	-7344	5024	2223	16	10	22	$270.42	$2.50	$123.86	$41.10	$0.00	$0.00	$19.84	$14.10	$34.40	$14.88	$0.00	$4.89	$10.08	72
18	6/20/2019	-4542	5498	1951	18	5	22	$250.24	$9.00	$123.86	$3.89	$0.00	$0.00	$22.32	$11.39	$34.40	$16.74	$0.00	$4.56	$11.34	61
19	5/21/2019	-995	3772	2777	20	12	22	$269.00	$10.00	$123.86	$27.96	$5.95	$0.00	$24.80	$6.69	$34.40	$18.60	$0.00	$5.01	$12.60	51
20	4/22/2019	777	3077	3854	28	13	28	$394.53	$14.00	$157.64	$30.29	$13.79	$0.00	$34.72	$6.57	$34.40	$26.04	$14.17	$7.38	$17.64	49
21	3/24/2019	5705	1948	7653	43	28	43	$804.10	$21.50	$242.09	$65.24	$127.51	$63.05	$53.32	$6.12	$34.40	$39.99	$104.06	$15.19	$27.09	34
22	2/21/2019	8679	535	9214	43	43	43	$1,016.18	$21.50	$242.09	$100.19	$149.17	$160.00	$53.32	$3.92	$34.40	$39.99	$158.30	$19.28	$27.09	30
23	1/22/2019	9493	287	9780	37	26	37	$957.11	$8.10	$208.31	$60.58	$118.88	$94.20	$17.50	$3.00	$34.40	$11.88	$173.15	$18.16	$6.27	35
24	12/19/2018	7052	557	7609	29	21	29	$736.96	$17.98	$163.27	$48.93	$143.41	$97.64	$38.86	$4.00	$34.40	$26.39	$128.63	$13.96	$13.92	39
27																					
28							**Total $**	**$6,450**	$161	$2,044	$668	$711	$462	$401	$91	$413	$297	$578	$121	$195	$6,141
29							"Fixed" $	$3,003	$30	$1,486	$47	$0	$0	$210	$35	$413	$201	$0	$55	$136	$2,612
30							Possible Savings	**$3,448**	**$131**	**$557**	**$621**	**$711**	**$462**	**$191**	**$56**	**$0**	**$96**	**$578**	**$66**	**$59**	$3,529
31																					
32						NOTE: Demand cost is reduced when solar generates a surplus									NOTE: Energy Cost Adjustment (ECA) goes to zero when solar generates a surplu						
33						Demand	$1,309	possible savings							ECA	$1,172	possible savings				

Table 7 Xcel Cost Data for 2020 - a 12-month period from 12/19/2019 to 12/31/2020. (Condensed Version)

	A	B	J	R	S	U	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
4	Customer Name	**FIRST UNIVERSALIST CHURCH**																
5	Account Number	53-2125618-2																
6	Account Address																	
7	Premises Number	301360724																
8	Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262																
9	Premises Status	CURRENT																
10	Service	ELECTRIC-1																
11																		
12																		
13	Last Read Date	Billing Days	Generation& Transmission Demand (kW)	Billable Demand (kW)	Demand (kW)	Total Electric Charges	Dem Side Mgmt Cost	ECA Off-Peak	Colo Energy Plan Adj	GRSA	Distribution Dmd	Purch Cap CostAdj	RESA FS	Gen & Transm Dmd	CACJA	Srv & Facility	ECA On-Peak	SPVTOUB OffPk
14	12/31/2020	32	14	28	28	$485.55	$15.68	$100.17	$4.60	$14.73	$157.64	$33.88	$1.29	$32.62	($0.84)	$36.17	$66.50	$0.00
15	11/29/2020	33	13	22	21	$402.06	$11.76	$72.84	$3.31	$15.59	$123.86	$25.41	$0.55	$30.29	($0.63)	$36.17	$0.00	$49.28
16	10/27/2020	29	16	31	31	$381.74	$17.36	$1.97		$16.26	$174.53	$37.51	$5.48	$4.52	($0.93)	$36.17	$0.00	$0.00
17	09/28/2020	32	9	22	11	$257.38	$6.16	$3.76		$12.82	$123.86	$13.31	$11.25	$36.99	($0.33)	$36.17	$0.00	$0.00
18	08/27/2020	29	10	22	13	$263.43	$7.28	$0.95		$12.05	$123.86	$15.73	$12.83	$41.10	($0.39)	$36.17	$0.00	$0.00
19	07/29/2020	30	8	22	12	$251.83	$6.50	$0.00		$11.10	$123.86	$14.52	$13.73	$32.88	($0.36)	$36.17	$0.00	$0.00
20	06/29/2020	29	8	22	12	$251.52	$7.44	$0.00		$11.10	$123.86	$14.52	$12.72	$32.88	($0.36)	$36.17	$0.00	$0.00
21	05/31/2020	33	3	22	8	$212.35	$4.96	$0.00		$9.61	$123.86	$9.68	$10.40	$6.99	($0.24)	$36.17	$0.00	$0.00
22	04/28/2020	28	15	25	25	$304.83	$15.50	$11.50		$12.19	$140.75	$30.25	$7.21	$34.95	($0.75)	$35.92	$0.00	$0.00
23	03/31/2020	29	22	29	29	$380.83	$17.98	$37.51		$14.33	$163.27	$35.09	$6.45	$51.26	($0.87)	$34.40	$0.00	$0.00
24	03/02/2020	11	22	30	30	$196.89	$6.82	$12.79		$2.54	$61.93	$13.31	$1.99	$18.80	$3.96	$12.61	$0.53	$25.15
25	01/22/2020	34	20	43	43	$839.22	$17.25	$91.06		($19.26)	$242.09	$33.66	$3.06	$46.60	$27.54	$34.40	$51.62	$136.71
26		349	13	27	22	**$4,228**	$134.69	$332.55	$7.91	$113.06	$1,683.37	$276.87	$86.96	$369.88	$25.80	$406.69	$118.65	$211.14
27			Average	Average	Average	$2,188	Demand											
28						$2,040	Other											

A indicated in Table 7, the electric bills for 2020 totaled $4,228 in 2020 down from $6,450 in 2019. In 2020, the FUCD solar PV system generated all the energy used by the renovated building, so no power was purchased from Xcel – in fact FUCD generated a surplus; nevertheless, Xcel charged $4,228 for "peak demand" fees and other administrative charges. The peak demand was around 43 kW in 2020 and it occurred in the February timeframe as it did in 2019.

Conclusion

The goal was to replace the obsolete fossil fuel-based energy system that was dumping around 120 metric tonnes of GHG into the atmosphere annually with a new 21st century zero GHG emission Energy System **without increasing the church operating budget.**

After the first year of operation (2019), the data indicated the renovated facility used 98,019 kWh of energy - more than predicted by the architectural team. The solar PV system produced 68,630 kWh in 2019, so there was an energy shortfall. The solar PV system design was found to be undersized for this level of activity. FUCD purchased energy from Xcel at a net electric cost of $3190 for this 12-month period. The cost difference compared to the fossil system ($19,625 in 2016) was $1820.

The second year of operation (2020), was during the COVID-19 pandemic. Use of the renovated facility was limited and energy use dropped from 98,019 kWh in 2019 to 66,731 kWh in 2020. FUCD paid Xcel $4,228 and Xcel paid FUCD around $3,276 in REC payments for a net electric cost of $952. The cost difference compared to the fossil system ($19,625 in 2016) was $-418 (savings)

6. Envisioning the Energy System of First Universalist Church Denver in the Near Future

Introduction.

As we observe today's energy technology trends, we can envision how electric systems are evolving. If homo sapiens decide to avoid creating the next mass extinction, they will **stop burning hydrocarbons** as a source of energy. We will then see the disappearance of coal, natural gas and other carbon burning electric generation facilities. We will see the appearance of multiple energy storage technologies [electrical/chemical/ mechanical storage technology, fixed and mobile] as illustrated in Figure 7.

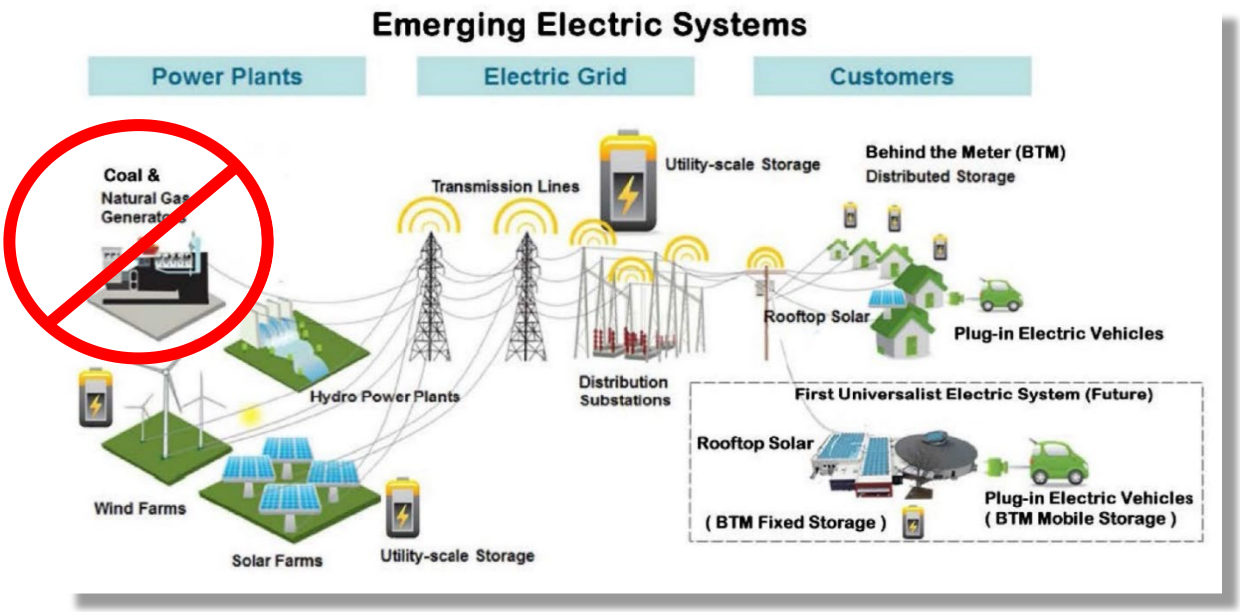

Figure 7 Emerging Electric Power Systems (Adapted from ***Vahid Madani, Ratan Das, Farrokh Aminifar, et.al.***[30]*)*

Emerging Electric System at First Universalist.

At First Universalist Church Denver, we can expect to see additional solar electric production (e.g., rooftop solar, carport solar in the parking lot, community solar) to assure net-zero energy operation as the facility is fully electrified in the near future (i.e., within 5-10 years).

We expect that the natural gas stove in the kitchen will be replaced with an electric induction stovetop and the gas oven replaced with an electric convection oven. With some 'behind the meter' (BTM) storage, the peak demand effects of turning on an electric burner can be mitigated. Within 5-10 years, all natural-gas burning should be stopped at FUCD, so the entire facility can be portrayed as a zero GHG emission facility.

As illustrated in Figure 8, we might expect to see the use of both fixed and mobile 'Behind- the-Meter' (BTM) electric storage (e.g., several stationary Tesla PowerWall 2s, and several member-owned EVs that plug-in to recharge on Off Peak periods **or** plug-in to donate energy during On Peak periods for the church[31] (e.g., Sunday mornings.) The on-site BTM storage would be used to level the weekly usage peaks (particularly on Sundays) and lower the utility company charges. The church would continue to remain on the grid and use the utility company as

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[30] "Distribution Automation Strategies Challenges and Opportunities in a Changing Landscape." Vahid Madani, Ratan Das, Farrokh Aminifar, et.al., IEEE Transactions on Smart Grid 6(4):2157-2165 · July 2015.

[31] Vehicle-to-Grid (V2G) and Vehicle-to-Building (V2B) technology is discussed in Appendix S-Q

a seasonal battery (deposit excess energy in the summer; withdraw energy in the winter.) Figure 8 also illustrates that the eGauge monitoring system (or equivalent) would be extended to provide additional data when the BTM storage capability is added.

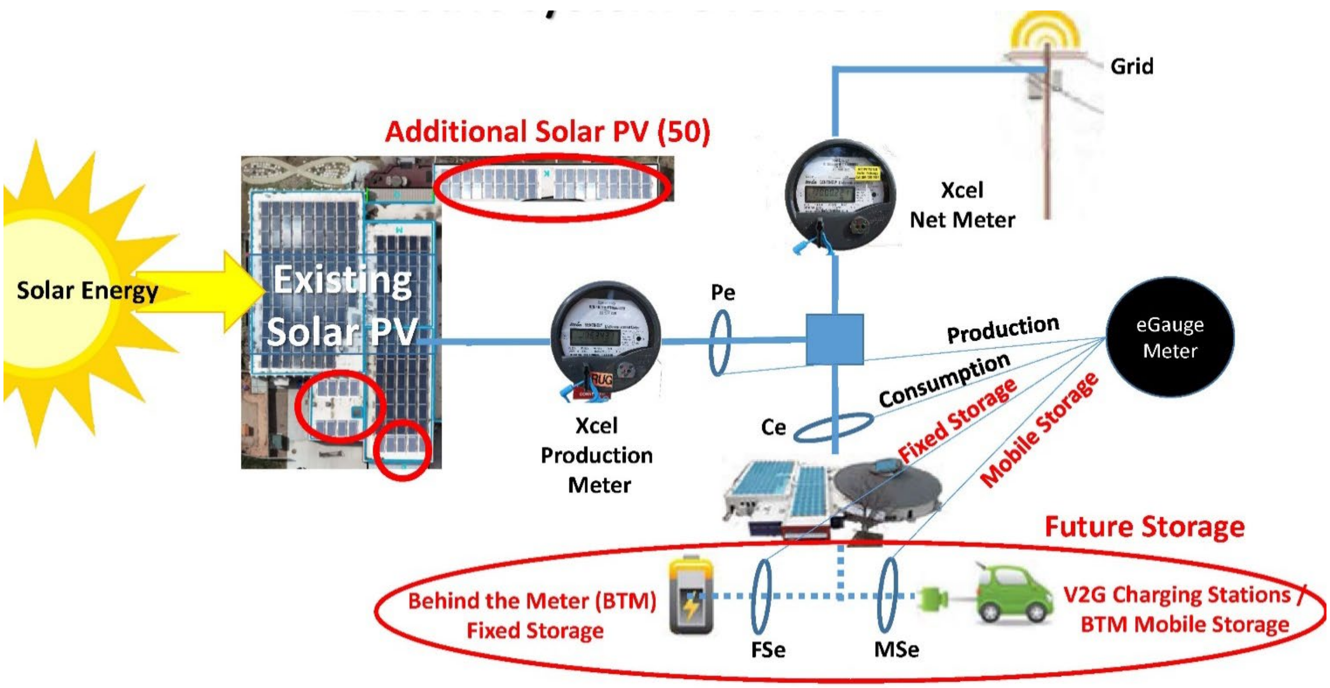


Figure 8 Envisioning a Future Sustainable Energy System for First Universalist Church Denver

Envisioning a Roadmap Toward a Sustainable Future

It is imperative that FUCD (perhaps the Green First Task Force specifically) develop a 10-20 year Energy Roadmap that is consistent with UU Principles and united behind the ever-evolving science of right relations with the interdependent web of life. It is imperative that FUCD make the effort to proceed mindfully along that path of right relations.

Among many other guidelines, we might consider a few important Rules of the Road: Do no harm (i.e. Stop dumping greenhouse gases into the atmosphere). Serve as a positive example in the local community. Promote evolving consciousness.

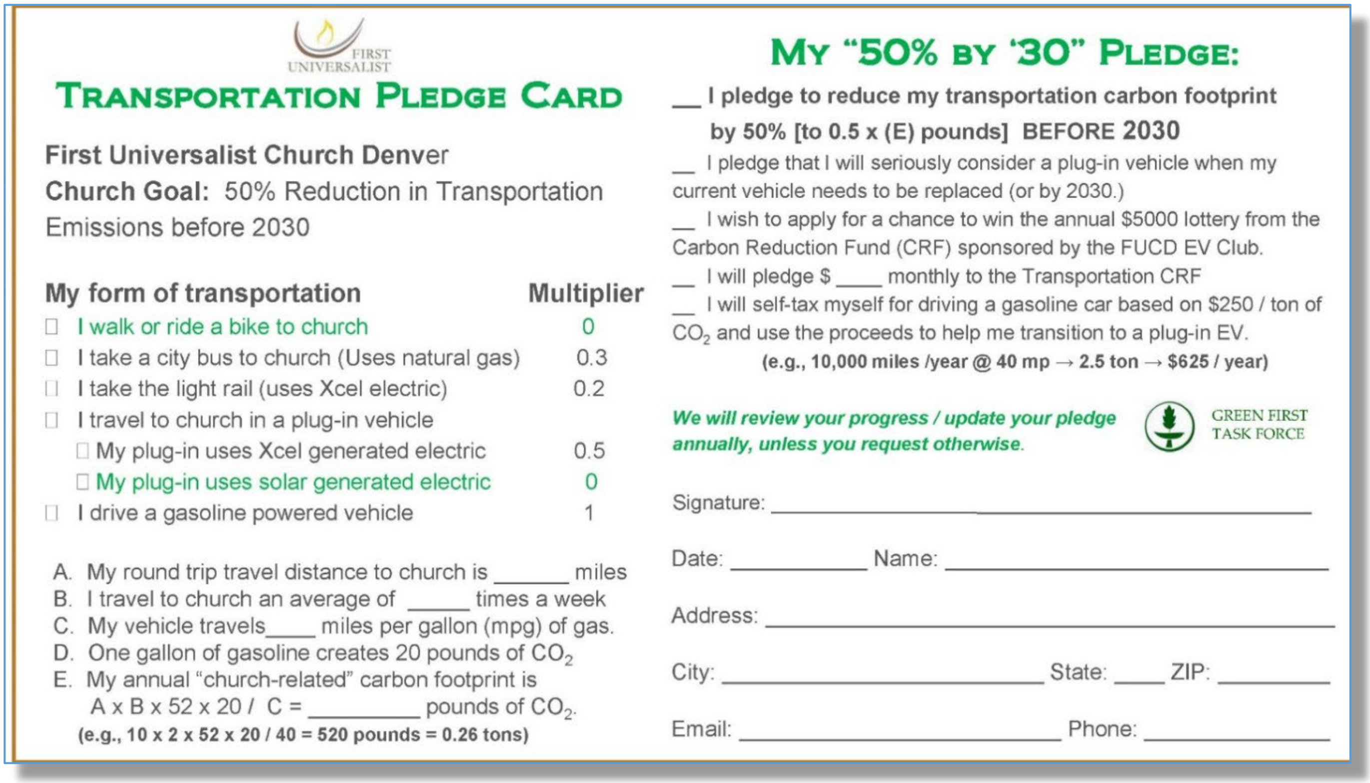
The Energy Roadmap will identify the FUCD plan to correct the energy production shortfall and achieve the Net Zero Energy goal and Net Zero GHG Emissions goal for the Energy System.

The Energy Roadmap acknowledges that the second-largest contributor to the church's carbon footprint is related to "transportation" of its staff and members. The transportation carbon footprint is estimated to be around 35 metric tonnes annually. This is an interesting item because it is not something the "church" administration or the Green First Task Force can manage/reduce directly. The reduction of this source of GHG emissions is dependent on church membership. Only when 50% of the members travel to church functions using plug-in electric vehicles (technically possible today) or hydrogen-powered vehicles (not possible with today's technology in the US) can we reduce the "church" transportation-related carbon footprint by 50%.

Helping Fellow Member Transition to Sustainable Transportation

Those who understand the priority of addressing climate change/global warming can, however, continue to educate/inform and otherwise assist their fellow member to be sure to consider a plug-in vehicle the very moment they consider replacing their current vehicle. The Green First Team could initiate programs that promote the transition to electric vehicles.

Example: *Green First could construct a Roadmap that includes a pledge by 50% of the member that they will seriously consider a zero-emission / plug-in EV when they have to replace their current vehicle (or something along these lines but less ambitious.) See Pledge Card sample below.*


FIRST UNIVERSALIST

TRANSPORTATION PLEDGE CARD

First Universalist Church Denver
Church Goal: 50% Reduction in Transportation Emissions before 2030

My form of transportation	Multiplier
☐ I walk or ride a bike to church	0
☐ I take a city bus to church (Uses natural gas)	0.3
☐ I take the light rail (uses Xcel electric)	0.2
☐ I travel to church in a plug-in vehicle	
☐ My plug-in uses Xcel generated electric	0.5
☐ My plug-in uses solar generated electric	0
☐ I drive a gasoline powered vehicle	1

A. My round trip travel distance to church is _______ miles
B. I travel to church an average of ______ times a week
C. My vehicle travels____ miles per gallon (mpg) of gas.
D. One gallon of gasoline creates 20 pounds of CO_2
E. My annual "church-related" carbon footprint is
A x B x 52 x 20 / C = _________ pounds of CO_2.
(e.g., 10 x 2 x 52 x 20 / 40 = 520 pounds = 0.26 tons)

MY "50% BY '30" PLEDGE:

__ **I pledge to reduce my transportation carbon footprint by 50% [to 0.5 x (E) pounds] BEFORE 2030**
__ I pledge that I will seriously consider a plug-in vehicle when my current vehicle needs to be replaced (or by 2030.)
__ I wish to apply for a chance to win the annual $5000 lottery from the Carbon Reduction Fund (CRF) sponsored by the FUCD EV Club.
__ I will pledge $ ____ monthly to the Transportation CRF
__ I will self-tax myself for driving a gasoline car based on $250 / ton of CO_2 and use the proceeds to help me transition to a plug-in EV.
(e.g., 10,000 miles /year @ 40 mp → 2.5 ton → $625 / year)

We will review your progress / update your pledge annually, unless you request otherwise.

GREEN FIRST TASK FORCE

Signature: ______________________________

Date: ___________ Name: ______________________

Address: ______________________________

City: ____________________ State: ____ ZIP: _________

Email: ____________________ Phone: ____________

The FUCD 'Carbon Footprint' before and after the BFF renovation is illustrated in Figure 1.

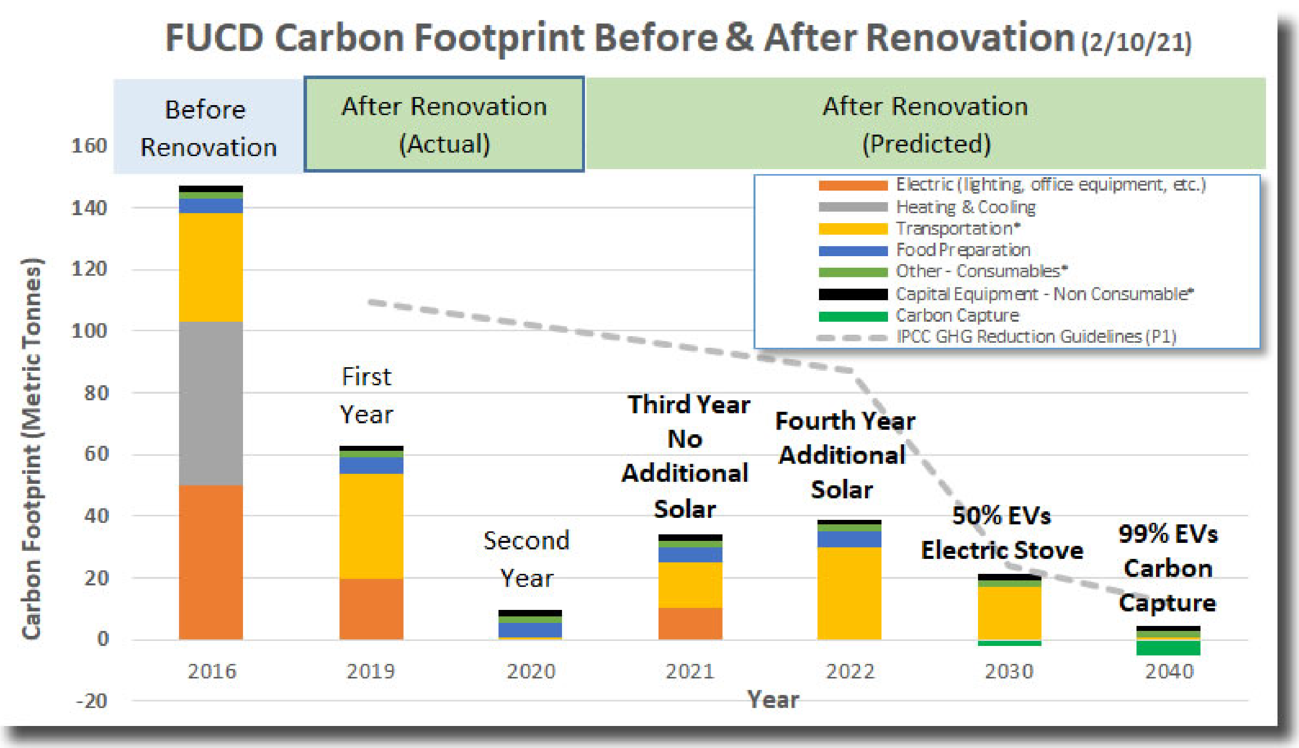


Figure 9 First Universalist Annual Carbon Footprint – Stepping Stones to Sustainable Operation in the Future

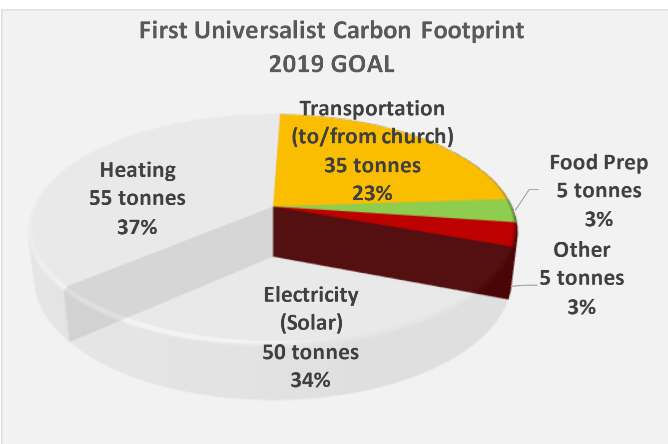
Carbon Footprint Before Renovation.

What is the carbon footprint of FUCD? How has the carbon footprint changed since the renovation" What about carbon capture / sequestration / carbon farming?

As indicated in Figure 1, in 2016, prior to the BFF renovation, the FUCD carbon footprint was quantified to be around 150 metric tonnes of CO_2 annually (See bar labelled 2016) – when the facility operated using energy derived from burning fossil fuel. There were six significant FUCD sources of the harmful greenhouse gases before the renovation. Of those, the three largest sources were associated with 1) generating electric power for the operating the facility, 2) heating the building, and 3) driving gasoline-powered cars to church events.

Carbon Footprint After Renovation – First Year.

The BFF renovation project reduced two of these sources significantly. After the first full calendar year of operation (2019), the carbon footprint had been reduced to around 60 tonnes – a 60 % reduction. It should be noted that one major source of GHG emissions was eliminated completely – i.e. burning natural gas to heat the facility. The renovation project replaced 10 gas-burning furnaces with 10 ground-source (geothermal) heat pump furnaces powered by solar electric. There are no GHG emissions associated with heating and cooling the renovated facility. The harm associated with electric power was also reduced significantly because FUCD generates its power using a rooftop solar PV system.



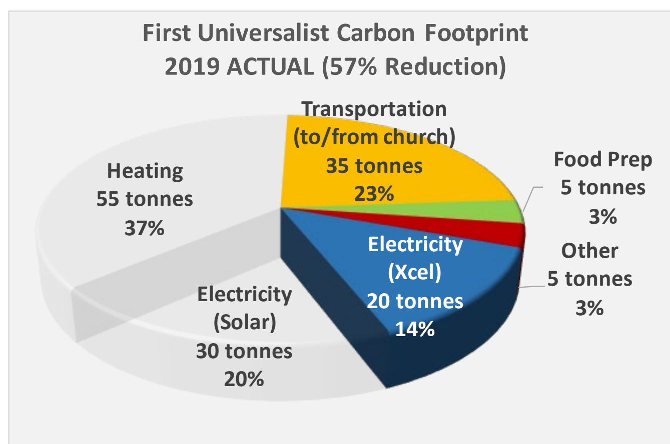


Figure 10 Carbon Footprint Reduction: GOAL versus ACTUAL for 2019

By adding a new sustainable energy system (solar electric and geothermal heating and cooling), FUCD reduced GHG emissions significantly as illustrated in Figure 17. However, the initial goal for the BFF renovation project was to eliminate emissions linked to heating and cooling the facility as well as emissions associated with generating electrical power. The first part of the goal was achieved, but the there were more activities at the church and use of the renovated facility than predicted – hence the use of energy was more than predicted. As a result, the solar PV system was not sized properly to provide all the energy needed to operate the building sustainably.

In this first year of operation, it became apparent that the energy usage of the renovated facility was much greater than expected/predicted by the architect. As a result, the solar PV system was found to be undersized for the new operation of the facility.

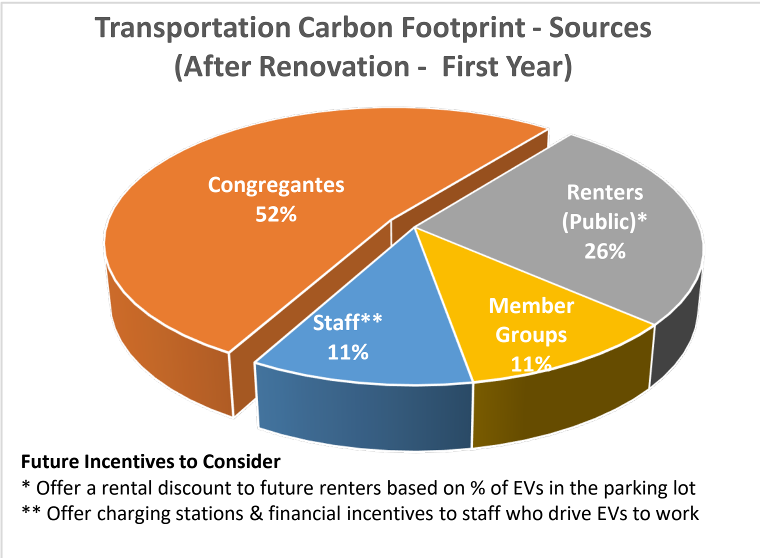


Figure 11 Carbon Footprint Linked to Transportation – First Year After Renovation

The third major contribution to the FUCD carbon footprint is associated with transportation to and from the church using gasoline-powered vehicles as illustrated in **Error! Reference source not found.**. Simple observation of the church parking lots during a Sunday Service indicates 90-95% of FUCD members and staff have not yet transitioned to emission free vehicles (e.g. electric vehicles).[32] This source of GHG emissions was unchanged by the renovation.

Carbon Footprint After Renovation – Second Year.

During the second year of operation (2020), most activities of the church were put on hold as a response to the COVID-19 pandemic. Sunday services were suspended and FUCD did not host any conferences; energy use dropped. As expected, the solar PV system produced about the same amount of energy in 2020 as it did in 2019. However, in 2020, the energy generated exceeded the usage in this limited mode of operation. As a result, FUCD met its Net Zero Energy goal – in fact there was a small surplus of energy generated (3%) during 2020. Althe so, casual observation of the church parking lots indicated very few cars except those of the staff; therefore the transportation related GHG emissions were minimal. A back-of-the-envelope calculation indicated the transportation emissions associated with the staff were similar to the GHG emissions avoided by the surplus of energy generated by the solar system. Albeit fortuitous, FUCD had a near zero carbon footprint for the year 2020 as indicated in Figure 1.

Carbon Footprint After Renovation - Third Year Projection.

A projection of the carbon footprint for 2021 is illustrated in Figure 1. It was assumed most members will be vaccinated for COVID-19 before the end of the year, allowing the facility to re-open appropriately, and start to return to a new normal usage by the end of 2021 – possibly approaching that of 2019.

Carbon Footprint After Renovation - Fourth Year Projection.

By 2022, it was assumed that additional solar modules would be installed on-site or in a community solar garden. It was not expected that there will be significantly more members driving electric vehicles to church functions, so in 2022, the major source of GHG emissions for FUCD will likely be associated with transportation to / from the church as illustrated in Figure 1.

[32] The Green First Task Force is exploring a program to help staff purchase EVs (not lease) with a zero interest loans to purchase an EV. (plus the agreement they would recycle/repurpose the vehicle responsibly when they no longer need it.) Members could create a capital fund for this purpose as an incentive for staff.

Carbon Footprint One Decade from Now.

By 2030, to comply with the IPCC GHG emission reduction guidelines, FUCD will be challenged. 50% of the vehicles in the parking lot will need to be emission free (e.g. electric or hydrogen powered) vehicles.[33] Also by 2030, it was expected that the natural gas stove/oven in the church kitchen would be replaced by an electric induction stovetop / electric convection oven so food could be prepared sustainably. As illustrated in Figure 1, the major source of GHG emission will be associated with church members who continue to drive gasoline powered vehicle to church events.

Carbon Footprint Two Decades from Now.

By 2040, it was assumed that nearly all church members will be driving a vehicle with zero emissions (e.g. an electric vehicle with a hydrogen fuel cell or battery charged from renewable energy.) It was also assumed the church grounds will include sustainable vegetation intended to capture and sequestration carbon (i.e. negative carbon emissions). If so, FUCD will be in complete compliance with the IPCC P1 pathway[34] that will limit global warming of the planet to 1.5 deg C as depicted by the dashed gray line in Figure 1.

Using the trajectory of the IPCC P1 pathway (described in Appendix B) as guidelines, (see dashed gray line in Figure 1), the FUCD Carbon Footprint Roadmap stays within the IPCC guidelines. FUCD can claim they are "still in the Paris Agreement."

Climate science tells that ALL human activities that search for, drill, dig, and extract, transport, refine, and burning carbon-based fuels of any kind (especially the tar sands product being reined at Suncor) is ecocidal - meaning it contributes to an impending global mass extinction of complex living beings. The sooner we transition to solar, wind, hydro, hydrogen and other non carbon fuels, the more lives o human and non-human species we can save. Suncor must be shut down. Medical science tells us that the discharge of carcinogenic substances including benzene by Suncor into our common air, water and soil is a structural form of violence that is killing and debilitating humans and other forms of life. Suncor must be shut down now. Their product is not just obsolete because their are safe, plentiful and healthy alternative sources of energy - we don't need to refine more tar sands oil. Based on their inability to be lawful citizens, in violation of civil society, they must be stopped operations immediately and denied a permit to proceed.

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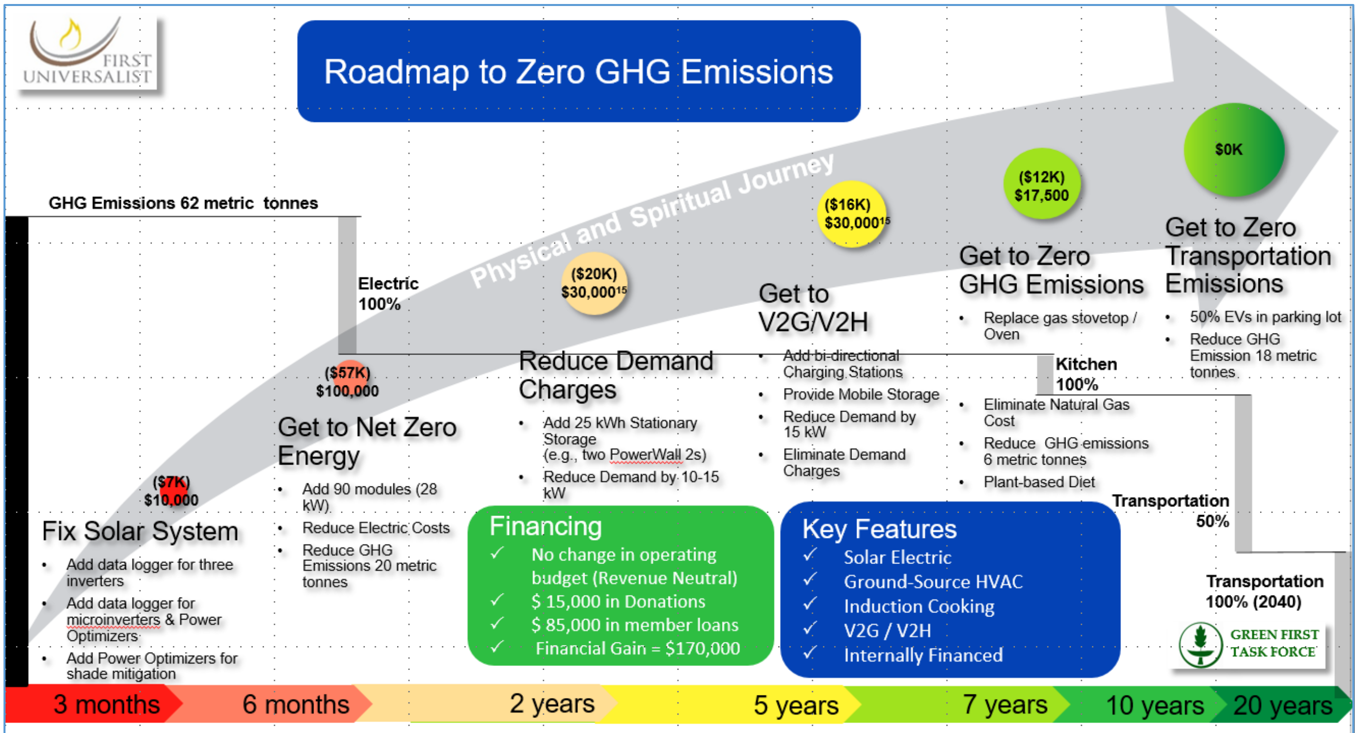
[33] The electrical energy for these EVs must be derived from renewable energy sources – not by burning carbon.

[34] Further discussion of the IPCC pathways can be found in Appendix B IPCC Pathways to 1.5 deg C.



This performance report for the first two years of operation identifies several possible reasons why there was a shortfall in energy production in 2019 and what we can do about it to meet our sustainability goals. Although the solar PV system and ground-source (geothermal) heat pump HVAC system are functioning properly (as designed), some other adjustments to the energy system are suggested, in addition to installing more solar PV modules to make up the shortfall in energy production.

Unfortunately, there was insufficient quantitative data available after the first year to recommend a specific path forward. In general, it became obvious that the size of the solar PV system would need to be increase to meet the Net Zero Energy goal if the new "normal" operations trended back to 2019 operations.

At the end of the first year, it became apparent that additional information (and monitoring instrumentation) was needed to develop a specific roadmap / path to reach our Net Zero Energy / Zero GHG emissions goals. The Green First Task Force funded and installed nearly two dozen sensors at the subarray level to obtain performance data needed to understand and address the energy shortfall observed in 2019.

After a second year of observation with the additional monitoring equipment and performance data, it was possible to better understand how the system works and how much additional solar equipment was needed to be at Net Zero Energy.

During the second year of operation, the Green First team also developed a Revenue Neutral funding model that is simply an extension of the successful funding approach used to purchase and install the initial solar system. The proposed funding approach does not require a change in the church budget. The needed capital to extend the current system can be obtained from member donations and low interest member loans. An implementation plan along with a proposed funding approach is provided in this report for Staff, Board and Congregational approval.

7. Conclusions

After the first full year of operation, there was enough performance data to verify the ground-source HVAC system was operating as designed; however, the lack of data for the solar PV system left the Green First team with more questions than answers.

During the second year of operation, the Green First team focused their attention on the solar PV system. They purchased and installed additional instrumentation to monitor the output of solar PV system at the subarray level. Their objective was to replicate the first year of operation and record additional information that would answer all of their questions. But the Universe threw a curve ball with COVID-19 and changed the usage of the facility dramatically. Nevertheless, even in this reduced mode of usage, they collected relevant information that resolved their questions about the performance of the solar PV system.

During the second year of operation, they were able to verify the accuracy of Xcel Net Meter and identify why the FUCD eGauge sensors that measure total usage were not as accurate as the Xcel Net Meter.

We were able to conclude that we were using the renovated facility more than the old facility, so the new normal mode of operation of the renovated facility requires more energy than the old facility – but the energy it uses is renewable.

We concluded we were in the right track, but just had not completed the trek; we needed to recalculate the energy usage and adjust the size of the solar PV system accordingly.

Although by transitioning to renewable energy, we increased the electrical energy by 36%, the utility cost increased by only 9%

The second year of operation provided data that allowed us to quantify how much the solar PV output was being reduced by shading. It turned out that the trees south of building along Hamden avenue were reducing the annual output by around 4%. We discovered that structural shading by Inverter boxes, mid parapet wall and other roof structure were reducing the output by an additional 2-3%. Going forward, it would be cost effective to consider mitigating the structural shading and regain some of lost output capability.

Having answered many of the questions about the energy, we were able to broaden our perspective and evaluate the congregational carbon footprint and how we can reduce it further.

A Roadmap for reducing our carbon footprint to near was developed and is being proposed for implementation. Going forward, we can invest in more solar capability, and within the next decade replace the natural gas stove with electric and help our members transition from gasoline powered vehicle to zero emissions vehicles. (EVs) We are on an exciting path that is in compliance with Paris Climate Accords of 2015. This path of using renewable energy is actually less expensive that using fossil fuel as an energy source – the church is financially ahead by switching to renewable energy.

We learned that in 2020, activities at the church were reduced/curtailed and the solar PV system generated all the power needed- however, even though we didn't purchase any power from Xcel, we were still charges $6500 for "peak demand fees" By adding storage, we can reduce this demand fee

We learned there is an emerging/exciting technology available called V2G that will allow us to install bi-directional charging stations – in doing so, members can help lower the peak demand charges of the facility by pluging in on a Sunday morning and "donating" say 30 miles of electric to the church – thereby reducing the peak demand by about 10 kW

The body of the report addressed several basic questions:

Is the new energy system performing properly?
Is the facility operating as a net zero Energy building as intended?
Is the facility operating with Zero GHG emissions?
Is the new energy system a Revenue Neutral renovation?
What adjustments are needed to fully meet the FUCD sustainability goals?
What is the post-pandemic Roadmap[35] for a zero carbon footprint? [36]

FUCD transitioned to renewable energy and avoided dumping nearly 100 metric tonnes of CO_2 into the atmosphere. An amazing (and admirable) accomplishment.

The solar PV system **generated less energy than predicted** by a solar sizing computer model, PVWATTS. The facility **consumed more energy than predicted** by the architect's heat load/energy use model. As a result, FUCD missed its Net Zero Energy goal by 43%.

Based on the Xcel Meter data, the FUCD solar PV system produced 68,630 kWh over the specified 12-month time period. During the past year of operation, the renovated facility consumed 98,019 kWh[37] of energy resulting in an inadvertent annual energy shortfall of 29,389 kWh (43%). This can be easily remedied by adding more solar modules.

A shortfall means FUCD purchased 29,389 kWh of energy from Xcel last year. The FUCD utility bill for electric was $6450 including Xcel "Demand Fees." This unexpected purchase of energy had two unintended consequences:

1) The additional cost contributed to missing the mark of being "Revenue Neutral" by $1820 (0.2% of the annual budget), and

2) Since 72% of the Xcel supplied energy was generated by burning hydrocarbons (aka fossil fuel), FUCD became responsible for over 20 metric tonnes of GHG emissions and other harmful materials that were unethically dumped into the atmosphere by Xcel to generate the FUCD shortfall.

Because FUCD did not quite make it to the Net Zero Energy finish line, the energy shortfall contributed to a less habitable planet for future generations.

To help correct these discrepancies, the energy usage can be reviewed to identify possible overlooked conservation measures; but, there is no question that FUCD needs to **increase solar electric production**.

There are two obvious ways to increase production.

1) Modify a portion of the current solar array to better respond to partial shading from the trees on the south side of the building along Hampden Ave., and

2) Add more solar modules onsite, and/or invest in offsite Community Solar.

Both avenues will be pursued.

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[35] The Post-Pandemic Roadmap assumes FUCD returns to new "normal operations" 1) in a manner that is consistent with the UU Principles; 2) as a responsible global citizen in compliance with the IPCC guidelines initiated in the Paris Agreement of 2015; and 3) as a positive example in the community - sharing information and resources with other faith-based organizations.

[36] See the Glossary for a detailed definition of 'Carbon Footprint.'

[37] Hourly average was 11 kW with Peak Billable Demand of 43 kW in Feb & Mar 2019)

8. Recommendations – Build on What is Working

After one year of operation, in general, the new energy system appears to be functioning properly as designed.

The solar PV system was inadvertently undersized for how the renovated facility is now is being used. The shortfall in energy production can be resolved by installing additional PV modules on the roof and in the parking lot. There is some space on the roof for additional modules (See Appendix U for an estimate).

There are 5 recommended adjustments to the Energy System, listed in Table 8.

Table 8 Suggested Adjustments in the New Sustainable Energy System

Recommended Upgrades to Energy System	Estimated Cost	Rationale
1) Add monitoring capability a. To the three the three subarrays with PVI 14TL inverters. COMPLETED To the three subarrays with microinverters COMPLETED b. To the existing 29 microinverters PENDING	a. $2000 - purchased and installed by Green First Task Force. COMPLETED b. $1700 – BriteStreet Proposal – ON HOLD	• **Needed to assure proper operation** • **Needed for long term maintenance** • **Needed to quantify shading effects** COMPLETED • **Fold effort into a larger project PENDING**
2) Shade Mitigation. a. **Tree shading** appears to affect 60-90 modules in the winter months and reduce output by around 4%. b. **Structural shading** of the front row of modules north of the mid- parapet wall reduces the system output by 2%. **PENDING**	**a.** Adding 60-90 Power Optimizers or micro inverters does not appear to be cost effective. **LOW PRIORITY** b. $1000 – 10 modules, front row at mid-parapet wall – **PENDING**	• **Maximize the performance of the current system degraded by partial shading (AS NEEDED)** • **Fold effort into a larger project PENDING**
3) Add modules to make up the 2019 shortfall of 29,389 kWh / year in power generation and reach the authorized 2016 goal of Net Zero Energy. This suggests an additional 28 kW solar PV capability. (Basis: 57 kW produced 67,800 kWh annually. Assuming 315W / module, 88 modules would be needed. There is some roof space for modules. The remainder could be installed as carport solar.	Use a "Revenue Neutral" financing model. There would be no change to the operating budget. The church is **Classical Economic Cost.** FUCD pays Xcel $6,450 / year for electric power. **Social Cost.** Xcel dumps 20 metric tonnes of GHG emissions into the atmosphere (social cost).	• **Needed to stop doing harm (20 metric tonnes of GHG emissions annually).** • **Needed to achieve net-zero energy.** • Should have been in the original design. • Capital required for additional solar is estimated to be around **$72,000.** "Revenue Neutral" financing requires **$25,000 in donations** and **$47,000 in 1.5% member loans, 15-year loan.** Annual payments remain the same as

		the current cost of Xcel electric ($6,450). $3,500 is re-directed to repay member lenders.
Total	• **No Additional Operating Cost** • **Funding by Member Donations/Loans**	
4) Add Stationary Storage (10 kW)	**$16,000 - $20,000**	• Needed to level peak demand
5) Add V2G or V2H capability (15 kW)	**$4,000 x 3 = $12,000**	• Needed to limit peak demand to under 25 kW • Consider the use of members' EVs as additional storage. Plug-in several EVs for the duration of the Sunday service. Operate off EV batteries on zero sun days.

Continue to base the requirement to reach the Net Zero Energy goal on ethics, morality and the UU Purposes & Principles. "It is not about the money."[38] Extend the existing system and financing approach to cross the finish line and achieve Net Zero Energy.

Upgrade and Extend the Current Solar PV System

1) Add monitoring capability to the existing 29 micro inverters and future micro inverters.
2) Add 10 micro inverters to the entire first row of modules shadowed by the mid parapet wall, Inverter boxes and other structure to reduce the effects of partial shading in the fall-winter-spring months. This performance data is needed to determine if relocating the three inverter boxes is appropriate.
3) Extend the solar array to increase production to at least 100,000 kWh per year.
4) Continue to explore the use of stationary and mobile storage to minimize peak demand and reduce demand charges.

Reapply to Xcel for additional solar modules (e.g. 30 kW)

Because FUCD has used the Xcel Meter data to determine the actual pre-pandemic energy usage in 2019 to be 98,019 kWh, there is justification to reapply for additional solar modules based on the Xcel Meter data. In theory, using the 120% regulation, FUCD would qualify for a system that produces 117,622 kWh per year. For two consecutive years our 57 kW rooftop solar PV system generated at least 68,630 kWh annually (That's a production factor of 1208 kWh /kW). In theory, we should be able to extend our solar system production by 48,992 kWh (from 68,630 kWh to 117,622 kWh.) Using the FUCD production factor of 1208 kWh /kW, we could add 40 kW. Using the PVWATTS production factor of 1480, we could add 33 kW. If we do not want to maximize the size of the solar allowable by Colorado regulations, we could drop back to a production goal of 100,000 kWh – a 31,500 kWh increase or 21- 26 kW we could add (a 37%-46% increase.)

Because a 37%-46% increase in production is required to meet our Net Zero Energy, Xcel will probably require a separate production meter for the new modules and there may not be any REC payments for this additional production. Regrettable, but that is the way today's social system is; it is designed to prefer profit over perpetuity of life.

[38] This phrase is borrowed from Tom Abood, a distinguished member of First Universalist Church Denver.

- If FUCD were to use the 120% ground rule, 120% of 98,019 kWh = 117,622 kWh. This would be the upper limit for a solar PV system at this point in the facility electrification effort.
    - FUCD has a system that produces 68,630 kWh (56.8 kW) with an actual production factor of 1208 kWh/kW
    - FUCD could add 48,992 kWh of production (40.6 kW rating)[39] for a total of 97.4 kW as an upper limit.
- Adding 29,389 kWh (24 kW rating) would be the breakeven amount.
- Some margin is recommended (e.g. 5%) as indicated in Table 9.

The cost estimates in Table 9 assume that possibly 50 modules could be added to the existing roof, and the remainder would be added to carport solar in the east parking lot (with a higher $/W factor).

Table 9 Additional Solar Options

Margin	Production kWh	To Be Added kWh	Rating kW	Additional kW	Modules		Additional Cost	
					315 W	350 W	50 @ $2.15/W ($33,862), remainder @ $3/W	50 @ $2.50/W ($43,750), remainder @ $3.50/W
0	98,019	29,389	81.1	24.3	77	69	$59,637	$67,550
5%	**102,920**	34,290	**85.2**	**28.4**	**90**	**81**	**$71,663**	**$81,725**
10%	107,821	39,191	89.3	32.5	103	93	$83,948	$96,425
20%	117,622	48,993	97.4	40.6	129	116	$108,518	$124,600

Summary. It is suggested that 'revenue neutral' funding approaches be created for the range of options until a specific path is decided. The lower end of the range would be to add 28 kW at a possible cost of $72,000 to $82,000 and the upper range would be to add 40 kW at a probably cost of around $108,000 to 125,000.

The first objective is to extend the solar PV system to be net zero as originally intended. An example revenue neutral funding approach is illustrated in Table 10. The capital would be assembled with $25,000 in donations and $47,000 in low interest member loans. We would no longer be

[39] Based on experience with the NREL PVWATTS computer model, a local NREL weather model could be used instead of the default weather model. As a result, the 1 kW production estimate for a roof-mounted system tilted 10 degree to the south would be 1190 kWh / kW. So FUCD should qualify for at least an additional 24 kW (Net Zero Energy) or at most an additional 39 kW system (120% Net Zero Energy). The actual (measured) production factor of the FUCD system is 68,630 kWh/56.8 kW = 1208 kWh/kW.

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Table 10 Solar Electric -Add 28 kW @ $2.15/W + Carport solar @$3/W

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL
Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)

MEMBER LENDER FINANCING "TRADITIONAL LOAN $ 25,010 GREEN GRANTS (DONATIONS)

EXAMPLE

ADD 28 kW

100% of 2019 Usage

FOSSIL FUEL ENERGY SYSTEM COSTS	
Current Electric Annual Bill	$3,500
Total	$3,500

RENEWABLE ENERGY SYSTEM COSTS			
Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)	$72,000	Base Grid Fees	$360
		Equip. Servicing	$200
Total Equipment Budget	$72,000	Annual O & M	$560

LIFE CYCLE COST ASSESSMENT	
20 Year Life Cycle Cost (Renewab	$67,996
Inflation / Energy Esca	3.0%
20 Year Life Cycle Cost (Fossil Fue	$96,856
20 Year Cost Reduction w/ Renew	$28,860

Organization's Total Budget		$770,000	(Optional)
"TRADITIONAL LOAN SERVICING" SCENARIO		1.5%	Interest Rate
100% Sustainable Energy System Cost	$72,000		
Dedicated Grants/D[illegible]ations for Energy System	$25,010	(35%)	
Financing with[illegible] Energy Loan	$46,990	(65%)	
[illegible]st	$5,514	15	year term
[illegible]ancing Cost	$52,504		
[illegible]tional)	$3,500		

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	[illegible]	[illegible]	[illegible]n Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$3,605	$577	$3,500	[illegible]	[illegible]	$4,077	($472)	($472)	0.5%
2	2022	$3,713	$594	$3,500	[illegible]	$4,094	$8,171	($381)	($853)	0.5%
3	2023	$3,824	$612	$3,500	[illegible]	$4,112	$12,284	($288)	($1,142)	0.5%
4	2024	$3,939	$630	$3,500	[illegible]	$4,130	$16,414	($191)	($1,333)	0.5%
5	2025	$4,057	$649	$3,500	$17,501	$4,149	$20,563	($92)	($1,425)	0.5%
6	2026	$4,179	$668	$3,500	$21,001	$4,168	$24,731	$11	($1,414)	0.5%
7	2027	$4,304	$688	$3,500	$24,502	$4,188	$28,920	$116	($1,299)	0.5%
8	2028	$4,433	$709	$3,500	$28,002	$4,209	$33,129	$224	($1,075)	0.5%
9	2029	$4,566	$730	$3,500	$31,502	$4,230	$37,359	$336	($739)	0.5%
10	2030	$4,703	$752	$3,500	$35,002	$4,252	$41,611	$451	($288)	0.6%
11	2031	$4,844	$775	$3,500	$38,503	$4,275	$45,887	$569	$280	0.6%
12	2032	$4,989	$798	$3,500	$42,003	$4,298	$50,185	$691	$971	0.6%
13	2033	$5,139	$822	$3,500	$45,503	$4,322	$54,507	$817	$1,788	0.6%
14	2034	$5,293	$847	$3,500	$49,003	$4,347	$58,854	$946	$2,734	0.6%
15	2035	$5,452	$872	$3,500	$52,504	$4,372	$63,227	$1,080	$3,813	0.6%
16	2036	$5,616	$898	$0	$52,504	$898	$64,125	$4,718	$8,531	0.1%
17	2037	$5,784	$925	$0	$52,504	$925	$65,050	$4,859	$13,390	0.1%
18	2038	$5,958	$953	$0	$52,504	$953	$66,003	$5,005	$18,395	0.1%
19	2039	$6,137	$982	$0	$52,504	$982	$66,985	$5,155	$23,550	0.1%
20	2040	$6,321	$1,011	$0	$52,504	$1,011	$67,996	$5,310	$28,860	0.1%
		$96,856 Total 20 yr Fossil Fuel Costs	$15,492	$52,504 Total Loan Payments		$67,996 Total 20 yr Renewable Energy Costs		$28,860 Total Cost Reduction/ Financial Gain		

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Table 11 Solar Electric -Add 28 kW @ $2.15/W + Carport solar @$3/W Plus Storage

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W) plus Storage (PowerWall 2 @ $8K)

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPA $ 27,590 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS		RENEWABLE ENERGY SYSTEM COSTS			
Current Electric Annual Bill	$4,500	Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W) plus	$72,000	Base Grid Fees	$360
		Storage (PowerWall 2 @ $8K)	$16,000	Equip. Servicing	$200
Total	$4,500	Total Equipment Budget	$88,000	Annual O & M	$560
		Organization's Total Budget		$770,000 (Optional)	
LIFE CYCLE COST ASSESSMENT		"TRADITIONAL LOAN SERVICING" SCENARIO		1.5% Interest Rate	
20 Year Life Cycle Cost (Renewable)	$82,990	100% Sustainable Energy System Cost	$88,000		
Inflation / Energy Escalation	3.0%	Dedicated Grants/Donations for Energy System	$27,590 (31%)		
20 Year Life Cycle Cost (Fossil Fuel)	$124,541	Financing with Member Energy Loan	$60,410 (69%)		
20 Year Cost Reduction w/ Renewable En	$41,551	Interest	$7,088	15 year term	
		Total Financing Cost	$67,498		
		Annual Loan Payments (Traditional)	$4,500		

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$4,635	$577	$4,500	$4,500	$5,077	$5,077	($442)	($442)	0.7%
2	2022	$4,774	$594	$4,500	$9,000	$5,094	$10,171	($320)	($762)	0.7%
3	2023	$4,917	$612	$4,500	$13,500	$5,112	[illegible]5,283	($195)	($957)	0.7%
4	2024	$5,065	$630	$4,500	$18,000	$5,13[illegible]	[illegible]413	($65)	($1,022)	0.7%
5	2025	$5,217	$649	$4,500	$22,499	[illegible]	[illegible]	$68	($953)	0.7%
6	2026	$5,374	$668	$4,500	$26,999	[illegible]	[illegible]	$206	($747)	0.7%
7	2027	$5,535	$688	$4,500	$31,49[illegible]	[illegible]	[illegible]	$347	($400)	0.7%
8	2028	$5,701	$709	$4,500	$3[illegible]	[illegible]	[illegible]	$492	$92	0.7%
9	2029	$5,872	$730	$4,500	[illegible]	[illegible]	[illegible]56	$642	$734	0.7%
10	2030	$6,048	$752	$4,500	[illegible]	[illegible]	$51,608	$796	$1,530	0.7%
11	2031	$6,229	$775	$4[illegible]	[illegible]	[illegible]	$56,883	$954	$2,484	0.7%
12	2032	$6,416	$798	$4,[illegible]	[illegible]	[illegible]	$62,181	$1,118	$3,602	0.7%
13	2033	$6,608	$822	$4,50[illegible]	[illegible]	[illegible]22	$67,503	$1,286	$4,888	0.7%
14	2034	$6,806	$847	$4,500	[illegible]	$5,347	$72,849	$1,459	$6,348	0.7%
15	2035	$7,010	$872	$4,500	[illegible]	$5,372	$78,221	$1,638	$7,986	0.7%
16	2036	$7,220	$898	$0	[illegible]98	$898	$79,119	$6,322	$14,308	0.1%
17	2037	$7,437	$925	$0	[illegible]67,498	$925	$80,044	$6,512	$20,820	0.1%
18	2038	$7,660	$953	$0	$67,498	$953	$80,997	$6,707	$27,527	0.1%
19	2039	$7,890	$982	$0	$67,498	$982	$81,979	$6,908	$34,435	0.1%
20	2040	$8,127	$1,011	$0	$67,498	$1,011	$82,990	$7,116	$41,551	0.1%
		$124,541 Total 20 yr Fossil Fuel Costs	$15,492	$67,498 Total Loan Payments		$82,990 Total 20 yr Renewable Energy Costs		$41,551 Total Cost Reduction/ Financial Gain		

EXAMPLE
ADD 28 kW Plus Storage
100% of 2019 Usage

Table 12 The other extreme ample is to use the 120% option and maximize the amount of solar that the regulations allow to be added.

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL
Solar Electric(39 kW@$2.15/W + Carport solar@$3/W) plus Storage (PowerWall 2 @ $8K)

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYI $ 56,880 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS		RENEWABLE ENERGY SYSTEM COSTS				
Current Electric Annual Bill	$5,000	Solar Electric(39 kW@$2.15/W + Carport solar@$3/W) plus	$108,000	Base Grid Fees	$360	
		Storage (PowerWall 2 @ $8K)	$16,000	Equip. Servicing	$200	
Total	$5,000	Total Equipment Budget	$124,000	Annual O & M	$560	
		Organization's Total Budget			$770,000	(Optional)
LIFE CYCLE COST ASSESSMENT		"TRADITIONAL LOAN SERVICING" SCENARIO			1.5%	Interest Rate
20 Year Life Cycle Cost (Renewable)	$90,488	100% Sustainable Energy System Cost	$124,000			
Inflation / Energy Escalation	3.0%	Dedicated Grants/Donations for Energy System	$56,880	(46%)		
20 Year Life Cycle Cost (Fossil Fuel)	$138,413	Financing with Member Energy Loan	$67,120	(54%)		
20 Year Cost Reduction with Renewable I	$47,925	Interest	$7,876		15	year term
		Total Financing Cost	$74,996			
		Annual Loan Payments (Traditional)	$5,000			

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$5,150	$577	$5,000	$5,000	$5,577	$5,577	($427)	($427)	0.7%
2	2022	$5,305	$594	$5,000	$9,999	$5,5[illegible]	$11,170	($289)	($715)	0.7%
3	2023	$5,464	$612	$5,000	$14,999	[illegible]	$16,782	($148)	($863)	0.7%
4	2024	$5,628	$630	$5,000	$19,999	[illegible]	$22,412	($2)	($865)	0.7%
5	2025	$5,797	$649	$5,000	$24,999	[illegible]	[illegible]28,061	$148	($717)	0.7%
6	2026	$5,971	$668	$5,000	$29,998	[illegible]	[illegible],728	$303	($413)	0.6%
7	2027	$6,150	$688	$5,000	$34,9[illegible]	[illegible]	[illegible]16	$462	$49	0.6%
8	2028	$6,335	$709	$5,000	[illegible]	[illegible]	[illegible]25	$626	$675	0.6%
9	2029	$6,525	$730	$5,000	[illegible]	[illegible]	[illegible]50,854	$795	$1,471	0.6%
10	2030	$6,721	$752	$5,00[illegible]	[illegible]	[illegible]	$56,606	$969	$2,440	0.6%
11	2031	$6,923	$775	[illegible]	[illegible]	[illegible]75	$62,381	$1,148	$3,588	0.6%
12	2032	$7,131	$798	[illegible]	[illegible]	$5,798	$68,179	$1,333	$4,921	0.5%
13	2033	$7,345	$822	[illegible]	[illegible]	$5,822	$74,000	$1,523	$6,445	0.5%
14	2034	$7,565	$847	$5,[illegible]	[illegible]	$5,847	$79,847	$1,718	$8,163	0.5%
15	2035	$7,792	$872	$5,00[illegible]	[illegible]	$5,872	$85,719	$1,920	$10,083	0.5%
16	2036	$8,026	$898	$0	[illegible]6	$898	$86,617	$7,128	$17,211	0.1%
17	2037	$8,267	$925	$0	[illegible]4,996	$925	$87,542	$7,342	$24,553	0.1%
18	2038	$8,515	$953	$0	$74,996	$953	$88,495	$7,562	$32,115	0.1%
19	2039	$8,770	$982	$0	$74,996	$982	$89,477	$7,788	$39,903	0.1%
20	2040	$9,033	$1,011	$0	$74,996	$1,011	$90,488	$8,022	$47,925	0.1%
		$138,413 Total 20 yr Fossil Fuel Costs	$15,492	$74,996 Total Loan Payments		$90,488 Total 20 yr Renewable Energy Costs		$47,925 Total Cost Reduction/ Financial Gain		

EXAMPLE
ADD 39 kW Plus Storage
120% of 2019 Usage

Consider adding storage

There are several reasons to consider adding Behind-the-Meter (BTM) Storage at this point.

1) Storage can level the peaks & valleys in the usage profile. When activated, certain electrical equipment tends to create power spikes in usage – be it a motor or heater element. A 3 kW load for 5 minutes could be supplied from a battery instead of drawing from the grid and contributing to the "Peak Demand."

   For example, it appears that a 20-30 kWh storage capability could reduce the Sunday morning usage profile to below 25 kW.

2) **Peak Demand Affect by an Electric stove/oven.** Storage will be required to transition the church's method of preparing food using natural gas stove/oven to using electric stovetop (e.g. induction heating). When a stovetop heating element is activated to a "high" setting it uses around 1.5 kW. Four "burners" turned on to a "high" setting at the same time would create a spike of around 6kW in the usage profile for as long as

the heater elements were on (e.g. 30 minutes). The energy used in this case would be 3 kWh that could be supplied by a battery rather than being drawn from the grid and adding 6 kW to the Peak Demand.

3) Storage could level the usage profile for future Charging Stations in the church parking lot.

Replacement of natural gas stove/oven with an electric stove. Gas usage by the kitchen was around 460 therms in both 2019 and 2020.

Approach

1) **Determine the amount of capital needed** to finish this project and reach the Net Zero Energy goal, the Zero GHG Emissions Goal and the Revenue Neutral Goal. Being 71% of the way to the finish line is not the same as crossing the finish line.

2) **Develop a plan to obtain the required capital** that does not increase the church budget. It would be advisable to approach the Board with a Revenue Neutral funding approach and with the funding already in place.

Based on recent past experience, obtaining capital from the annual FUCD operating budget is a non-starter. The Green First Task Force was advised in 2015-2016 that any proposal that would increase the operating budget would not be accepted by the Board of Trustees. However, a proposal that was "Revenue Neutral" (i.e., did not increase the operating budget) could be approved.

3) It would be advisable to have concurrence from an independent review team (selected by the Board?) similar to what was used before.

Develop "Revenue Neutral" funding models

There is now enough information to explore "Revenue Neutral" funding models using existing spreadsheets developed for the original renovation project. Several cases were evaluated with the "revenue neutral" spreadsheet model.

Phase I – Completion of Initial Goal to be Net Zero Energy

The first objective is to make adjustments to the current solar PV system to improve its performance.

The second objective is to achieve Net Zero Energy by adding enough solar modules to generate 100% of the energy used by the church.

Phase II – Reduce Peak Demand Charges.

The third objective is to reduce the "demand" charges by withdrawing energy from on-site battery storage during periods of peak demand (e.g. on Sunday.) Adding on-site storage is also a stepping-stone that leads to future electrification of the kitchen and replacement of the natural gas stove/oven with an electric version as well as implementation of mobile storage (Electric Vehicle to Grid – V2G technology) .

Phase III – Reduce Total Carbon Footprint

The fourth objective is to support the long-range goal of reducing the transportation associated GHG emissions due to members driving gasoline powered vehicles to church events. Adding bi-directional charging stations would support the transition of EVs AND it would allow members with EVs to "donate" energy to the church during peak demand periods (e.g. Sunday services) thereby reducing the inequitable demand charges.

Objective# 1 Propose a Revenue Neutral Funding Model to "fix/adjust" the current solar system.

The first objective is to adjust the current solar system to improve performance.

- **Option A.** Eliminate the string amplification effects of partial tree shading. Tree shading is not observed during the summer months, nor during late spring or early fall. Partial tree shading affects nearly all (e.g. 60- 90 modules) on the former Forum roof in the winter months. The reduction in system output due to tree shading was measured to be around 4% of the annual output.
  - Adding power optimizers to 60- 90 modules would eliminate the string amplification effects of tree shading and reduce the tree shading effect to around 2%. This is equivalent to gaining 1.1 kW of additional solar PV output.
  - According to a City Electric quote, 30 power optimizers would cost around $3,000, so 60 would be around $6,000 and 90 around $9,000 to mitigate the string amplification effects.
  - This investment to increase system output is equivalent to $6/W to $9/W. This is not the best use of the capital. **Option A is NOT RECOMMENDED**.
  - $6,000 to $9,000 could be used to purchase 3 kW- 4kW of rooftop solar @ $2.15/W, or 2 kW -3 kW of carport solar @ $3/W.
- **Option B.** Structural shading results in a 2% reduction of system output. Adding power optimizers (or micro inverters) to the first row of modules north of the mid parapet wall would mitigate the "string amplification" for partial structural shading and reduce it to around 1%. This is equivalent to gaining 0.6 kW of output production.
  - The approximate cost to install 10 power optimizers or micro inverters would be around $1000
  - This is equivalent to investing $1000 to gain 0.6 kW = $1.60/W. **RECOMMENDED**.
- **Option C.** Add the capability to monitor all micro inverters and optimizers. City Electric submitted a cost estimate of $1700. This "fix" will not increase the output of the system but it will help monitor the modules that are being shaded by the structure. This will provide information about whether it is cost effective to change the location of the inverter boxes. **RECOMMENDED**.

Summary. The total cost of this project is around $2,700. These adjustment to the system will increase output around 3% and save around $500 annually. The project, although value-added, is too small to warrant elevating it to the Board of Trustee or Congregational level. It would be best to incorporate these work items into a larger project.

Table 13 Case #1 - Example of a Revenue Neutral-Funding Model – Fix Current System

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYMENT" $ 1,060 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS			RENEWABLE ENERGY SYSTEM COSTS			
Current Electric Annual Bill	850		Additional Solar PV	$0	Base Grid Fees	$0
Lost REC Revenue	-		Shading Mitigation Cost	$3,000	Equip. Servicin	$0
			Monitoring: Microinverters/Power	$1,700	Annual O & M	$0
			Monitoring: 15 strings-3 Inverters	$2,000		
			Storage (PowerWall 2 @ $8K)	$0		
Total	850		Total Equipment Budget	$6,700		
"TRADITIONAL LOAN SERVICING" SCENARIO						
100% Sustainable Energy System Cos	6,700					
Dedicated Grants/Donations for Energ	1,060	(16%)				
Financing with Member Energy Loan	5,640	(84%)				
Interest	305	7 year term @	1.5% Interest Rate			
Total Financing Cost	5,945					
Annual Loan Payments (Traditional)	849					
25 Year Life Cycle Cost (Renewable)	5,945					
25 Year Life Cycle Cost (Fossil Fuel)	31,904	3.0% Inflation / Energy Escalation Rate				
25 Year Cost Reduction with Solar/Ge	25,959			Organization's Total Budg	$828,870	(Optional)

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2020	$876	-	$849	$849	$849	$849	$27	$27	0.1%
2	2021	$902	-	$849	$1,699	$849	$1,699	$53	$79	0.1%
3	2022	$929	-	$849	$2,548	$849	$2,548	$80	$159	0.1%
4	2023	$957	-	$849	$3,397	$849	$3,397	$108	$267	0.1%
5	2024	$986	-	$849	$4,246	$849	$4,246	$137	$404	0.1%
6	2025	$1,016	-	$849	$5,096	$849	$5,096	$167	$570	0.1%
7	2026	$1,046	-	$849	$5,945	$849	$5,945	$197	$767	0.1%
8	2027	$1,077	-	$0	$5,945	$0	$5,945	$1,077	$1,844	0.0%
9	2028	$1,109	-	$0	$5,945	$0	$5,945	$1,109	$2,953	0.0%
10	2029	$1,142	-	$0	$5,945	$0	$5,945	$1,142	$4,095	0.0%
11	2030	$1,176	-	$0	$5,945	$0	$5,945	$1,176	$5,271	0.0%
12	2031	$1,211	-	$0	$5,945	$0	$5,945	$1,211	$6,482	0.0%
13	2032	$1,247	-	$0	$5,945	$0	$5,945	$1,247	$7,729	0.0%
14	2033	$1,284	-	$0	$5,945	$0	$5,945	$1,284	$9,013	0.0%
15	2034	$1,323	-	$0	$5,945	$0	$5,945	$1,323	$10,336	0.0%
16	2035	$1,363	-	$0	$5,945	$0	$5,945	$1,363	$11,699	0.0%
17	2036	$1,404	-	$0	$5,945	$0	$5,945	$1,404	$13,103	0.0%
18	2037	$1,446	-	$0	$5,945	$0	$5,945	$1,446	$14,549	0.0%
19	2038	$1,489	-	$0	$5,945	$0	$5,945	$1,489	$16,038	0.0%
20	2039	$1,534	-	$0	$5,945	$0	$5,945	$1,534	$17,572	0.0%
21	2040	$1,580	-	$0	$5,945	$0	$5,945	$1,580	$19,152	0.0%
22	2041	$1,627	-	$0	$5,945	$0	$5,945	$1,627	$20,779	0.0%
23	2042	$1,676	-	$0	$5,945	$0	$5,945	$1,676	$22,455	0.0%
24	2043	$1,726	-	$0	$5,945	$0	$5,945	$1,726	$24,181	0.0%
25	2044	$1,778	-	$0	$5,945	$0	$5,945	$1,778	$25,959	0.0%
		$31,904	-	$5,945		$5,945		$25,959		
		Total 25 yr Fossil Fuel Costs		Total Loan Payments		Total 25 yr Renewable Energy		Total Cost Reduction/ Financial		

Case # 2 Funding Model to "fix" system AND add 24 kW of production (Net Zero Energy)

The second case to consider "fixes" the current solar system (See Case #1) and adds 28 kW more solar modules. Total cost as indicated in

The "donors" could say their donation of $14,573 had a return of 735% ($107,148) over 25 years - nearly 30% /year. The "lenders" could say their 'socially responsible investment' in the form of a 1.5% loan resulted in actually reducing GHG emissions by 21 metric tonnes per year for an expected 25 years – that's 525 tonnes less $CO2_{eq}$ thanks to their loan – and they got their principle back with some interest. Everyone can be proud; they helped their organization achieve Net Zero Energy status in full compliance with the 2015 Paris Agreement.

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL
Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)

MEMBER LENDER FINANCING "TRADITIONAL LOAN $ 25,010 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS		RENEWABLE ENERGY SYSTEM COSTS			
Current Electric Annual Bill	$3,500	Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)	$72,000	Base Grid Fees	$360
				Equip. Servicing	$200
Total	$3,500	Total Equipment Budget	$72,000	Annual O & M	$560
		Organization's Total Budget		$770,000	(Optional)
LIFE CYCLE COST ASSESSMENT		"TRADITIONAL LOAN SERVICING" SCENARIO		1.5%	Interest Rate
20 Year Life Cycle Cost (Renewabl	$67,996	100% Sustainable Energy System Cost	$72,000		
Inflation / Energy Esca	3.0%	Dedicated Grants/Donations for Energy System	$25,010	(35%)	
20 Year Life Cycle Cost (Fossil Fue	$96,856	Financing with Member Energy Loan	$46,990	(65%)	
20 Year Cost Reduction w/ Renew	$28,860	Interest	$5,514	15	year term
		Total Financing Cost	$52,504		
		Annual Loan Payments (Traditional)	$3,500		

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$3,605	$577	$3,500	$3,500	$4,077	$4,077	($472)	($472)	0.5%
2	2022	$3,713	$594	$3,500	$7,000	$4,094	$8,171	($381)	($853)	0.5%
3	2023	$3,824	$612	$3,500	$10,501	$4,112	$12,284	($288)	($1,142)	0.5%
4	2024	$3,939	$630	$3,500	$14,001	$4,130	$16,414	($191)	($1,333)	0.5%
5	2025	$4,057	$649	$3,500	$17,501	$4,149	$20,563	($92)	($1,425)	0.5%
6	2026	$4,179	$668	$3,500	$21,001	$4,168	$24,731	$11	($1,414)	0.5%
7	2027	$4,304	$688	$3,500	$24,502	$4,188	$28,920	$116	($1,299)	0.5%
8	2028	$4,433	$709	$3,500	$28,002	$4,209	$33,129	$224	($1,075)	0.5%
9	2029	$4,566	$730	$3,500	$31,502	$4,230	$37,359	$336	($739)	0.5%
10	2030	$4,703	$752	$3,500	$35,002	$4,252	$41,611	$451	($288)	0.6%
11	2031	$4,844	$775	$3,500	$38,503	$4,275	$45,887	$569	$280	0.6%
12	2032	$4,989	$798	$3,500	$42,003	$4,298	$50,185	$691	$971	0.6%
13	2033	$5,139	$822	$3,500	$45,503	$4,322	$54,507	$817	$1,788	0.6%
14	2034	$5,293	$847	$3,500	$49,003	$4,347	$58,854	$946	$2,734	0.6%
15	2035	$5,452	$872	$3,500	$52,504	$4,372	$63,227	$1,080	$3,813	0.6%
16	2036	$5,616	$898	$0	$52,504	$898	$64,125	$4,718	$8,531	0.1%
17	2037	$5,784	$925	$0	$52,504	$925	$65,050	$4,859	$13,390	0.1%
18	2038	$5,958	$953	$0	$52,504	$953	$66,003	$5,005	$18,395	0.1%
19	2039	$6,137	$982	$0	$52,504	$982	$66,985	$5,155	$23,550	0.1%
20	2040	$6,321	$1,011	$0	$52,504	$1,011	$67,996	$5,310	$28,860	0.1%
		$96,856 Total 20 yr Fossil Fuel Costs	$15,492	$52,504 Total Loan Payments		$67,996 Total 20 yr Renewable Energy Costs		$28,860 Total Cost Reduction/ Financial Gain		

Table 14 is around $71,663. Assuming this will save $4,752 annually, a revenue-neutral model would require $14,573 in donations and $63,730 in low-interest loans to finance this equipment with no change in the church budget. [a preliminary survey has identified a source of $10,000 in donations and a source for $10,000 in loans.] **Need $4,573 in grants/donations and 53,790 in loans.**

The loans would be paid off in 15 years. There would be a financial gain of $107,148 for FUCD over a 25-year period.

The "donors" could say their donation of $14,573 had a return of 735% ($107,148) over 25 years - nearly 30% /year. The "lenders" could say their 'socially responsible investment' in the form of a 1.5% loan resulted in actually reducing GHG emissions by 21 metric tonnes per year for an expected 25 years – that's 525 tonnes less $CO_{2\ eq}$ thanks to their loan – and they got their principle back with some interest. Everyone can be proud; they helped their organization achieve Net Zero Energy status in full compliance with the 2015 Paris Agreement.

DRAFT

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)

MEMBER LENDER FINANCING "TRADITIONAL LOAN $ 25,010 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS

Current Electric Annual Bill	$3,500
Total	$3,500

LIFE CYCLE COST ASSESSMENT

20 Year Life Cycle Cost (Renewabl	$67,996
Inflation / Energy Esca	3.0%
20 Year Life Cycle Cost (Fossil Fue	$96,856
20 Year Cost Reduction w/ Renew	$28,860

RENEWABLE ENERGY SYSTEM COSTS

Solar Electric (28 kW @ $2.15/W + Carport solar @$3/W)	$72,000	Base Grid Fees	$360
		Equip. Servicing	$200
Total Equipment Budget	$72,000	Annual O & M	$560

Organization's Total Budget	$770,000	(Optional)
"TRADITIONAL LOAN SERVICING" SCENARIO	1.5%	Interest Rate
100% Sustainable Energy System Cost	$72,000	
Dedicated Grants/Donations for Energy System	$25,010	(35%)
Financing with Member Energy Loan	$46,990	(65%)
Interest	$5,514	15 year term
Total Financing Cost	$52,504	
Annual Loan Payments (Traditional)	$3,500	

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$3,605	$577	$3,500	$3,500	$4,077	$4,077	($472)	($472)	0.5%
2	2022	$3,713	$594	$3,500	$7,000	$4,094	$8,171	($381)	($853)	0.5%
3	2023	$3,824	$612	$3,500	$10,501	$4,112	$12,284	($288)	($1,142)	0.5%
4	2024	$3,939	$630	$3,500	$14,001	$4,130	$16,414	($191)	($1,333)	0.5%
5	2025	$4,057	$649	$3,500	$17,501	$4,149	$20,563	($92)	($1,425)	0.5%
6	2026	$4,179	$668	$3,500	$21,001	$4,168	$24,731	$11	($1,414)	0.5%
7	2027	$4,304	$688	$3,500	$24,502	$4,188	$28,920	$116	($1,299)	0.5%
8	2028	$4,433	$709	$3,500	$28,002	$4,209	$33,129	$224	($1,075)	0.5%
9	2029	$4,566	$730	$3,500	$31,502	$4,230	$37,359	$336	($739)	0.5%
10	2030	$4,703	$752	$3,500	$35,002	$4,252	$41,611	$451	($288)	0.6%
11	2031	$4,844	$775	$3,500	$38,503	$4,275	$45,887	$569	$280	0.6%
12	2032	$4,989	$798	$3,500	$42,003	$4,298	$50,185	$691	$971	0.6%
13	2033	$5,139	$822	$3,500	$45,503	$4,322	$54,507	$817	$1,788	0.6%
14	2034	$5,293	$847	$3,500	$49,003	$4,347	$58,854	$946	$2,734	0.6%
15	2035	$5,452	$872	$3,500	$52,504	$4,372	$63,227	$1,080	$3,813	0.6%
16	2036	$5,616	$898	$0	$52,504	$898	$64,125	$4,718	$8,531	0.1%
17	2037	$5,784	$925	$0	$52,504	$925	$65,050	$4,859	$13,390	0.1%
18	2038	$5,958	$953	$0	$52,504	$953	$66,003	$5,005	$18,395	0.1%
19	2039	$6,137	$982	$0	$52,504	$982	$66,985	$5,155	$23,550	0.1%
20	2040	$6,321	$1,011	$0	$52,504	$1,011	$67,996	$5,310	$28,860	0.1%
		$96,856 Total 20 yr Fossil Fuel Costs	$15,492	$52,504 Total Loan Payments		$67,996 Total 20 yr Renewable Energy Costs		$28,860 Total Cost Reduction/ Financial Gain		

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Table 14 Case#2 - Example of a Revenue Neutral-Funding Model – Fix Current System & Make Net Zero Energy

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL					
MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYMENT"		$ 14,573 GREEN GRANTS (DONATIONS)			
FOSSIL FUEL ENERGY SYSTEM COSTS		**RENEWABLE ENERGY SYSTEM COSTS**			
Current Electric Annual Bill	3,374	Additional Solar PV	$71,663	Base Grid Fees	$0
Lost REC Revenue	1,378	Shading Mitigation Cost	$3,000	Equip. Servicing	$0
		Monitoring: Microinverters/Power	$1,700	Annual O & M	$0
		Monitoring: 15 strings-3 Inverters	$2,000		
		Storage (PowerWall 2 @ $8K)	$0		
Total	4,752	Total Equipment Budget	$78,363		

"TRADITIONAL LOAN SERVICING" SCENARIO			
100% Sustainable Energy System Cos	78,363		
Dedicated Grants/Donations for Energ	14,573	(19%)	
Financing with Member Energy Loan	63,790	(81%)	
Interest	7,485	15 year term @	1.5% Interest Rate
Total Financing Cost	71,275		
Annual Loan Payments (Traditional)	4,752		
25 Year Life Cycle Cost (Renewable)	71,275		
25 Year Life Cycle Cost (Fossil Fuel)	178,423	3.0% Inflation / Energy Escalation Rate	
25 Year Cost Reduction with Solar/Ge	107,148		Organization's Total Budg $828,870 (Optional)

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2020	$4,894	-	$4,752	$4,752	$4,752	$4,752	$142	$142	0.6%
2	2021	$5,041	-	$4,752	$9,503	$4,752	$9,503	$289	$432	0.6%
3	2022	$5,192	-	$4,752	$14,255	$4,752	$14,255	$440	$872	0.5%
4	2023	$5,348	-	$4,752	$19,007	$4,752	$19,007	$596	$1,468	0.5%
5	2024	$5,508	-	$4,752	$23,758	$4,752	$23,758	$756	$2,225	0.5%
6	2025	$5,673	-	$4,752	$28,510	$4,752	$28,510	$921	$3,146	0.5%
7	2026	$5,843	-	$4,752	$33,262	$4,752	$33,262	$1,091	$4,237	0.5%
8	2027	$6,018	-	$4,752	$38,013	$4,752	$38,013	$1,266	$5,504	0.5%
9	2028	$6,199	-	$4,752	$42,765	$4,752	$42,765	$1,447	$6,951	0.5%
10	2029	$6,385	-	$4,752	$47,517	$4,752	$47,517	$1,633	$8,584	0.4%
11	2030	$6,577	-	$4,752	$52,268	$4,752	$52,268	$1,825	$10,410	0.4%
12	2031	$6,774	-	$4,752	$57,020	$4,752	$57,020	$2,022	$12,432	0.4%
13	2032	$6,977	-	$4,752	$61,772	$4,752	$61,772	$2,225	$14,657	0.4%
14	2033	$7,186	-	$4,752	$66,523	$4,752	$66,523	$2,434	$17,092	0.4%
15	2034	$7,402	-	$4,752	$71,275	$4,752	$71,275	$2,650	$19,742	0.4%
16	2035	$7,624	-	$0	$71,275	$0	$71,275	$7,624	$27,366	0.0%
17	2036	$7,853	-	$0	$71,275	$0	$71,275	$7,853	$35,219	0.0%
18	2037	$8,089	-	$0	$71,275	$0	$71,275	$8,089	$43,308	0.0%
19	2038	$8,332	-	$0	$71,275	$0	$71,275	$8,332	$51,640	0.0%
20	2039	$8,582	-	$0	$71,275	$0	$71,275	$8,582	$60,222	0.0%
21	2040	$8,839	-	$0	$71,275	$0	$71,275	$8,839	$69,061	0.0%
22	2041	$9,104	-	$0	$71,275	$0	$71,275	$9,104	$78,165	0.0%
23	2042	$9,377	-	$0	$71,275	$0	$71,275	$9,377	$87,542	0.0%
24	2043	$9,658	-	$0	$71,275	$0	$71,275	$9,658	$97,200	0.0%
25	2044	$9,948	-	$0	$71,275	$0	$71,275	$9,948	$107,148	0.0%
		$178,423 Total 25 yr Fossil Fuel Costs	-	$71,275 Total Loan Payments		$71,275 Total 25 yr Renewable Energy		$107,148 Total Cost Reduction/ Financial		

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYMENT" $ 36,470 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS			
Current Electric Annual Bill		$3,374	
Current Gas Utility Annual Bill		$0	
New building saving (OPTIONAL)	0%	$0	
Annualized Equipment Replacement Cost		$0	Average
Total		$3,374	
LIFE CYCLE COST ASSESSMENT			
20 Year Life Cycle Cost (Renewable)		$66,107	
Inflation / Energy Escalation Rate		3.0%	
20 Year Life Cycle Cost (Fossil Fuel)		$93,355	
20 Year Cost Reduction with Renewable Energy		$27,248	

RENEWABLE ENERGY SYSTEM COSTS				
Solar Electric (39 kW @ $2.15/W	$81,770		Base Grid Fees	$360
Geothermal	$0		Equip. Servicing	$200
Total Equipment Budget	$81,770		Annual O & M	$560
Organization's Total Budget			$770,000	(Optional)
"TRADITIONAL LOAN SERVICING" SCENARIO			1.5%	Interest Rate
100% Sustainable Energy System Cost		$81,770		
Dedicated Grants/Donations for Energy System		$36,470 (45%)		
Financing with Member Energy Loan		$45,300 (55%)		
Interest		$5,315	15	year term @
Total Financing Cost		$50,615		
Annual Loan Payments (Traditional)		$3,374		

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$3,475	$577	$3,374	$3,374	$3,951	$3,951	($476)	($476)	0.5%
2	2022	$3,579	$594	$3,374	$6,749	$3,968	$7,920	($389)	($866)	0.5%
3	2023	$3,686	$612	$3,374	$10,123	$3,986	$11,906	($300)	($1,166)	0.5%
4	2024	$3,797	$630	$3,374	$13,497	$4,004	$15,910	($207)	($1,373)	0.5%
5	2025	$3,911	$649	$3,374	$16,872	$4,023	$19,934	($112)	($1,486)	0.5%
6	2026	$4,028	$668	$3,374	$20,246	$4,042	$23,976	($14)	($1,500)	0.5%
7	2027	$4,149	$688	$3,374	$23,621	$4,062	$28,039	$87	($1,414)	0.4%
8	2028	$4,273	$709	$3,374	$26,995	$4,083	$32,122	$190	($1,224)	0.4%
9	2029	$4,401	$730	$3,374	$30,369	$4,104	$36,226	$297	($927)	0.4%
10	2030	$4,533	$752	$3,374	$33,744	$4,126	$40,353	$407	($521)	0.4%
11	2031	$4,669	$775	$3,374	$37,118	$4,149	$44,502	$520	($1)	0.4%
12	2032	$4,809	$798	$3,374	$40,492	$4,172	$48,674	$637	$636	0.4%
13	2033	$4,953	$822	$3,374	$43,867	$4,196	$52,871	$757	$1,392	0.4%
14	2034	$5,102	$847	$3,374	$47,241	$4,221	$57,092	$881	$2,273	0.4%
15	2035	$5,255	$872	$3,374	$50,615	$4,246	$61,338	$1,009	$3,282	0.4%
16	2036	$5,413	$898	$0	$50,615	$898	$62,236	$4,515	$7,797	0.1%
17	2037	$5,575	$925	$0	$50,615	$925	$63,161	$4,650	$12,447	0.1%
18	2038	$5,742	$953	$0	$50,615	$953	$64,114	$4,789	$17,236	0.1%
19	2039	$5,914	$982	$0	$50,615	$982	$65,096	$4,932	$22,168	0.1%
20	2040	$6,091	$1,011	$0	$50,615	$1,011	$66,107	$5,080	$27,248	0.1%
		$93,355 Total 20 yr Fossil Fuel Costs	$15,492	$50,615 Total Loan Payments		$66,107 Total 20 yr Renewable Energy Costs		$27,248 Total Cost Reduction/ Financial Gain		

Case # 3 Funding Model

The third case "fixes" the current solar system (See Case #1), adds 28 kW more solar modules (See Case #2) AND **adds about 25 kWh of fixed storage**[40] **to level usage and reduces Peak Demand charges to their minimum**. Total cost as indicated in Table 15 increases $20,000 to around $98,363. If the church usage were leveled to its annual average usage, the Peak Demand would be 11.4 kW. So, in theory, it is possible with adequate storage to reduce the Peak Demand to below 25 kW year-round.

Perhaps more importantly, having onsite energy storage creates the opportunity to replace the natural gas stove/oven in the kitchen with a 21st-century electric induction stovetop and electric convection oven. The 1.5 kW spikes that occur when you turn on a burner to the high setting would be leveled by the storage system. Ethical eating requires ethical food preparation – burning natural gas is not ethical. With storage capability, the church can eliminate all-natural gas burning from the facility – the entire facility could be considered Zero GHG emissions – not just the Energy System.

[40] The storage capability is intended to reduce the Peak Demand on Sunday and Special Events. The exact amount of savings has not yet been estimated.

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RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

Solar Electric (39 kW @ $2.15/W)

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYMENT" $ 21,650 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS

Current Electric Annual Bill	$4,000	
Annualized Equipment Replacement Cost	$0	Average
Total	$4,000	
LIFE CYCLE COST ASSESSMENT		
20 Year Life Cycle Cost (Renewable)	$63,489	
Inflation / Energy Escalation	3.0%	
20 Year Life Cycle Cost (Fossil Fuel)	$110,706	
20 Year Cost Reduction w/ Renewable Energy	$47,217	

RENEWABLE ENERGY SYSTEM COSTS

Solar Electric (39 kW @ $2.15/W)	$49,550	Base Grid Fees	$360
Storage (PowerWall 2 @ $8K)	$16,000	Equip. Servicing	$200
Total Equipment Budget	$65,550	Annual O & M	$560

Organization's Total Budget	$770,000	(Optional)
"TRADITIONAL LOAN SERVICING" SCENARIO	1.5%	Interest Rate
100% Sustainable Energy System Cost	$65,550	
Dedicated Grants/Donations for Energy System	$21,650	(33%)
Financing with Member Energy Loan	$43,900	(67%)
Interest	$4,097	12 year term
Total Financing Cost	$47,997	
Annual Loan Payments (Traditional)	$4,000	

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2021	$4,120	$577	$4,000	$4,000	$4,577	$4,577	($457)	($457)	0.6%
2	2022	$4,244	$594	$4,000	$7,999	$4,594	$9,170	($350)	($806)	0.6%
3	2023	$4,371	$612	$4,000	$11,999	$4,612	$13,782	($241)	($1,047)	0.6%
4	2024	$4,502	$630	$4,000	$15,999	$4,630	$18,412	($128)	($1,175)	0.6%
5	2025	$4,637	$649	$4,000	$19,999	$4,649	$23,061	($12)	($1,187)	0.6%
6	2026	$4,776	$668	$4,000	$23,998	$4,668	$27,728	$108	($1,078)	0.6%
7	2027	$4,919	$688	$4,000	$27,998	$4,688	$32,416	$231	($847)	0.6%
8	2028	$5,067	$709	$4,000	$31,998	$4,709	$37,125	$358	($489)	0.6%
9	2029	$5,219	$730	$4,000	$35,998	$4,730	$41,855	$489	$0	0.6%
10	2030	$5,376	$752	$4,000	$39,997	$4,752	$46,606	$624	$625	0.6%
11	2031	$5,537	$775	$4,000	$43,997	$4,775	$51,381	$762	$1,387	0.6%
12	2032	$5,703	$798	$4,000	$47,997	$4,798	$56,179	$905	$2,292	0.6%
13	2033	$5,874	$822	$0	$47,997	$822	$57,001	$5,052	$7,344	0.1%
14	2034	$6,050	$847	$0	$47,997	$847	$57,848	$5,203	$12,547	0.1%
15	2035	$6,232	$872	$0	$47,997	$872	$58,720	$5,360	$17,907	0.1%
16	2036	$6,419	$898	$0	$47,997	$898	$59,618	$5,521	$23,428	0.1%
17	2037	$6,612	$925	$0	$47,997	$925	$60,543	$5,687	$29,115	0.1%
18	2038	$6,810	$953	$0	$47,997	$953	$61,496	$5,857	$34,972	0.1%
19	2039	$7,014	$982	$0	$47,997	$982	$62,478	$6,032	$41,004	0.1%
20	2040	$7,224	$1,011	$0	$47,997	$1,011	$63,489	$6,213	$47,217	0.1%
		$110,706 Total 20 yr Fossil Fuel Costs	$15,492	$47,997 Total Loan Payments		$63,489 Total 20 yr Renewable Energy Costs		$47,217 Total Cost Reduction/ Financial Gain		

Table 15 Case#3: Revenue Neutral Funding Model – Fix System, Make Net Zero Energy, Reduce Demand w/ Storage

RENEWABLE ENERGY SYSTEM PROPOSAL - REVENUE NEUTRAL

MEMBER LENDER FINANCING "TRADITIONAL LOAN REPAYMENT" $ 15,703 GREEN GRANTS (DONATIONS)

FOSSIL FUEL ENERGY SYSTEM COSTS		RENEWABLE ENERGY SYSTEM COSTS		
Current Electric Annual Bill	4,780	Additional Solar PV	$71,663	Base Grid Fees
Lost REC Revenue	1,378	Shading Mitigation Cost	$3,000	Equip. Servicin
		Monitoring: Microinverters/Power	$1,700	Annual O & M
		Monitoring: 15 strings-3 Inverters	$2,000	
		Storage (PowerWall 2 @ $8K)	$20,000	
Total	6,157	Total Equipment Budget	$98,363	

"TRADITIONAL LOAN SERVICING" SCENARIO			
100% Sustainable Energy System Cos	98,363		
Dedicated Grants/Donations for Energ	15,703	(16%)	
Financing with Member Energy Loan	82,660	(84%)	
Interest	9,699	15 year term @	1.5% Interest Rate
Total Financing Cost	92,359		
Annual Loan Payments (Traditional)	6,157		
25 Year Life Cycle Cost (Renewable)	92,359		
25 Year Life Cycle Cost (Fossil Fuel)	231,212	3.0% Inflation / Energy Escalation Rate	
25 Year Cost Reduction with Solar/Ge	138,853	Organization's Total Budg	$828,870 (Optional

	Year	Old Utility Bill plus Replacement	New Operating Cost	Member Loan Servicing	Cum Disbursement to Members	Renewable Energy Utility Bill	Cum Utility Cost	Reduction in Energy Expenses (Resources for other Programs)	Cum Cost Reduction	Energy % of Church Total Budget
1	2020	$6,342	-	$6,157	$6,157	$6,157	$6,157	$185	$185	0.7%
2	2021	$6,532	-	$6,157	$12,315	$6,157	$12,315	$375	$559	0.7%
3	2022	$6,728	-	$6,157	$18,472	$6,157	$18,472	$571	$1,130	0.7%
4	2023	$6,930	-	$6,157	$24,629	$6,157	$24,629	$773	$1,903	0.7%
5	2024	$7,138	-	$6,157	$30,786	$6,157	$30,786	$981	$2,884	0.7%
6	2025	$7,352	-	$6,157	$36,944	$6,157	$36,944	$1,195	$4,078	0.6%
7	2026	$7,573	-	$6,157	$43,101	$6,157	$43,101	$1,416	$5,494	0.6%
8	2027	$7,800	-	$6,157	$49,258	$6,157	$49,258	$1,643	$7,137	0.6%
9	2028	$8,034	-	$6,157	$55,415	$6,157	$55,415	$1,877	$9,014	0.6%
10	2029	$8,275	-	$6,157	$61,573	$6,157	$61,573	$2,118	$11,131	0.6%
11	2030	$8,523	-	$6,157	$67,730	$6,157	$67,730	$2,366	$13,497	0.6%
12	2031	$8,779	-	$6,157	$73,887	$6,157	$73,887	$2,622	$16,119	0.5%
13	2032	$9,042	-	$6,157	$80,045	$6,157	$80,045	$2,885	$19,003	0.5%
14	2033	$9,313	-	$6,157	$86,202	$6,157	$86,202	$3,156	$22,159	0.5%
15	2034	$9,592	-	$6,157	$92,359	$6,157	$92,359	$3,435	$25,594	0.5%
16	2035	$9,880	-	$0	$92,359	$0	$92,359	$9,880	$35,474	0.0%
17	2036	$10,176	-	$0	$92,359	$0	$92,359	$10,176	$45,650	0.0%
18	2037	$10,481	-	$0	$92,359	$0	$92,359	$10,481	$56,131	0.0%
19	2038	$10,795	-	$0	$92,359	$0	$92,359	$10,795	$66,926	0.0%
20	2039	$11,119	-	$0	$92,359	$0	$92,359	$11,119	$78,045	0.0%
21	2040	$11,453	-	$0	$92,359	$0	$92,359	$11,453	$89,498	0.0%
22	2041	$11,797	-	$0	$92,359	$0	$92,359	$11,797	$101,295	0.0%
23	2042	$12,151	-	$0	$92,359	$0	$92,359	$12,151	$113,446	0.0%
24	2043	$12,516	-	$0	$92,359	$0	$92,359	$12,516	$125,962	0.0%
25	2044	$12,891	-	$0	$92,359	$0	$92,359	$12,891	$138,853	0.0%
		$231,212 Total 25 yr Fossil Fuel Costs	-	$92,359 Total Loan Payments		$92,359 Total 25 yr Renewable Energy		$138,853 Total Cost Reduction/ Financial		

But you can't achieve this degree of leveling simply by restricting certain loads with a usage control system (e.g., Brayden Control System). The degree of leveling needed requires using Behind-the-Meter (BTM) storage in the form of fixed storage and mobile storage with vehicle-to-grid (V2G) capability. Asia and Europe have developed and are using V2G in growing numbers. The 2018 (and later) Nissan Leaf has V2G capability built-in. (See Appendix S for more information.)

Perhaps even more exciting is that onsite storage creates another opportunity to add mobile storage to the Energy System on Peak Demand days. By using bidirectional charging stations, it will be possible to have members with EVs plug-in and instead of charging their vehicle, they could donate energy during the church event they were attending. Two stationary PowerWall2 could provide 5 kW of power each for several hours on Sunday and reduce the grid demand by 10 kW. If three members plugged in, they could provide 5 kW each for two hours (equivalent to 33 miles) for a total of 15 kW. This combination of stationary and mobile storage would reduce the Peak Demand from 40 kW to 15 kW on Sunday. Members with plug-in vehicles charge up at home using solar energy and donate 30-40 miles to the church while they are attending an event.

With the growing number of plug-in vehicles in the church parking lot, it is theoretically possible (even today) to have several members plug-into a two-way charging station with V2G capability and "donate" energy on Sunday morning (or on special congregational events.)

Assuming storage & V2G capability will save more than $6157 annually, a revenue-neutral model would require $15,703 in donations and $82,660 in low-interest loans to finance this equipment with no change in the church budget. [a preliminary survey has identified a source of $10,000 in donations and $10,000 in loans]. **Need $5,700 in donations and $72,660 in loans.**

The loans would be paid off in 15 years. There would be a financial gain of at least $138,000 for FUCD over a 25 year period.

The "donors" could say their donation of $15,703 had a return of 879% ($138,000) over 25 years - nearly 35% /year. The "lenders" could say their 'socially responsible investment' in the form of a 1.5% loan resulted in actually reducing GHG emissions by 21 metric tonnes per year for an expected 25 years – that's 525 tonnes less $CO_{2\,eq}$ (over the expected design life of the equipment) thanks to their loan – and they got their principle back with some interest. Everyone can be proud; they helped their organization achieve Net Zero Energy status in full compliance with the 2015 Paris Agreement. By investing in some onsite storage, they reduced the "Demand Charges" to the bare minimum and increased the value of their Energy System. Onsite storage allowed them to use 21st-century electric cooking and prepare food ethically.

Table 16 Exploration of Revenue Neutral Funding to Achieve Net Zero Energy Operation and Reduced Utility Expenses - Summary

Case #1: "Fix" Current System	
• **Shading Mitigation (Power Optimizers)** • **Monitoring Microinverters / Optimizers** • **Monitoring 3 Inverters /15 Strings** **Total**	**$3000** **$1700** **$2000** **$6700**
Operating Revenue: $850	**$1,069 Donations** **$5,640 Loan** **7 years** **$2,080 Gain**
Case #2: Case #1 plus Net Zero Energy	
• **"Fix" Current System** • **Add 28 kW Solar PV Capability** **Total**	**$6,700** **$71,663** **$78,363**
Operating Revenue: $3374 +$1378 =$4752	**$14,573 Donate** **$63,790 Loan** **15 years** **$107,148** Gain
Case #3: Case #2 plus Storage	
• **"Fix" Current System** • **Net Zero Energy** • **Energy Storage to Reduce Peak Demand** **Total**	**$6,700** **$71,663** **$20,000** **$98,363**

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Operating Revenue: $4780+$1378=$6157	**$15,703 Donate** **$82,660 Loan** **15 years** **$138,853** Gain

9. Roadmap / Plans to Go Forward.

Celebrate the success in applying the UU principles, in walking the talk by reducing GHG emissions and harm caused to the interdependent web of life. Celebrate the "Lessons Learned" as early adapters of this 21st-century sustainable energy technology. Then move on.

Plan to Restore the eGauge Monitoring System

Xcel has forced FUCD to remove the monitoring sensors that measure the total energy consumed by the church facility. This must be remedied ASAP to allow FUCD to monitor/manage its energy usage.

Plan to Fix a Few Items Associated with the HVAC System

As part of the office area restructuring, several items can be addressed that will improve the operation of the HVAC system. This includes: 1) adding additional heating/cooling capability because Heat Pump Furnace #4 is undersized and has to operate excessively to maintain set temperatures. 2) Adding heating and cooling capability to the "music office" area (this was overlooked in the renovation design), and 3) Add another return duct at the rear wall of the dais. These three items are unfinished business from the original BFF renovation project.

Plan to Get to Net Zero Energy

Acknowledge the goal line of Net Zero Energy is still a few yards ahead and requires a bit more effort to reach. Extend the current energy production capability (i.e., add more solar modules) to match current usage and reach the Net Zero Energy goal.

1) Determine the amount of additional solar production required
2) Obtain a cost estimate
3) Develop a Revenue Neutral Funding Model
4) Solicit Pledges for Donations and low-interest Member Loans
5) Have Project and Funding Plan reviewed by Green First Task Force, Staff, Independent Reviewers
6) Prepare and Present Plan/Funding to Board of Trustees for Approval
7) If necessary, schedule congregational approval.

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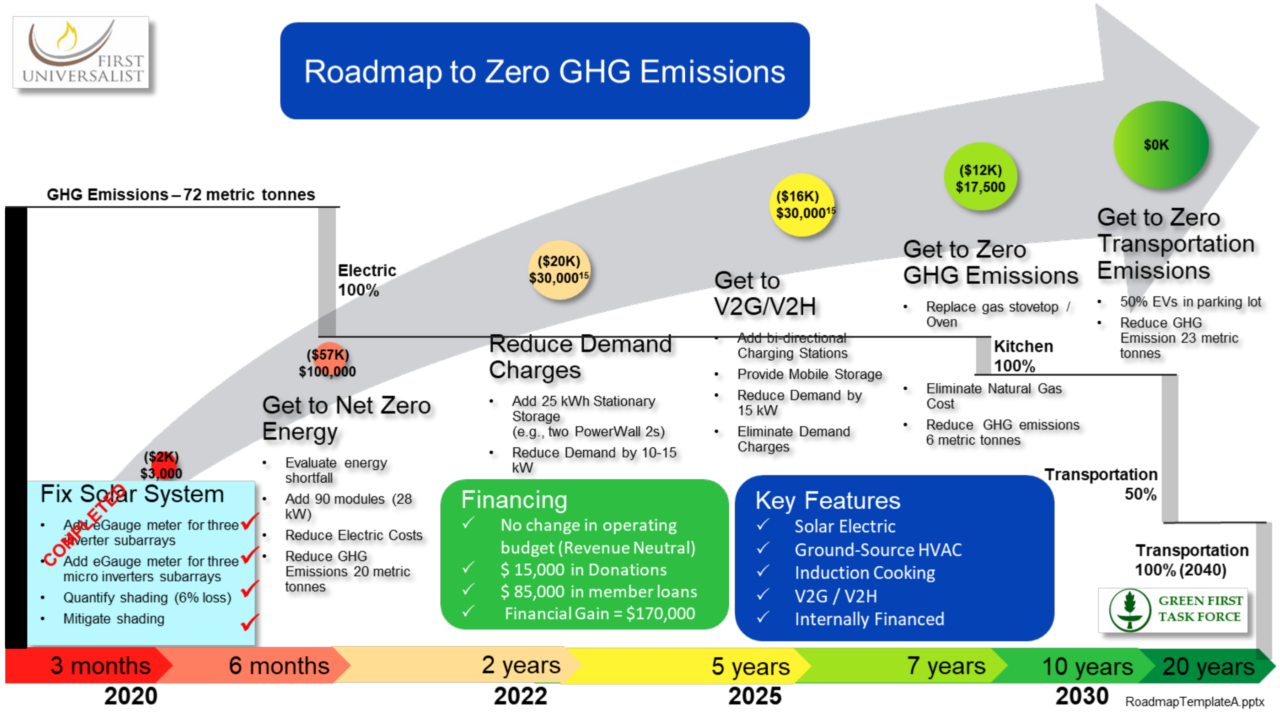


Figure 12 Roadmap to Zero GHG Emissions

Plan to "Fix" a few items on the current solar PV system

Add mitigation for partial shading if warranted;

Plan to Reduce Monthly Costs (e.g. Xcel charges)

Reduce Peak Demand Charges by installing BTM storage. Peak demand for 1-2 hrs on Sunday morning can be 3 times the average weekday demand. 25 kWh of storage (e.g., two Powerwall 2s) would eliminate the Sunday Peaks as would 2 Tesla, 2 Bolt, 2 Nissan Leafs plugged in to "donate" energy.

Plan to Transition Church Landscaping to Regenerative Landscaping (Maximize Carbon Capture)

Plan to Help Members Transition to Electric Vehicles

Plan to Replace Gas Stove/Oven in Kitchen

Plan to Help 100% of Church Members Develop Their Personal Plan for Zero Emissions

Plan to Promote the Interfaith Green Building Initiative (Metro Area Faith-Based Organizations)

Glossary

Carbon Footprint: 'Carbon Footprint' is a quaint euphemism alluding to the deadly ubiquitous harm humans are causing to our global family of interdependent life on planet Earth as we needlessly continue to burn carbon materials as a source of energy. Oddly, this behavior that has a crushing existential impact on future life is expressed innocently as "metric tonnes of CO_2" dumped into the atmosphere annually. By focusing on the root cause of this physical harm, we avoid having to quantify the violent consequences of our behavior. We do not have to acknowledge the premature deaths – the end of life – we are causing. Perhaps even more tragically, we avoid having to enumerate the number of heart wrenching extinctions – the end of birth – we are causing by our fear or reticence to transition to alternative energy sources and stop burning carbon.

Congregational Carbon Footprint: This term denotes the sum total of all carbon emissions related to the existence of and operation of the church. The carbon footprint of First Universalist Church Denver would include the carbon (greenhouse gas) emissions associated with generating the electrical power used by the church, the emissions caused by burning natural gas, wood, or any other carbon materials for heating or cooling or food preparation or ceremonial practices. [41] The Congregational Carbon Footprint also includes GHG emission associated with transportation. So the footprint would include the emissions of the gasoline cars in the church parking lot (and on the neighborhood streets) that were driven by members & visitors to the Sunday services and other church related meetings; by renters who drive to the church for their events; and during the week when the staff drives gasoline powered cars to work.

GHG Emissions: Greenhouse gas (GHG) emissions refers to all emissions linked to the operation of the enterprise that contribute to global warming/climate change. The primary source of GHG emissions is known to be the extraction/transport/burning of hydrocarbons.

Harvesting Energy: The concept of "honorably harvesting energy" is wisdom handed down from indigenous cultures. Source: "*Braiding Sweetgrass*: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants," by

[41] A candle burning for one hour produces around 10 grams of CO_2 / hour. A human exhales about 30-40 grams of CO_2 / hour. Ref: https://www.globe.gov/explore-science/scientists-blog/archived-posts/sciblog/2008/08/11/release-of-carbon-dioxide-by-individual-humans/comment-page-1/index.html A gasoline car that burns fuel at a rate of 40 miles / gallon and is driving at 40 miles / hour would be burning 1 gallon/hr. Each gallon of gas produces 20 pounds of CO_2 or 9,060 gm of CO_2 / hour. Driving this car 5 miles to/from church (10 miles round trip) would burn ¼ of gallon of gasoline (5 pounds) or 2,265 grams of CO_2

First Universalist Renewable Energy System - 2018

1/29/2021

Onsite Energy Utilization

- Surface Area available for harvesting Solar energy & Earth's thermal energy
  - 1.7 acres (75,000 ft^2)
- 57 kW Solar Photovoltaic System Surface Area
  - 179 solar modules,
  - 18 ft^2 / module,
  - Total area of 3222 ft^2
  - **4% of the FUCD property harvests Sun's solar energy.**
- Ground-Source Heat Pump HVAC System Surface Area
  - Twelve(12) 400 ft deep boreholes,
  - Each borehole is 20 feet apart,
  - Ground loop surface area is 60' x 80'
  - Total area of 4800 ft^2
  - **6% of the FUCD property harvests Earth's thermal energy.**

FUCD_EnergySystemSurfaceArea.pptx

Net Zero Energy: This term is used to donate many situations. In the Green Building sector, there is a rather complex set of conditions linked to Net Zero Energy as discussed in "**Denver's Net Zero Energy (NZE) New Buildings & Homes Implementation Plan January 2021**" (https://www.denvergov.org/files/assets/public/climate-action/documents/denver-nze-implementation-plan_final_v1.pdf?mc_cid=08ac00a33c&mc_eid=57994f354a)

> ***What is Net Zero Energy? Denver defines "Net Zero Energy (NZE)" as a new building or home that is highly energy-efficient and fully powered from on-site and/or off-site renewable energy. This means that new buildings and homes will be: (1) Highly Energy Efficient, (2) All-Electric, (3) Powered by Renewable Energy, and (4) Providers of Demand Flexibility for the Grid. Each of these is a foundation of net zero energy in Denver and addressed in detail in this NZE Plan.***

The FUCD use of the term Net Zero Energy was initially limited to the first three Denver criteria. However, when we began evaluating the "Congregational Carbon Footprint" based on the Interfaith Power & Light Congregation Carbon Calculator for Cool Congregations, we became aware that GHG emissions created by congregants, staff and renters traveling to the church in gasoline powered cars also contributed to the FUCD carbon footprint. We began to consider the need for charging stations, on-site energy storage, and even bi-directional charging stations to utilize Vehicle-to-Grid technology to reduce peak demand. So in effect, the FUCD Implementation Plan for getting to Zero GHG emissions now includes "Demand Flexibility for the Grid" and is completely consistent with the Denver definition of NZE

Pandemic (Wikipedia with annotations in italics): A **pandemic** is an epidemic of disease that has spread across a large region, for instance worldwide. *Global warming/climate change has spread across the entire planet.*

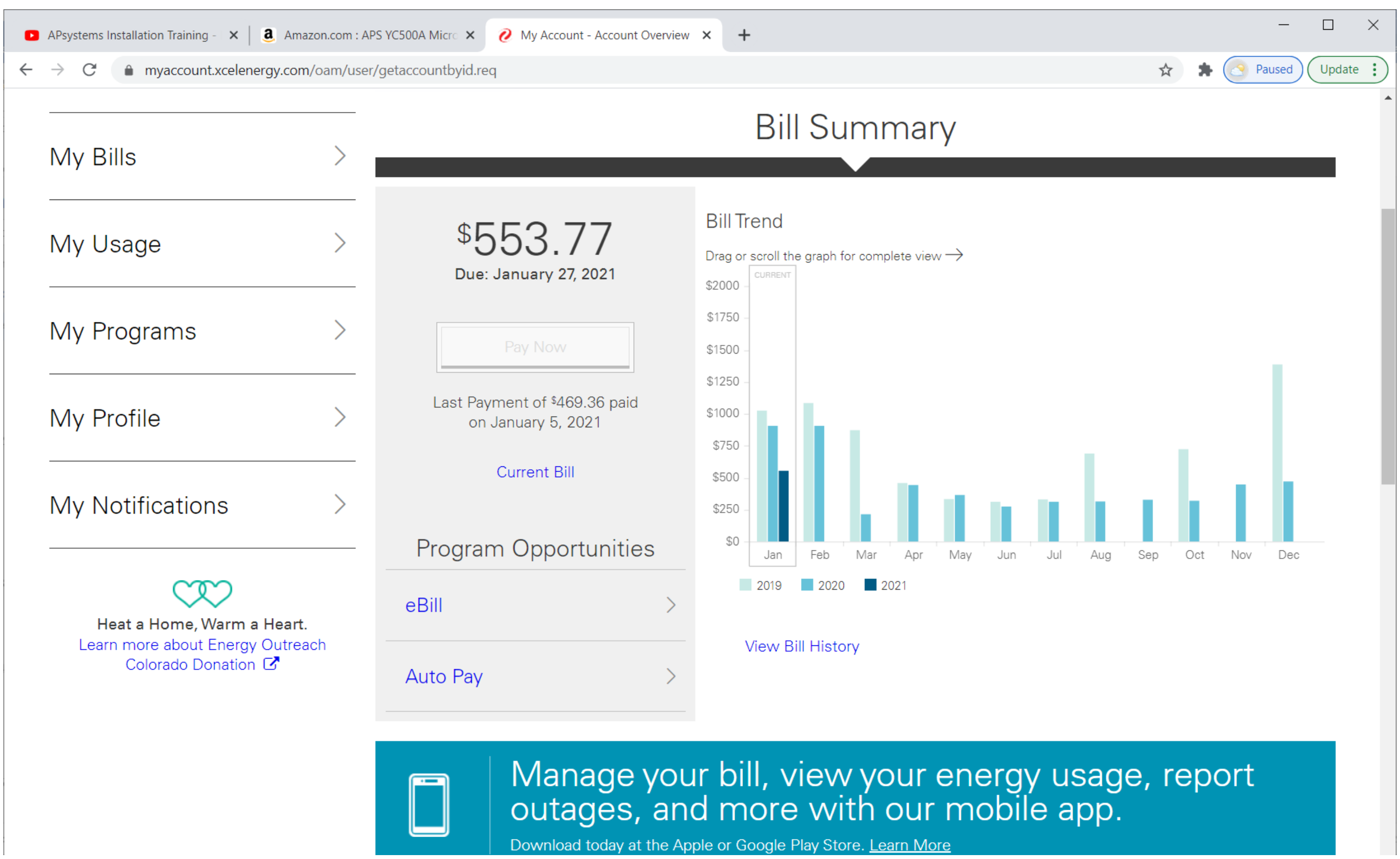
> An **epidemic** is the rapid spread of disease to a large number of people in a given population within a short period. For example, for the past 8,000 centuries the concentration of CO_2 in the atmosphere has remained less than 300 ppm. *Within the last century, CO_2 levels have increased from under 300 ppm to over 400 ppm.*
>
> A **disease** is a particular abnormal condition that negatively affects function of an organism, and that is not due to any immediate external injury. *Climate change is negatively affecting all living systems not just homo*

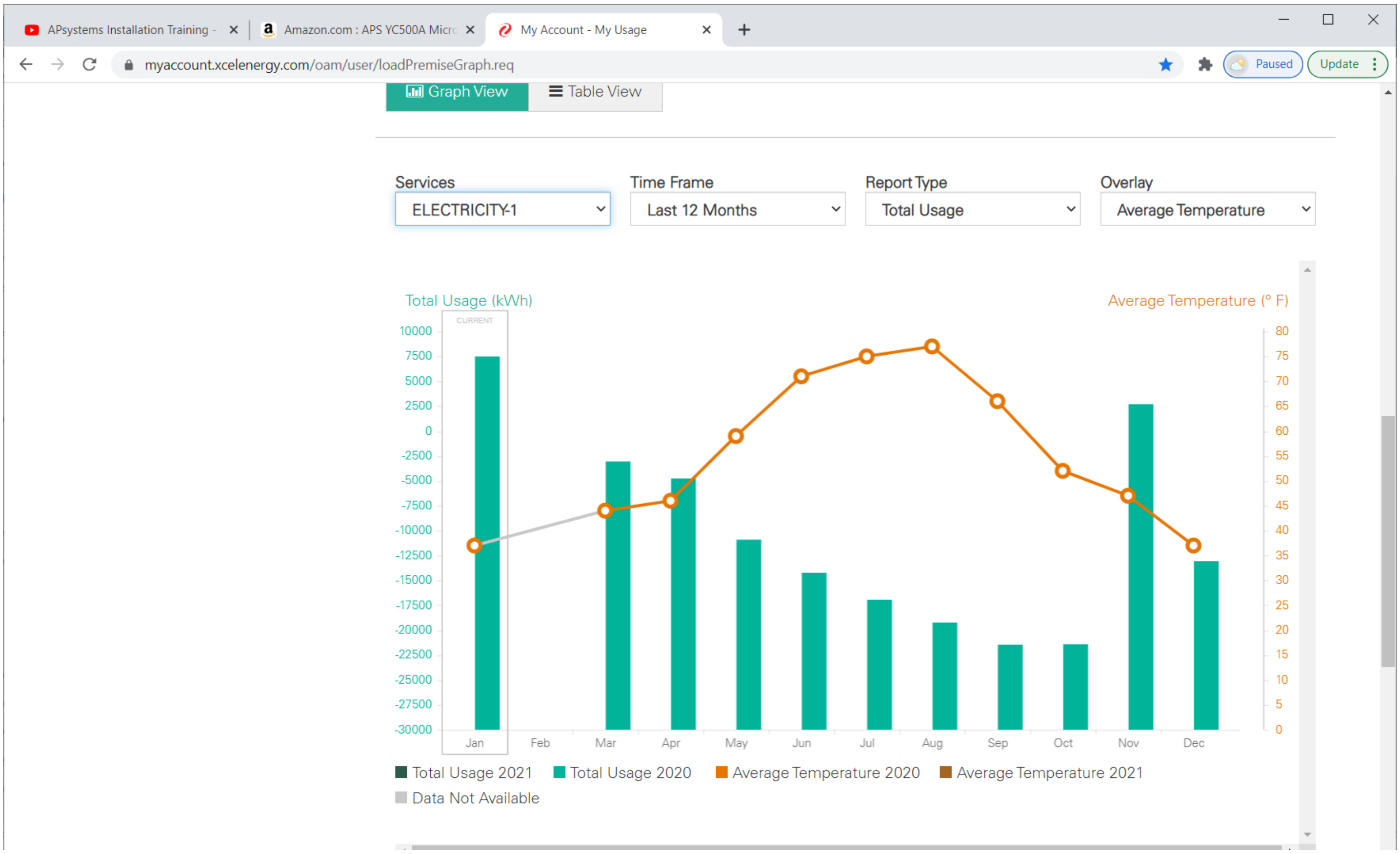
sapiens. Diseases are often known to be medical conditions that are associated with specific symptoms and signs. *Symptoms and signs of climate change include increased temperatures particularly at the poles, record breaking extreme weather , floods and droughts, acidification of oceans, bleaching of coral, increased rate of extinction of living species, sea level rise and dislocation of island people, and coastal populations.*

A disease may be caused by external factors or by internal dysfunctions. *The root causes of Gaia's disease seem to be an internal dysfunction we can characterize as unsustainable ecocidal* ***human*** *behavior from many perspectives in many sectors of our diverse societies. A diagnosis might be a higher order cancer (a social cancer) that has metastasized within many civil societies. The only known vaccination seems to be an injection of ethics / morality.*

Seventh UU Principle: "Respect for the interdependent web of all existence" is the seventh UU principle. A member of the Green First Task Force, Tom Abood, prefers a slight variation of this principle' "**Reverence for the interdependent web of all existence."**

Sustainable Energy System: The sustainable energy system uses sources of energy that are inexhaustible (so called renewable – e.g. sunlight, thermal energy of the Earth), zero carbon emissions, and (ideally) already onsite (no energy imports). For this project, the scope of the 'energy system' for operating the facility was limited to electrical energy need to power the facility and thermal energy needed or heating and cooling the facility. The energy required for food preparation, transportation to and from the church, and manufacturing products used by the church is not included in the "Energy System" but must be included in the church's carbon footprint.





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Time Frame
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Report Type
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Average Temperature
Total Usage (kWh)
Average Temperature (° F)
CURRENT
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7500
5000
2500
0
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-5000
-7500
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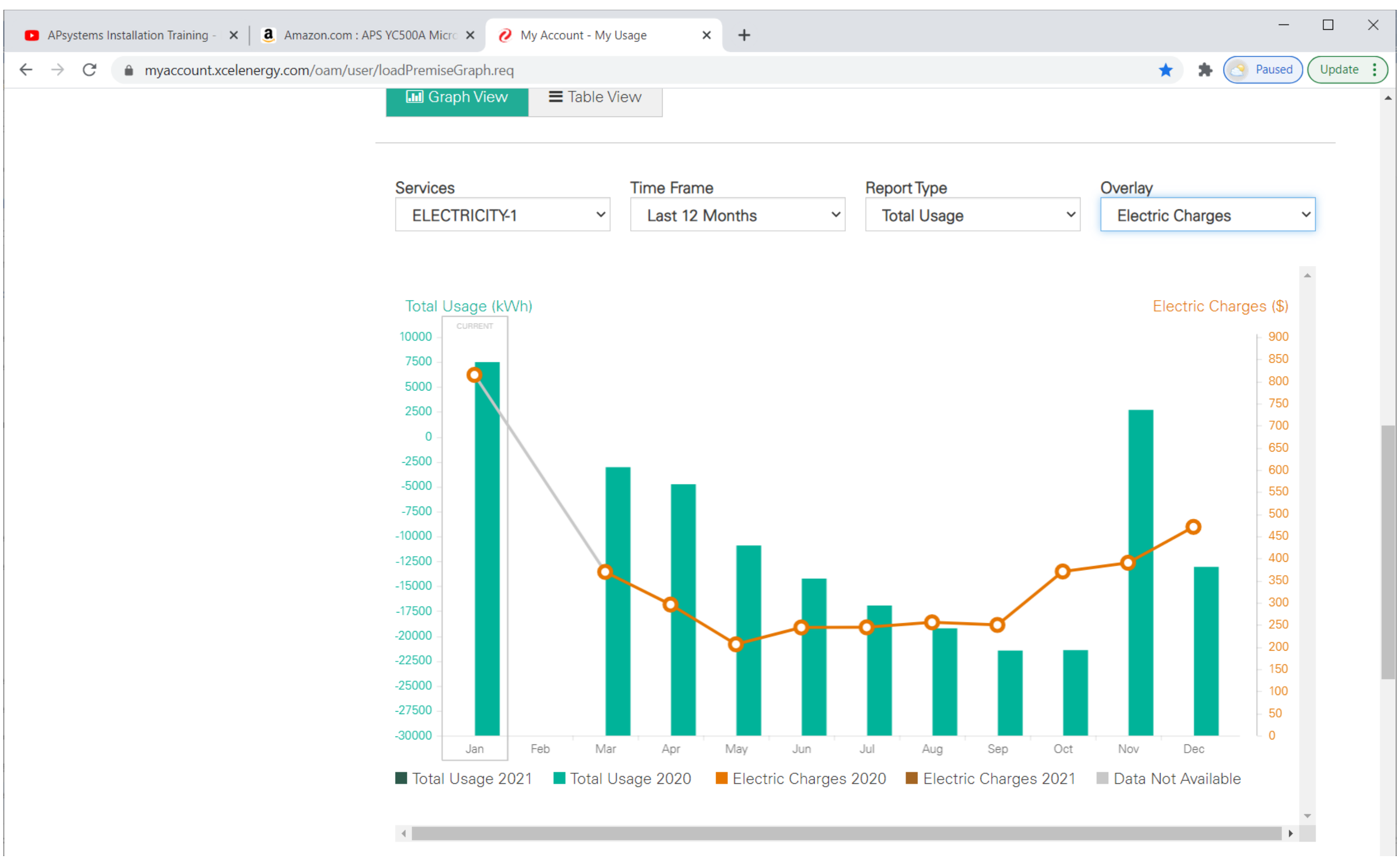

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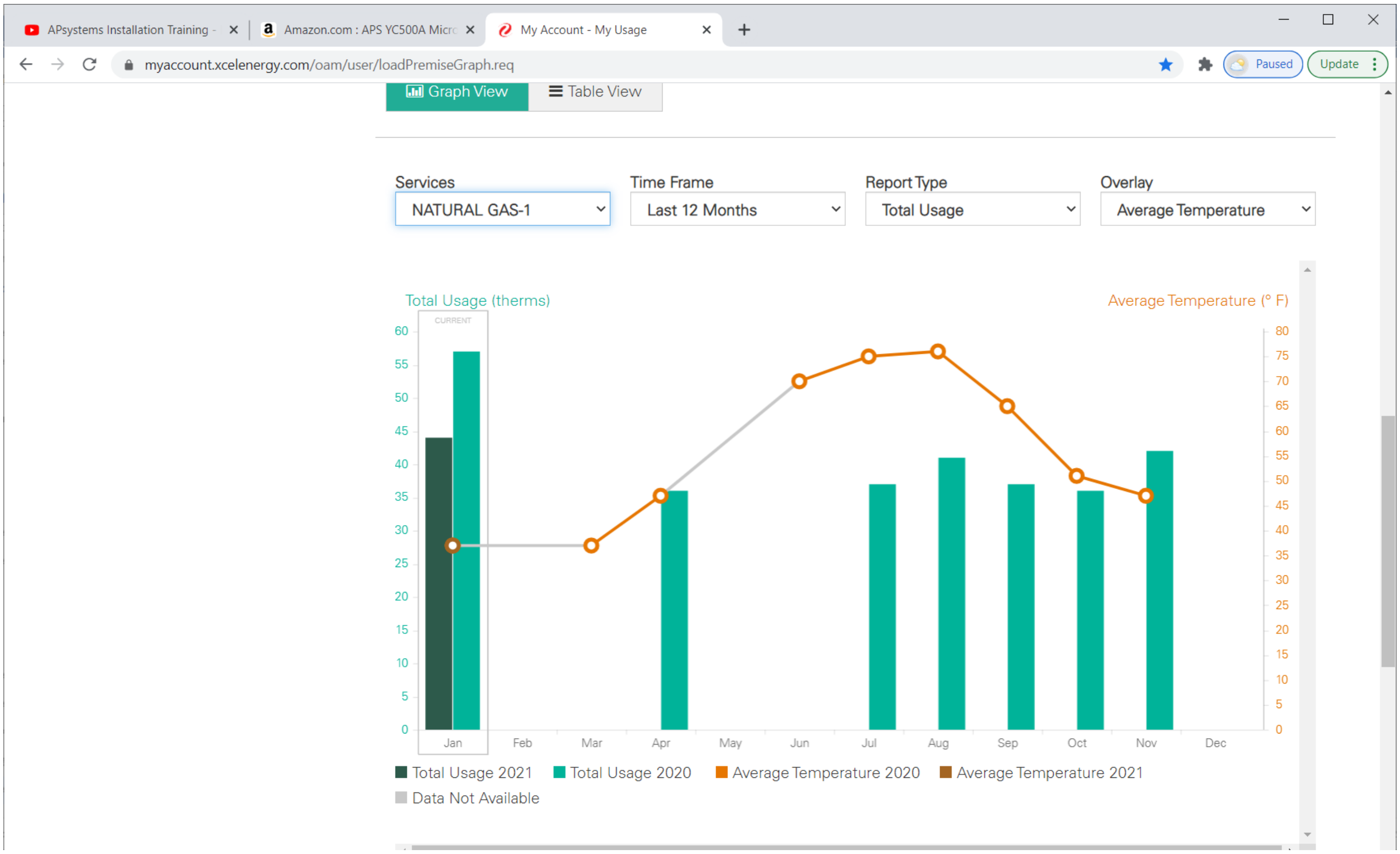
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Time Frame
Last 12 Months
Report Type
Total Usage
Overlay
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Average Temperature 2021
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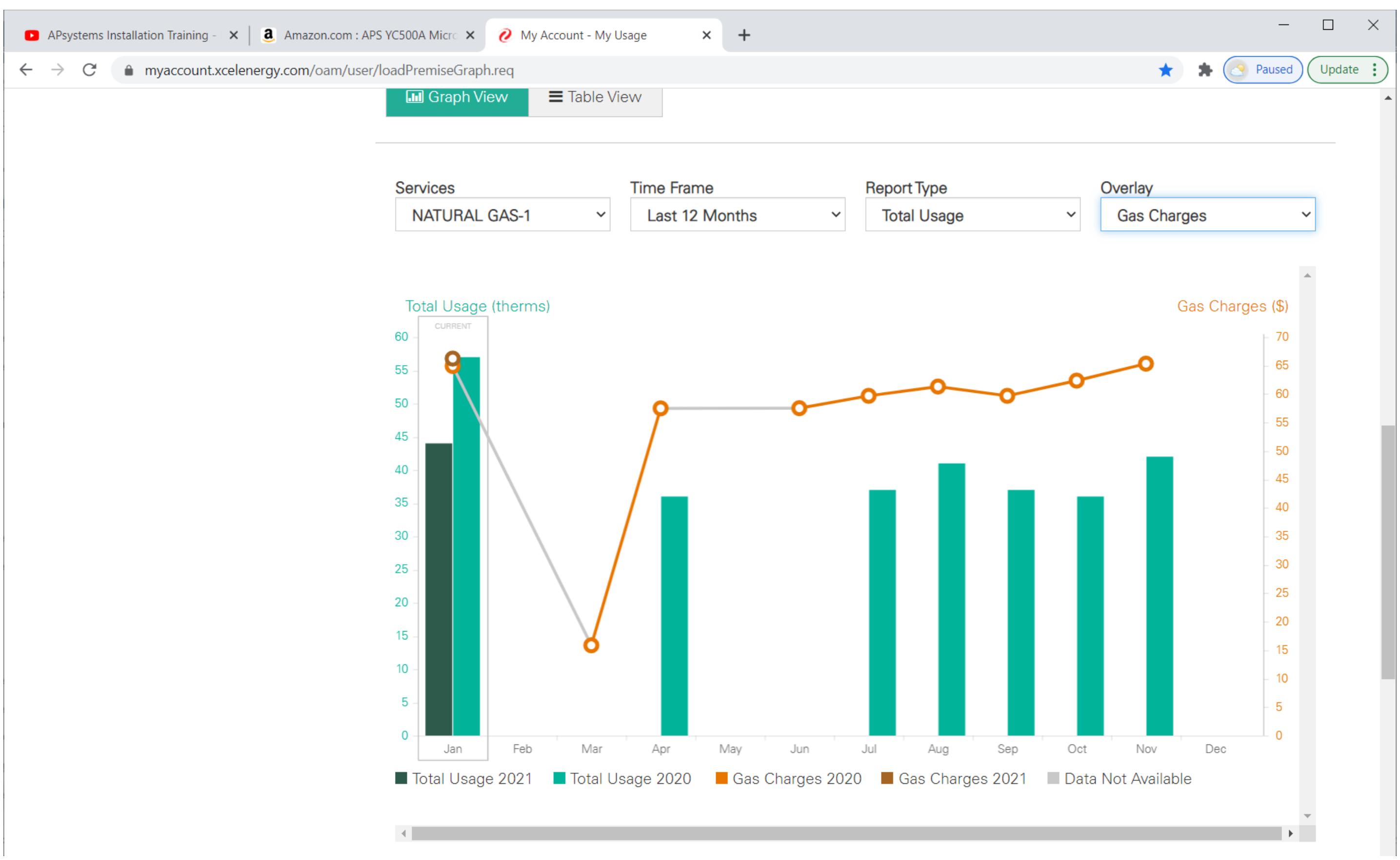
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Total Usage (therms)
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Gas Charges 2020
Gas Charges 2021
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We, the member congregations of the Unitarian Universalist Association; covenant to affirm and promote journeying toward spiritual wholeness by working to build a diverse multicultural beloved community by our actions that accountably dismantle racism and other oppressions in our institutions and ourselves.

Appendix A Keeling Curve as Applied to First Universalist Church Denver

Introduction

On Earth Day 50, 22 April 2020 the entire human species was in some version of a quarantine intended to limit the transmission of the coronavirus (SARS-CoV-2) that is causing a respiratory disease known as COVID-19.

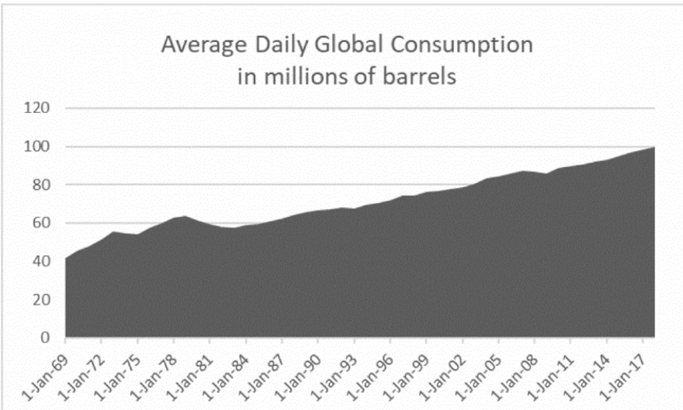

Figure 13 Average Daily Global Consumption of Oil (only one of many forms of carbon humans burn) in millions of Barrels. The US consumes 20 million barrels per day.

Meanwhile, seemingly oblivious to the exploding viral pandemic, humans continue to be involved in a behavioral pandemic that appears to us to be moving at the pace of melting glaciers. However, this recent pathological human behavior that is hell-bent on burning carbon as an energy source is occurring like an explosion in the context of 3.8 billion years of evolution of life on planet Earth.

Humans continue to dig, drill, frack, extract, transport and burn previously sequestered ancient hydrocarbons in increasing amounts year after year. We are now extracting around 10 gigatonnes of carbon each year that had been safely sequestered deep underground. Then we burn it. The result is 37 gigatonnes of CO_2 that is mindlessly dumped it into the atmosphere to become a part of the ongoing carbon cycle.

By adding more carbon to Gaia's carbon cycle without increasing the amount of photosynthesis that removes the carbon, the atmosphere continues to accumulate more and more greenhouse gases as measured by the Keeling Curve illustrated in Figure 14 .[42]

[42] The "saw tooth" nature of the Keeling Curve shows the seasonal variation. There is more land mass in the northern hemisphere, hence there are more photosynthetic species taking in CO_2 during the northern summer than the southern summer. As a result, the level of CO_2 in the atmosphere dips to an annual minimum during the northern summer.

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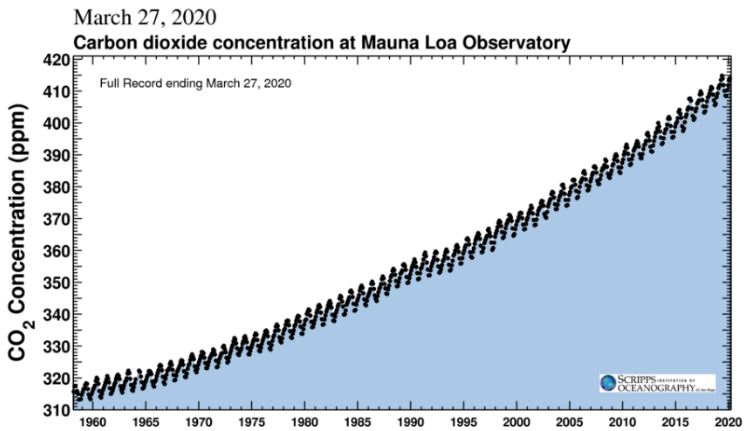

Figure 14 Keeling Curve - CO_2 measurements started at around 315 ppm in 1958. Concentration is now around 415 ppm in 2020.

When the concentration of greenhouse gas in the atmosphere increases, Nature's response is based on well-known laws of physics, and Earth's temperature increases with all the unintended consequences.

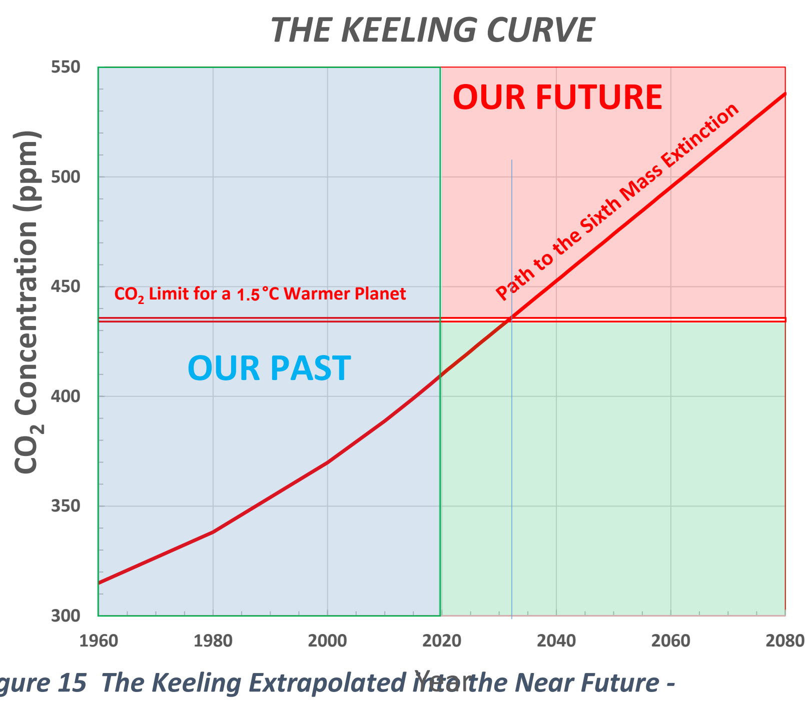

Figure 15 The Keeling Extrapolated into the Near Future - A Path to the Sixth Mass Extinction on Planet Earth

In Figure 15, the Keeling curve of the past is extrapolated with a simple linear path into the future. If there is no change in our behavior, this becomes a path to the Sixth Mass Extinction of complex living species on planet Earth. If there is no change in our behavior, the atmosphere with be filled with enough greenhouse gases to warm the planet by 1.5 degree C around 2030. (See where the red horizontal line positioned at around 435 ppm crosses the projected Keeling Curve).

Prior to the FUCD building renovation project completed in 2018, First Universalist was contributing to the fossil-fuel-burning pandemic by dumping around 150 metric tonnes of greenhouse gas into the atmosphere every year..

Figure 16 illustrates the carbon footprint before the renovation – 50 tonnes linked to electric power that was generated by burning coal and natural gas, 55 tonnes linked to heating with natural gas, and an estimated 35 tonnes linked to transportation (i.e. members driving gasoline cars to Sunday services and other church activities.)

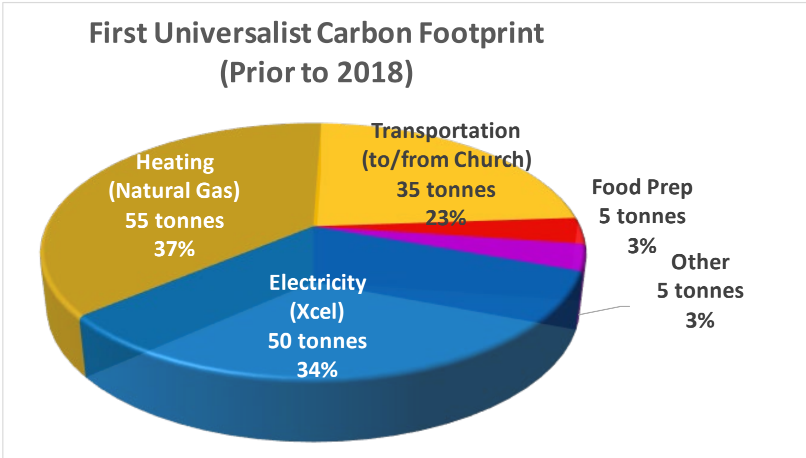

Figure 16 First Universalist Carbon Footprint Prior to Renovation (2018)

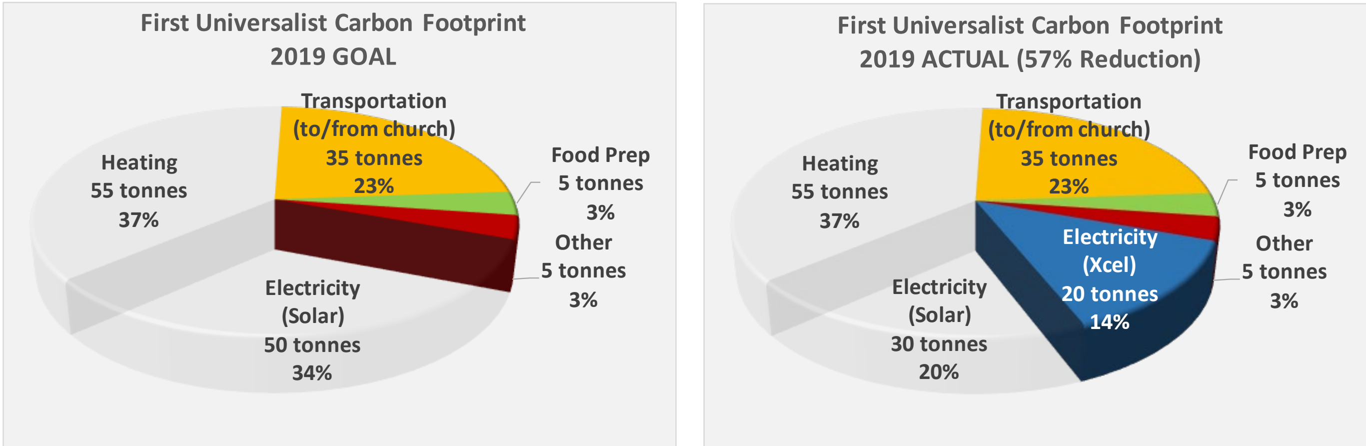

Figure 17 Carbon Footprint Reduction: GOAL versus ACTUAL for 2019

By adding a new sustainable energy system (solar electric and geothermal heating and cooling), FUCD reduced GHG emissions significantly as illustrated in Figure 17. However, the initial goal for the BFF renovation project was to eliminate emissions linked to heating and cooling the facility as well as emissions associated with generating electrical power. The first part of the goal was achieved, but the there were more activities at the church and use of the renovated facility than predicted – hence the use of energy was more than predicted. As a result, the solar PV system was not sized properly to provide all the energy needed to operate the building sustainably.

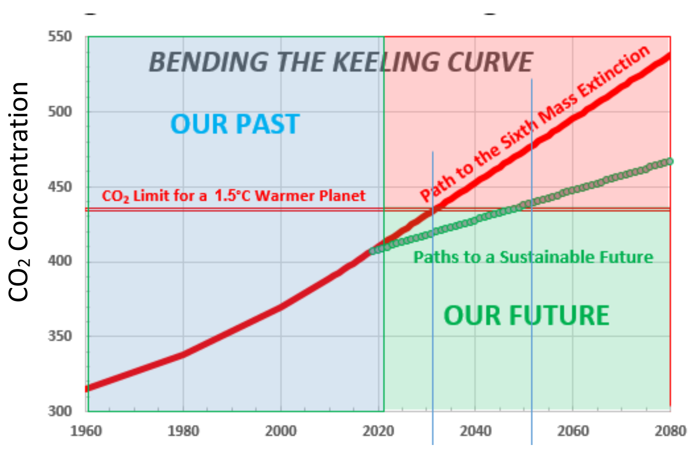

Figure 18 The BFF Renovation Reduced GHG Emissions and Bent the FUCD Keeling Curve Downward Significantly

and bent the Keeling Curve as shown in Figure 18. This is a great beginning. On this path, the 1.5 deg C redline will not exceeded until around 2050

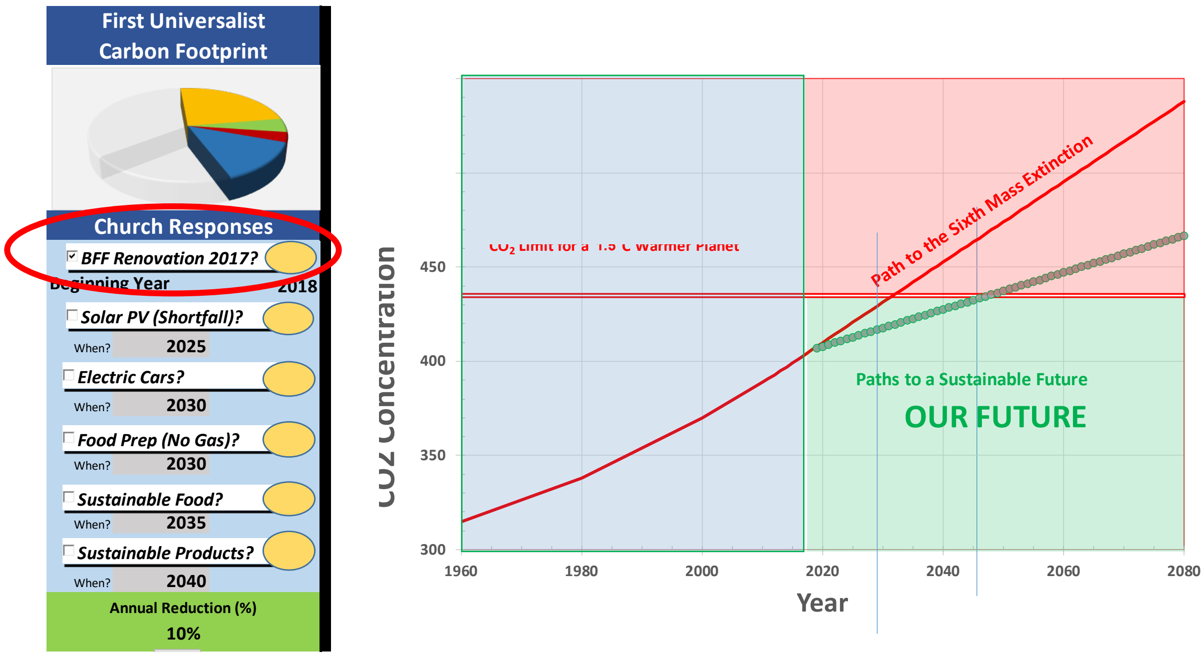

Figure 19 Carbon Footprint after Renovation - GHG Emissions associated with Electric and Heating were Reduced by 80 Metric Tonnes.

As illustrated by the solid green line in Figure 19, FUCD is now on a path with reduced emissions that will reach the carbon budget for 1.5 deg C around 2045 at which point the facility will no longer be in compliance with the IPCC carbon budget.

By adding more solar PV modules and reducing the GHG emissions further, FUCD will bend their Keeling curve even further to that shown in

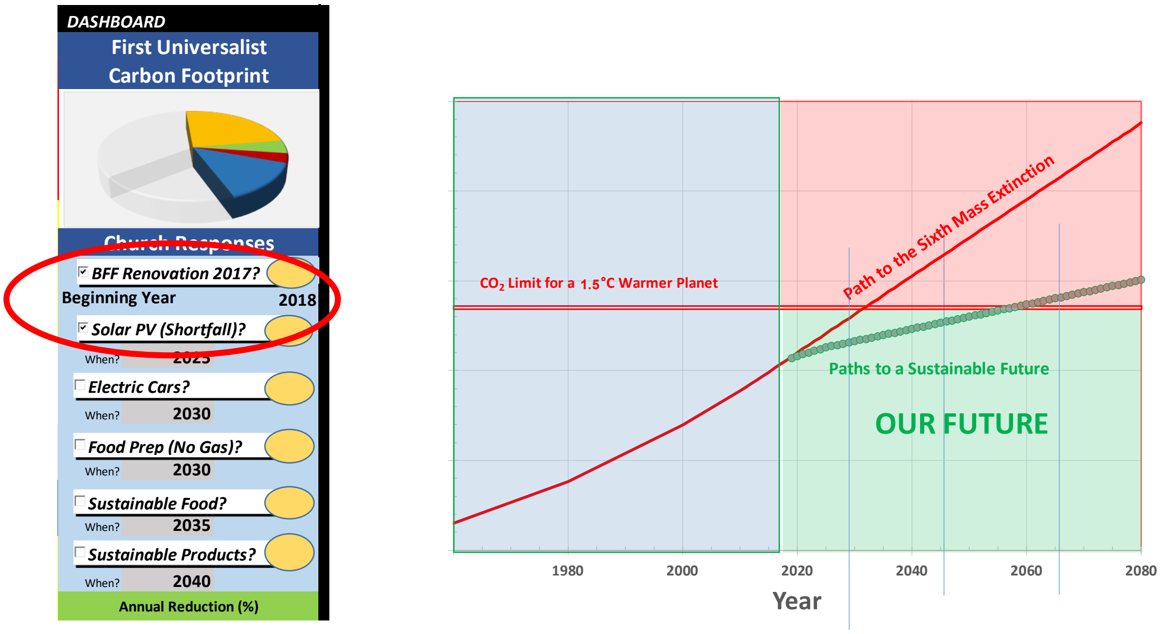

Figure 20 ***Carbon Footprint after Renovation and Adding Solar PV Modules to Achieve Zero Net Energy. GHG Emission reduced further by 30 metric tonnes.***

However, it is not until FUCD reduces the carbon footprint associated with transportation – specially by having congregants transition to zero emissions / electric vehicle charged with renewable energy emission free will the Keeling Curve bend over to a near horizontal position indicating zero GHG emissions.

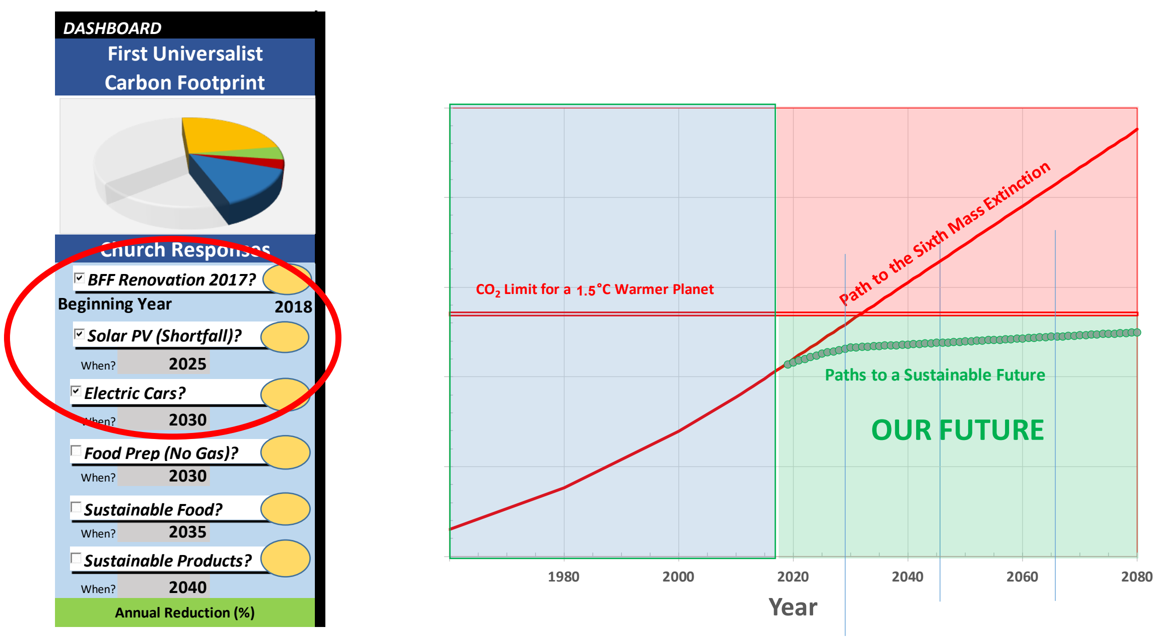

Figure 21 Carbon Footprint after Renovation, Adding Solar PV Modules to Achieve Zero Net Energy, and Transitioning to Electric Vehicles. Further reduction of emissions by 35 tonnes.

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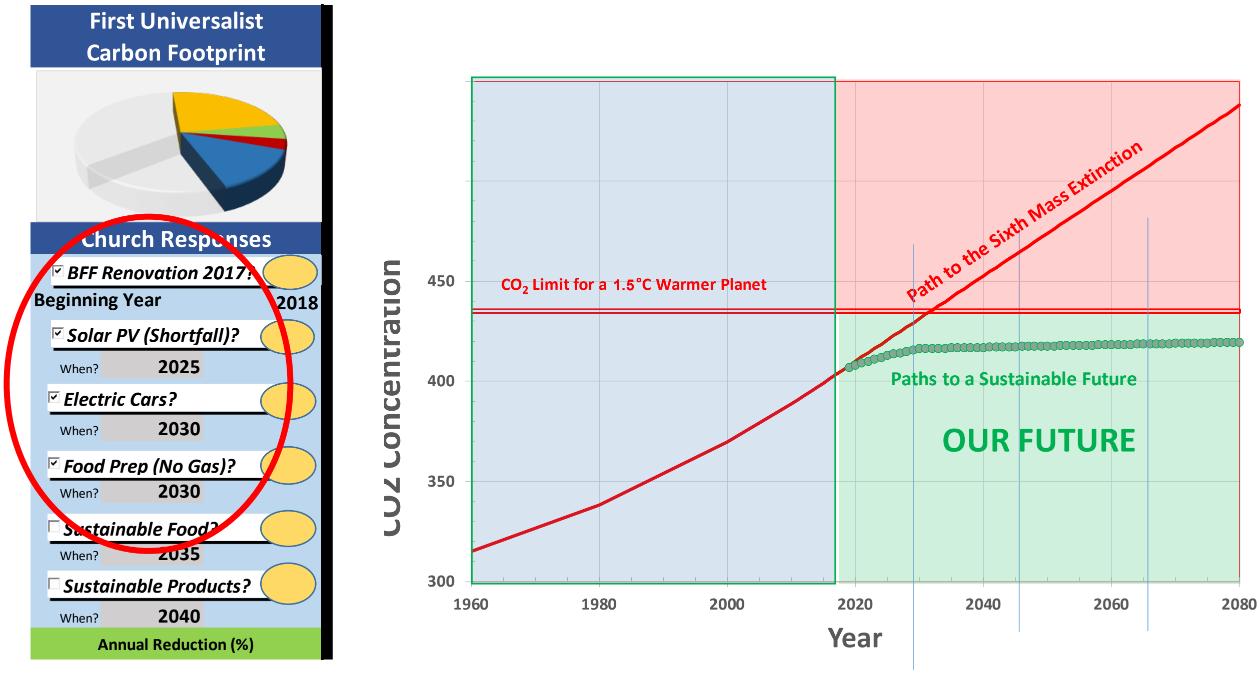


Figure 22 Carbon Footprint after Renovation, Adding Solar PV Modules to Achieve Zero Net Energy, Transitioning to Electric Vehicles, and Replacing Natural Gas Stove with Electric. Further reduction of emissions by 5 tonnes.

In summary, First Universalist is dealing with two major concerns at the moment:

1) Responding to the spread of the coronavirus
2) Responding to global warming/climate change

There is an unexpected nexus between the Corona virus pandemic and climate change that deserves discussion.

We seem to need a new morality that reflects reality – ethics that revere truth – where truth is synonymous with the Laws of the Universe.

Climate Change / Global Warming

In response to climate change/ global warming, the Congregation voted in November 2016 to transition to a sustainable energy system using solar electric and ground-source heating and cooling. The goal was to stop doing harm to future generation by becoming a Net Zero Energy and Zero GHG Emissions facility. The building renovation was completed in 2018. Last year (2019) was the first full year of uninterrupted operation of the renovated facility that allowed us to evaluate our annual energy use. What we found was unexpected:

1) The renovated facility used more energy than the architectural team had calculated. They predicted we would use 75,000 kWh. The Xcel net meter indicated we used 98,000 kWh over a 12-month period.

2) We sized our solar PV system to produce at least 82,000 kWh annually. The Xcel solar production meter indicated our solar PV system generated around 68,000 kWh last year.

3) As a result, we purchased around 30,000 kWh from Xcel Energy in 2019 to make up our energy shortfall. Xcel created around 20 tonnes of GHG emissions to generate the 30,000 kWh because they generate most of their electrical power by burning fossil fuels.

Summary of "Normal Operations" prior to the COVID-19 pandemic:

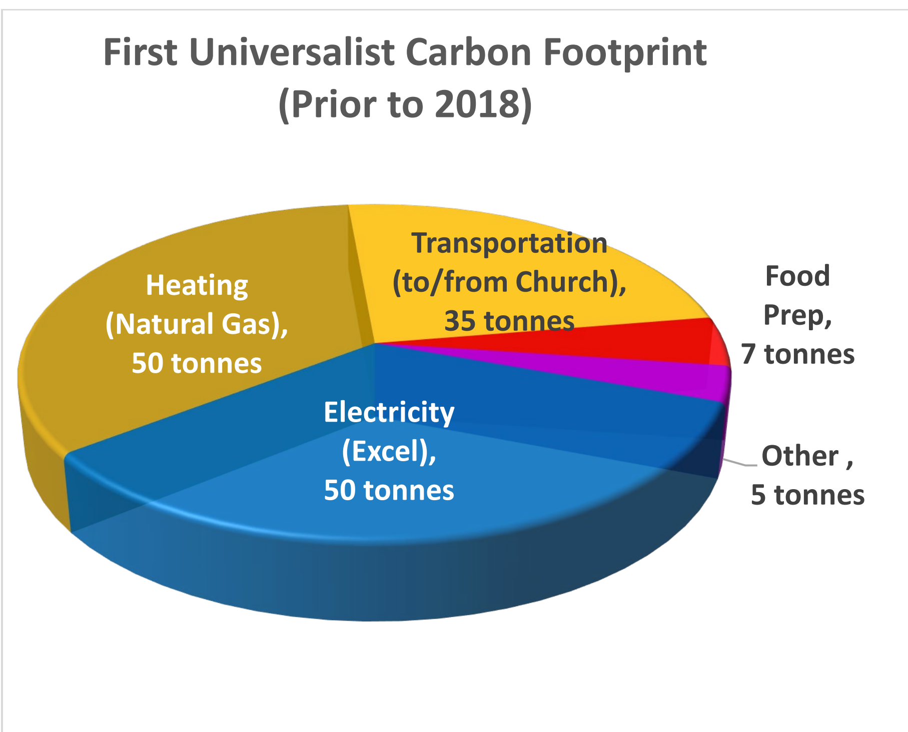
- We harvested enough sunlight in 2019 to generate 2/3 of the energy we consumed and we reduced our GHG emissions by around 80 metric tonnes. Although we did not reach our goal of Net Zero Energy, we did "Bend Our Keeling Curve" significantly as illustrated by the green line. The renovated facility put us on a path to stay below the IPCC remaining carbon budget indicated by the horizontal red line @ 440 ppm) until the year 2045 (where the green line crosses the horizontal red line).

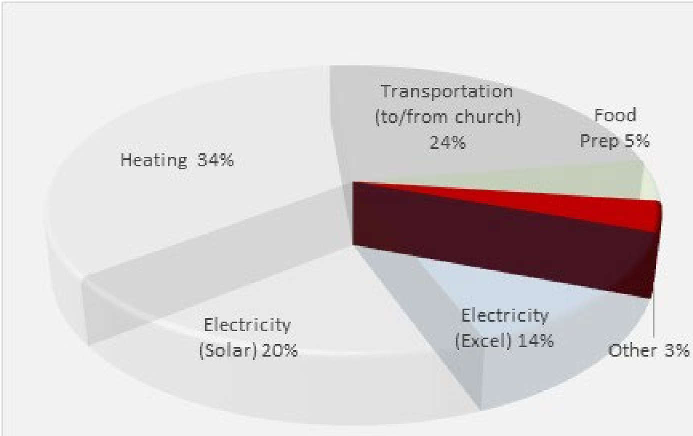
- To achieve our goal of Net Zero Energy (and Zero GHG Emissions) we need to adjust the size of solar PV system upward, assuming we plan to operate the church facility normally as we did in 2019 (after a COVID-19 vaccine has been developed and deployed and all our members can safely meet together again.)

COVID-19 Limited Operations

On Earth Day 50, we will still be in a mode of reduced operations in response to the coronavirus. This mode of operation requires less energy so the existing solar PV system is adequately sized, and we are temporarily at Net Zero Energy with Zero GHG Emissions.

In this mode of limited operations, our parking lot is nearly empty. Before the COVID-19 pandemic, our "Transportation Carbon Footprint" was around 35 metric tonnes per year because most of our church members drive gasoline-powered vehicles to church. Although the number is growing, approximately 5% of the church members drive plug-in vehicles charged by solar electric. With an empty parking lot, our transportation–related GHG emissions have gone to near zero.





On Earth Day 50, First Universalist was a NET ZERO / ZERO EMISSIONS facility. As indicated in Figure 23, FUCD bent the Keeling curve to stay below the CO_2 limit for a 1.5°C warmer Earth (temporarily until operations resume).

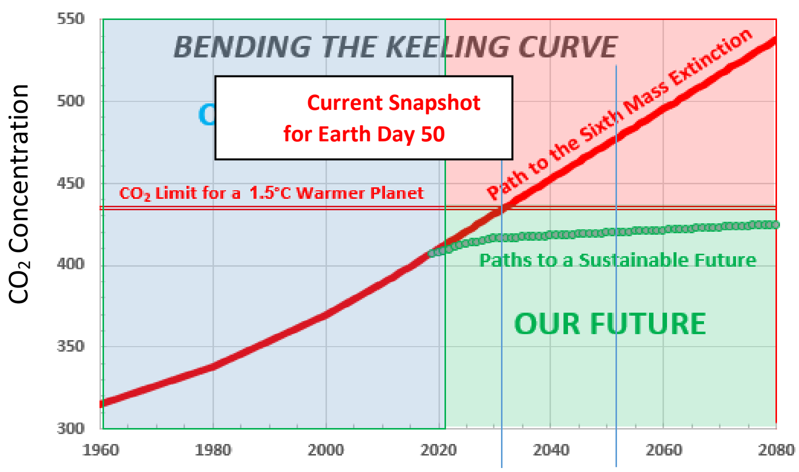


Figure 23 Keeling Curve of our Renovated Facility with the COVID-19 Limited Operations.

Summary

On Earth Day 50, First Universalist will be temporarily operating in a manner that is consistent with medical science and climate science and consistent with our UU Principles.

Temporarily FUCD is operating in compliance with CDC guidelines AND as a Net Zero Energy and Zero GHG Emissions organization.

The Staff and Board will continue to review and update our response to the coronavirus that is consistent with the latest medical science as operations return to normal over the coming months.

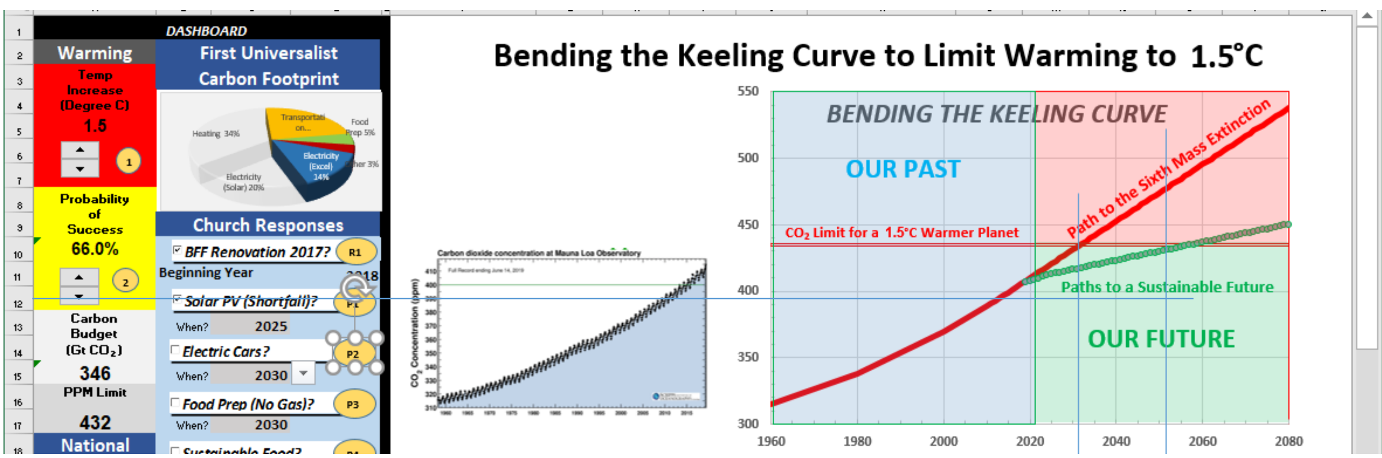
The “time-out” caused by the viral pandemic allowed FUCD to re-evaluate their response to the fossil fuel pandemic so they can keep the Keeling Curve bent as shown in Figure 3.

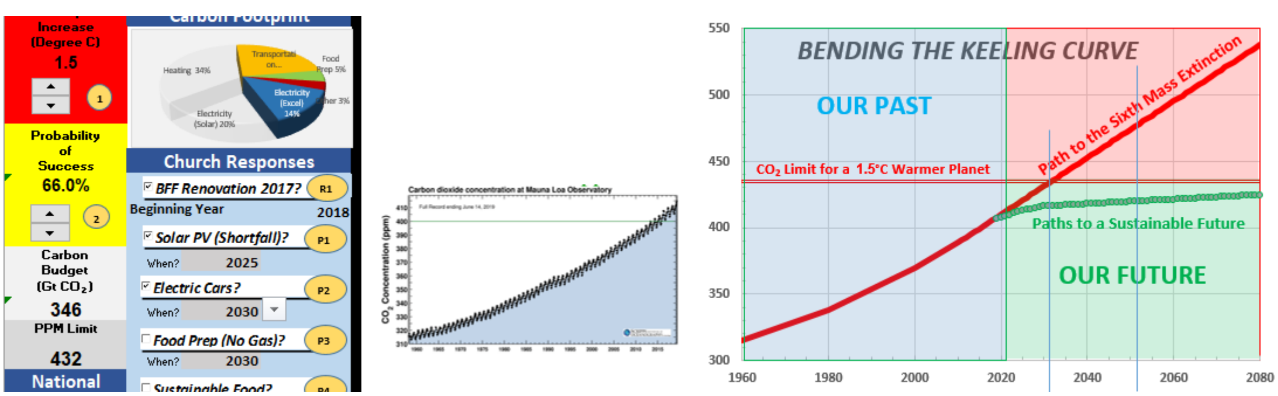
The Green First Task Force will continue to review and update the 10-year plan to reduce GHG emissions to zero consistent with the latest climate science. Future activities will investigate if any changes are required in the HVAC or energy system to assure safe healthy operation of the facility or to comply with any new CDC regulations. Future activities will explore ways to assist members make the transition to plug-in vehicles when they consider a new car over the next 10 years. (Currently an estimated 5% of the church members use electric vehicles to attend church services and other events; 95% use gasoline-powered vehicle. The goal is to flip those numbers by 2030. Then we will see 95% of the cars in the First Universalist parking lot that have zero emissions.)

The Green First Task Force will collaborate with the Staff and Board representatives and submit a revised Zero Emissions Plan to the Board for approval and implementation (similar to the approach used to for the initial energy system.) Documented by: Milt Hetrick.

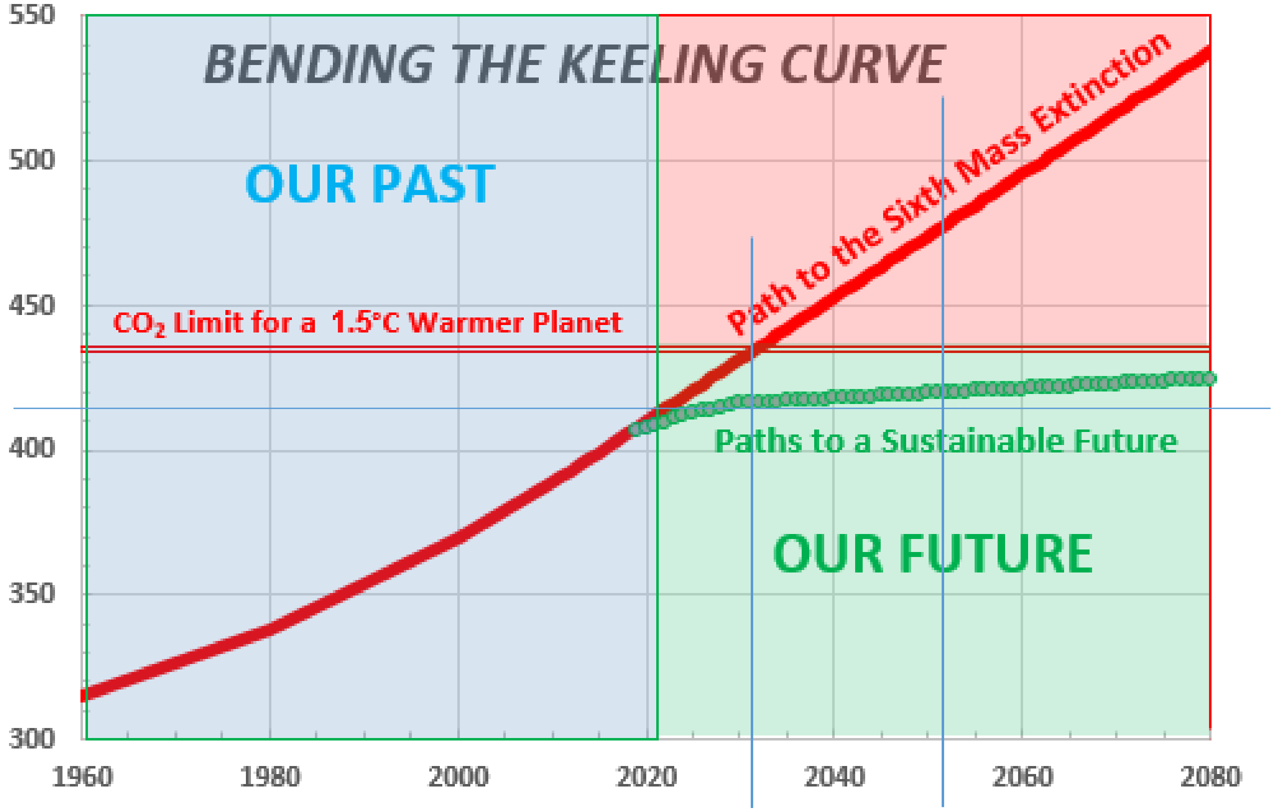
"The eyes of the future are looking back at us and they are praying for us to see beyond our own time."
---Terry Tempest Williams

After adding more solar to be Net Zero Energy





When only the vehicles in our parking lot are powered by gasoline (circa 2030)



Points to Ponder

"The arc of evolution bends in the direction of right relationships with the interdependent web of life or it breaks. " --- Adapted from "The Arc of the Moral Universe Is Long, But It Bends Toward Justice," --- Theodore Parker, 1853.

"Winning slowly is the same as losing when dealing with the coronavirus and climate change." ---adapted from "Winning slowly is the same as losing." --- Bill McKibben, Rolling Stone, 2017

"The eyes of the future are looking back at us and they are praying for us to see beyond our own time."
---Terry Tempest Williams

"[to global leaders]… You are failing us… young people are starting to understand your betrayal… The eyes of all future generations are upon you."

--- Greta Thunberg, UN Assembly, 2019

The Coronavirus and Climate Change: How We're Making the Same Mistakes, [Charles Kutscher]

https://medium.com/@chuck.kutscher/the-coronavirus-and-climate-change-how-were-making-the-same-mistakes-2cd01cce2295

Part II The Xcel Model

Intro – earth rise – spaceship earth – alone is space –

Physics of climate change

The information contained in the IPCC AR5 report and the 2018 1.5 Special Report was used to construct a mathematical model, using Microsoft Xcel to display the information graphically.

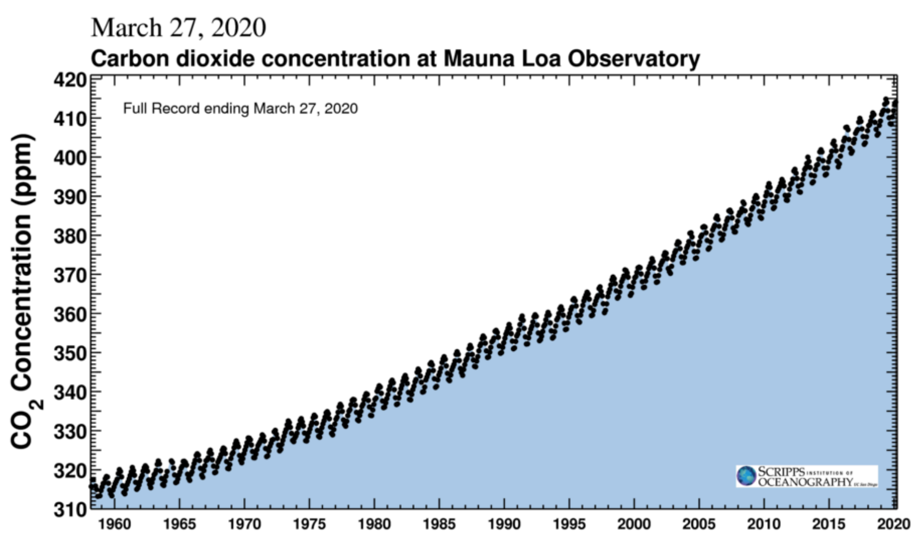
Of particular interest was to describe the urgency of climate change from the perspective of the Keeling Curve and from the perspective of the remaining carbon budget

The two perspectives tell the same story but from different frames

PPM

The well known organization 350.org – co-founded by Bill McKibben is an example of using the concentration of GHG in the atmosphere as one way of describing the root cause – the main variable that humans are affecting – to describe the problem

Show the Keeling curve



Explain how the Keeling curve can be personalized and applied nationally, at the state level, at the local level, at the organization level (FUCD) at the family & personal level

We apply it at the FUCD level

Carbon Budget

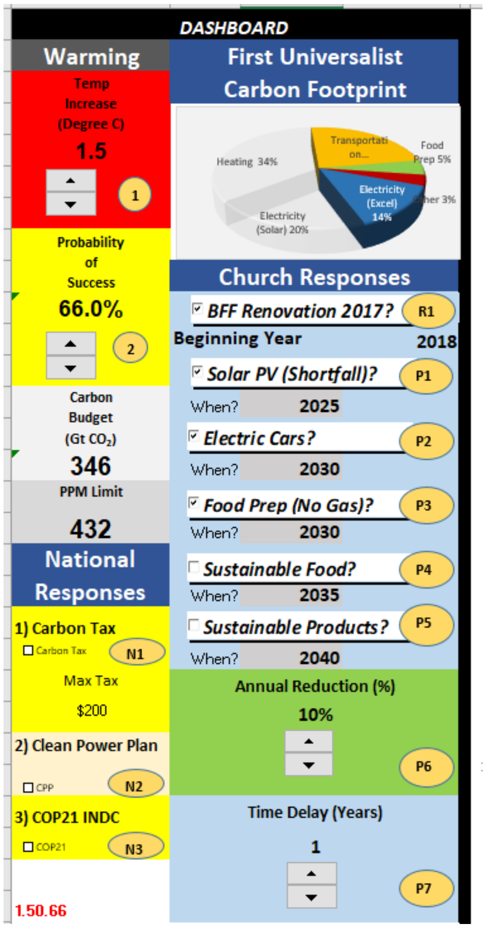
The less known but equally valid approach is to focus on the carbon budget.

It has been well established that the amount og GHG in the atmosphere affects the overall temperature of planet – too little GHG and the planet becomes a snowball. Too much GHG heat trapping gas in the atmosphere and planet get too warm - and example is

Greta

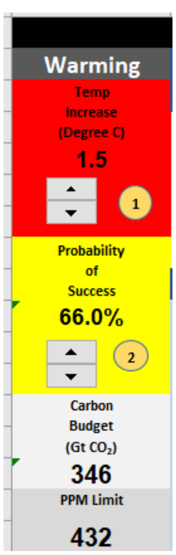
The Xcel Display Model

Made up of the dashboard panel on the left side and the results panel on the right side



The dashboard panel is divided into several areas:

Temperature Increase



1) The condition of the planet we want to leave for future generations - described as the "average temperature" – somewhat misleading because some regions will be significantly warmer – such as the polar regions will have no year round land or sea ice; some regions will experience temperature so hot, there are considered lethal for natural complex living systems without some form of life support (protective clothing, air conditioning, limiting exposure time, etc.
IPCC has investigated two conditions extensively 1.5 deg C or a 2 deg C warmer planet.

Probability of Success

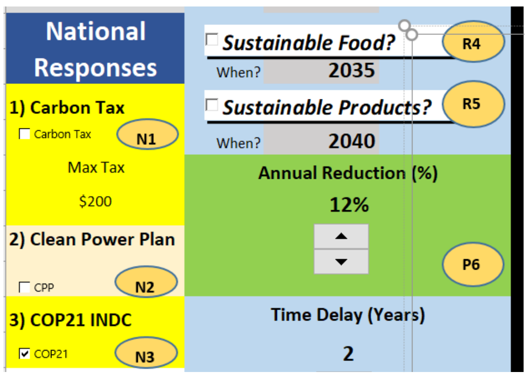
2) Climate science continues to evolve. It involves the most meticulous observations of planet earth, living systems and physical laws ever undertaken. It is difficult to test because of scale – we don't have planet B to run experiments with. There are over a dozen "climate models" developed by researchers in a number of countries. Each contains a slightly different set of physical laws or emphasizes different physics or uses different ways to "solve the governing equations" So there are different results predicted – like hurricane tracks.

IPCC has created three levels of confidence based on the predictions of the various models. 67%, 50 %, and 33%

Once you have determined the type of planet you want to leave for your children and their children, the IPCC provides a table that tells us how much more GHG i.e. CO_2 we can add before we get to that condition.

In this case we see for 1.5 and 66% we see the carbon budget is 346 gigatonnes (345 billion metric tonnes).   If we add that much more carbon to the atmosphere and assume that around 45% is absorbed by plant life as these living system pull CO2 out of the air and convert it into biomass (carbohydrates, sugars, food for animals) then there will be 432 ppm of CO2 in the atmosphere.   There is now 416.   When I was born there was around 300 ppm. Two years ago there was 410. We are adding around 2-3 ppm / year according to the Keeling Curve.

National Responses



Although the national response of the United States is currently underwhelming, there have been several initiatives suggested but not implemented.

a) A carbon burning tax assessed by the number of tons of CO_2 produced by burning the fuel.   The proposal that has been suggested for the last 5 years is to assess a tax of $10/ton that increases $10 / ton each year for the next 20 years.

b) A “Clean Power Plan” that would limit the emissions of power generating plants to that produced by natural gas burnuing plants – thereby causing coal fired plants to be phased out over several years.

Adherence to the goals set by the US in response to the Paris Agreement of 2015 – the INDCs

Each of this “plans” is examined in light of the IPCC 1.5 Guidelines.   All appear to be necessary; none are sufficient.

Church Response

On 6 November2016, the First Universalist congregation voted unanimously to add a sustainable energy system to the ongoing Building for the Future $4.5 M renovation program.   Based on the architect’s estimate, this would require a 57 kW rooftop solar PV system and a the replacement of the 10 natural gas furnaces (and individual air conditioning units) with 10 ground-source (geothermal) heat pump furnaces for heating and cooling (a 45 ton rated HVAC system) at a cost of around $450,000 (10% of the total renovation project).   The new HVAC system became operational on Christmas Eve 2017; the rooftop solar PV system was activated in June 2018.

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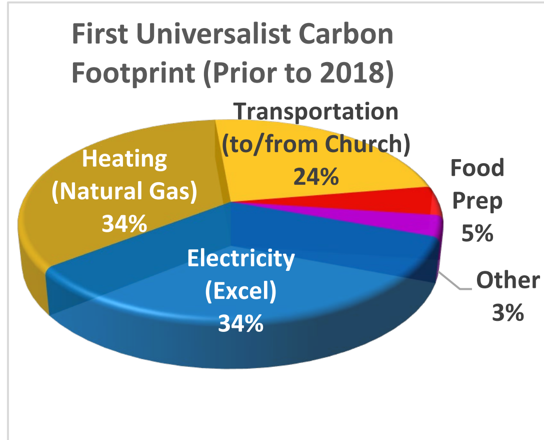
Carbon Footprint of First Universalist - Pie chart



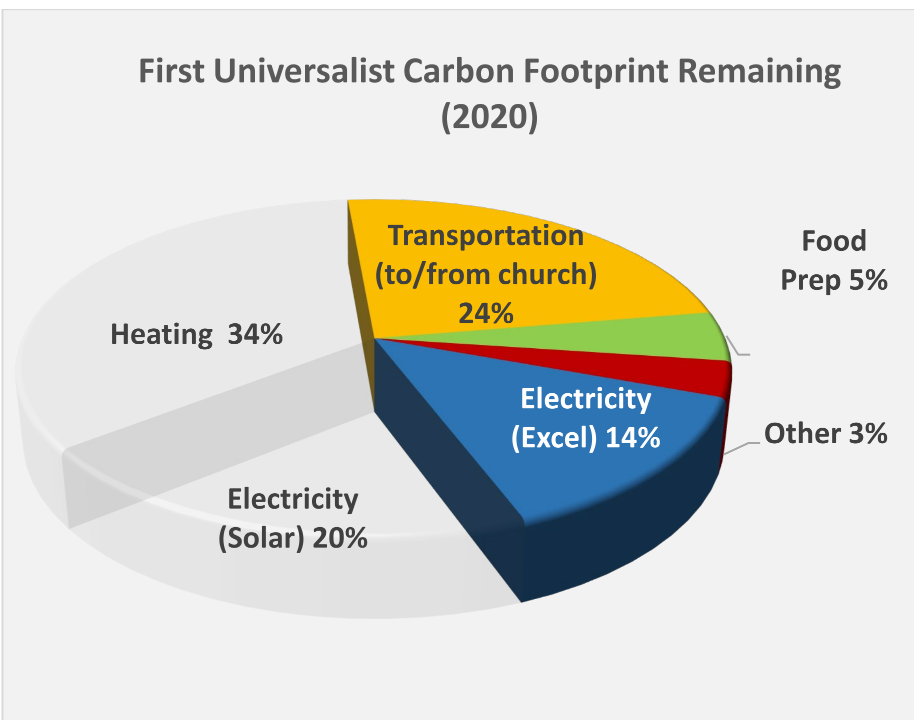
Before the BFF renovation, the carbon footprint of the church is shown in the pie chart below. Prior to 2018, approximately 100 - 120 metric tonnes were being dumped into the atmosphere each year to operate the church. Recently we recognized that another major source of GHG emissions (~35 tonnes) was linked to "transportation" when members and staff travel to church for Sunday services and other church functions in gasoline powered vehicles.

The different sources of GHG emissions are compared in the Pie Chart:

- 34% (50 tonnes): Xcel generation of electrical power by burning coal and natural gas,
- 34% (50 tonnes): First Universalist heating the church facility and DHW by burning natural gas.
- 24% (35 tonnes): Members and Staff driving to church for Sunday services and other church functions by burning gasoline vehicle.
- 5% (7 tonnes): Members preparing food at church for special events using the natural gas stove & oven.

As the first steps toward sustainability, the Green First Task Force became advocates for energy conservation (new windows, more insulation in the walls and ceiling, use of natural lighting as much as possible, use of LED lighting,…), Zero Waste (use of recycled, repurposed materials, …),and renewable energy (solar electric, ground-source (geothermal) heat pump technology for heating and cooling. 70% of the FUCD GHG emissions were linked to electric power and the HVAC system.

Show the pie chart results of the BFF renovation

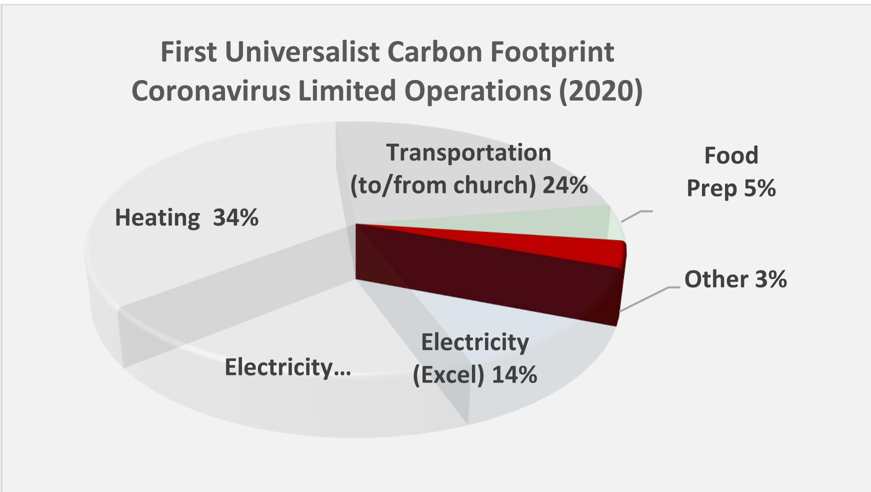


After a full year of operation, it was determined that the facility was using more electrical power than it was generating – there was a shortfall in energy. The new energy system did avoid 80 metric tonnes of GHG emissions, but because some energy was still purchased from Xcel, Xcel dumped around 20 tonnes of CO2 into the atmosphere on our behalf.

Add in the graphic for the KC bent over

Coronavirus

Then came the Coronavirus and operations at the church changed. The energy usage decreased because Sunday services ceased, staff members began working at home, there were no cars in the parking lot, no one was using the kitchen to prepare food.



At this point, the church is operating with near zero GHG emissions. Data for the month of March 2020 indicate the solar PV system is generating a surplus of energy with the limited operations. So the Both the Net Zero Energy and Zero Emissions goals are being met.

First Universalist can say, temporarily we are doing no harm. As antibody tests become available and members are identified who are immune to the virus, and church operations begin to slowly resume, the energy usage will increase and we will see more gasoline powered vehicles in the parking lot. We would expect a vaccine to be available in 18 months, so at least by then the church will be operating nearly as it was in 2019. The carbon footprint will increase. The First Universalist Keeling Curve will start to bend back upward. It is important in the meantime to develop a 10 – year plan that minimizes the increase in carbon footprint – the plan must indicate how we will get to near zero emissions by 2030 and stay within the carbon budget.

Insert Plan

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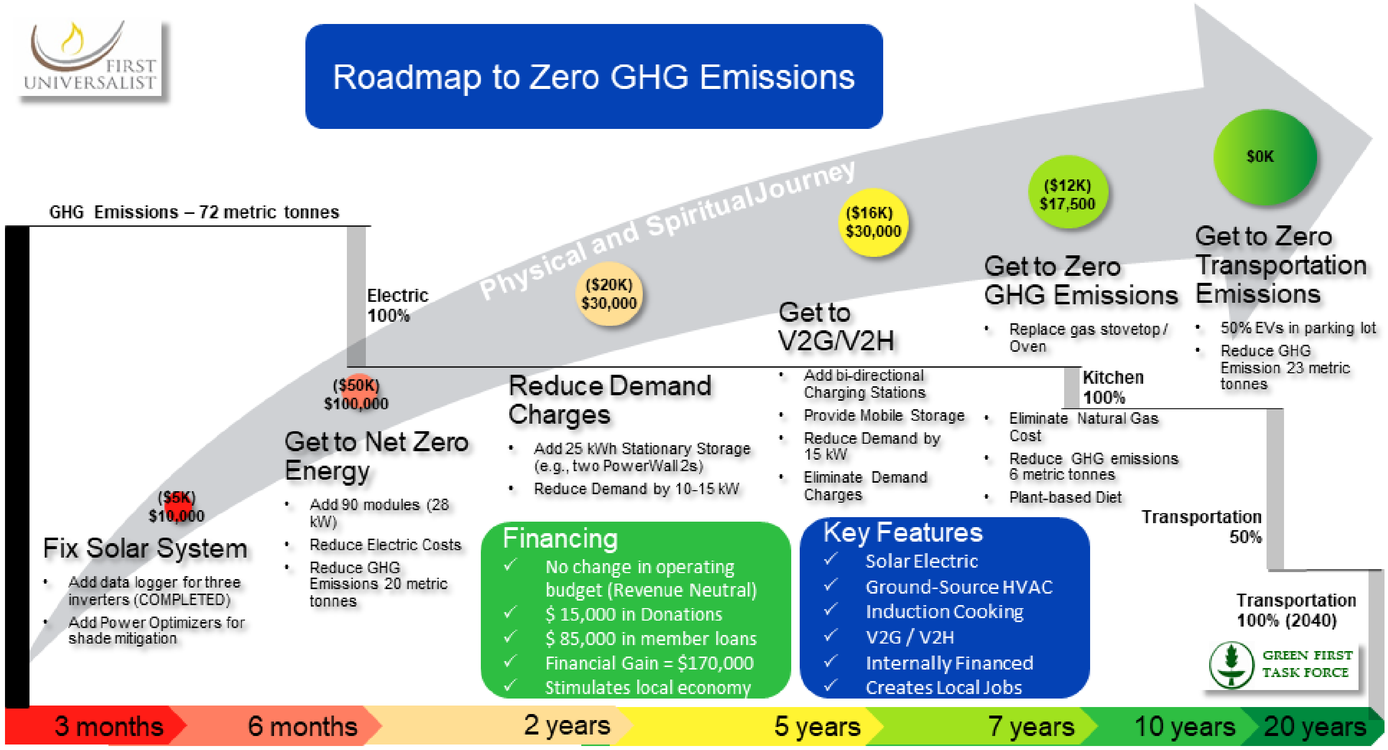


Add in the graphic for the KC bent over

Mention nature only responds to the KC – not human thoughts and prayers or human rhetoric or human intentions – only human actions that reduce levels of GHG

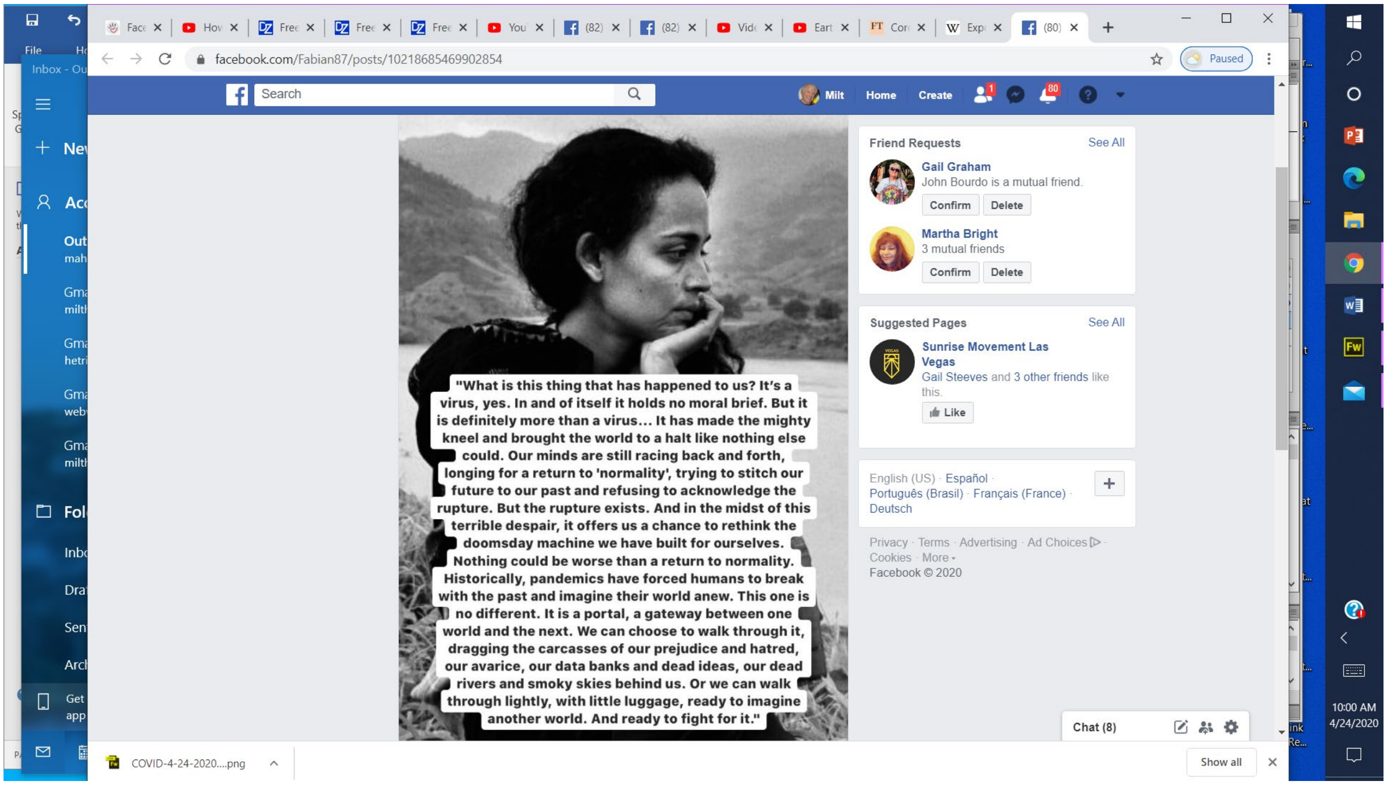
All activities can be rated in terms of how much they reduce GHG emissions.

The more we reduce this year, the more time we buy for future generations –

Waiting 5 or 10 years to transition from fossil fuel will be too late –

Run thru each scenario

1) Add solar
    a. Show how that bends the Curve
    b. Show how that lowers the curve and buys more time and a gentler glide path to zero
2) The only viable goal is to stop burning – reduction is no longer an option – everyone must have a 10 year plan – the GFT is here to help you develop such a plan
3) Can we say that everyone on the GFTF has a plan?



https://www.ft.com/content/10d8f5e8-74eb-11ea-95fe-fcd274e920ca

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https://www.ft.com/content/10d8f5e8-74eb-11ea-95fe-fcd274e920ca

"What is this thing that has happened to us? It's a virus, yes. In and of itself it holds no moral brief. But it is definitely more than a virus. Some believe it's God's way of bringing us to our senses. Others that it's a Chinese conspiracy to take over the world.

Whatever it is, coronavirus has made the mighty kneel and brought the world to a halt like nothing else could. Our minds are still racing back and forth, longing for a return to "normality," trying to stitch our future to our past and refusing to acknowledge the rupture. But the rupture exists. And in the midst of this terrible despair, it offers us a chance to rethink the doomsday machine we have built for ourselves. Nothing could be worse than a return to normality.

Historically, pandemics have forced humans to break with the past and imagine their world anew. This one is no different. It is a portal, a gateway between one world and the next.

We can choose to walk through it, dragging the carcasses of our prejudice and hatred, our avarice, our data banks and dead ideas, our dead rivers and smoky skies behind us. Or we can walk through lightly, with little luggage, ready to imagine another world. And ready to fight for it."

Arundhati Roy's latest novel is 'The Ministry of Utmost Happiness'

Appendix B IPCC Pathways to 1.5 deg C

Using the IPCC global emissions pathway chart in SPECIAL REPORT: GLOBAL WARMING OF 1.5 ºC See Figure 24

https://www.ipcc.ch/sr15/chapter/spm/ The Green First Task Force recommends following path P1 because it defers the least amount of carbon capture burden on future generations of the four example pathways shown in this graphic. Path P1 starts at around 38 billion tonnes in 2020 and declines to around 15 billion tonnes by 2030 – a 60% reduction. Emission are further reduced to around 7-8 billion tonnes by 2040 – an 80% reduction. Around 2100, the P1 pathway requires negative emissions (carbon capture) of around 15 billion tonnes (- 15% of today's emissions – a significant technical challenge that has not been demonstrated on a commercial scale).

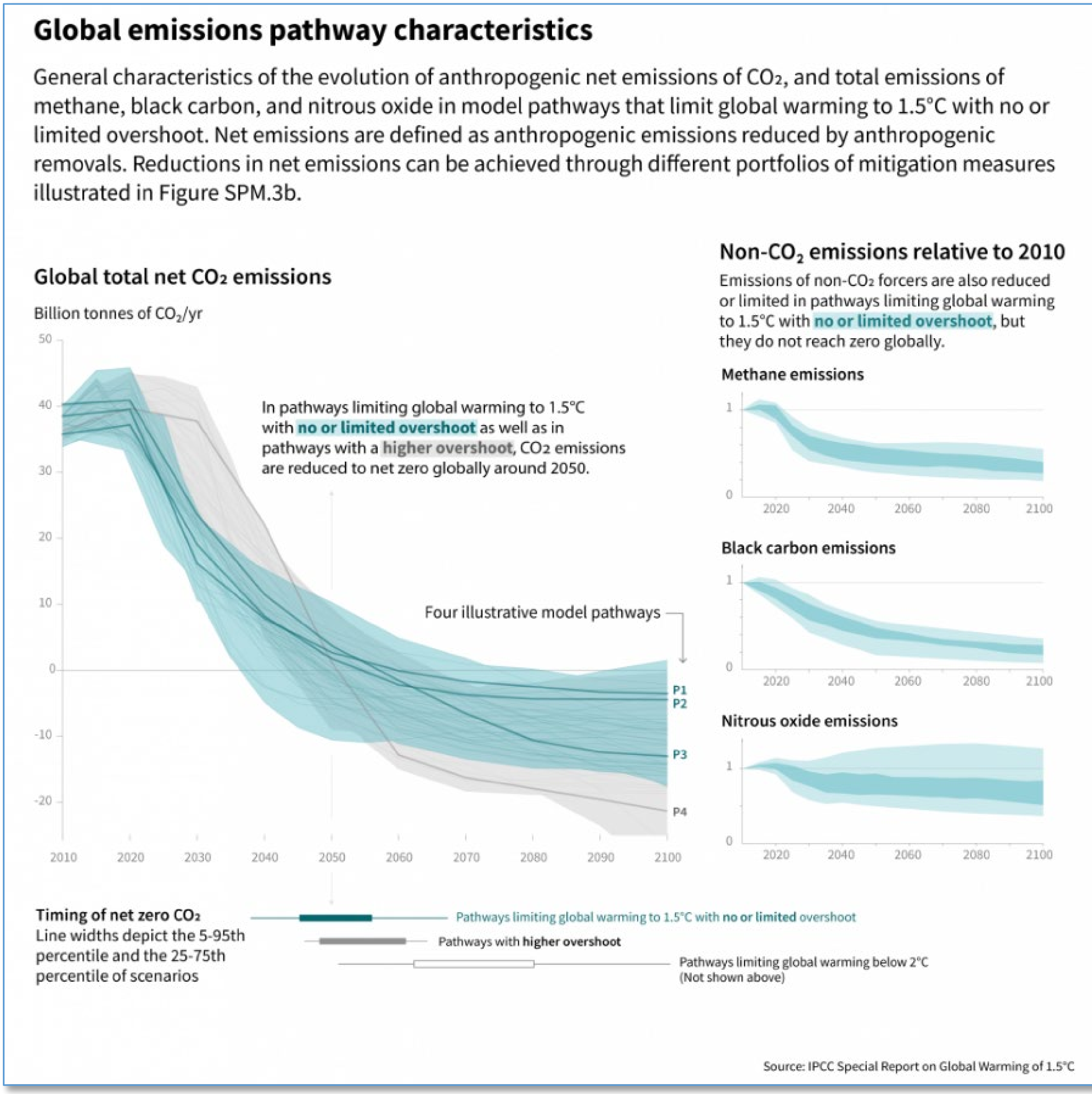

Figure 24 IPCC Global Emissions Pathways to 1.5 Deg C
Reference: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SPM3a-1008x1024.png

Many people and organizations (e.g. Xcel) seem to like P3. This path to 1.5 deg C requires around 50% reduction by 2030 and 25% by 2040 and zero around 2055; but then negative emissions (carbon capture) of -30% out in 2100. Of course, Oil & Gas prefer P4 that delays any action in the near term – dramatically goes to zero emissions in 2050 and then has to make heroic efforts in the future to capture / sequester carbon at a rate of -50% of today's emissions.

The Carbon Footprint chart takes into account the planned fuel mix for Xcel Energy at various future dates. For example, the following article says that Xcel plans to generate 55% of their power from renewable sources by 2026.

https://www.denverpost.com/2018/06/06/xcel-energy-power-plan-would-cut-carbon-emissions-by-half-use-renewable-sources-for-55-percent-of-power/

FUCD is becoming more and more independent from the Xcel fuel mix by transitioning to renewable energy that is already on-site (as a congregation and as individuals). The bar on the left uses an Xcel fuel mix of 78% fossil fuel, 22% renewable used in 2014-2016 when we started the renovation project. The 2019 – 2021 bars use the fuel mix currently in effect of 72% fossil fuel, 28% renewable. The church does not plan to buy any electric from Xcel in 2026. If we did, we would use the 45% fossil fuel; 55% renewable fuel mix plan Xcel has forecast.

The Xcel fuel mix in 2026 does of course affect the transportation sector when we think about transitioning to electric vehicles. The FUCD transportation carbon footprint has not been well researched – it is simply a "ball park" estimate at this point. The 35 metric tonnes of GHG emissions assumed for transportation is estimated for 2016 & 2019 to reflect that the staff, most of our members, and most renters who used the facility drove gasoline powered cars to church. We might guess that a dozen members drive plug-in vehicles to church, but not more than 2 dozen. The second year (2020) bar should include some carbon footprint to reflect that the staff still drove to work using fossil fuel in 2020, but it was a small amount and is not shown. The reduced level of transportation carbon projected for 2021 assumes we might start opening up the facility near the end of the year. The 2022 bar assumes we are back to 2019 activities. The 2030 bar assumes that ½ of our members/staff/renters drive to church in an electric vehicle that is charged using 100% renewable energy (zero emissions). Many of the members who have an EV also have rooftop solar or have invested in solar modules in a community solar garden. If members with an EV charge their vehicle with Xcel electric, we would have to add some carbon to reflect the Xcel fuel mix. If 50% of the members/renters/staff do drive EVs in 2030 but use Xcel electric, our carbon footprint will be larger than that shown in the graphic and we will exceed the IPCC P1 pathway.

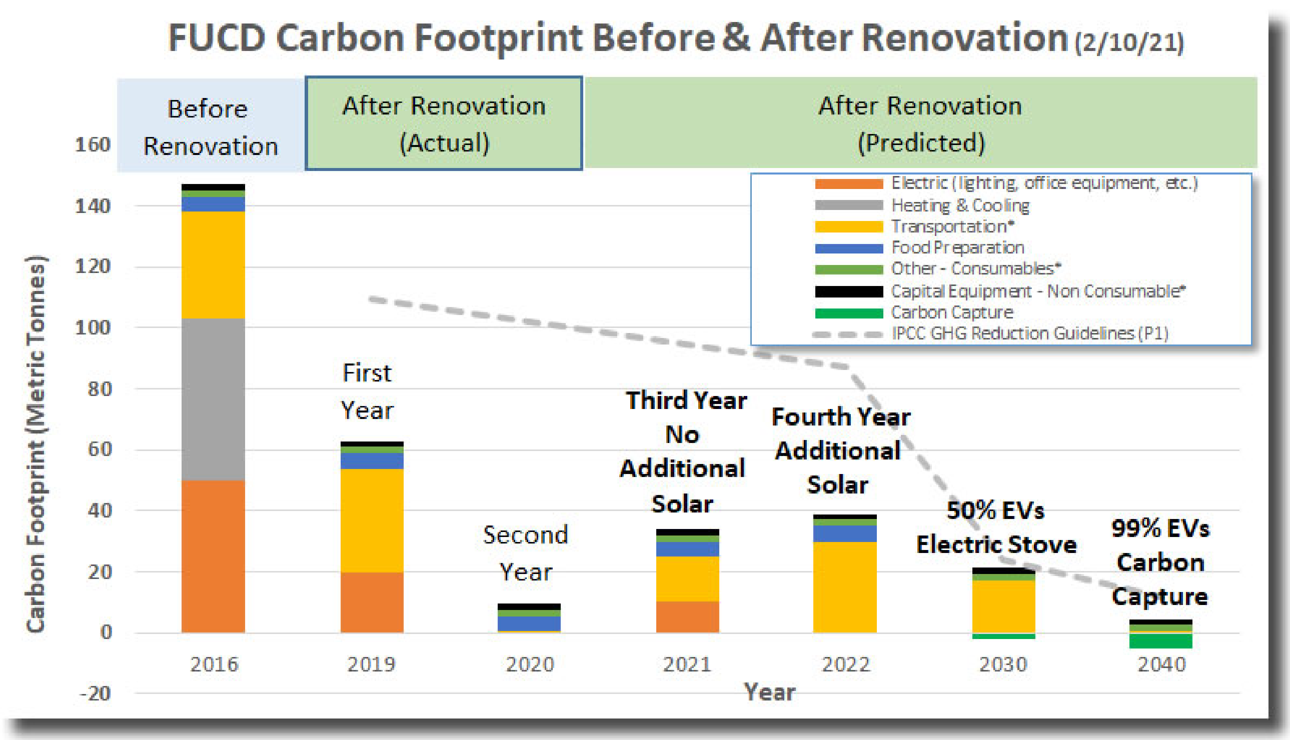

Figure 25 FUCD Carbon Footprint Before & After Renovation (2/10/2021)

As mentioned at one of the Green First Task Force meetings, "Our members don't like to be told what path to take." And that is certainly a true statement. A Roadmap that reduces the FUCD carbon footprint to near zero by 2040 is not negotiable however. The path to reduce the carbon footprint is left to the individual. Everyone needs a personal plan on how they (and the organization that are a part of) are going to get to zero GHG emissions.

I think that a good project for Green First and our friends in the climate action movement would be to keep the pressure on Xcel to keep making progress on their renewable fuel commitments. Agree. Have you noticed that nothing is being proposed by Xcel to phase out their sale of natural gas, propane, etc. They are not proposing any transition programs or financial support for replacing natural gas stoves, furnaces, fire places, BBQ grills, buses, etc. with an electrified / zero emission version. So when they say 55% of their power from renewable sources it does not reflect any plan to reduce the GHG emissions from the natural gas products they also sell. Inventing another lie like CNG (Clean Natural Gas) is not going to bend the Keeling curve downward and slow global warming. So yes, we need to keep the pressure on Xcel.

Another possible project for Green First might be to engage our youth and conduct a program focused on reducing our transportation related footprint – we could have our youth help conduct a survey / inventory of how many EVs are in the parking lot compared to gasoline cars so we could get some actual data to work with. Then we could better monitor our progress in transitioning to zero emission vehicles (or walk, bike, car pool, EV Uber,…)

Appendix C Basis for the unexpected increase in operating cost

The basis for the unexpected increase in operating cost

From a financial perspective, there were several items that were more costly than expected.

1) The solar PV system was found to be undersized as discussed previously. As a result, there was a shortfall in energy generation. The church had to purchase 29,389 kWh of energy from Xcel. This was an unexpected cost.
2) If demand exceeds 25 kW, the customer is no longer eligible for the Commercial "C" rate schedule. Xcel initiated a new SPVTOU-B rate schedule for commercial customers who have installed solar PV. The new rate schedule has several "demand" components:
   a) The Peak Demand is the highest 60 minutes integrated demand during the entire 30-day bill period,
   b) The Generation & Transmission Demand is the highest 60-minute demand between 2 pm and 6 pm M-F

   The church usage on Sundays and special events routinely exceed 25 kW. The "Peak Demand" cost schedule is particularly egregious for faith-based organizations that have their peak demand one day a week (Sundays for First Universalist) but much lower usage rates during the other six days of the week as illustrated in Figure 26.

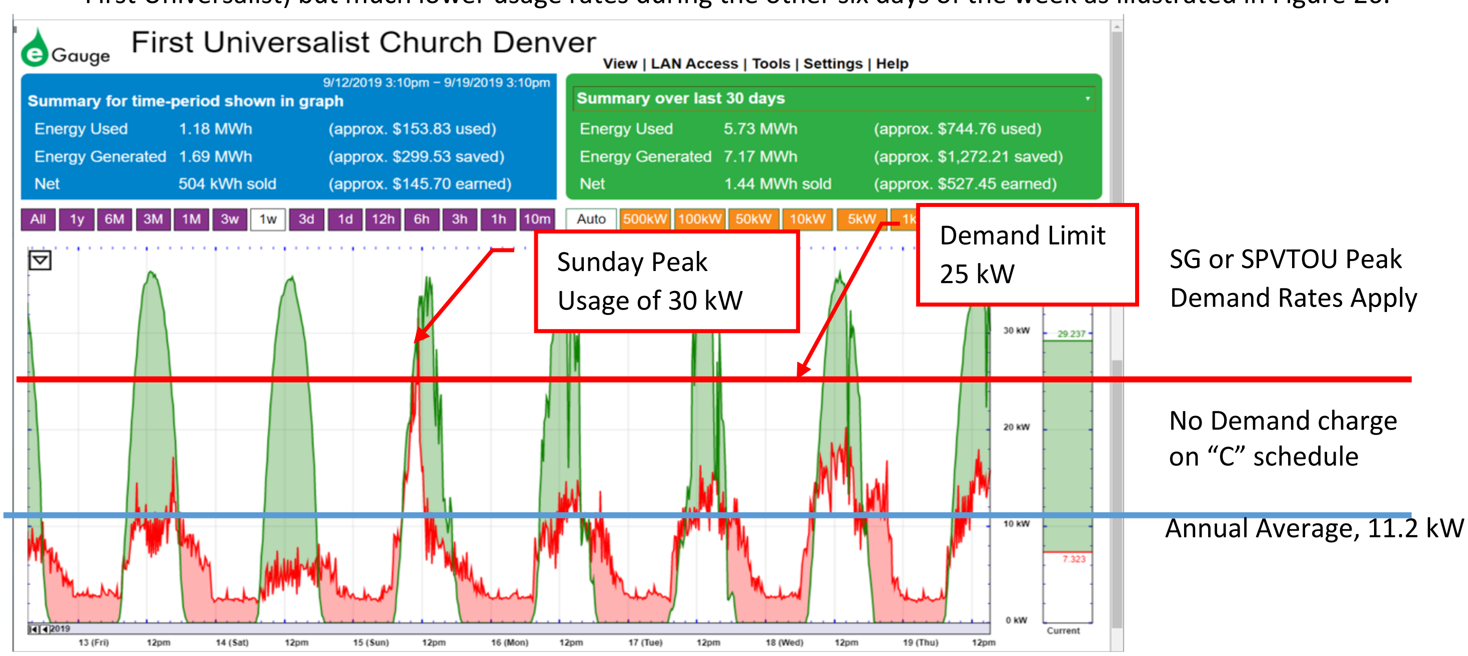

Figure 26 Actual Data for Solar Energy Generated (green) and Energy Used (red) - Week of 12 Sept to 19 Sept 2019.

Another example. Near the end of July, 200 folks attended the "Association for Music Ministries" Annual Conference (Thu, July 25th, 8:30am – Sat, July 27th, 11:30am.) Apparently, the sound equipment and A/C for that many people consumed a lot of electric as illustrated in Figure 27. Peak demand was around 41 kW on Thursday, Friday & Saturday. (Note peak solar production is also around 40 kW around noon.) It is unlikely that a power control system can limit use on Sundays and special events to under 25 kW to avoid Xcel's atrocious "Demand Charge."

If the "Demand Limit" were to be raised to 50 kW (to encourage the transition to renewable energy), then it would be possible to control FUCD usage below that limit. This seems like a viable short-term solution for faith-based organizations and small commercial businesses. The annual average usage is around 11 kW. Onsite BTM storage of around 20-30 kWh could possibly limit peak demand to under 25 kW.

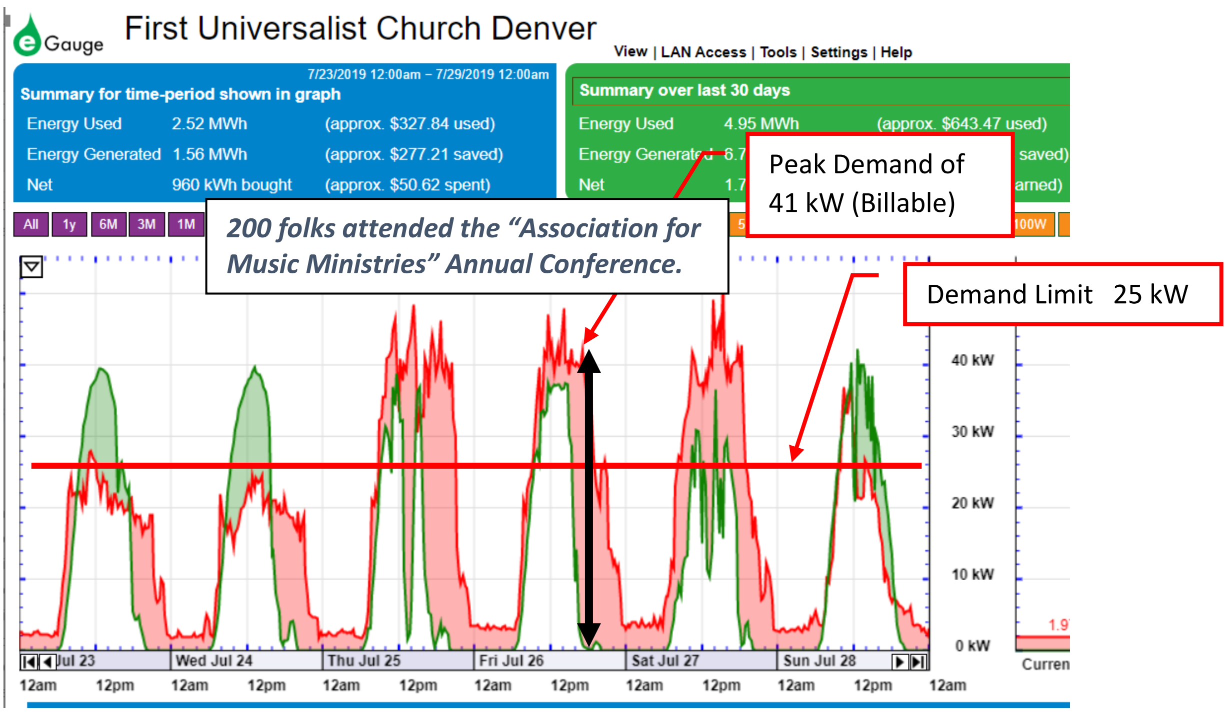

Figure 27 Actual Data for Solar Energy Generated (green) and Energy Used (red) - Week of 23 July to 28 July 2019.

The unexpected need to purchase additional power combined with the new "Demand" charges resulted in a bill of **$6450 for 29,389 kWh of energy**. Inventing and implementing a new complicated SPVTOU rate schedule for small commercial users who have added solar (including First Universalist Church Denver) was a clever way to charge solar customers **$0.22 / kWh** compared to the former non-solar commercial rate of $0.17 / kWh. That is a 29% increase for commercial customers like First Universalist Church Denver who add solar.

First Universalist Church was lucky. At the beginning of 2017, it applied for the limited Solar*Rewards® rebate program. Its application was accepted. As a result, First Universalist was able to offset $3220 of the SPVTOU Demands charges with Renewable Energy Credits (REC). This reduced its effective unit cost of electric to $0.11 / kWh.

Further discussion of the Xcel Billing Data.

The Xcel billing information is presented in Table 17. A portion of this information is displayed graphically in Figure 29 to Figure 31. Using December 2018 as an example, the values recorded by the Xcel Meters can be explained as follows: Start with the December solar "Production" of 3,426 kWh (found in Column AW of Table 17) is displayed just above the image of the Production Meter. According to the "Net Meter" 557 kWh were delivered to the grid by the “customer” (See Column G of Table 17). According to the Net Meter, Xcel delivered 7609 kWh to the building. The net amount used by the facility was then 3,426 (Produced) – 557 (Delivered to the grid) + 7,609 (Delivered by Xcel) = 10,477 KWh. In May, it becomes more interesting because the solar PV system generates more energy than the facility needs to operate so the excess is stored in the “Energy Bank.” The ‘Production Meter’ for May (Row 21 Col U), indicates the solar PV system generated 6,727 kWh of energy. The Net Meter indicates that 3,772 kWh were delivered to the grid and Xcel delivered 2,777 kWh to the facility for operations. So the facility consumed 6,727-3,772+2,777 kWh = 5732 kWh to operate in May. Because the solar PV system produced more than required by the facility, the excess 995 kWh was exported to the grid. Xcel uses Column C to keep track of what is in the bank and denotes that it owes First Universalist some energy by using a minus sign (e.g. – 995 kWh). June is even a better solar month and 3,547 kWh are deposited in the bank for a total balance of -4,542 (Row 20 col C).

DRAFT

Table 17 Condensed Version of Xcel Billing Statement

Customer Name	FIRST UNIVERSALIST CHURCH															
Account Number	**53-2125618-2**															
Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262															
Service	ELECTRIC-1															
		I+L+N+S K-G	U-G+K	**NET METER DATA 53-2125618-2**												**PRODUCTION METER**
Last Read Date	**Billing Days**	**Electrical Usage (kWh)**	**Facility Usage / Consumption**	**Off Pk Delivered by Xcel (kWh)**	**On Pk Delivered by Xcel (kWh)**	**Total Delivered by Customer (kWh)**	**ECA On Pk (kWh)**	**Off Net Generated by Customer (kWh)**	**Total Delivered by Xcel (kWh)**	**Off Pk Net Delivered by Xcel (kWh)**	**Off Pk Delivered by Customer (kWh)**	**On Pk Net Delivered by Xcel (kWh)**	**On Pk Delivered by Customer (kWh)**	**ECA Off Pk (kWh)**	**On Net Generated by Customer (kWh)**	**Production Meter Data (kWh) 53-0012186178-0**
11/18/2019	29	-3511	7920	5886	0	1099	1452	543	5886	0	1099	0	0	3335	2968	3133
10/20/2019	31	-8298	5920	2930	230	3065	0	5330	3160	0	2571	0	494	999	2968	5825
9/19/2019	30	-8393	6993	2478	762	3458	0	5689	3240	0	1968	0	1490	1192	2704	7211
8/20/2019	29	-5175	8095	2668	1003	3309	0	3199	3671	0	1777	0	1532	1502	1976	7733
7/22/2019	32	-7344	5893	1842	381	5024	0	4365	2223	0	3060	0	1965	0	2979	8694
6/20/2019	30	-4542	4345	1814	137	5498	0	3147	1951	0	3966	0	1532	0	1395	7892
5/21/2019	29	-995	5732	2777	0	3772	0	995	2777	0	3772	0	0	230	0	6727
4/22/2019	29	777	7069	3854	0	3077	0	0	3854	777	3077	0	0	1899	0	6292
3/24/2019	31	5705	11178	7653	0	1948	1466	0	7653	5705	1948	0	0	4239	0	5473
2/21/2019	30	8679	12189	9214	0	535	3720	0	9214	8679	535	0	0	4959	0	3510
1/22/2019	34	9493	12207	9780	0	287	3385	0	9780	9493	287	0	0	6108	0	2714
12/19/2018	33	7052	10478	7609	0	557	2275	0	7609	7052	557	0	0	4777	0	3426
	367	**31,706**	**98,019**	**58,505**	**2,513**	**31,629**	**12,298**	**23,268**	**61,018**	**31,706**	**24,617**	**0**	**7,013**	**29,240**	**14,990**	**68,630**
		Shortfall	**29,389**				*41,538*	*38,258*		*31,706*	*31,630*					

"Bank" Balance

This attempt to display the Xcel Meter data graphically did identify two anomalies that indicate there are still features of the Xcel billing that we do not understand. In Aug, there was a 1,807 kWh reduction in the amount banked that is not understood. In September, there is an unexplained 3,000 kWh deposit into the Energy Bank. It may have something to do with 'On Peak' and 'Off Peak' ECA.

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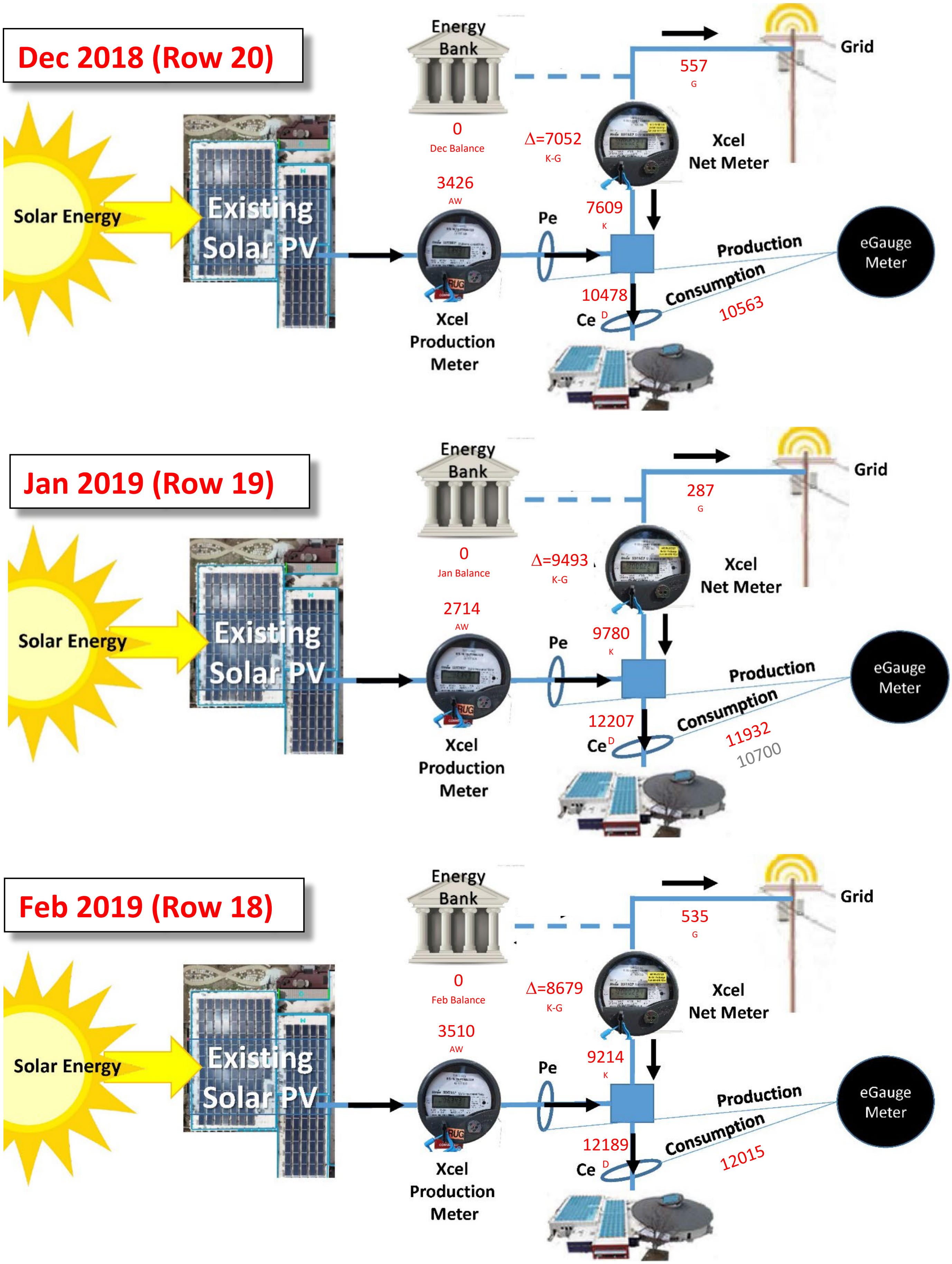


Figure 28 Dec 2018 to Feb 2019

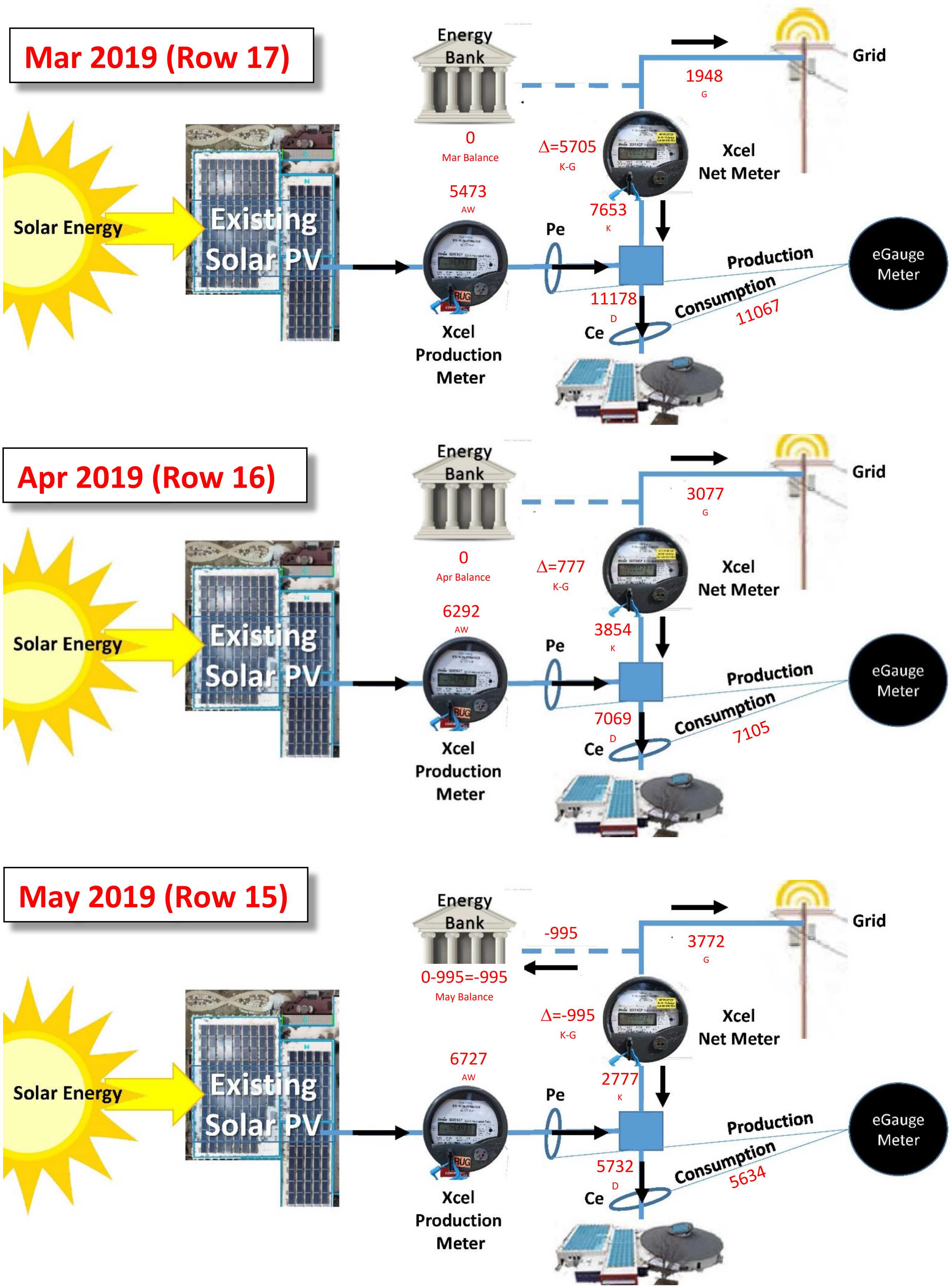
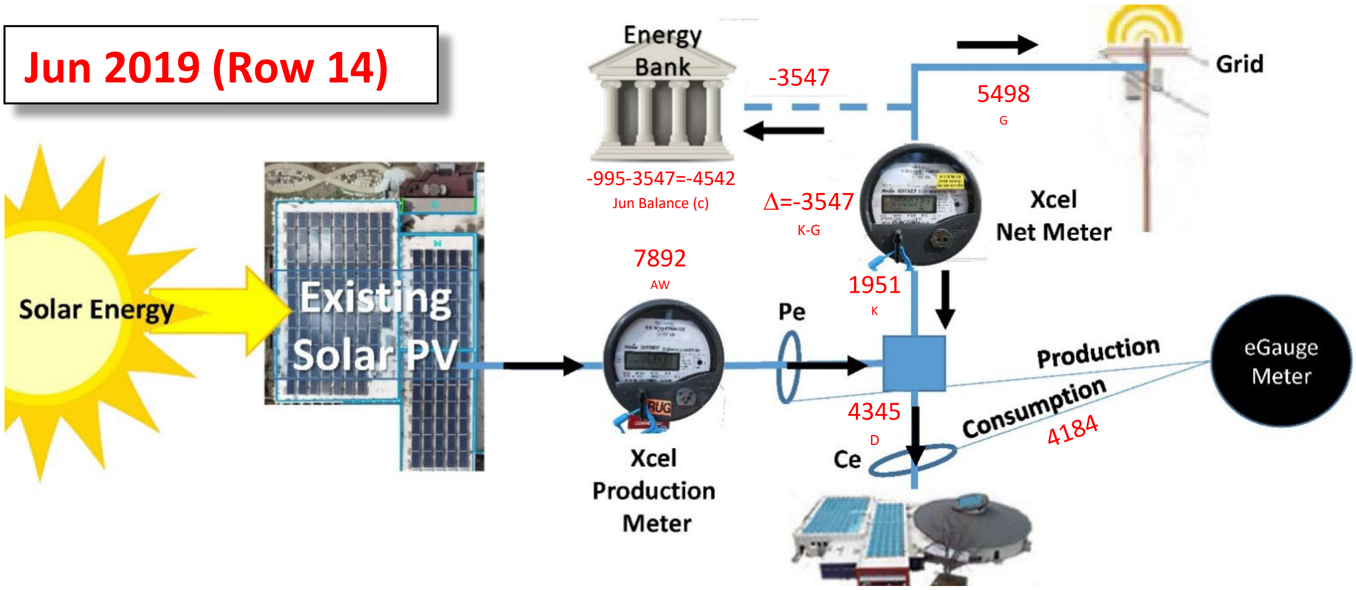
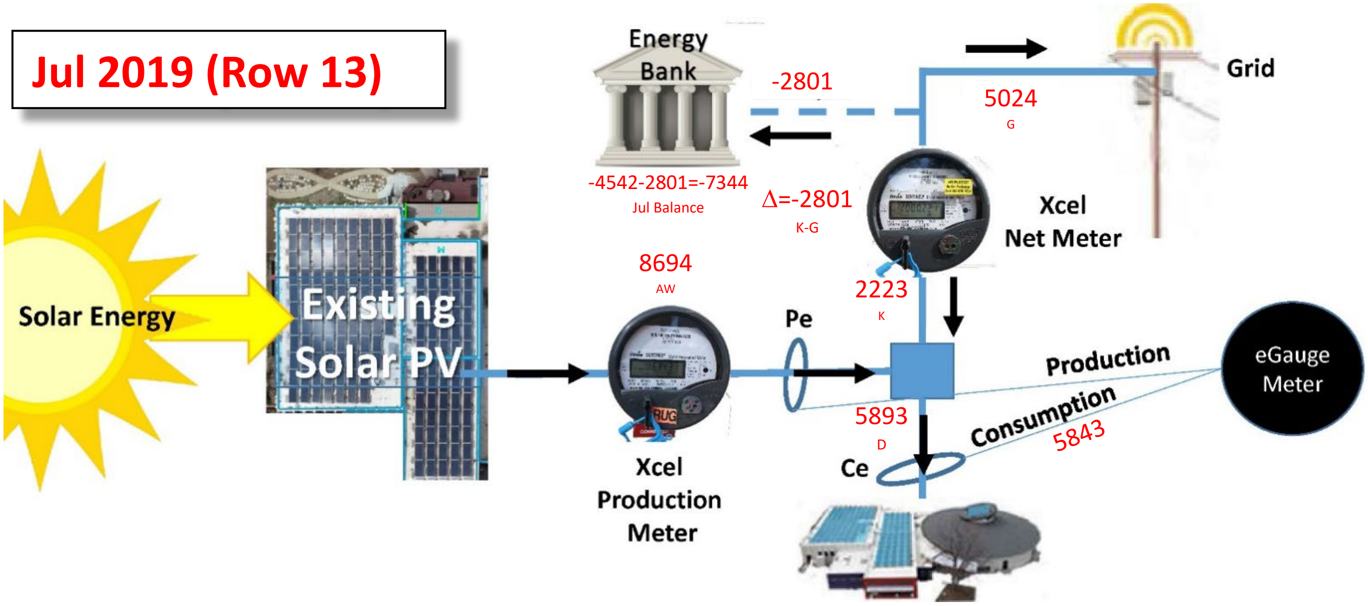


Figure 29 Mar 2019 to May 2019





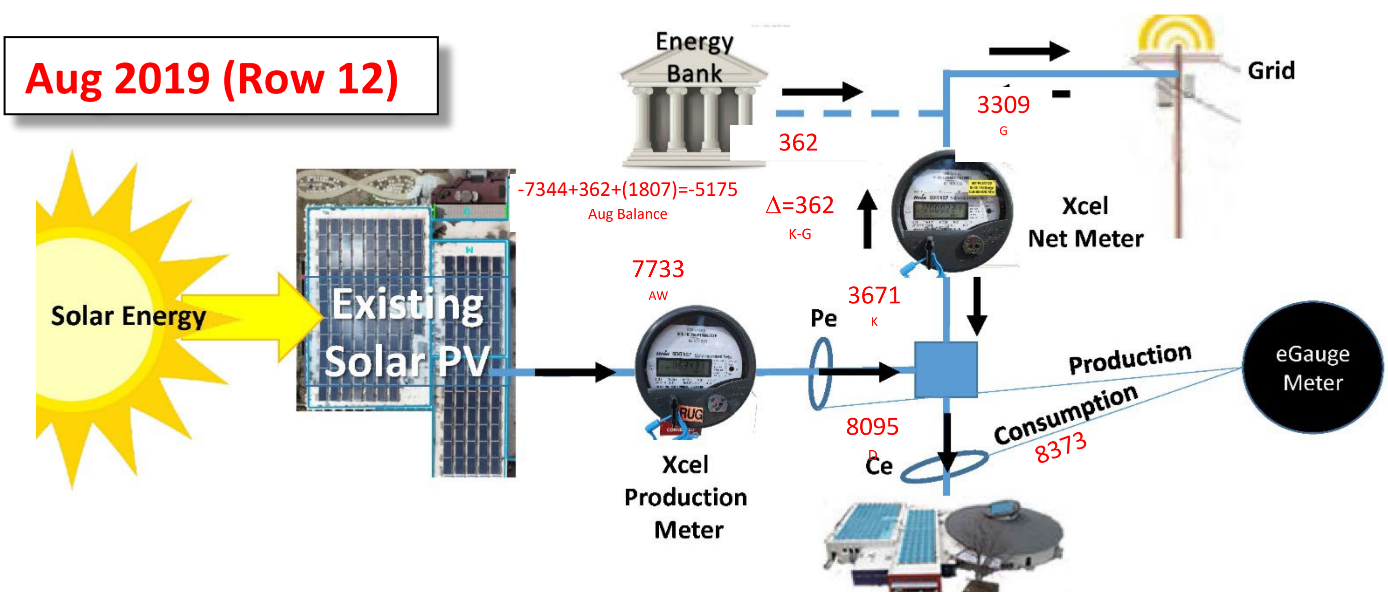


Figure 30 Aug 2019 to Jun 2019

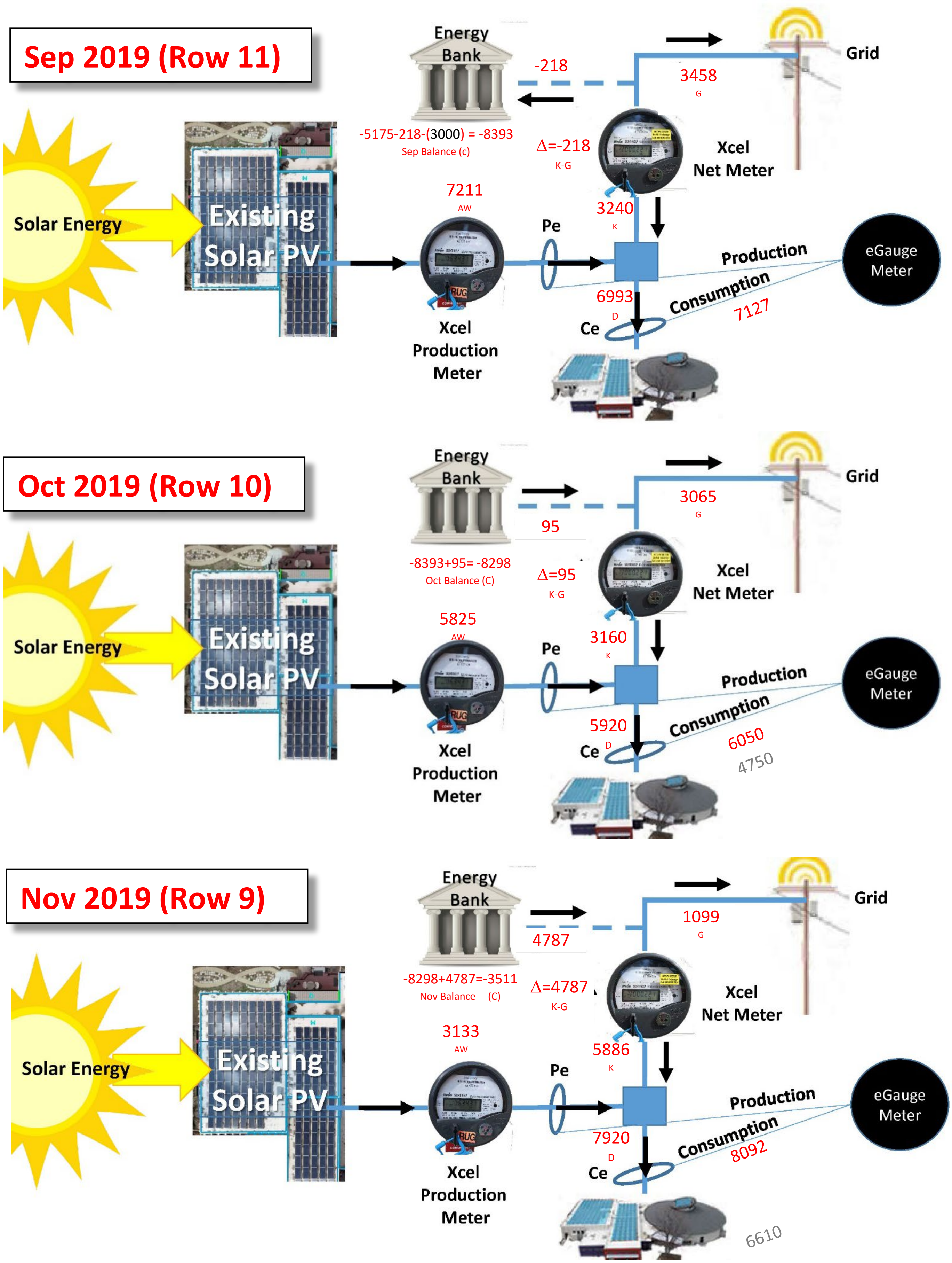


Figure 31 Sep 2019 to Nov 2019

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Table 18 Condensed Version of Xcel Energy Billing – EMPHASIS on ANNUAL COST SAVINGS

2	Customer Name		FIRST UNIVERSALIST CHURCH																		
11		C	G	L	F	K	S	U	X	Z	AD	Y	AG	AA	AB	AE	AF	AH	AI	AJ	AK
12	Last Read Date	Electrical Usage (kWh)	Total Delivered by Customer (kWh)	Total Delivered by Xcel (kWh)	Demand (kW)	Generation & Transmission Demand (kW)	Billable Demand (kW)	Total Electric Charges	Dem Side Mgmt Cost	Distribution Dmd	Gen & Transm Dmd	**ECA Off-Peak**	**ECA On-Peak**	Purch Cap CostAdj	RESA FS	Srv & Facility	CACJA	SPVTOUB OffPk	Renew. Energy Std Adj	Trans Cost Adj	Average Temperature (° F)
13	11/18/2019	-3511	1099	5886	32	24	32	$514.14	$16.32	$180.16	$55.92	$74.87	$46.61	$39.68	$2.88	$34.40	$29.76	$0.00	$9.73	$20.16	40
14	10/20/2019	-8298	3065	3160	18	11	22	$286.45	$9.18	$123.86	$16.03	$8.98	$0.00	$22.32	$7.02	$34.40	$16.74	$0.00	$5.32	$11.34	56
15	9/19/2019	-8393	3458	3240	19	12	22	$318.86	$9.69	$123.86	$49.32	$30.19	$0.00	$23.56	$11.87	$34.40	$17.67	$0.00	$5.84	$11.97	72
16	8/20/2019	-5175	3309	3671	41	41	41	$632.48	$20.91	$230.83	$168.51	$38.05	$0.00	$50.84	$13.14	$34.40	$38.13	$0.00	$11.80	$25.83	76
17	7/22/2019	-7344	5024	2223	16	10	22	$270.42	$2.50	$123.86	$41.10	$0.00	$0.00	$19.84	$14.10	$34.40	$14.88	$0.00	$4.89	$10.08	72
18	6/20/2019	-4542	5498	1951	18	5	22	$250.24	$9.00	$123.86	$3.89	$0.00	$0.00	$22.32	$11.39	$34.40	$16.74	$0.00	$4.56	$11.34	61
19	5/21/2019	-995	3772	2777	20	12	22	$269.00	$10.00	$123.86	$27.96	$5.95	$0.00	$24.80	$6.69	$34.40	$18.60	$0.00	$5.01	$12.60	51
20	4/22/2019	777	3077	3854	28	13	28	$394.53	$14.00	$157.64	$30.29	$13.79	$0.00	$34.72	$6.57	$34.40	$26.04	$14.17	$7.38	$17.64	49
21	3/24/2019	5705	1948	7653	43	28	43	$804.10	$21.50	$242.09	$65.24	$127.51	$63.05	$53.32	$6.12	$34.40	$39.99	$104.06	$15.19	$27.09	34
22	2/21/2019	8679	535	9214	43	43	43	$1,016.18	$21.50	$242.09	$100.19	$149.17	$160.00	$53.32	$3.92	$34.40	$39.99	$158.30	$19.28	$27.09	30
23	1/22/2019	9493	287	9780	37	26	37	$957.11	$8.10	$208.31	$60.58	$118.88	$94.20	$17.50	$3.00	$34.40	$11.88	$173.15	$18.16	$6.27	35
24	12/19/2018	7052	557	7609	29	21	29	$736.96	$17.98	$163.27	$48.93	$143.41	$97.64	$38.86	$4.00	$34.40	$26.39	$128.63	$13.96	$13.92	39
27																					
28							Total $	$6,450	$161	$2,044	$668	$711	$462	$401	$91	$413	$297	$578	$121	$195	$6,141
29							"Fixed" $	$3,003	$30	$1,486	$47	$0	$0	$210	$35	$413	$201	$0	$55	$136	$2,612
30							Possible Savings	**$3,448**	**$131**	**$557**	**$621**	**$711**	**$462**	**$191**	**$56**	**$0**	**$96**	**$578**	**$66**	**$59**	$3,529
31																					
32						NOTE: Demand cost is reduced when solar generates a surplus									NOTE: Energy Cost Adjustment (ECA) goes to zero when solar generates a surplu						
33						Demand	$1,309	possible savings							ECA	$1,172	possible savings				

Discussion of Table 18 Condensed Version of Xcel Energy Billing – EMPHASIS on ANNUAL COST SAVINGS

Table 18 displays more of the Xcel billing information pertaining to cost rather than the quantity of energy. Color-coding has been added that visually indicates the time of the year (Rows) and the categories (Columns) where the high (red) electric costs reside. Lowest costs are indicated in green cells.

As indicated, operating the facility in the colder months requires more energy than in the summer months. Peak 'Electric Charges' of $1,016 (column U) were in February. The table also illustrates the Energy Cost Adjustment (ECA) costs total to around $1,172 – these costs should go to zero when the solar PV system generates a surplus (See Rows 17 & 18.) The table also illustrates that the Demand Costs (total of $1,309) can also be reduced by additional production by reducing the "peaks" in the usage profile (e.g. by installing an active power control system or better yet by adding Behind-the-Meter (BTM) storage to level the peak demands

Correlation between "Delivered by Xcel" and Total Electric Charges

Although the SPVTOU-B rate schedule is very complicated, there is a rough correlation between the amount of energy "delivered" by Xcel and the Monthly Charges. The fixed fees and the "Demand Charges" make this correlation a bit fuzzy. As indicated by the linear approximation, the first-order estimate of the Xcel charges is $0.10 x Energy Delivered by Xcel + $50. Some of the energy "Delivered by Xcel" was originally generated by FUCD and deposited in the Energy Bank.

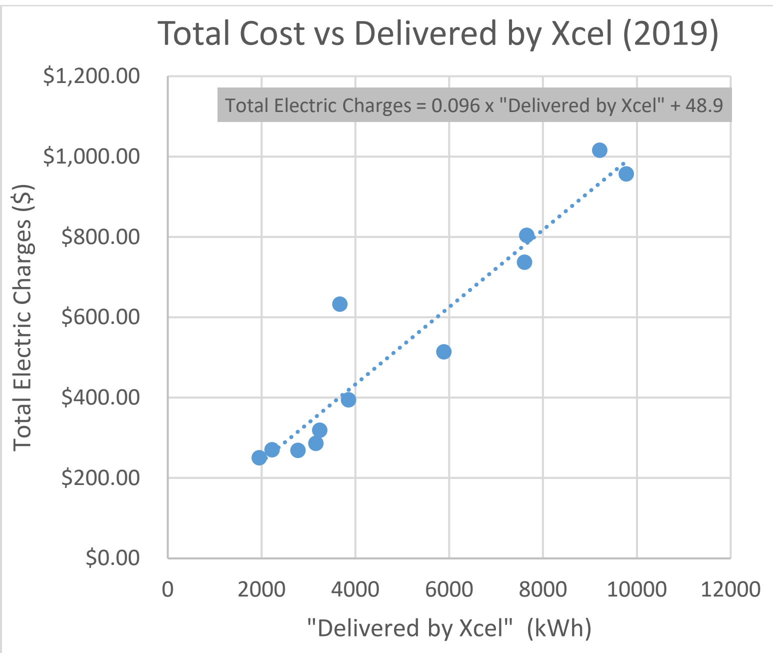

Figure 32 Approximate Cost vs Amount of Energy Delivered by Xcel

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Response From Xcel Energy Support Personnel (Jan 14, 2020)

From: Xcel Energy Business Solutions Center <bsc@xcelenergy.com>
Sent: Tuesday, January 14, 2020 2:57 PM
To: john@bringenberg.com
Subject: Billing anomaly at our FUCD account

Billing & Payment | Start, Stop, Transfer | Programs & Rebates | Outage & Emergencies

Hello John,

Account: 53-2125618-2

Thank you for contacting Xcel Energy.

We reviewed the document you provided us regarding your concerns about solar billing at the service address. In this email we will go over questions you brought forward to us.

Regarding your interpretation of the Production Meter you asked us to verify if you are viewing the data correctly. Yes, the total production from 12/19/18 to 11/18/19 appears to be 68,630. You were also viewing the RECs (Renewable Energy Credits) correctly as well.

Please use the spreadsheet that we provided in this email as a reference as we answer your other questions. We highlighted sections of the document to help you find the information we will be referring to.

How much energy (kWh) did the church purchase from Xcel over the past 12 months?

The church purchased 31,706 kWh. This number is based on the total Off Peak Net Delivered by Xcel Energy. This also includes On Peak Net Delivered by Xcel Energy but that portion was read at zero.

How much energy did the church facility use/consume over the past 12-months?

The total amount consumed was 98,019 kWh. To acquire this number we took the Total Delivered by Xcel (kWh) then added it to the Production Meter (kWh) and we subtracted the Total Delivered by Customer (kWh).

It should appear as follows:

Total Delivered by Xcel (kWh) + Production Meter (kWh) - Total Delivered by Customer (kWh) = Total Consumption

61,018 + 68,630 - 31,629 = 98,019 kWh

We also submitted a request to have someone check the electric meter to make sure it is hooked up appropriately and registering correctly. It can take some time to get this order completed but we will notify you of the results.

Your voice matters! Please take a short survey to let my Supervisor know how well I did.

Thank you for contacting us. I was happy to help.
Sincerely,

John M.
Xcel Energy | Responsible By Nature
Customer Service - Business Solutions Center
Attn: BSC Correspondence P.O. Box 8, Eau Claire, WI 54702
P: 800.481.4700 **F:** 800.311.0050
E: bsc@xcelenergy.com

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Table 19 Table provided by Xcel Energy 1/14/2020 for Reference purposes (Same information is contained in Table 17)

	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1					Report Date	1/13/2020													
2				2018-01-13 to 2020-01-13															
3	Customer Name	FIRST UNIVERSALIST CHURCH																	
4	Account Number	53-2125618-2																	
5	Account Address																		
6	Premises Number	3E+08																	
7	Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262																	
8	Premises Status	CURRENT																	
9	Service	ELECTRIC-1																	
10																			
11																			
12	Last Read Date	Billing Days	Electrical Usage (kWh)	ECA On Pk (kWh)	Off Net Generated by Customer (kWh)	Generation& Transmission Demand (kW)	Total Delivered by Xcel (kWh)	On Pk Net Delivered by Xcel (kWh)	Off Pk Delivered by Customer (kWh)	Off Pk Net Delivered by Xcel (kWh)	On Pk Delivered by Customer (kWh)	ECA Off Pk (kWh)	Billable Demand (kW)	On Net Generated by Customer (kWh)	Demand (kW)	On Pk Delivered by Xcel (kWh)	Off Pk Delivered by Xcel (kWh)	Total Delivered by Customer (kWh)	Production Meter (kWh)
13	11/18/2019	29	-3511	1452	543	24	5886	0	1099	0	0	3335	32	2968	32	0	5886	1099	3133
14	10/20/2019	31	-8298	0	5330	11	3160	0	2571	0	494	999	22	2968	18	230	2930	3065	5825
15	9/19/2019	30	-8393	0	5689	12	3240	0	1968	0	1490	1192	22	2704	19	762	2478	3458	7211
16	8/20/2019	29	-5175	0	3199	41	3671	0	1777	0	1532	1502	41	1976	41	1003	2668	3309	7733
17	7/22/2019	32	-7344	0	4365	10	2223	0	3060	0	1965	0	22	2979	16	381	1842	5024	8694
18	6/20/2019	30	-4542	0	3147	5	1951	0	3966	0	1532	0	22	1395	18	137	1814	5498	7892
19	5/21/2019	29	-995	0	995	12	2777	0	3772	0	0	230	22	0	20	0	2777	3772	6727
20	4/22/2019	29	777	0	0	13	3854	0	3077	777	0	1899	28	0	28	0	3854	3077	6292
21	3/24/2019	31	5705	1466	0	28	7653	0	1948	5705	0	4239	43	0	43	0	7653	1948	5473
22	2/21/2019	30	8679	3720	0	43	9214	0	535	8679	0	4959	43	0	43	0	9214	535	3510
23	1/22/2019	34	9493	3385	0	26	9780	0	287	9493	0	6108	37	0	37	0	9780	287	2714
24	12/19/2018	33	7052	2275	0	21	7609	0	557	7052	0	4777	29	0	29	0	7609	557	3426
25	Total	367		12298	23268	246	**61018**	0	24617	**31706**	7013	29240	363	14990	344	2513	58505	**31629**	**68630**

How do I know how much energy my system produced? Is that reflected on the bill?

As a solar customer, of course you're interested in knowing how much total energy your system is producing. However, you won't find that information on your Xcel Energy bill.

Our net meter only measures energy that touches our grid (if we deliver energy to your home, or if you deliver energy to our system), so that we can track how much energy we need to bill you for, or how much we owe you. Unfortunately, if your PV system produces energy that's used by your home and doesn't ever make it to the grid, that isn't captured on your bill.

However, if you have both a Sentinel meter AND a production meter, you can calculate the amount of solar energy your home used up during a billing period.

1) Before you start, grab your net and production meter bills (be sure they cover the same billing period) and locate the "Meter Reading Information" tables on each one.
2) On your production meter bill, look in the "Usage" column and find the kWh amount shown. Write it down. (On the sample bill it's 357 kWh.)
3) Next, on your Sentinel meter bill, find the "Total Delivered by Customer" line, and then locate the number in the "Usage" column. Write it down. (On the sample bill, it's 39 kWh.)
4) Subtract the Step 3 amount from Step 2. The end calculation is the amount of solar energy in kWh your home used during that billing period that never touched the grid. (Example: 357 kWh – 39 kWh = 318 kWh)

*Important notes:

- If you have a standard net meter, you won't have the information needed for this calculation.
- The usage on the production bill will never match the usage of total delivered by customer, unless there was no generation of electricity at the home.

Xcel Energy® | RESPONSIBLE BY NATURE®

This is the amount of **Solar Energy** used by the building. You then add the amount of non-solar energy delivered by Xcel to determine the total consumption of the building

Figure 33 2014 Xcel Instructions on How to Read their Bill

Appendix D Energy System Monitoring Meters (Renovated Facility) in 2019.

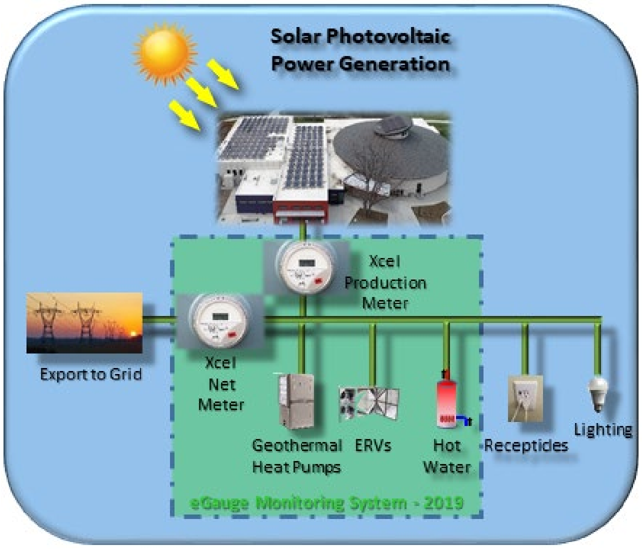


Figure 34 Solar Powered Sustainable Operations at FUCD 2018-019

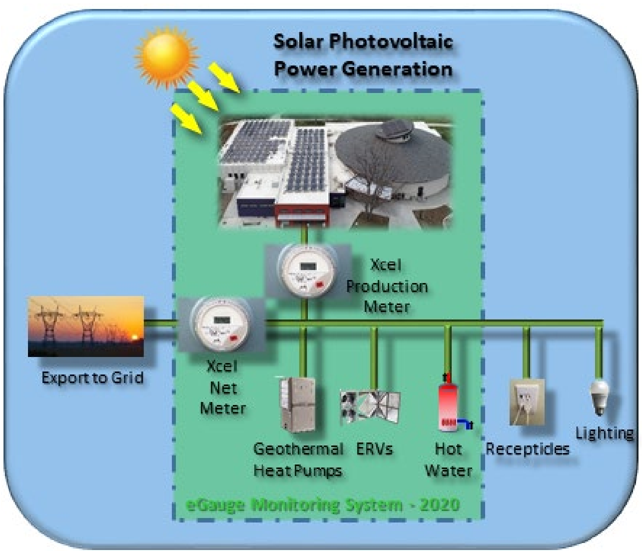


Figure 35 Solar Powered Sustainable Operations at FUCD 2020

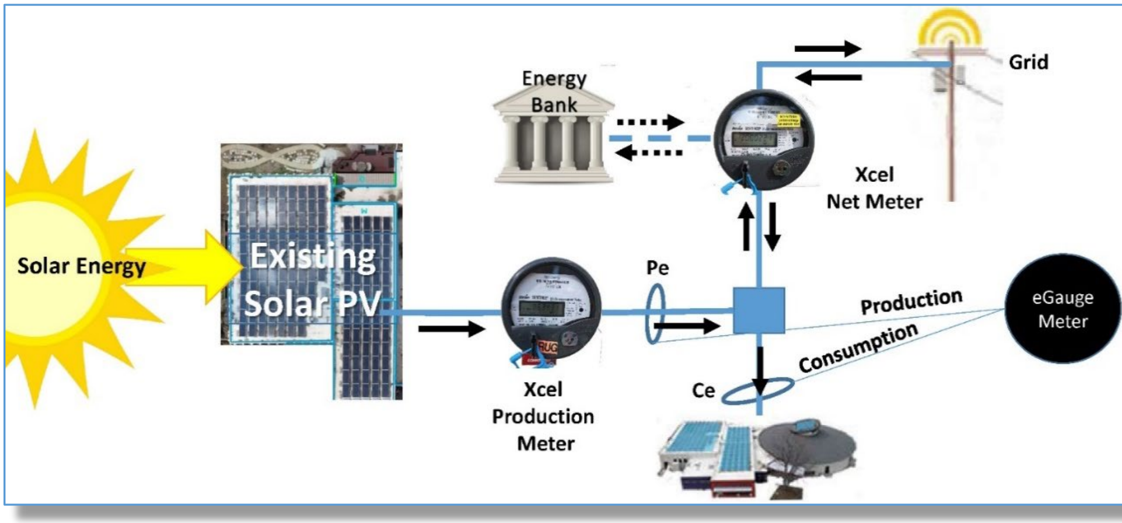


Figure 36   FUCD Energy System showing Xcel and eGauge Energy Meters in 2019

Figure 36 illustrates the FUCD Energy System metering equipment in 2019 and identifies the following :

1) the location of Xcel Production Meter that measures the amount of energy (kWh) produced by the solar PV system,

2) the location of the Xcel Net Meter that measures the amount of energy (kWh) transferred into the grid (when the solar PV system is generating excess power) or withdraw from the grid (e.g., at night when the solar PV is not generating power), and

3) the eGauge Meter that monitors the energy produced (Pe) similar to the Xcel Production Meter and the energy consumed by the facility (Ce). (See Appendix D for details about the eGauge Meter.) The eGauge system is not intended to replicate the system level Xcel Net Meter measurements (available to FUCD on a monthly basis) but was added to provide additional information about energy production and usage on a daily basis for better energy management.

The relationships between the Xcel and eGauge monitoring systems can be expressed as follows:

Energy Produced (Xcel) = Energy_Produced (Xcel Production Meter) **[eq 1a]**

Energy Produced (eGauge) = Pe (eGauge Meter) **[eq 1b]**

Energy Consumed (Xcel - calculated)[43] = Energy_Produced (Xcel Production Meter)
– Energy_Delivered_by_Customer (Xcel Net Meter)
+ Energy_Delivered_by_Xcel (Xcel Net Meter) **[eq 2a]**

Energy Consumed (eGauge) = Ce (eGauge Meter) **[eq 2b]**

If there is a discrepancy between the Xcel and eGauge data, the Xcel data takes precedent and is assumed to be the most accurate.

Note: Although the eGauge equipment is ANSI C12.20 Revenue Grade Accuracy Compliant, it was never intended to be used with revenue-grade accuracy by FUCD. The goal was to install a state-of-the-art energy monitoring system at an affordable price. The intent was to use the eGauge monitoring system to obtain meaningful performance data for components within the facility and use the eGauge real-time visualization tools to reduce energy usage and operating costs.

[43] The energy **consumed** by the building is discussed in more detail later in this report.

Xcel Energy Meters

Xcel Energy installed two meters for billing purposes that operate continuously.

One Xcel meter referred to as the "Production Meter," measures the amount of power generated by the solar PV system. This energy production information is needed to assess the Renewable Energy Credits ($0.045 / kWh) paid to the church monthly.

The second Xcel meter is a "Net Meter" that measures the difference between what is being produced and what is being consumed. The "Net Meter" is very important because it determines several cost schedules. First, it measures the net amount of energy the church buys from Xcel; secondly, it monitors the net peak demand. If the net demand exceeds 25 kW during any 15-minute period, there is a significant demand fee imposed for that billing period.

Xcel provides monthly Production Meter and Net Meter information but not daily or hourly data. The Xcel billing information is complex, hard to understand and difficult to integrate for 12 months to determine the annual usage.

eGauge Monitoring System

To better understand the energy usage of the facility, it was necessary to install a church-owned eGauge monitoring system[44] that measures the energy consumed by key equipment / appliances minute by minute.

The eGauge solar production measurement was compared to the Xcel Production meter and found to agree within 0.5% thereby validating the measurement accuracy of the eGauge system.

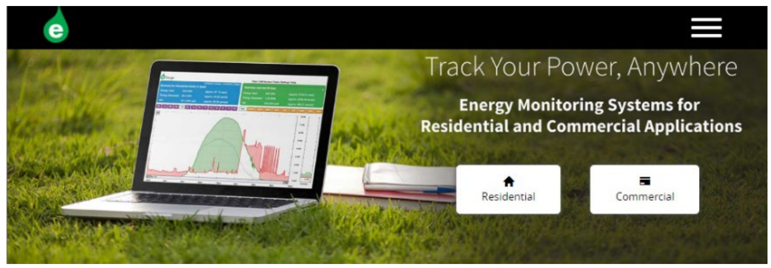


Figure 37 An eGauge Can Monitor Electricity on Every Circuit with Precision and Accuracy

[44] The eGauge is a CT meter *and b*etter than a kWh Meter. It can measure the power of individual circuits in our electric panel using sensors called current transformers (CTs). The meter also displays our energy data on a webpage in real-time and updates the information every second, revealing potential problems that you could never discover with a simple utility bill. See https://www.egauge.net/ for details.

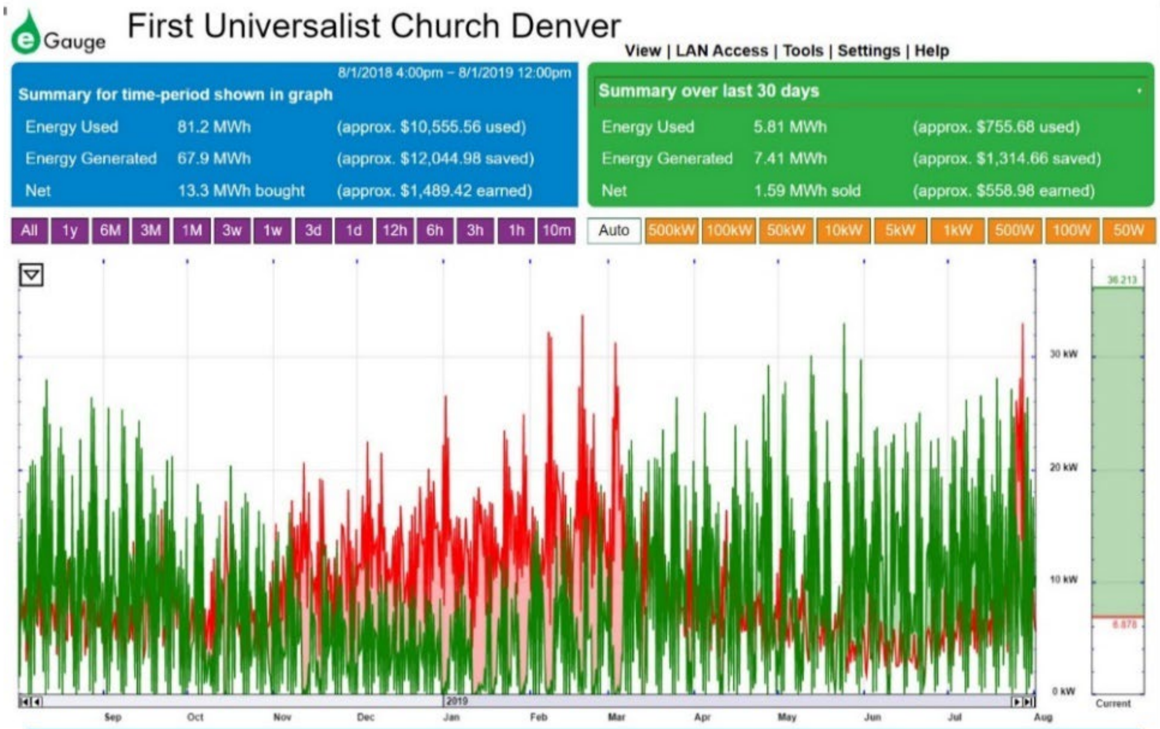
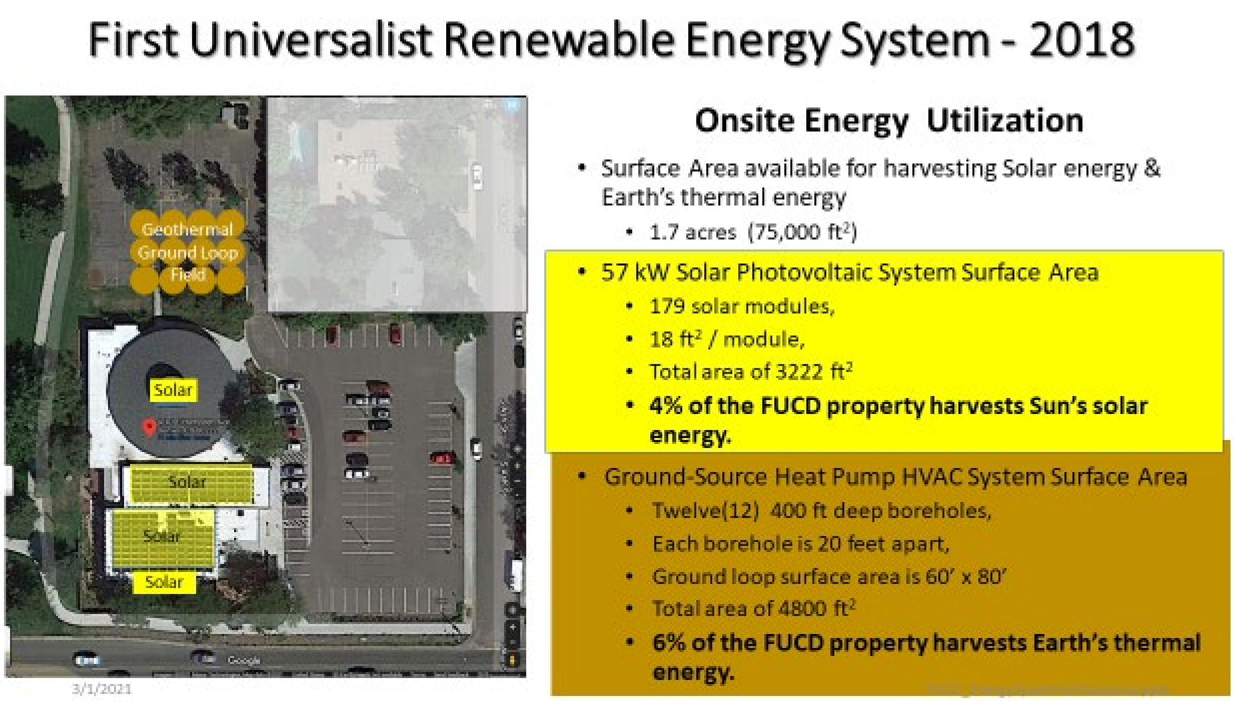


Figure 38 Comparison of Annual Power Production with Power Usage between 8/1/2018 and 8/1/2019.

Appendix E Energy Generation / Production



Energy Requirements of the Renovated Facility

The goal was to install a solar photovoltaic system that produced enough solar generated electric to operate the renovated facility sustainably. So how much energy will be required?

The architectural team estimated the new building would require 75,349 kWh of energy annually for normal operations. [See the red circle in Table 31, Col O.] This is about 5% more electric consumption than the old building used.

Note: It was anticipated that the electrical usage would increase somewhat due to the replacement of gas-burning furnaces with ground-source heat pumps. To be able to exchange free thermal energy with the ground (instead of burning natural gas for thermal energy), a heat pump furnace uses an additional electric motor to operate the heat pump compressor

Row 36 of Table 31 is the same as Row 31 but combines the electrical energy required by the geothermal heat pumps for both heating & cooling. The architect **predicted 22,657 kWh of electrical energy** would be required to provide 86,777 kBTU (25,426 kWh) of cooling in the summer and 230,268 kBTU (67,469 kWh) of heating in the winter. This corresponds to a composite Coefficient of Performance (COP) of 4.1. In other words, one unit of electrical energy to operate the heat pump (compressor and blower motors) will exchange 4.1 units of (free) thermal energy for heating & cooling.

The architect's estimates of the energy required for domestic hot water (DHW) was 131 therms (3825 kWh).

Table 20 Architect's Pre-construction Assessment of Annual Energy Usage

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
28	Annual Usage (NEW DESIGN - SOLAR/GEOTHERMAL - DMA Model)																
29	System	Receptacle Loads (Solar)		Lighting (Solar)		Cooling EER (BTUh/Watts) = (Solar/Ground-Source Heat Pumps)	14.0	Heating COP= 4.1 (Solar/Ground-Source Heat Pumps)			DHW (Solar/Air-Source Heat Pump)			Total Energy Usage			
30	Name	kBtu	KWh	kBtu	KWh	kBtu	kWh	kBtu	kWh	Therms	kBtu	kWh	Therm	kBtu	kWh	Therms	
31	Predictions	*17,983*	5,270	*148,753*	43,597	*21,159*	6,201	*56,147*	16,456	*562*	*13,050*	3,825	*131*	*257,165*	75,349	*692*	Electric - Solar PV
32								230,268	*67,469*	*2,303*				230,268	*67,469*		Heating - Thermal Energy from Earth
33		(RED Denotes Thermal Energy)				86,777	*25,426*							86,777	*25,426*		Cooling - Thermal Energy into Earth
34		(Values in italics are alternate units)												317,045	*92,894*		Total Thermal Energy Exchanged
36	Predictions		5,270		43,597	22657					3825			75349			

Pre-installation Predictions of Solar PV System Performance

The state-of-the-art computer model, PVWATTS, developed and maintained by the National Renewable Energy Lab (NREL) was used to calculate the size of a solar PV system capable of producing all the power needed to operate the renovated facility.

To use the PVWATTS analysis tool, the user simply provides basic information about the size of the solar system, its location geographically, the orientation and the tilt of the solar module. For example, a 1 kW system (approximately 3 modules) installed on a roof in the Denver, CO area, tilted 10 degrees due south would be expected to produce 1,485 kWh/year as illustrated in Figure 39. The "Default" weather model for Boulder, CO was used for this assessment. The fine print in the upper right portion of the chart indicates the range of uncertainty in the solar system performance for this location is 1379 to 1528 kWh.

RESOURCE DATA SYSTEM INFO RESULTS

RESULTS

Print Results

1,485 kWh/Year*

System output may range from 1,379 to 1,528 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.35	85	9
February	4.23	97	11
March	5.44	135	15
April	6.11	142	16
May	6.75	155	17
June	7.41	160	18
July	7.23	159	18
August	6.53	146	16
September	5.81	128	14
October	4.60	108	12
November	3.76	91	10
December	3.12	79	9

Figure 39 PVWATTS Assessment of a 1 kW System Tilted 10 degrees indicates the Nominal Production is 1,485 kWh/year. The system output range is 1,379 to 1,528 kWh due to uncertainties in weather, etc.

Xcel regulations[45] limit solar generation to 120% of annual usage or in this case to 90,420 kWh / year. Using the PVWATTS energy production factor of 1,485 kWh / kW, the largest solar system that can be installed is limited to 60.6 kW. A decision was made to install a 57 kW rated solar system predicted to generate 84,460 kWh annually (with an uncertainty range of 78,430 to 86,900 kWh.) The 57 kW system theoretically provided a 12% margin on energy production.

The First Universalist Solar PV System is comprised of two types of solar modules, tilted at three different angles, using several different inverters and micro inverters, on several different "strings" or circuits. Different segments are labeled in **Error! Reference source not found.** and characterized in ***Table 21***.

.

The PVWATTS computer model indicated the equipment should produce **84,281** kWh annually. According to NREL, the range of uncertainty for the PVWATTS model is **78,266** kWh to **86,727** kWh. The prediction by the model was expected to be accurate to within -7% and +3%. The nominal value of 84,281 kWh, not the lower possible number, was used for sizing purposes with the thought it provided a 10-12 % margin to account for uncertainties.

PV

The difference between the expected output and the actual output of the solar PV system was 15,651 kWh – **a 19 % shortfall in expected power generation.**

[45] These regulations are based on (and consistent with) Colorado legislation that was influenced heavily by lobbying of the 'for-profit' utility companies serving the state as a regulated monopoly. The regulations are monitored & details are modified by the Colorado (Public Utility Commission (PUC) independent of but appointed by the governor's office.

Table 21 Quantitative Assessment of FUCD Solar PV System Performance (Using the PVWATTS Model and Actual Modules)

Array Location	# Modules	Module Rating (W)	Type/ Model/ Inverter	Array Rating (kW)	Tilt (deg)	PVWATTS Factor (kWh/kW)	PVWATTS Annual Production (kWh)
A	18	300	Silfab 300W Modules w/ (9) APS Microinverters	5.4	14	1542 *1432* *1587*	8327 *7,663* *8,494*
B	65	320	Jinko Solar 320W Modules (JKM320M-72)	20.8	10	1499 *1392* *1543*	31179 *28,683* *31,782*
C	90	320	Jinko Solar 320W Modules (JKM320M-72)	28.8	10	1499 *1392* *1543*	43171 *39,715* *44,006*
D	6	300	Silfab 300W Modules w/ (3) APS Microinverters	1.8	87	1212 *1126* *1248*	2182 *2,205* *2,444*
	179			**56.8**			**84,859** **78,266** **-8%** | **86,727** **2%**

The PVWATTS model indicated the 56.8 kW system should produce around **84,859** kWh annually for a composite production factor of 1494 kWh/kW; however, the Xcel Production Meter measured only **68,630** kWh during the first year of operation (the less accurate eGauge Meter verified this production value.) The difference between the expected output and the actual output of the solar PV system was 16,229 kWh. The solar PV production was 19 % less than expected. **The FUCD composite production factor, 68,630/56.8 = 1208 kWh/kW** (instead of the predicted 1494 kWh/kW).

Summary. The actual performance of the solar PV system turned out to be outside the expected range of performance – an indication that:

1) the monitoring system used to measure the Energy Production is not being interpreted properly, or
2) the 57 kW system is not working properly, or
3) the initial sizing analysis / computer modeling was performed incorrectly, or
4) the default "weather model" used by PVWATTS was not accurate for Denver , CO in 2019, or
5) significant shading is occurring at FUCD that was not considered in the original sizing analysis.

All five areas are examined in this report.

Xcel Production Meter

As illustrated in Figure 36, the Xcel production meter is positioned within the electrical circuit to monitor/measure the power produced by the solar PV system.

Table 22 Xcel Billing Data from the Production Meter (17 Nov 2018 to 18 Nov 2019)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Customer Name	FIRST UNIVERSALIST CHURCH											
2	Account Number	**53-0012186178-0**											
3	Account Address												
4	Premises Number	304744058											
5	Premises Address	4101 E HAMPDEN AVE UNIT PV PROD DENVER CO 80222-7262											
6	Premises Status	CURRENT											
7	Service	ELECTRIC-1											
8	**Last Read Date**	**Billing Days**	**Electrical Usage (kWh)**	**Read Method**	**Billable Demand (kW)**	**Demand (kW)**	**Total Energy (kWh)**	**Electric Charges**	**Total Electric Charges**	**Total Electric Charges / Day**	**Med Program Mnthly Rec**	**Com and Ind Prod Mtr**	**Average Temperature (° F)**
9	11/18/2019	29	0	Actual	36	36	3,133	($138.44)	($138.44)	($4.77)	($148.82)	$9.30	40
10	10/20/2019	31	0	Actual	35	35	5,825	($266.31)	($266.31)	($8.59)	($276.69)	$9.30	56
11	9/19/2019	30	0	Actual	0	0	7,211	($332.14)	($332.14)	($11.07)	($342.52)	$9.30	72
12	8/20/2019	29	0	Actual	45	45	7,733	($356.94)	($356.94)	($12.31)	($367.32)	$9.30	76
13	7/22/2019	32	0	Actual	47	47	8,694	($402.59)	($402.59)	($12.58)	($412.97)	$9.30	72
14	6/20/2019	30	0	Actual	47	47	7,892	($364.49)	($364.49)	($12.15)	($374.87)	$9.30	61
15	5/21/2019	29	0	Actual	50	50	6,727	($309.15)	($309.15)	($10.66)	($319.53)	$9.30	51
16	4/22/2019	29	0	Actual	47	47	6,292	($288.49)	($288.49)	($9.95)	($298.87)	$9.30	49
17	3/24/2019	31	0	Actual	49	49	5,473	($249.59)	($249.59)	($8.05)	($259.97)	$9.30	34
18	2/21/2019	30	0	Actual	37	37	3,510	($156.35)	($156.35)	($5.21)	($166.73)	$9.30	30
19	1/22/2019	34	0	Actual	30	30	2,714	($118.56)	($118.56)	($3.49)	($128.92)	$9.30	35
20	12/19/2018	33	0	Actual	29	29	3,426	($152.42)	($152.42)	($4.62)	($162.74)	$9.30	39
21		**367**					**68,630**	**Xcel Production Meter**			**-$3,259.95**	**Rebate (REC)**	

As indicated in Table 22, Row 21 Col G, according to the Xcel Production Meter, **the solar PV system produced 68,630 kWh over this 12 month period.**

The church receives a monthly REC payment of $0.0475 / kWh produced as a rebate through the Xcel Solar Rewards® Program during each billing period. For example, Row 10, Col G "Total Energy" shows that 5825 kWh was generated by the solar PV system between 9/20/2019 and 10/20/2019. The church received a check from Xcel for $0.0475 / kWh x 5825 kWh = $276.69. Row 21 Col K, indicates the **church received monthly checks from Xcel totaling $3,259.95** during this 12-month time period.

Verification Energy Production is being Measured Properly.

One approach to validating the accuracy of the eGauge monitoring system is to compare its measurements to the Xcel Energy commercial meter that monitors/measures the solar system production. The following is correspondence with Xcel explaining that they changed out the original meter on October 30th, 2018 (No reason was provided).

> Thank you for contacting Xcel Energy.
>
> On June 1st, 2018, electric meter 81995861[46] was installed with an opening reading of zero that would register the total production of the solar system at this location. That meter was removed on October 30th, 2018 with a removing reading of **34798**. Altogether the production from June 1st to October 30th totaled 34,798 kWh.

By selecting the period of June 1, 2018, to Oct 30, 2018, for displaying the eGauge data, the result is shown in Figure 41 to be 34,000 kWh (See red ellipse in the blue box). This indicates the eGauge monitoring system is accurate to within 2% of the Xcel production meter.

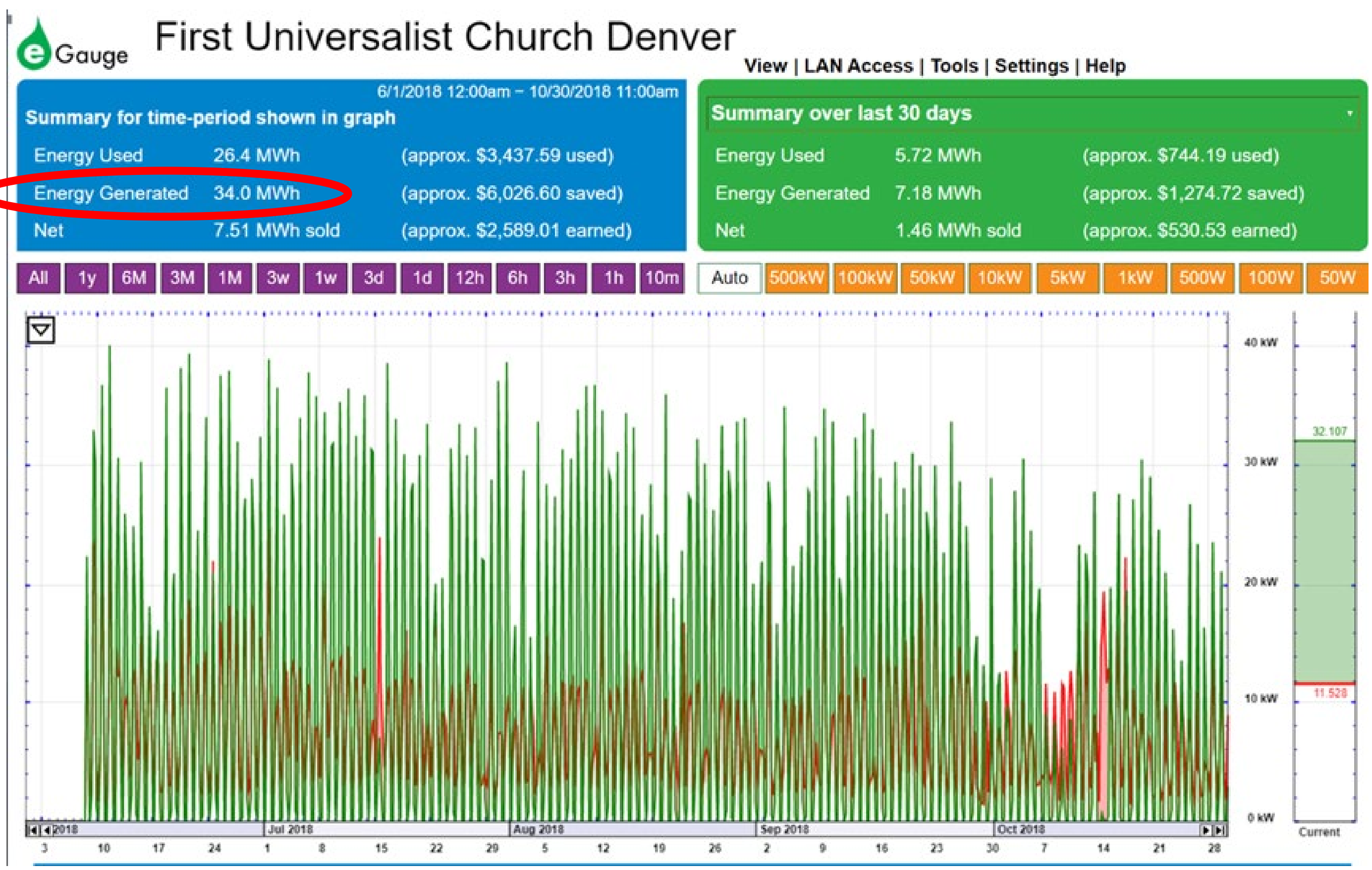


Figure 41 eGauge Information for 1 June 2018 to 30 October 2018 indicates (Solar) Energy Generated to be 34.0 MWh.

The Xcel memo goes on to explain how to derive the solar production in the future.

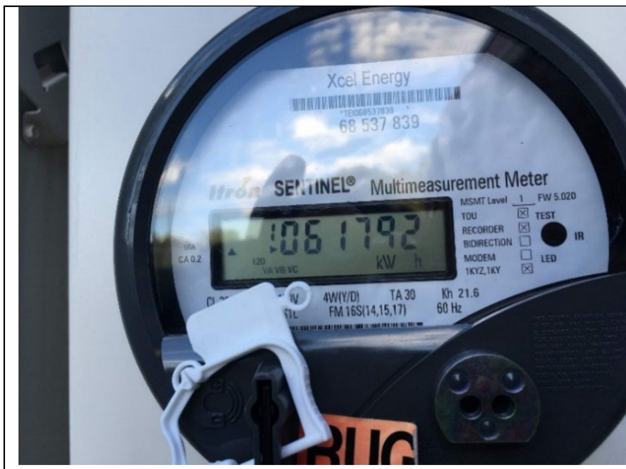
[46] This serial number was incorrect in the original Xcel correspondence.

On October 30th, 2018 electric meter 68537839, the current meter onsite, was installed with an opening reading of zero. With the reading from your picture of 29371, there has been an additional amount of production from October 30th, 2018 up to the date you had taken the picture of 29,371 kWh.

Altogether from the meter installation date of June 1st up to the date of your picture, the total production is 34,798+29,371 = 64,169 kWh.

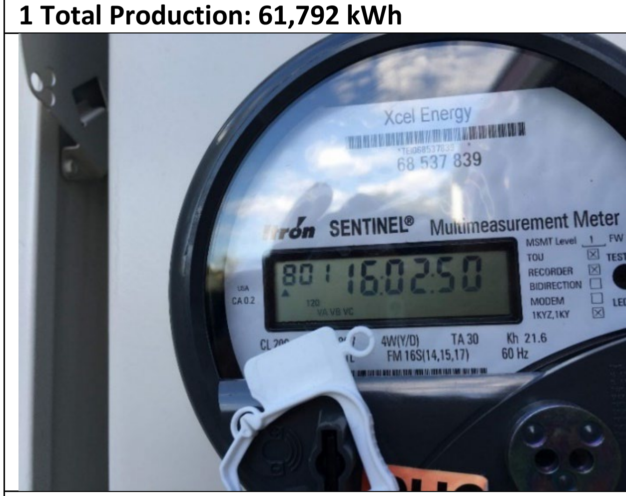
Because of that meter exchange, your current meter onsite is only going to display the production from October 30th up to current.

Using a recent reading of the Xcel production meter shown in Figure 42, we see that on 9/19/2019 the solar PV system had generated 61,792 kWh of energy since the meter was installed on October 30, 2018. We can compare this to the production measurement from the eGauge monitoring system for the same time interval. As indicated in Figure 43, the eGauge system recorded solar production as 61,200 kWh. This indicates the eGauge system is accurate to within 0.3% of the Xcel production meter.

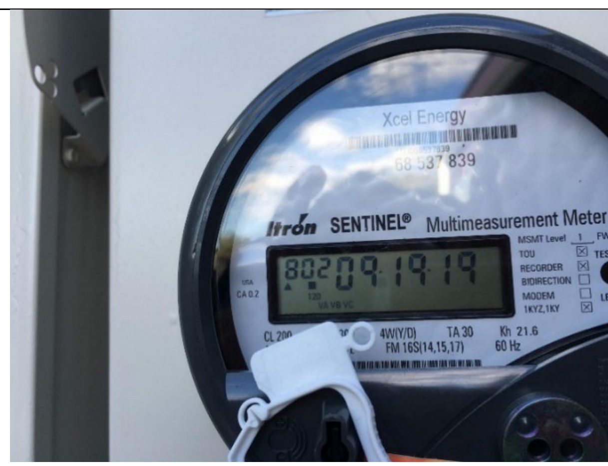


1 Total Production: 61,792 kWh

11 Production at this moment: 42.572 kW



801 Time: 4:02:50 pm



802 Date: 09/19/2019

Figure 42 Xcel Production Meter Readings on 9/19/2019

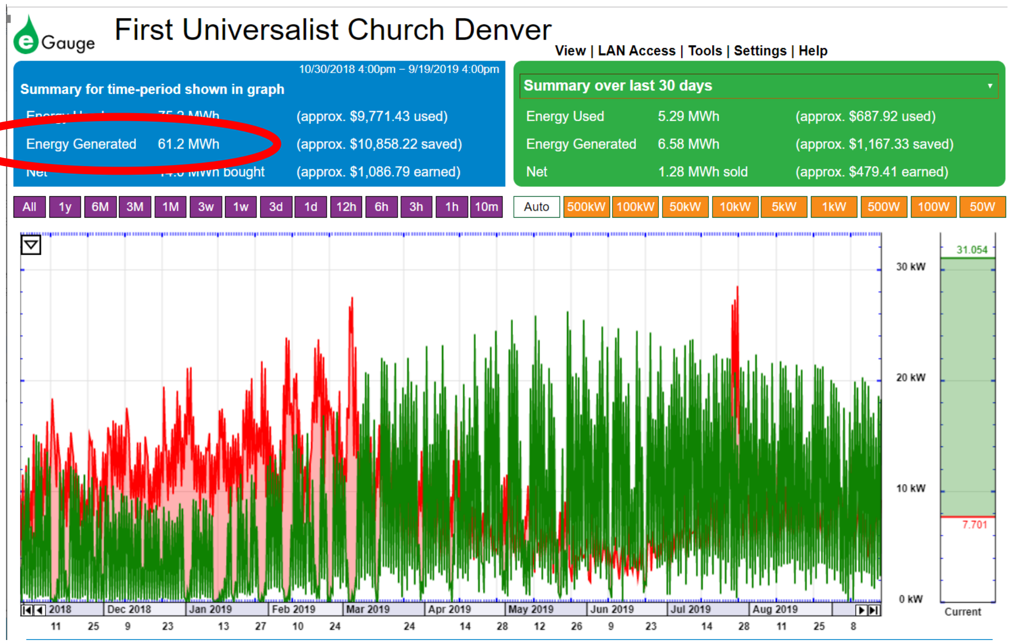


Figure 43 eGauge Measurement of the Solar PV Production from 10/30/2018 to 9/19/2019

Conclusion.

The Xcel Production Meter and the eGauge Meter measurement of 'Energy Generated' agree adequately to within less than 1%. The eGauge monitoring system is monitoring the Energy Generated accurately and is not an explanation of the production shortfall.

Appendix G Monitoring Three Inverters – 15 strings of 10 modules

Solectria PVI 14TL(x2) 208V 3Phase 600VDC Inverter Characteristics

The inverters are grid-Interactive Inverter(s), **Solectria PVI 14TL**(x2) (208V 3Phase 600VDC) that are mounted on the roof next to sub-arrays. According to the Yaskawa literature, an option for this model inverter includes "web-based monitoring."

YASKAWA

PVI 14TL

3-Ph Transformerless String Inverters

Features

- 600 VDC
- Best in class efficiency
- Touch-safe fuses
- Dual & wide MPP tracking zones
- Modbus communications
- Integrated DC fused string combiner
- DC arc-fault protection

Options

- Web-based monitoring
- Shade cover
- DC/AC disconnect covers
- Roof mount array brackets
- DC combiners bypass

Yaskawa Solectria Solar's PVI 14TL is compact, transformerless three-phase inverters with a dual MPP tracker. This inverter comes standard with AC and DC disconnects, user-interactive LCD, and an integrated fused string combiner. Its small, lightweight design makes for quick and easy installation and maintenance. This inverter includes an enhanced DSP control, comprehensive protection functions, and advanced thermal design enabling highest reliability and uptime. The PVI 14TL also comes with a standard 10 year warranty. Options include web-based monitoring, shade cover, DC/AC disconnect covers, DC combiners bypass, and roof mount array bracket.

SOLECTRIA SOLAR

Figure 44 PVI 14TL Inverter Characteristics

PVI 14TL

Specifications

	PVI 14TL
DC Input	
Absolute Maximum Open Circuit Voltage	600 VDC
Operating Voltage Range	180-580 VDC
Max Power Input Voltage Range (MPPT)	300-540 VDC
MPP Trackers	2 with 4-fused inputs per tracker
Maximum Operating Input Current	25 A per MPPT (50 A)
Maximum Available PV Current (Isc x 1.25)	45 A per MPPT (90 A)
Maximum PV Power (per MPPT)	9.5 kW
Strike Voltage	300 V
AC Output	
Nominal Output Voltage	208 VAC, 3-Ph
AC Voltage Range (Standard)	-12%/+10%
Continuous Output Power	14 kW
Maximum Output Current	39 A
Maximum Backfeed Current	0 A
Nominal Output Frequency	60 Hz
Output Frequency Range	59.3-60.5 Hz (adjustable 55-65 Hz)
Power Factor	Unity, >0.99 (±0.8 adjustable)
Fault Current Contribution (1 Cycle RMS)	70.4 A
Total Harmonic Distortion (THD) @ Rated Load	< 3%
Grid Connection Type	3ø+/N/GND (4-wire)
Efficiency	
Peak Efficiency	96.7%
CEC Efficiency	96.0%
Tare Loss	4 W
Integrated String Combiner	
Fused Positions	8 fused positions (4 positions per MPPT) 15 A (fuse by-pass available)
Temperature	
Ambient Temperature Range	-13°F to +140°F (-25°C to +60°C) Derating occurs over +50°C
Storage Temperature Range	-22°F to +158°F (-30°C to +70°C)
Relative Humidity (non-condensing)	0-95%
Operating Altitude	13,123 ft/4,000 m (derating from 6,562 ft/2,000 m)
Data Monitoring	
SolrenView Web-based Monitoring	Optional, External
Revenue Grade Monitoring	Optional, External
External Communication Interface	RS-485 Modbus RTU
Testing & Certifications	
Safety Listings & Certifications	UL 1741/IEEE 1547, CSA C22.2#107.1
Testing Agency	ETL
FCC Compliance	FCC part 15 B
Warranty	
Standard Limited Warranty	10 Years
Enclosure	
Acoustic Noise Rating	< 50 dBA @ 3 m
AC/DC Disconnect	Standard, fully-integrated
Dimensions (H x W x D)	41.6 in. x 21.4 in. x 8.5 in. (1057 mm x 544 mm x 216 mm)
Weight	141 lbs (64 kg)
Enclosure Rating and Finish	Type 4, Polyester Powder-Coated Aluminum

Specifications subject to change.

SOLECTRIA SOLAR

Yaskawa Solectria Solar
360 Merrimack Street
Lawrence, MA 01843
solectria.com

1-978-683-9700
inverters@solectria.com

DOCR-070252-U | September 2018

YASKAWA

Figure 45 PVI 14TL Inverter Characteristics (continued)

Third-Party Monitoring Systems.

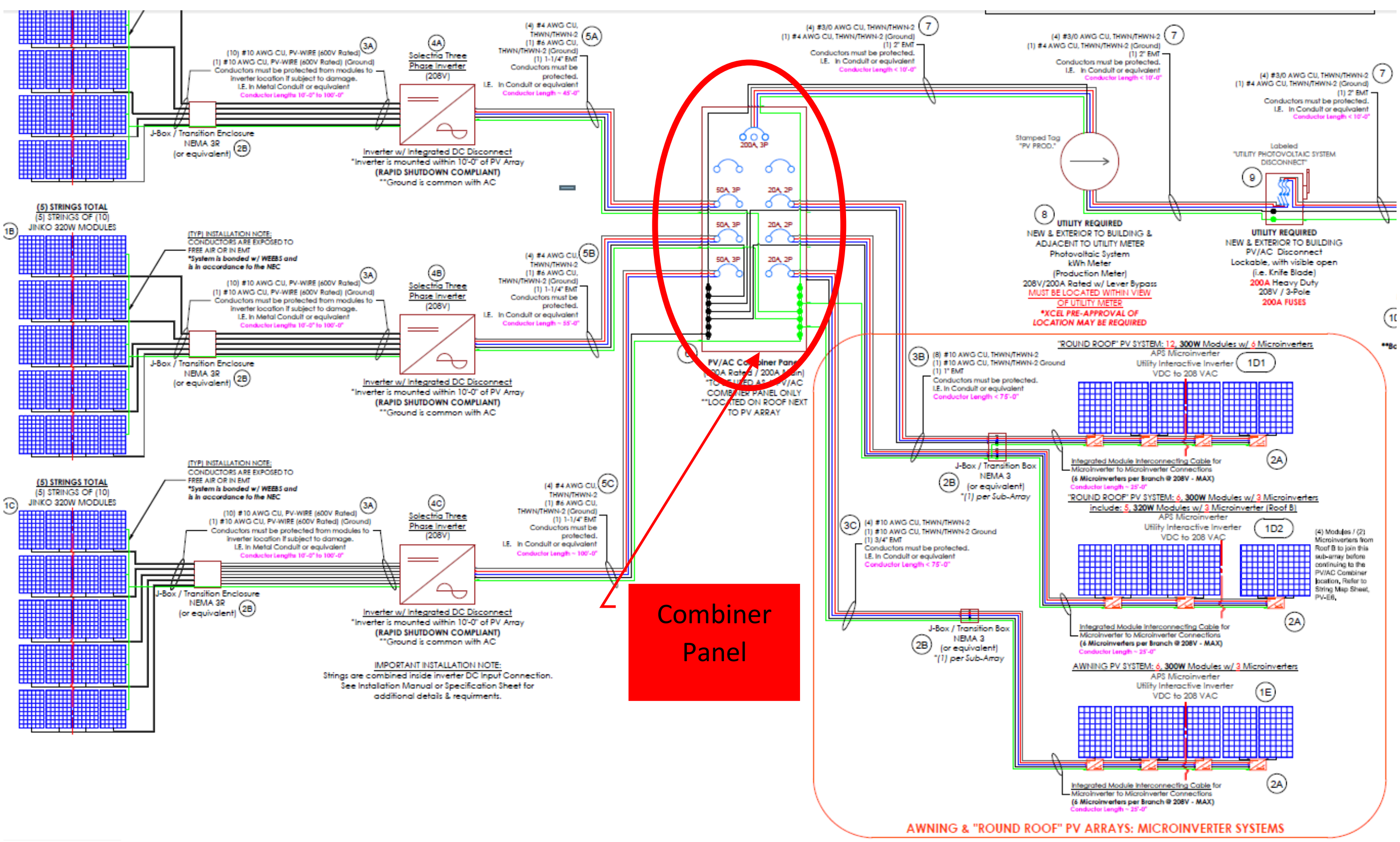
eGauge Meter

It is also possible to install an eGauge monitoring system in the “Combiner Panel” on the roof to measure the AC output from the inverters as well. As indicated in the charts, the PV/AC Combining Panel appears to contain all the circuits we want to monitor for the entire system – and it is next door to Inverter #3 that processes the strings that are affected by tree shading.

The Combiner Panel appears large enough to accommodate the eGauge meter, but we would need to pull off the panel cover to verify. So the only challenge is to pull an ethernet cable (Cat 5) from the router up to it.

We could use 50 amp CTs – they are relatively small, so there should be room.

I’ve highlighted one option (eGauge3) that seems to be cost effective to start with. It happens to have the potential (with added cost) to be able to monitor up tp 9 strings of DC output should we need string data. It does not get down to the module level. Should we need that level of detail, we would have to install the equipment quoted by BriteStreet to get that module data ($1700)



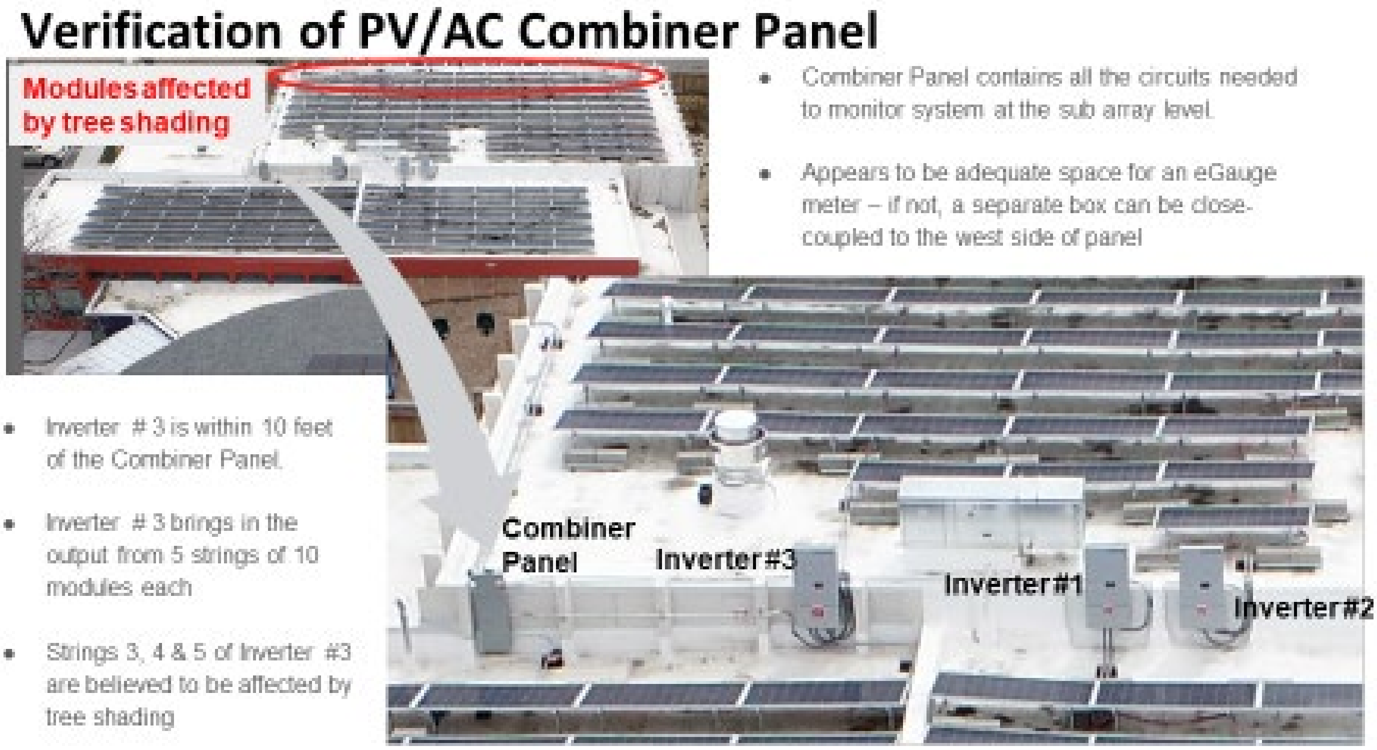


Table 23 Comparison of a Third Party Monitoring System with the SolarView Gateway

	eGauge 1	eGauge 2	eGauge 3	SolarView Gateway
Data Logger	Total System Output for current system only. AC Power data for three inverters plus other 3 sub arrays.	Total System Output for current & future Net Zero /Final system. AC Power data for four inverters plus other 3 sub arrays.	Total System Output for current & future Net Zero /Final system. AC Power data for four inverters plus other 3 sub arrays. String level data for shading evaluation.	AC Power for three current inverters plus 2 future inverters
Problem Resolution:	What is the total output of the current system? How much difference in production between Inverter #3(Tree Shading) and Inverters 1 & 2 (No tree shading)	Case eGauge1 plus What is the total output of the future (final) Net Zero system?	Case eGauge 1& 2 plus String level data for shading evaluation	How much difference in production between Inverter #3 (Tree Shading) and Inverters 1 & 3, 4 , 5 (No tree shading)
Description of Monitoring	3 Inverters (9 CTs) Awning array (2 CTs)* Oculus (2 CTs)* 5 Others (2 CTs)*	3 Inverters (9 CTs) Awning array (2-3 CTs) Oculus (2-3 CTs) 5 Others (2-3 CTs) Future string (2-3 CTs)	3 Inverters (CTs 9) Awning array (2-3 CTs) Oculus (2-3 CTs) Other (2-3 CTs) Future string (3 CTs) 3-9 DC Strings (3 CTs) can be added	(See Case eGauge1) 3 inverters (9 CTs) Future inverter (3 CTs)
Total # CTs	15	17-21	24	N/A
CT Cost $35 AC $275 DC	15 x $35 = $525	17 x $35 = $595	21 x $35 = $735 3 x $275 = $825 $1560	
Meter Type	15 CT slots	30 CT slots	30 CT slots	5+ inverters
Meter Cost	$550	$900	$900	$1000-$1200 (3 phase)
Ethernet to Router	Yes	Yes	Yes	Yes

CAT5	No	No	Yes, between Inverter #3 and Panel	No
Modbus Cable	No	No	No	Yes, daisy chain three or more inverters
Volunteer Labor	Yes, Ethernet cable to PV/AC Combiner Panel	Yes, Ethernet cable to PV/AC Combiner Panel	Yes, Ethernet cable to PV/AC Combiner Panel	Yes, Ethernet cable to Inverter #2
Non-Volunteer Labor	N/A	N/A	N/A	$500-$1000
Total	$1075 Total system output for current system only	$1495 (∆ = $420 for future Net Zero total system output plus potential to monitor up to 9 DC strings)	$2460 (∆ = $930 string level data for shade evaluation)	$1500 -$2200 (∆ = $425-$1125 more than baseline) Same data as Baseline – inverters only

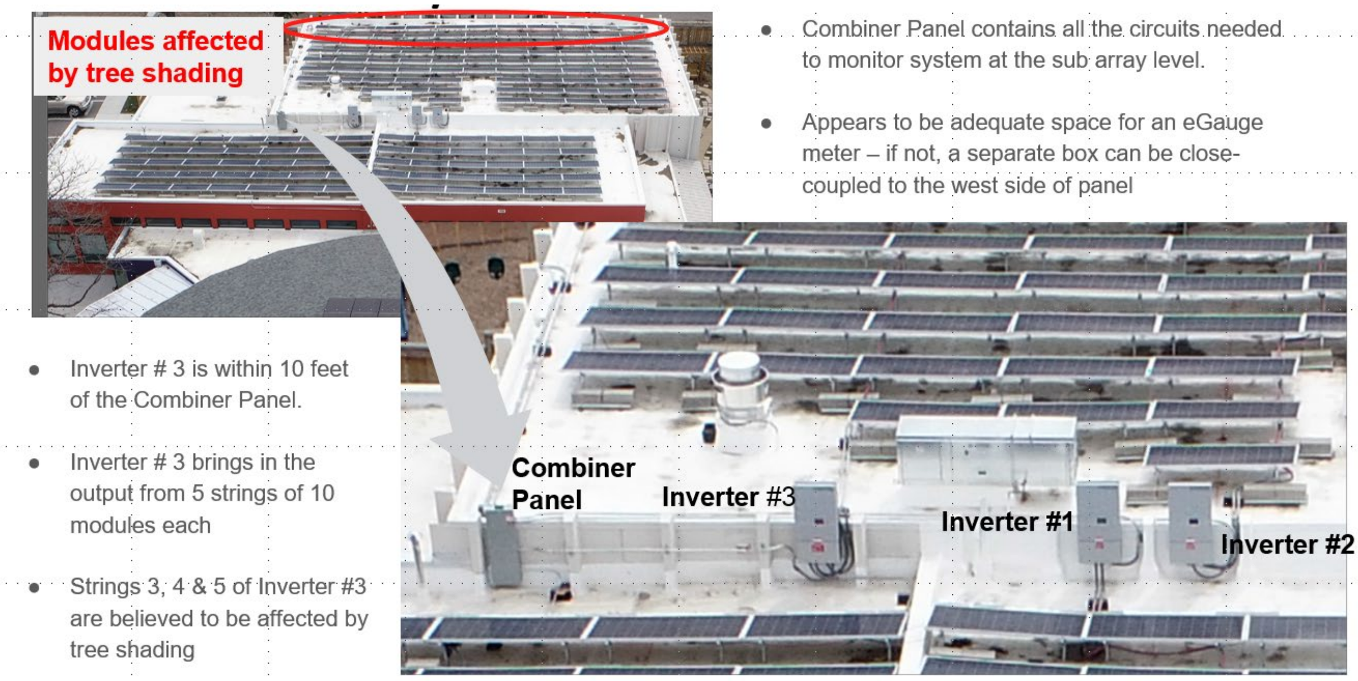
- Assumes two phases (2 CTs are required)

Appendix H Open Items Related to Adding Instrumentation to the Energy System

Adding an eGauge meter to monitor the solar system performance.

Adding an eGauge monitoring system is a DIY option that can be completed using church volunteers. The ideal location of the eGauge meter is inside the Combiner Panel on the roof.

Instrumenting the Combiner Panel on the Roof with an eGauge Meter



The preferred installation approach requires pulling an Ethernet cable between the router and the Combiner Panel. The cable can follow and be attached to the outside of the existing conduit.

The eGauge will provide power information about the following subarrays:

	CT Assignment	Line Assignment	Size	
Inverter 1 (50 modules)	CT1, CT2, CT3	L1, L2, L3	10 mm	No significant shading affects
Inverter 2 (50 modules)	CT4, CT5, CT6	L1, L2, L3	10 mm	No significant shading affects
Inverter 3 (50 modules)	CT7, CT8, CT9	L1, L2, L3	10 mm	Strings 3, 4, and 5 are affected by tree shading
Oculus Subarray (12 modules)	CT10, CT11	L1, L2 (TBD)	10 mm	No significant shading affects
Awning (6 modules)	CT12, CT13	L2, L3 (TBD)	10 mm	All modules affected by tree shading
Other Subarray (5 flat roof & 6 Oculus modules)	CT14, CT15	L3, L1 (TBD)	10 mm	No significant shading affects
Total System	CT16, CT17, CT18	L1, L2, L3	16 mm	Total System Output

Critical Path items:

1) Inspect the Combiner Panel and verify: a) Is there room for the eGauge meter? Or do we need a dedicated enclosure box?	**John**

b) Is there room to install the 50 amp clamshell CTs? c) Are the Oculus, Awning and "Other" subarrays wired as two phase? How are they assigned to L1, L2, L3?	
2) Pull ethernet cable from router to Combiner Panel	**John**
3) Procure eGauge equipment	**Milt**
4) Physical installation of CTs and eGauge meter	**John** **Milt (if after 1 April)**
5) Software setup & validation	**John** **Milt (if after 1 April)**

BriteStreet Quote for adding an eGauge meter to monitor the solar system performance.

BriteStreet™
Your Solar Solutions Provider

Attn. John Bringenberg

First Universalist Church

4101 E Hampden Denver, CO 80222

This is an estimate for the work requested at First Universalist Church for the installation of an Egauge monitoring unit. The work needed to do this includes the installation of 9 CTs and the control unit. The total cost for Egauge materials is $1237. And the Labor to complete this project is $200. In total $1437 for the work to be completed.

Egauge	$659
9x CTs	$378
Egauge Enclusure	$200
Labor	$200
Total	$1437

This appears to be a reasonable quote in line with what we expect. The meter proposed is the 15 slot model for $658 (retails @ $550) and the 9 CTs for $378 would be the 50 amp version (retail @ $35 x 9 = $315).

BriteStreet is proposing a separate enclosure from the Combiner Panel – probably the 14" x 12" Powered Enclosure Kit (retails @ $185)	Option A: a simple 10" x 8" v 4" enclosure (retails @ $99 from eGauge)	Option B: a simple 14" x 12" v 6" AMP1426 enclosure (retails @ $61 from www.Wistexllc.com)
		

Total BriteStreet cost is $1437. This will provide an ability to measure the power output from the 3 existing inverters. There is no mention of pulling an ethernet cable up to the eGauge enclosure, so perhaps it is assumed that First Universalist (John B) provides that?

If the installation of the ethernet cable is included, we might consider the following: First Universalist provides the equipment (that includes 6 more CTs to monitor the other subarrays with micro inverters so we have the entire system output at the subarray level) and BriteStreet installs it for $250. When additional modules are installed on the roof, they will likely be wired into the Combiner Panel. So 3 more CTs can be added by Green First later to measure the new upgraded system output.

Comparison of eGauge Monitoring Options – BriteStreet & Green First

	BriteStreet eGauge	Green First eGauge
Data Logger	System Output for current 150 string inverter modules only. AC Power data for three inverters.	Total System Output for current & future Net Zero / Final system. AC Power data for current & future inverters plus 3 current (& future) sub arrays.
Problem Resolution:	What is the output from each of the three inverters to determine effect of tree shading	BriteStreet Case plus What is the total output of the future (final) Net Zero system.
EQUIPMENT		
Description of Monitoring	3 Inverters (9 CTs)	3 Inverters (9 CTs) Awning array (2 CTs) Oculus (2 CTs) Other subarrays (2 CTs) Total (3 CTs) Future inverters (up to 5) (3- 5 CTs) Future subarrays (up tp 7) (2-14 CTs) Use of DC CTs to monitor strings (up to 9) (1-9 CTs)
Total # CTs	9	18 Plus up to 12 for future growth
CT Cost	9 x $42 = $378	18 x $35 = $630
Meter Type	15 CT slots	30 CT slots
Meter Cost	$659	$900
Enclosure	$200	$61
INSTALLATION		
Paid Labor	$200	N/A
Volunteer Labor	Yes, Ethernet cable to PV/AC Combiner Panel	Yes, Ethernet cable to PV/AC Combiner Panel
Ethernet to Router	Yes	Yes
Additional CAT5	No	No
SUMMARY		
Total	**$1437** Three Inverter output only	**$1591** Total output; individual inverter output; Awning; Oculus; "5 Other" subarray; plus future growth (Δ = $154 for future Net Zero total system output plus potential to monitor up to 9 DC strings)

Possible compromise. Green First buys/provides equipment. BriteStreet installs (e.g. $250 labor) OR we just do it ourselves. The hard part of the eGauge installation is getting the Ethernet cable up to the Combiner Panel.

BriteStreet Quote for installing the ECU (micro inverter data logger)

The ECU will provide module level data for 29 modules. Only the 6 awning modules are affected by shading. Quite frankly we do really care about their output – they are there for "Show" rather than performance or we would have located then on the flat roof. So who cares about the module level data on any of these 29 modules? Assuming we install the eGauge in the Combiner Panel, we already have the subarray level output data from these 29 modules. (See Section 3.0)

BriteStreet submitted two quotes.

BriteStreet
Your Solar Solutions Provider

Attn. John Bringenberg

First Universalist Church

4101 E Hampden Denver, CO 80222

This is a proposal for the work requested at First Universalist Church for connecting the existing micro inverters with a monitoring ECU. This requires the installation of a YC500A Energy Control Unit and the connection of a CAT5 ethernet cable. The Labor to get all of the serial numbers from the existing micro inverters and to connect the ECU will cost $1400. The new ECU Equipment will cost $336.46. In total $1736.46 for the work to be completed.

In reference to the first quote from Britestreet for adding the gateway for the micro inverters, we would like to offer the following comments.

Equipment: $336

Labor: $1400 (@$50 / hr
= 28 hr = 3.5 person days.

(Considered excessive – see explanation below. $200 would be more reasonable.

Total cost < $600)

BriteStreet
Your Solar Solutions Provider

Attn. John Bringenberg

First Universalist Church

4101 E Hampden Denver, CO 80222

This is a proposal for the work requested at First Universalist Church for connecting the existing micro inverters with a monitoring ECU. This requires the installation of a YC500A Energy Control Unit and locating all of the microinverter serial numbers. The Labor to get all of the serial numbers from the existing micro inverters and to connect the ECU will cost $500. The new ECU Equipment will cost $336.46. In total $836.46 for the work to be completed.

The second quote was a bit more reasonable.

Equipment: $336

Labor: $500 (@$50 / hr
= 10 hr
= 2 people for 5 hrs

Still considered excessive – see explanation below – One person for 4 hrs or $200 would be more reasonable.

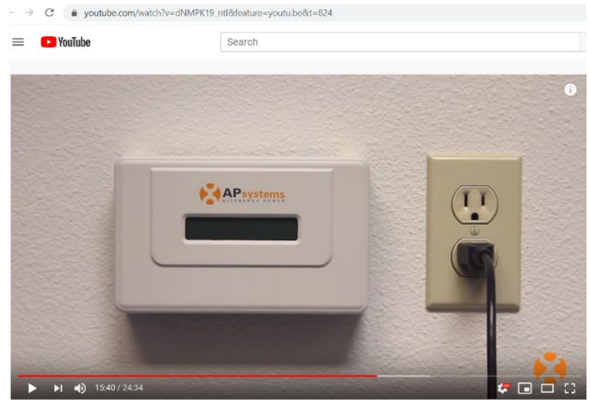
There are a number of training videos available that describe how to install the ECU. For example, you might start with the following: ID Stickers / Array Map

https://youtu.be/dNMPK19_ntI?t=710

The video reminds the installer to **remove a stickers from each micro inverter and affix it to the "Array Map."** Then when the solar modules are in place, it is a simple matter of scanning the serial numbers for setting up the ECU. Notice each micro inverter is connected to two (2) solar modules designated as "A" and "B." There are 29 solar modules involved, so there may be around 15-16 YC500 micro inverters involved. We assume that Brite Street created an "Array Map" and either retained a copy or provided a copy of the Array Map to First Universalist with the final data package / user manual upon completion of the contract. IF not they owe us one.

The next segment of video describes the steps for setting up the ECU: ECU https://youtu.be/dNMPK19_ntI?t=824

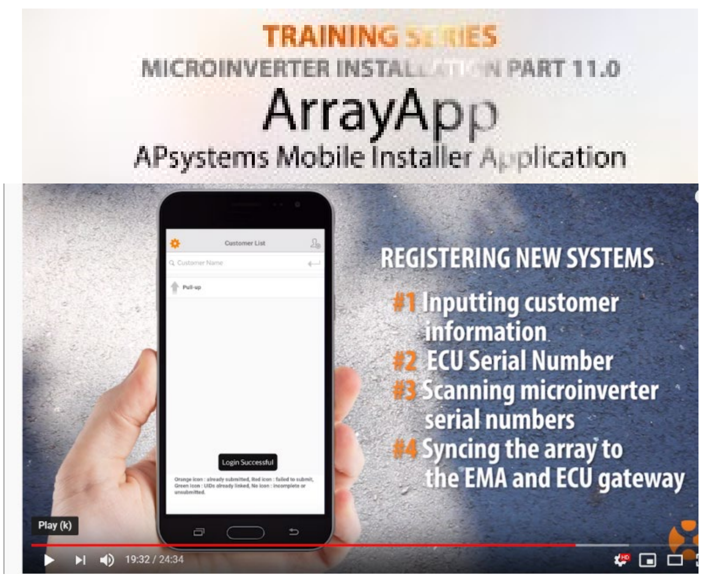
The ECU is to be located as "**electrically close**" to the solar array as possible.

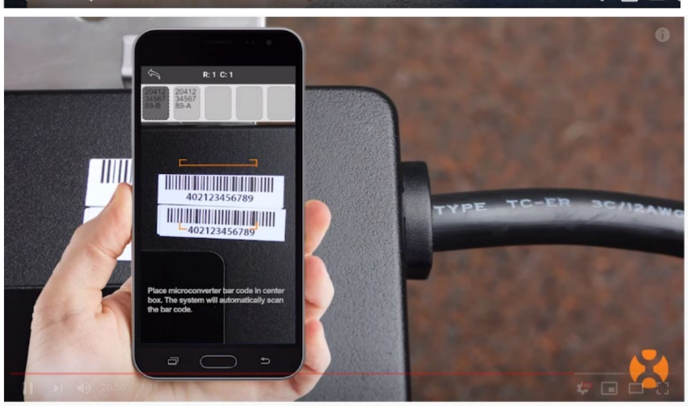


Questions:

1) What about locating the ECU near an outlet in the router room? We can then use a short ethernet cable to the router.
2) If that does not work because it is not electrically close enough, what about placing it in the mechanical room in the basement close to the main electrical gear? Would need to pull an ethernet cable over to that room if there is not one there already.
3) Backup. Could always put the ECU in the Combiner Panel on the roof and pull an ethernet cable up to it since the eGauge requires an ethernet cable up to the Combiner Panel.
4) Is a WIFI connection is possible?

Next, the video describing how to setup the ArrayApp is very useful. See https://youtu.be/dNMPK19_ntI?t=1090

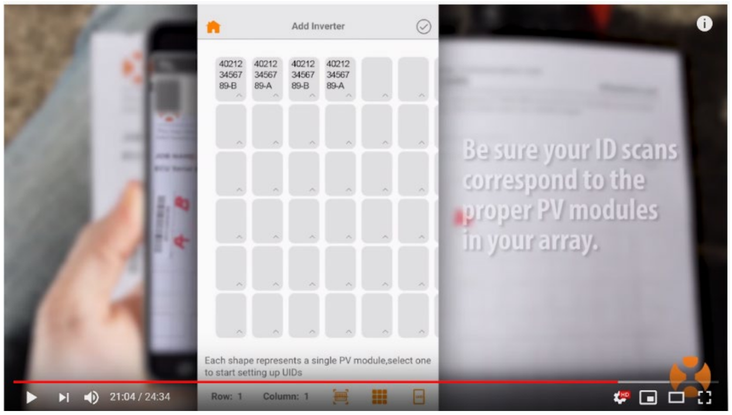




APsystems Installation Training - FULL VERSION

This video discusses the four (4) registration steps.

Of particular interest is step #3 – Scanning micro inverter serial numbers and locating them on the graphical array map. There is no need to go on the roof if one has that Array Map from the initial installation. Scanning the 28 serial numbers in with the phone might take a few minutes.



Assuming the ECU can be located inside, relatively near the router for easy access using an ethernet cable, there is no need to go up on the roof. Church personnel could actually set this ECU up, but BriteStreet or City Electric (someone with a contractor's license) would be required to register the array.

Charging us 28 hrs to install the ECU is very excessive. I **would estimate 4 hrs ($200) would be more reasonable.** And a single person could do it and not even have to get on the roof.

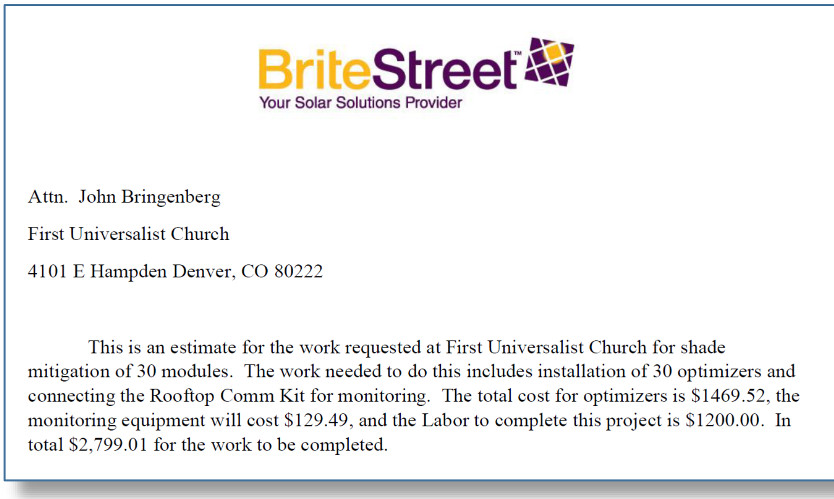
If the labor is due to a requirement to physically remove the modules to view the serial numbers because they were not properly recorded by BriteStreet during initial installation, **that cost should NOT be borne by First Universalist. That map should have been one of the deliverables. (Would Cris have this in the church files?)**

(Other shortcuts to reduce labor in the event BriteStreet never made an array map during initial installation: At a minimum, the serial numbers of all the micro inverters must be available. The 3 micro inverters for the 6 awning panels will be obvious from output levels – their order is irrelevant until there is a problem. The five separate modules that are not on the oculus are very easy to reach. They may have 3 micro inverters. We could place an opaque cover over these modules one at a time and identify them without any labor to detach the modules from the rails. The remaining 18 modules are on the oculus – again their exact location in that subarray is irrelevant at the moment and can be further defined if / when there might be a problem with one of them. Knowing they are part of the oculus is adequate)

It is frustrating that two years after the installation of our system, the micro inverters are now 'obsolete' and any new micro inverters will use a different ECU that probably doesn't talk to the old ECU and allow us to see a complete system of all the micro inverter modules.

In my opinion, spending $837 on this module level monitoring system is a low priority item. I suggest we table this proposal.

BriteStreet Quote for Power Optimizers



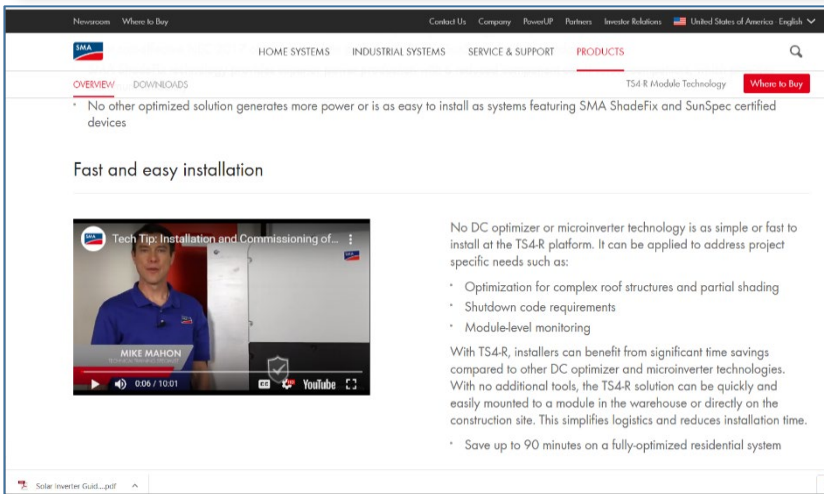
BriteStreet
Your Solar Solutions Provider

Attn. John Bringenberg

First Universalist Church

4101 E Hampden Denver, CO 80222

This is an estimate for the work requested at First Universalist Church for shade mitigation of 30 modules. The work needed to do this includes installation of 30 optimizers and connecting the Rooftop Comm Kit for monitoring. The total cost for optimizers is $1469.52, the monitoring equipment will cost $129.49, and the Labor to complete this project is $1200.00. In total $2,799.01 for the work to be completed.



The quote from BriteStreet indicates they are probably proposing to use the SMA TS4 optimizers (made by Tigo).[47] **We need to find out what model they would install. E**xample: TS4-R-O

30 Optimizers: $1470
Gateway: $130 (This gateway requires a SMA inverter and we have a non-SMA inverter so the actual gateway cost is probably closer to $350)

Labor: $1200 (@$50 /hr, 24 hrs)
(Three people - 1 day)

Total: $2800 - **$3000**

The video entitled "*Installation and Commissioning of the Power+ Solution Rooftop Communications Kit P2*" is very helpful.
See https://youtu.be/EBYDdMLNsDw

It provides the installation steps for the power optimizers.

For a discussion of Monitoring plus remote Rapid Shutdown plus Optimization (TS4-R-O), See https://www.youtube.com/watch?v=Is9gWIHk82k

For a Tigo video of the TS4-R installation, see https://www.youtube.com/watch?v=NcGUV4Y1fAs
How this Kit interfaces with our brand of inverter, the Yaskawa PVI 14TL, relies on BriteStreet's expertise.

At most, we have room to add around 50 more modules on the roof. There is some shading on the southwest corner of the office area roof by a small tree, so we would want to consider micro inverters or power optimizers for the additional modules on the roof. The output from the new modules would feed into the existing Combiner Panel

[47] SolarEdge also makes a good power optimizers, but they require the installation of a SolarEdge inverter. We have the Yaskawa PVI 14 TL.

	There may be roof space for roughly 50 additional modules (max)		A Google Sunroof view of the facility just before renovation identifies roof areas with partial shading

We may want to consider a fourth inverter with power optimizers on several strings to mitigate partial shading on the southwest corner of the office roof. We could monitor the total power output of the new Inverter #4 with eGauge and monitor the modules with optimizers with the SMA Power + Rooftop Communications Kit.

Appendix I Awning Solar Subarray Performance

Actual production versus theoretical performance is provided for a few months since the new monitoring system was installed.

Tribute to Gaia

Seems that we lost the results provided in an Xcel spreadsheet for the eGauge output as well as the predicted PVWATTS data. Not sure where it all went – it was downloaded as data 11

To replace the energy shortfall, FUCD purchased of 29,389 kWh from Xcel Energy. Xcel burned hydrocarbons to generate this electrical energy and dumped around 21 metric tonnes of GHG into the atmosphere. So the Zero Emissions Goal was not reached in 2019.

The Revenue Neutral goal was not achieved; it was necessity to buy energy from Xcel.

ADD 2020 TABLE HERE

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4426

12/22/2020 3:19 pm MT

- Shows height of deciduous tree #1 (east). No leaves. Approx. 25' high; 32' wide
- View of modules for Inverter #1 subarray
- Shows shadow @ 3:19 pm MT

Note: At the time of the day these photos were taken (between 3:19 & 3:37 pm), the 12 solar modules on the oculus roof tilted at 14 degrees were producing more power than any of three sets of 50 modules tilted at 10 degrees.

The Sun angles were probably around 10 degrees above the horizon and about 225-230 degrees azimuth.

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4427

12/22/2020 3:19 pm MT

- Shows height of Tree 2. Approx. 32’ high; 25’ wide. No leaves
- Notice deposit on lower portion of modules in the foreground
- View of modules for Inverter #3

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4428

12/22/2020 3:19 pm MT

- Shows height of both trees.
- No leaves
- Tree #1 (east - left) Approx. 25’ high;32’ wide
- Tree #2 (west-center right) Approx. 32’ high; 25’ wide

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4430

12/22/2020 3:20 pm MT

- Shows parapet wall
- Wall shadow almost reaches modules
- Post contribute shadows. Raised about 6 " above the wall
- Inverters 2 & 3 are casting shadows on the first row of modules and partial onto second row

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4431

12/22/2020 3:20 pm MT

- Shows parapet midwall
- Wall shadow almost reaches modules
- Posts contribute shadows on front row of Inverter #1 modules.

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4432

12/22/2020 3:20 pm MT

- Looking east we can see the Inverter #1, two posts, and Combiner Panel casting shadows in late afternoon on solar modules
- One module is completely shaded – a part of Inverter #1

Illustration of SketchUp

- SketchUp is a 3-D computer Modelling Tool that includes a sun shadowing feature as a function day of the year and time of day.
- Computer was very useful for visualizing the movement of shadows during the day – particularly in the winter months when the Sun angles are low and shadows are long.
- SketchUp help identify "structural shading"
- Computer model was not used to estimate power losses due to shading

4433

12/22/2020 3:21 pm MT

- Shows parapet midwall,
- Looking east we can see the Inverter #3, Inverter #2, Inverter #1 two posts, and Combiner Panel casting shadows into the second row

DRAFT

Shadows from computer model

4434

John's Shadow

12/22/2020 3:21 pm MT

- Looking west, showing modules in southern most row (Connected to Inverters 1 & 3)
- Shows shadows from branches of deciduous tree to the south into third row
- Shadows from low southern parapet wall / posts do not reach front modules

4436

12/22/2020 3:22 pm MT

- Looking east, showing modules in southern most row (connected to Inverters 1 & 3)
- Shows deciduous trees to the south

4437

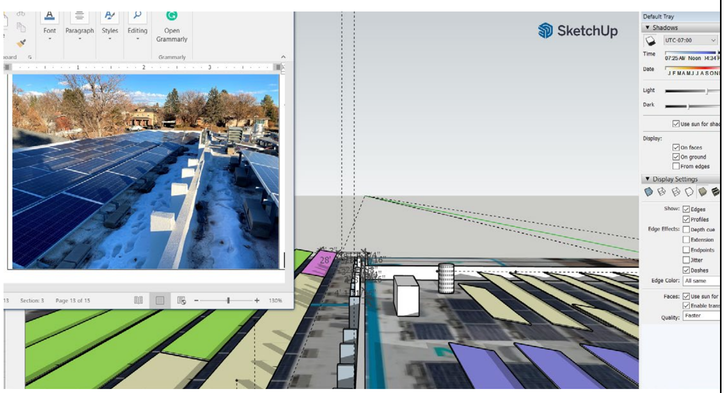
12/22/2020 3:23 pm MT

- Looking east, showing modules in southern most row (Connected to Inverters 1 & 3)
- Shows deciduous tree branch shadows – no leaves

4439

12/22/2020 3:24 pm MT

- Looking east, showing modules in northern most rows (Connected to Inverter #2) Front row is connected to Inverter # 1


SketchUp

4440

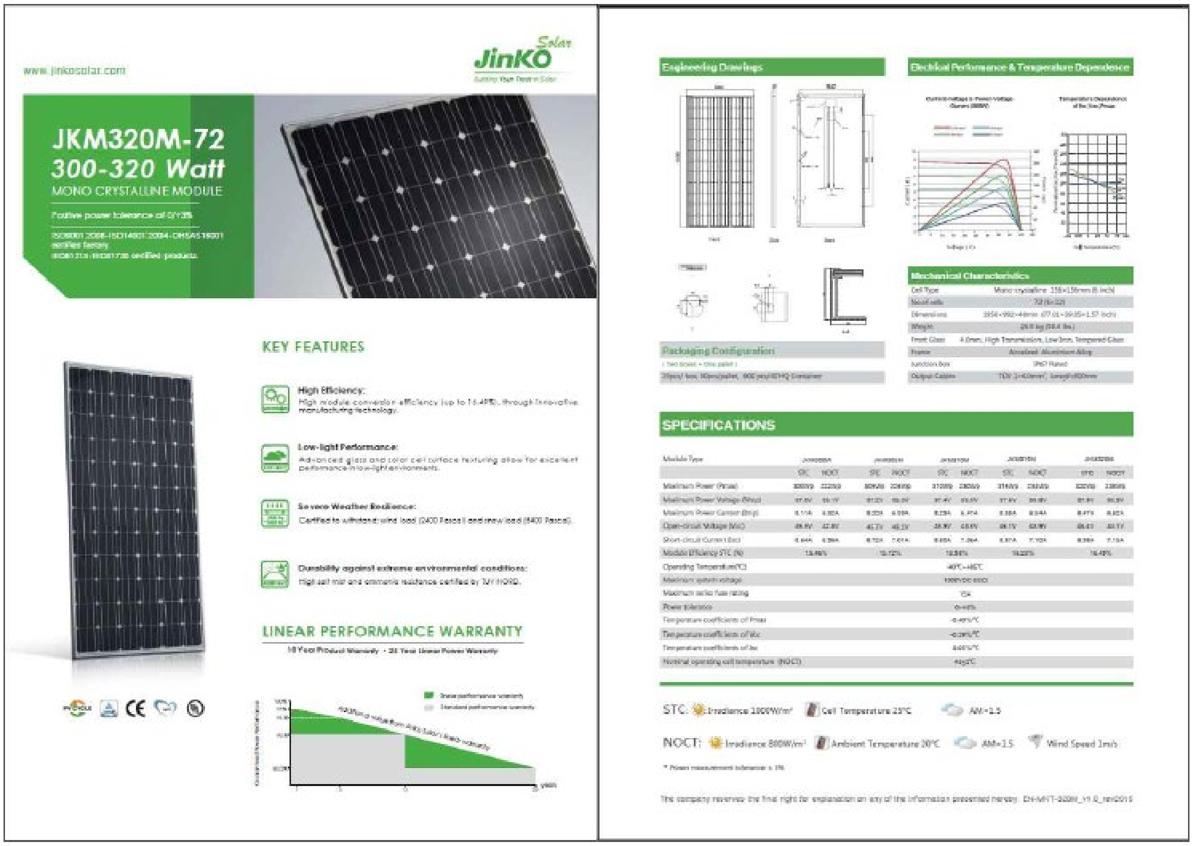
12/22/2020 3:36 pm MT

- Looking west, showing modules in northern most rows (Connected to Inverter #2)
- Shadow over lower row of cells (leftmost row)
- Portion still in sunlight has a dust/dirt deposit probably from snow sliding down the 10 degree tilt to "bottom" of module wiping the surface clean, But not all snow gets to roof. Some snow piles up and then melts leaving the dust/dirt deposit behind.
- The next snow or rain might remove some of the deposit (or not). It seems to cover most of 1 of the 6 longitudinal rows of cells.
- The deposit would appear to affect the insolation (energy) available to those cells under the deposit.

4441

12/22/2020 3:37 pm MT

- Looking west, showing modules in northern most rows (Connected to Inverter #2)
- Shadow over lower row of cells
- Portion still in sunlight has a dust/dirt deposit probably from snow sliding down to "bottom" of module wiping the surface clean, then some piling up and melting – the dirt / deposit remains.



__Spoiler alert:__ As a commercial customer with a solar system, they discovered the "monthly bill" for __the Net Meter account is necessary but not sufficient to quantify how much energy their building used each month__. This report describes how an Xcel commercial customer with a solar system must download a spreadsheet for the Net Meter account containing around 40 columns of information (two of those columns are needed). The commercial customer then downloads a second spreadsheet for the Production Meter account (a separate account); only one column is needed that defines the total amount of energy generated by the solar system that month. Then the Xcel customer can calculate the energy consumed by their facility for the month using the following formula:

Energy Consumed = Energy_Produced (Production Meter Account, Col G) ***[Eq #1]***
– Energy_Delivered_by_Customer (Net Meter Account, Col G)
+ Energy_Delivered_by_Xcel (Net Meter Account, Col K)

Determining how much energy a facility uses daily/ monthly is essential for good energy conservation and energy management. The equation for "Energy_Consumed" is a simple calculation, but reason & logic suggests that if a civil society is really trying to promote the transition to renewable energy, the "energy consumed" information would be more forthcoming by the utility company.

Energy Production. At the end of the first year, the investigation verified the Xcel production meter and the FUCD eGauge production meter agreed to within 1%; however, the annual solar production of the new system was 18% lower than predicted by the NREL PVWATTS computer model.[48] Why was the output of the FUCD solar system so much lower than predicted? Was there an equipment failure? Was there shading from trees? Or was it due to computer

[48] The advertised uncertainty of the computer model was around 6-7%. So the 18% variance was not expected.

modelling inaccuracy? The report describes how the Green First team explored these (and other) possibilities and why they had to add more instrumentation to obtain data that could resolve these unknowns.

When they did not find any malfunctioning equipment, they surmised that tree shading was probably reducing the output performance of the system, but could not quantify the shading impact until they acquired more detailed performance data.

Energy Consumption. At the end of the first year, there was a 20% difference between the Xcel Net Meter and the FUCD eGauge monitoring system related to the building's annual energy consumption. Why was there a discrepancy in the energy consumption measurements? The Xcel and eGauge measurements agreed on solar production. This difference in energy usage measurements initiated another investigation.

After the second year of operation, the additional instrumentation and data provided insight into what adjustments are needed to the energy system to achieve Net Zero Energy. These adjustments are necessary to achieve the sustainability goals when the church re-opens and resumes new "normal" operations.

The body of the report addresses several basic questions:

Is the new energy system performing properly?
Is the facility operating as a net zero Energy building as intended?
Is the facility operating with Zero GHG emissions?
Is the new energy system a Revenue Neutral renovation?
What adjustments are needed to fully meet the FUCD sustainability goals?
What is the post-pandemic Roadmap[49] for a zero carbon footprint? [50]

Carbon Footprint. This report acknowledges that the FUCD annual Carbon Footprint was around 150 metric tonnes in 2016 (before the renovation). The renovated facility reduced the carbon footprint to 60 metric tonnes in 2019 with normal operations and to less than 10 metric tonnes in 2020 with limited COVID-19 operations. The reduced carbon footprint indicates First Universalist Church of Denver intends to be a responsible global citizen and comply with the Paris Agreement of 2015.

Roadmap to Zero GHG Emissions. After two years of operation of the new sustainable energy system, the investigative team concludes the system is operating as designed and capable of meeting the congregational goals – if some secondary adjustments are made. A proposal for a path to zero GHG emission is also provided in this report.

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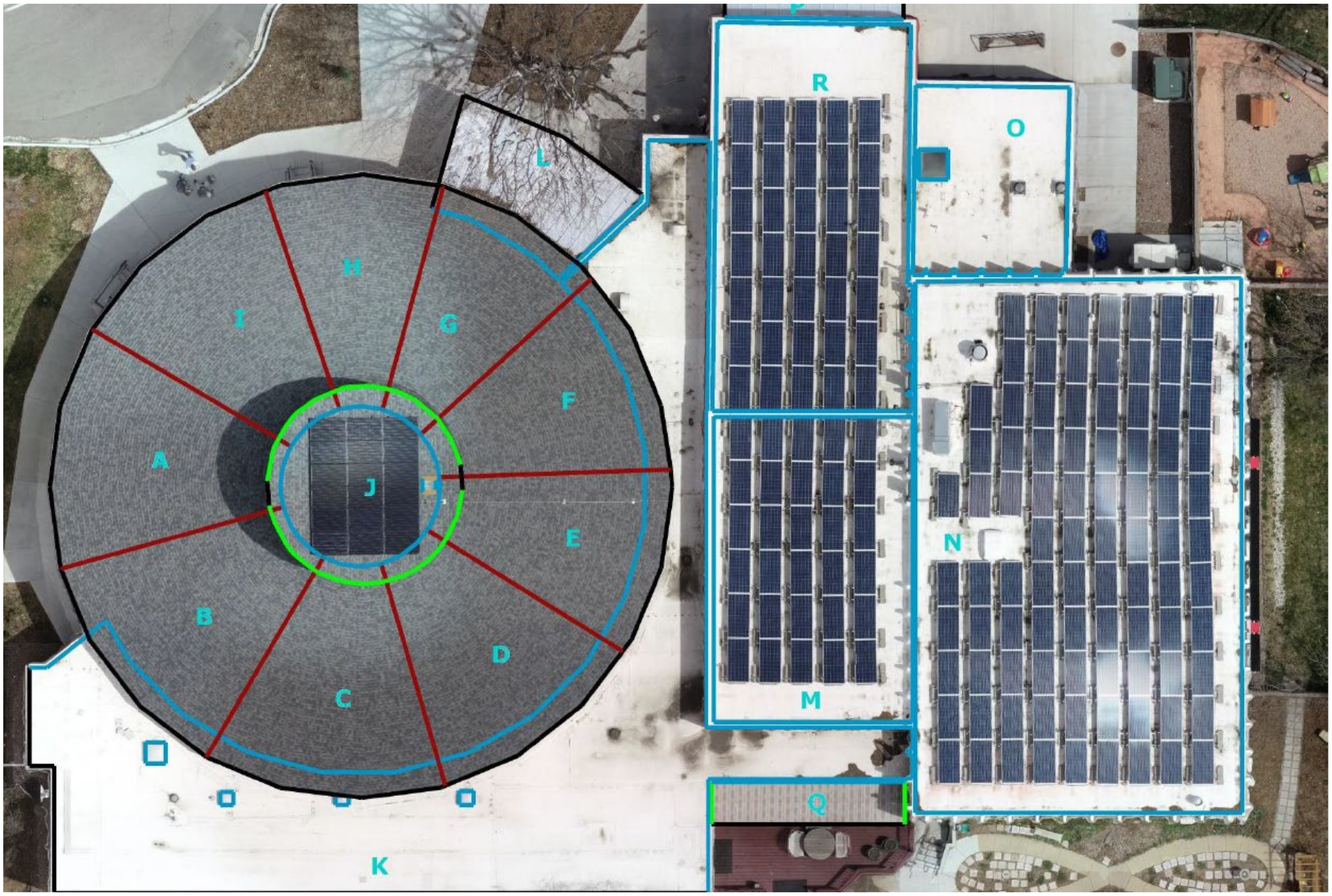
[49] The Post-Pandemic Roadmap assumes FUCD returns to new "normal operations" 1) in a manner that is consistent with the UU Principles; 2) as a responsible global citizen in compliance with the IPCC guidelines initiated in the Paris Agreement of 2015; and 3) as a positive example in the community - sharing information and resources with other faith-based organizations.

[50] See the Glossary for a detailed definition of 'Carbon Footprint.'

Appendix J Structural Shading due to Walls & Circuit Panels

This is a discussion of observations of the three subarrays with micro inverters.



Subarray "Oculus 12".

The "Oculus 12" subarray can be considered as the performance standard. It consists of 12 of the 18 300 W modules on the roof of the oculus. Modules positioned on the oculus are tilt toward the south 14 degrees (a 3:12 pitch) and cannot be shaded by trees or other structure. So any changes in power output must be attributed to natural changes in the solar radiation due to cloud cover, or snow, dirt, or ice deposited on the modules.

"Oculus 6 Plus Flat Roof 5"

A second subarray that uses micro inverters is labelled "Oculus 6 plus Flat 5 " This subarray consists of 6 modules (300W) on the oculus (tilted 14 degrees) whose output we know from the first subarray and 5 modules (320 W) on the flat roof (tilted 10 degrees to the south). These 5 modules are located along the mid parapet wall between Friendship Hall and the former Forum (rectangular building to the south). Two modules are located behind a taller portion of the wall (that could have some shading in the winter months) and three are located behind a shorter section of this wall where structural shading is unlikely. There is no possibility of shading the 6 modules on the oculus roof in this string of 11 modules. Therefore, if we observe any unexpected power output from this subarray, we would first investigate the five(5) modules on the flat roof near the taller portion of the wall. It is conceivable there could be some structural shading from the wall or a circuit panel and the three Inverter boxes that extend above the wall. Note these 11 modules use micro inverters, so there is no "string" amplification effect involved.

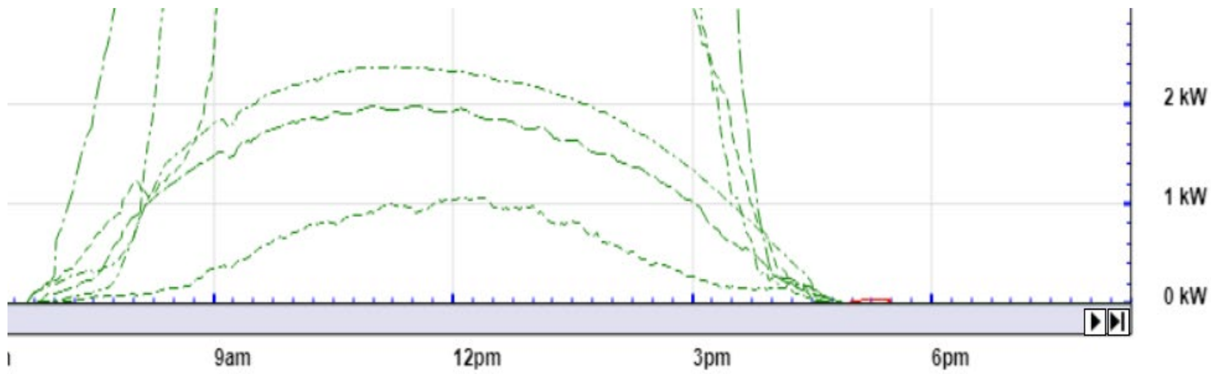
By reverse engineering and estimated dimensions/distances from the drone photos, we can begin to get a sense of whether this is a plausible explanation. The assessment / analysis does suggest the use of an Excel spreadsheet.

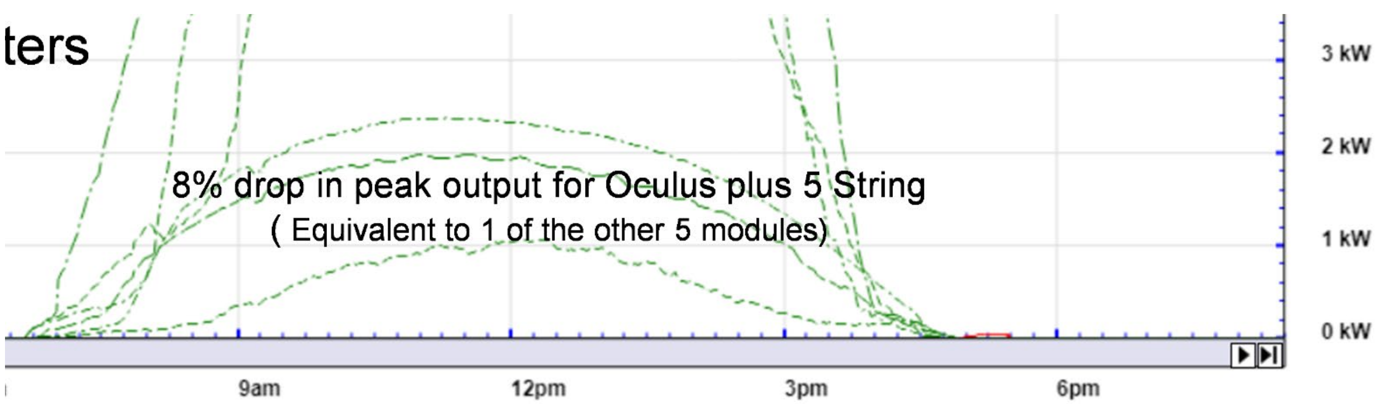
And there is change in the output of string 2 that is not observed in String1 –the only source of shading is the 2-3 foot wall just south of the 5 modules.

"Awning 6"

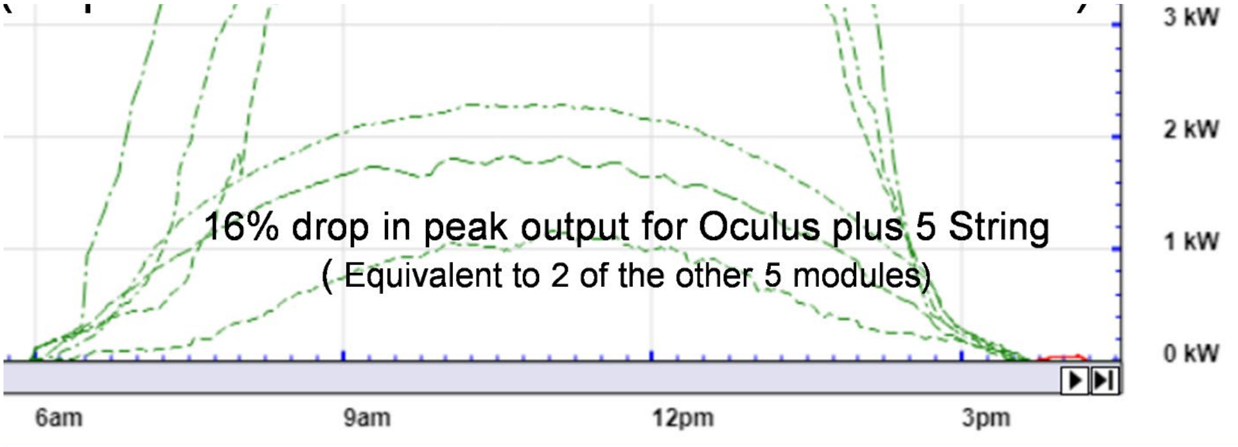
We have considered the 6 modules in the "Awning 6" subarray separately. In theory, the 6 modules in the "Awning" array would produce ½ the power of the 12 Oculus modules – since they are identical but just tilted 87 degree whereas the Oculus modules are tilted 14 degrees.

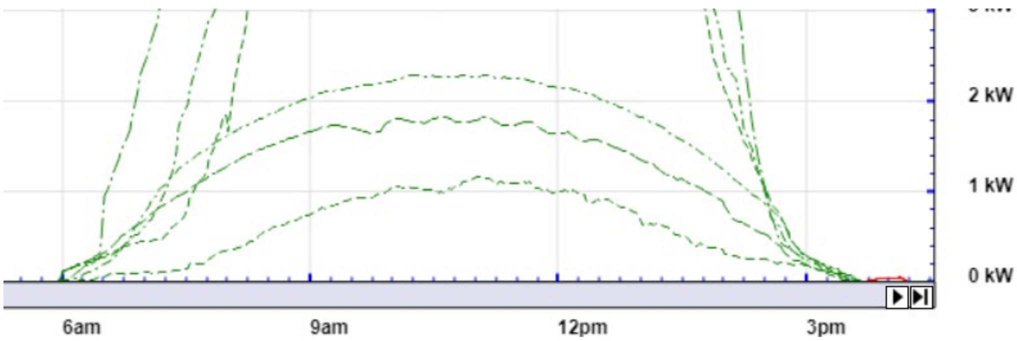
Copy Sep,Oct, and Nov graphics here and then discuss them.





October 29, 2020 Sun elevation 40 deg





November 13, 2020 Sun Elevation 30 deg

Conclusion: The three subarrays with micro inverters seem to be performing as expected. Their response to the changing sun azimuth angle during the year appears to be consistent with analytical models.

Shading Effects. The “Oculus” subarray has an ideal location and there is no shading from trees or other structure.

Likewise with 6 of the 11 modules in the “Oculus plus 5” subarray. The 5 modules of this subarray that are located on the flat roof are not affected by any tree shading and it appears there is insignificant shading from the adjacent wall south the modules and the protruding circuit panel and Inverter #1.

It was previously understood that the 6 modules referred to as the “Awning” subarray would be subject to significant shading, but the shading effect is minimized as much as possible by the use of micro inverters on each module. The “Awning” subarray contributes less than 3 % to the total solar array output. The 87 degree tilt angle of these 6 modules increases their performance in the winter months and fortuitously there are no leaves on the trees at that time of the year.

Appendix K Monitoring Micro Inverters - AP System Installation

https://www.youtube.com/watch?v=8D_t0WTmafE

29 of the modules use micro inverters, APS YC500i. There is a ECU capability.   Retail cost ~$350-$400 plus labor to load in the 29 serial numbers and setup the EMA (requires a contractors license).

There may be a quote from City Electric .

Appendix L How does the PVWATTS Weather Model affect the Predicted Production of a Solar PV system?

One of the more important goals of the BFF renovation project was to install a sustainable energy system that could be described as a Net Zero Energy system. That meant that the solar PV system would be sized to harvest enough sunlight to generate all the electrical power need to operate the facility. Simply stated, the new energy system was intended to produce the same amount of energy that the facility consumed.

Energy Production (i.e. generation) = Energy Consumption (i.e. usage).

The architectural team (Barrett Studios) used state of the art computer models to predict how much electrical energy the renovated facility was going to use; their estimate of annual energy usage was 75,349 kWh. This information was conveyed to the solar installer (BriteStreet) who indicated a 57 kW rated solar PV system would provide at least 75,349 kWh of energy annually with some margin. When the actual production turned out to be 68,630 kWh in 2019, the Green First team initiated an investigation to understand why the production was lower than expected. (Production was 68,958 kWh in 2020.)

This section of the report documents an investigation of how the weather model embedded in PVWATTS affects the predicted production of a solar PV array. The effect of weather was examined from an annual, monthly, daily and hourly perspective.

What is PVWATTS? (Ref: https://pvwatts.nrel.gov/pvwatts.php)

"PVWatts® Calculator is a web application developed by the National Renewable Energy Laboratory (NREL) that estimates the electricity production of a grid-connected roof- or ground-mounted photovoltaic system based on a few simple inputs.

To use the calculator, you provide information about the system's location and basic design parameters. PVWatts® calculates estimates of the system's annual and monthly electricity production.

Important Note. PVWatts® is suitable for preliminary studies of a photovoltaic system that uses modules (panels) with crystalline silicon or thin film photovoltaic cells. PVWatts® production estimates do not account for many factors that are important in the design of a photovoltaic system. …you should work with a qualified professional to make final design decisions based on an assessment of the system location and using more detailed engineering design."

You begin the PVWatts® assessment by defining the location of the solar PV system, either as the street address, zip code, or latitude and longitude of the system's location. PVWatts® uses this information to automatically identify solar resource data available (i.e. sun angles, weather,…) at or near the system's location.

"Solar resource data is solar irradiance and meteorological data that describe the conditions at the system's location. PVWatts® uses hourly typical meteorological year (TMY) data from the **NREL National Solar Radiation Database (NSRDB)**. The calculator estimates the monthly and annual electricity production of a photovoltaic system using an hour-by-hour simulation over a period of one year."

"To represent the system's physical characteristics, PVWatts® requires values for six inputs:

- DC system size
- Module type
- Array type
- System losses
- Array tilt angle

- Array azimuth angle"

Using the Default Weather Model in PVWATTS.

Prior to installation, the Green First team conducted an independent assessment of the proposed solar PV system – specifically to verify a 57 kW system was the appropriate size. The Green First team provided the location of the facility and allowed the PVWATTS model to use its default weather model "NREL International" to predict the energy produced by the system annually.

By simply typing in the address of the church, PVWATTS translates the information to latitude and longitude coordinates for computation of the Sun angles and solar radiation incident on the solar array. PVWATTS selects a default weather model for meteorological data unless the user intervenes and selects a "legacy" weather model as described in Figure 46.

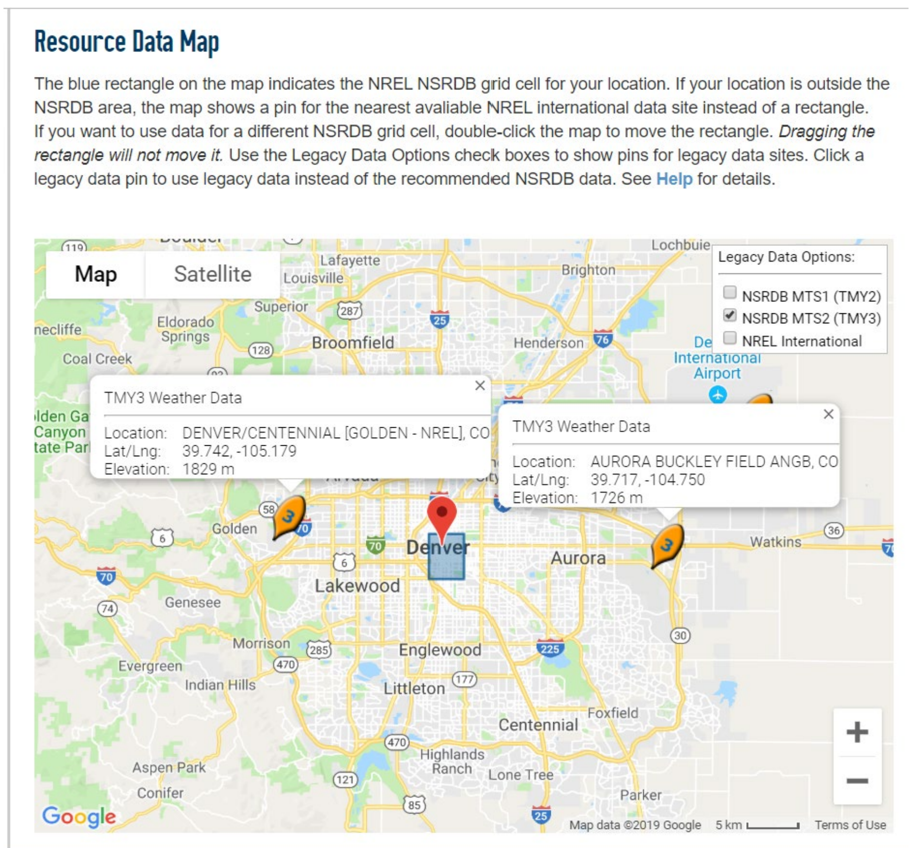


Figure 46 PVWATTS Weather Resource Data Map

The independent assessment indicated a system consisting of 179 modules (panels) rated at 56.8 k W mounted on a flat roof tilted to the south 10 degrees, is predicted to have an annual production of 85,128 kWh / year as indicated in Figure 47. The production ratio of this system was then calculated to be 1499 kWh/kW.

The actual production measured by the Xcel production meter and verified by the FUCD eGauge meter was 68,630 kWh in 2019 (nearly 20% lower than predicted by PVWATTS using the default weather model.)

In retrospect, instead of using the default weather model, it would have been better to use one of the nearby Legacy Data Options such as the "NSRDB MTS2 (TMY3)" weather sites – either the Buckley or NREL location as a source of historical weather data as illustrated in Figure 46.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at https://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

Disclaimer: The PVWatts® Model ("Model") is provided by the National Renewable Energy Laboratory ("NREL"), which is operated by the Alliance for Sustainable Energy, LLC ("Alliance") for the U.S. Department Of Energy ("DOE") and may be used for any purpose whatsoever.

The names DOE/NREL/ALLIANCE shall not be used in any representation, advertising, publicity or other manner whatsoever to endorse or promote any entity that adopts or uses the Model. DOE/NREL/ALLIANCE shall not provide

any support, consulting, training or assistance of any kind with regard to the use of the Model or any updates, revisions or new versions of the Model.

YOU AGREE TO INDEMNIFY DOE/NREL/ALLIANCE, AND ITS AFFILIATES, OFFICERS, AGENTS, AND EMPLOYEES AGAINST ANY CLAIM OR DEMAND, INCLUDING REASONABLE ATTORNEYS' FEES, RELATED TO YOUR USE, RELIANCE, OR ADOPTION OF THE MODEL FOR ANY PURPOSE WHATSOEVER. THE MODEL IS PROVIDED BY DOE/NREL/ALLIANCE "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY DISCLAIMED. IN NO EVENT SHALL DOE/NREL/ALLIANCE BE LIABLE FOR ANY SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER, INCLUDING BUT NOT LIMITED TO CLAIMS ASSOCIATED WITH THE LOSS OF DATA OR PROFITS, WHICH MAY RESULT FROM ANY ACTION IN CONTRACT, NEGLIGENCE OR OTHER TORTIOUS CLAIM THAT ARISES OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THE MODEL.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

85,128 kWh/Year*

System output may range from 79,075 to 87,639 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.35	4,831	534
February	4.35	5,614	620
March	5.55	7,825	865
April	6.13	8,138	899
May	6.84	8,949	989
June	7.56	9,318	1,030
July	7.08	8,993	994
August	6.55	8,290	916
September	5.84	7,281	805
October	4.66	6,334	700
November	3.72	4,995	552
December	3.17	4,559	504
Annual	**5.40**	**85,127**	**$ 9,408**

Location and Station Identification

Requested Location	4101 East Hampden Ave., Denver CO
Weather Data Source	Lat, Lon: 39.65, -104.94 0.2 mi
Latitude	39.65° N
Longitude	104.94° W

PV System Specifications *(Residential)*

DC System Size	56.8 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	10°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	0.111 $/kWh

Performance Metrics

Capacity Factor	17.1%

Figure 47 PVWATTS Default Weather Model

The measured annual energy production of our 57 kW rated system in 2019 was 68,630 kWh. The PVWATTS prediction (using the default weather model) was nominally 84,128 kWh, 18% lower than expected.

RESULTS

77,473 kWh/Year*

System output may range from 71,965 to 79,758 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	2.96	4,197	464
February	3.61	4,717	521
March	5.25	7,463	825
April	6.00	8,029	887
May	6.21	8,424	931
June	6.31	8,170	903
July	6.24	8,056	890
August	6.15	7,983	882
September	5.38	6,934	766
October	4.01	5,495	607
November	3.64	4,939	546
December	2.09	3,067	339
Annual	**4.82**	**77,474**	**$ 8,561**

Location and Station Identification

Requested Location	4101 East Hampden Ave., Denver CO
Weather Data Source	(TMY3) DENVER/CENTENNIAL [GOLDEN - NREL], CO 14 mi
Latitude	39.74° N
Longitude	105.18° W

PV System Specifications *(Residential)*

DC System Size	56.8 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	10°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	0.111 $/kWh

Performance Metrics

Capacity Factor	15.6%

Figure 48 PVWATTS Alternate Weather Model - NREL(Golden)

If the weather model for the NREL site in Golden had been selected, the annual energy production at this location would have been predicted to be 77,473 kWh instead of 85,128 kWh / year illustrated in Figure 48. The energy production factor would have been 1364 kWh/ kW instead of the 1499 kWh / kW that was used.

The actual production in 2019 was 68,630 kWh (still 11% lower than predicted by PVWATTS using this alternative weather model.)

Summary. The weather model used by PVWATTS has a significant influence on the predicted performance of the solar PV system from an annual perspective.

What about the accuracy / uncertainty associated with the PVWATTS Calculator?

All attempts to physically and mathematically describe the laws of the Universe are approximations.

NREL documents the probable uncertainty in the PVWATTS model. For the default weather model, the nominal prediction of annual energy production was 85,128 kWh. As indicated in Figure 47, the range of uncertainty is 79,075 kWh to 87,639 kWh, but the actual production of 68,630 kWh falls outside this range. The uncertainty using the alternative weather model ranged from 71,965 kWh to 79,758 kWh (See Figure 48), so the actual production of 68,630 kWh was still outside the expected range of uncertainty. The uncertainties are displayed graphically in Figure 49.

Several possible explanations come to mind. 1) The appropriate weather model has not been found, 2) There is something else going on that is not being considered in the computer modelling.

Summary. The advertised uncertainty in the PVWATTS Calculator does not explain the discrepancy between the predicted energy production and the actual production for 2019.

Unfortunately, at that point there was no way to pursue this issue further because the only information available was the total power output. There was no performance information at the subarray or module levels to further investigate this system performance concern.

A study was initiated to:

1) Identify what instrumentation could be added to provide more performance data.
    a. 29 of the 179 modules already use micro inverters that monitor the power output of the individual modules, but the capability to record this information and access the data via the internet was not included in the original system.
    b. The three inverters that are connected to the remaining 150 modules should also have the capability of monitoring their power output.
2) Obtain cost estimates to purchase and install this additional monitoring equipment.
3) Select the most cost-efficient approach to obtain additional data and install it.
4) Record and analyze data over several months to determine if the less than expected power output is due to:
    a. An inaccurate prediction by the PVWATTS computer model (e.g., incorrect weather model; incorrect geometry / sun angles, etc.),
    b. An equipment malfunction,
    c. A reduction in the solar irradiance incident
        i. on some of the modules due to shading by trees, and /or
        ii. more cloud cover / cloudy days that specified in the historical weather models, or
    d. Other unknowns

PVWATTS Calculator Examined from an Hourly/ Daily/Weekly Perspective

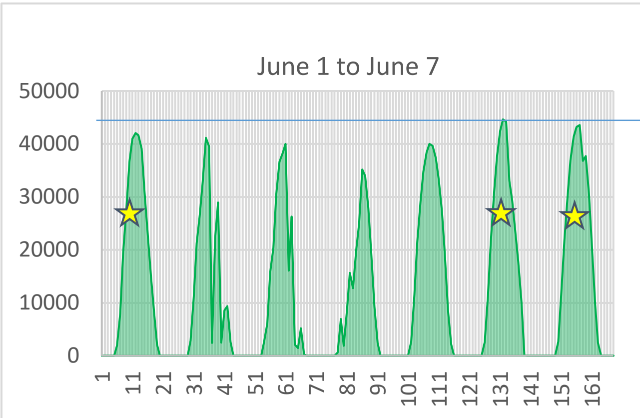
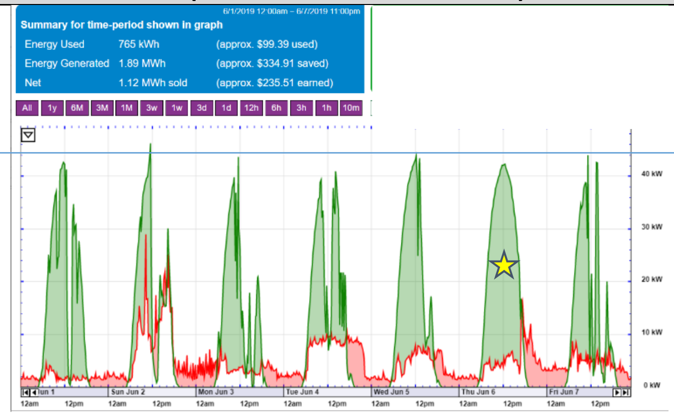
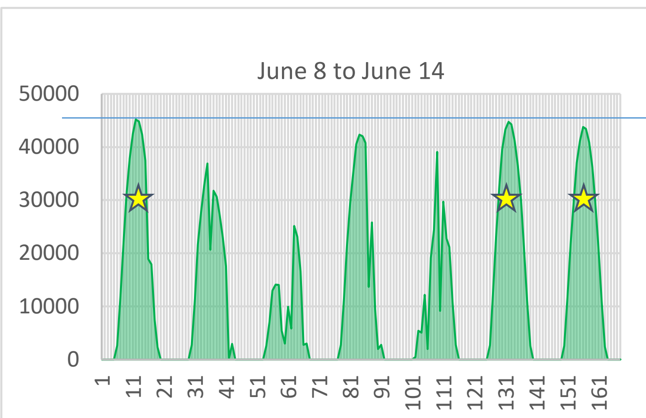
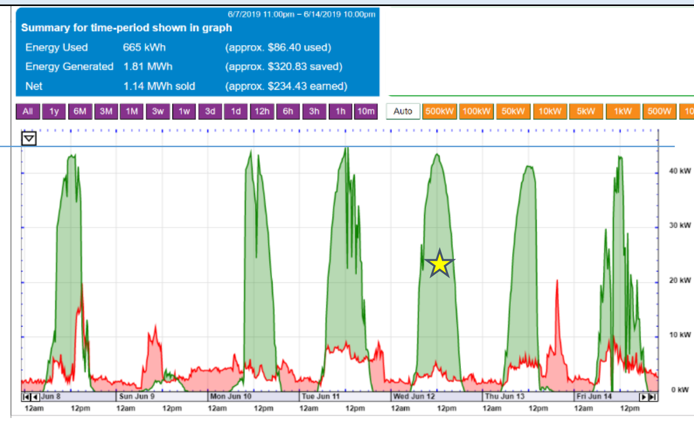
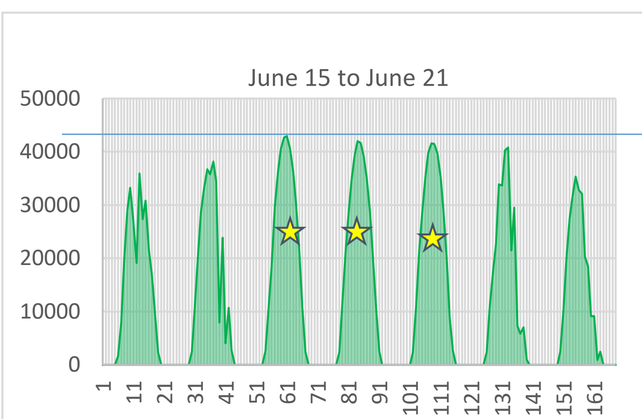
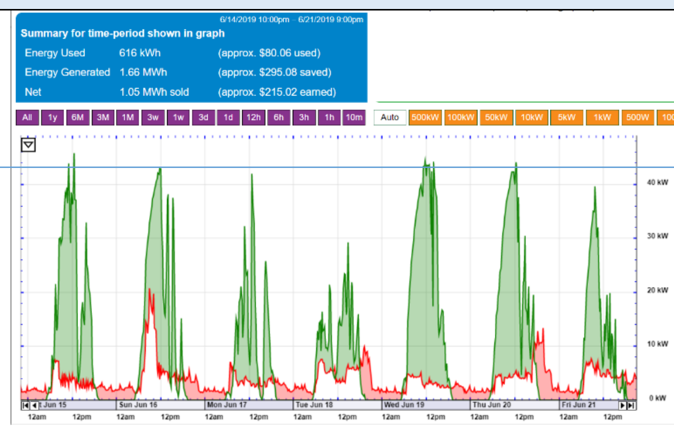
Figure 50 provides a comparison of PVWATTS predictions with eGauge actual measurements for energy production for the month of June. Upon comparing those days with full sun (indicated with a “yellow star”, the Peak Power Production was 42.5 – 45.0 kW for both the computer model and the actual solar PV system. This validates the sun angles and panel tilt angles were modeled correctly. We notice however, there is significant day-to-day variation during the month – due to weather.

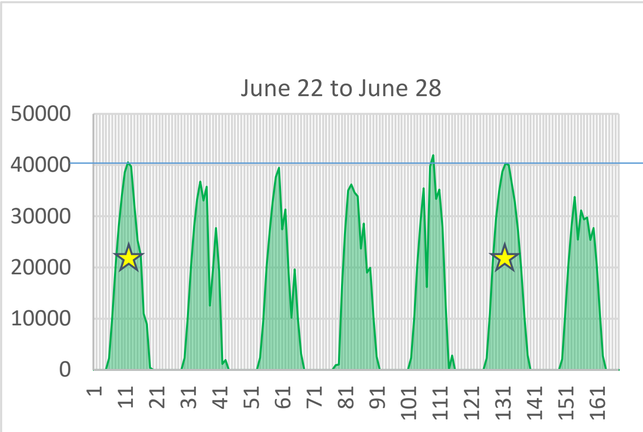
The PVWATTS weather model assumed there were 12 “Full Sun” days in the month of June whereas there were only 3 “Full Sun” days (June 6th , 12th & 28th) that occurred in June 2019. **In real life, there were disruptive clouds that reduced energy production in varying degrees for 27 of the 30 days.**

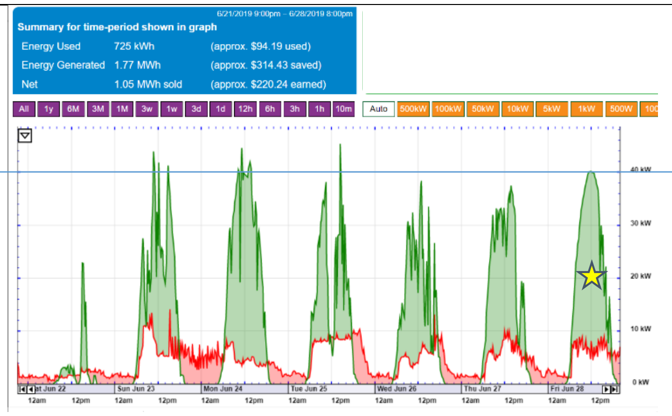
The PVWATTS predicted energy production for June was 9,142 kWh. The actual June 2019 production was 7601 kWh. **Actual production in June 2019 was 17% less than predicted by the default weather model.**

Based on the actual production data from eGauge, the peak usage of nearly 30 kW typically occurs on a Saturday or Sunday. During weekdays, energy usage is generally around 10 kW.

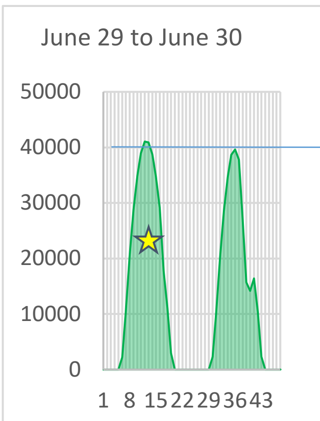
DRAFT

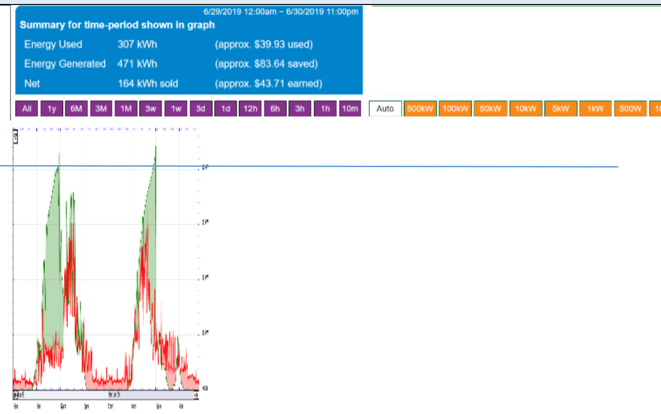
Comparison of PVWATTS Prediction with eGauge Actual Measurements for Energy Production	
PVWATTS "Hourly" Data for Energy Production **(Using Default Weather Model)**	eGauge Meter Measurements **(Actual Weather June 2019)**
	
2,113 kWh (Predicted) ☆ Yellow star denotes a "perfect sun-day" – no clouds	1,890 kWh (Actual) Δ = -10%
	
2,078 kWh (Predicted)	1,810 kWh (Actual) Δ = -13%
	
2,175 kWh (Predicted)	1,660 kWh (Actual) Δ = -24%





2,127 kWh (Predicted) | 1,770 kWh (Actual) Δ = -17%





649 kWh (Predicted) | 471 kWh (Actual) Δ = -27%

PVWATTS	ACTUAL
• 12 "Full Sun" days used in the PVWATTS weather model. • 9,142 kWh - predicted production by PVWATTS. • Peak Power Production: 42.5 – 45.0 kW	• 3 "Full Sun" days (June 6th & 12th) actually occurred in June 2019. (Full Sun=No disruptive clouds to reduce production.) • 7,601 kWh - actual June Production. (17% less than predicted) • Peak Power Production: 42.5 – 45.0 kW • Peak usage of nearly 30 kW typically occurs on a Saturday or Sunday. • On weekdays, energy usage is generally around 10 kW.

Summary for June 2019 : Weekly Totals (kWh)

Predicted	Actual
2113	1890
2078	1810
2175	1660
2127	1770
649	471
9,142 kWh	7,601 kWh

- **Actual production in June 2019 was 17% less than predicted by PVWATTS default weather model**
- **Default weather model for Denver used 12 full sun days in June; actual in 2019 was 3 full sun days**
- **Peak Power around noon predicted by PVWATTS and measured by eGauge were similar – indicating geometry, location, tilt angle, etc. were modelled correctly.**

*Figure 50 **Comparison of PVWATTS Prediction with eGauge Actual Measurements for Energy Production – (Default Weather Model used more full sun days that actually observed in June.)***

Summary. A daily/weekly comparison of the PVWATTS Calculator results with the actual production measured by the eGauge monitoring system allows us to conclude the following:

- PVWATTS predicts the correct peak power around noon on those days where weather (i.e. cloudy skies,…) is not involved. **This indicates the geometry, geographical location, tilt angle, etc. were modelled correctly.**
- The default weather model in PVWATTS used 12 full sun days for the month of June. The eGauge monitoring system indicates there were actually only 3 full sun days in June of 2019. This helps explains why PVWATTS over predicted production by 17% in June.

Weather Model Uncertainties - How does Peak Production Compare?

By eliminating the weather variable, it is possible to compare sunny days in the PVWATTS model for the Denver-Boulder area with sunny days at First Universalist Church in Denver.

It is possible to download "hourly" production predictions from PVWATTS and compare peak generation to the eGauge measurements. Figure 51 is a PVWATTS plot of predicted Energy Generation for one week in Sept (Sept 13th to Sept 19th) We immediately notice the daily profiles vary from day to day reminding us that the PVWATTS computer utilizes a "weather model" (to be discussed later and in Appendix F.) The plot shows that 2 of the days on the right side of the graphic were "perfect" sun days with few clouds. The peak generation on these days was between 35,000 and 40,000 Watts – say 37.5 kW.

The same week was selected in the actual eGauge data for the First Universalist solar PV system and displayed in Figure 52 and Figure 53. In 2018 (Figure 52), three days during the week (Sept 13, 14,15) were nearly "perfect" sun days; peak generation on that day was around 37.5 kW – **the same as the PVWATTS computer model prediction**. In 2018 (Figure 53), two days during the week (Sept 13, 14) were nearly "perfect" sun days; peak generation on that day was around 37.5 kW – **the same as the PVWATTS computer model prediction**.

For this particular week, PVWATTS predicted solar electric production to be 1506 kWh; the FUCD solar system produced 1680 kWh in 2018 and 2019 – 12 % more than predicted. On an annual basis, PVWATTS predicted the solar PV system would produce 84,621 kWh; actual measurements were 68,630 kWh (20% lower than predicted.)

In September, there are still leaves on the trees. There is no evidence indicating shading has a measurable effect on the total system performance. We can see the effects of clouds during 4 days of the week shown in Figure 53. This same observation will be seen repeatedly later in this report.

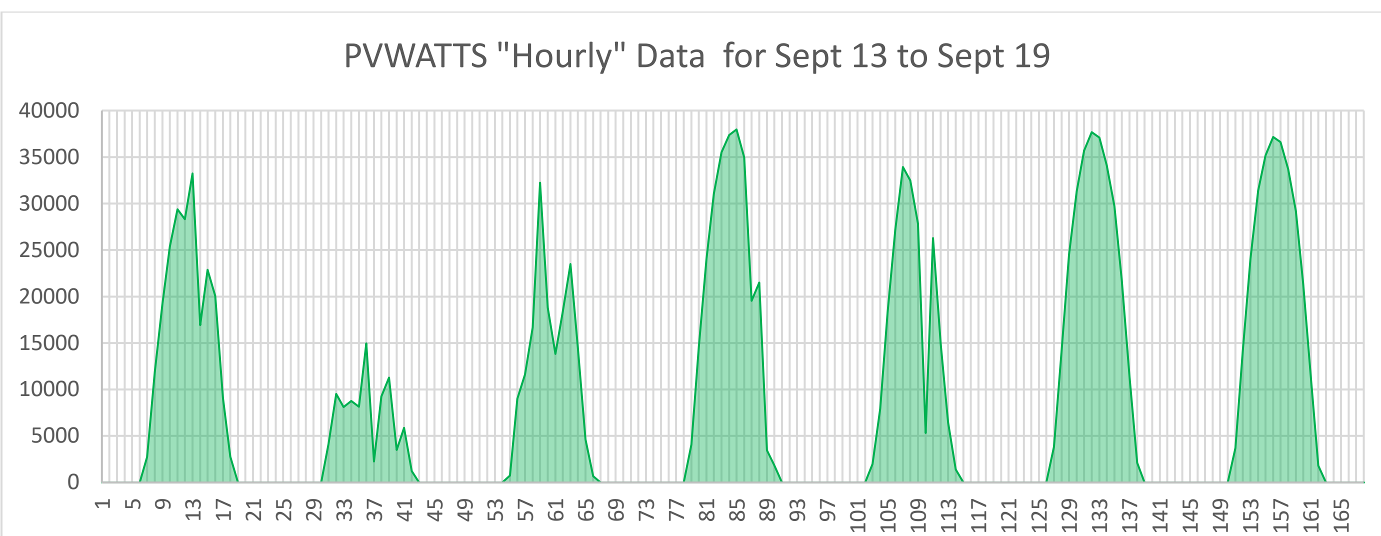


Figure 51 PVWATTS Hourly Data for a Week in September. Production for this week: 1506 kWh.

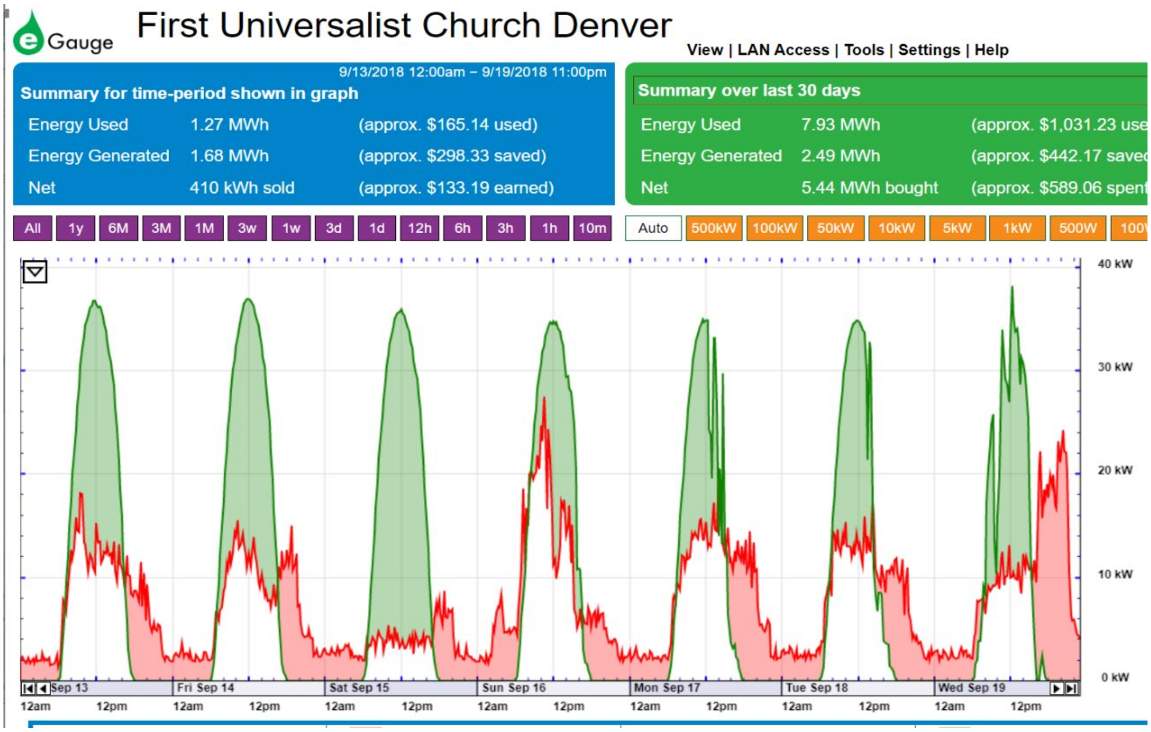


Figure 52 Weather Effect 2018 - Actual Solar Production Data for the Week of 13 Sept to 19 Sept 2018. Production for the Week: 1680 kWh.

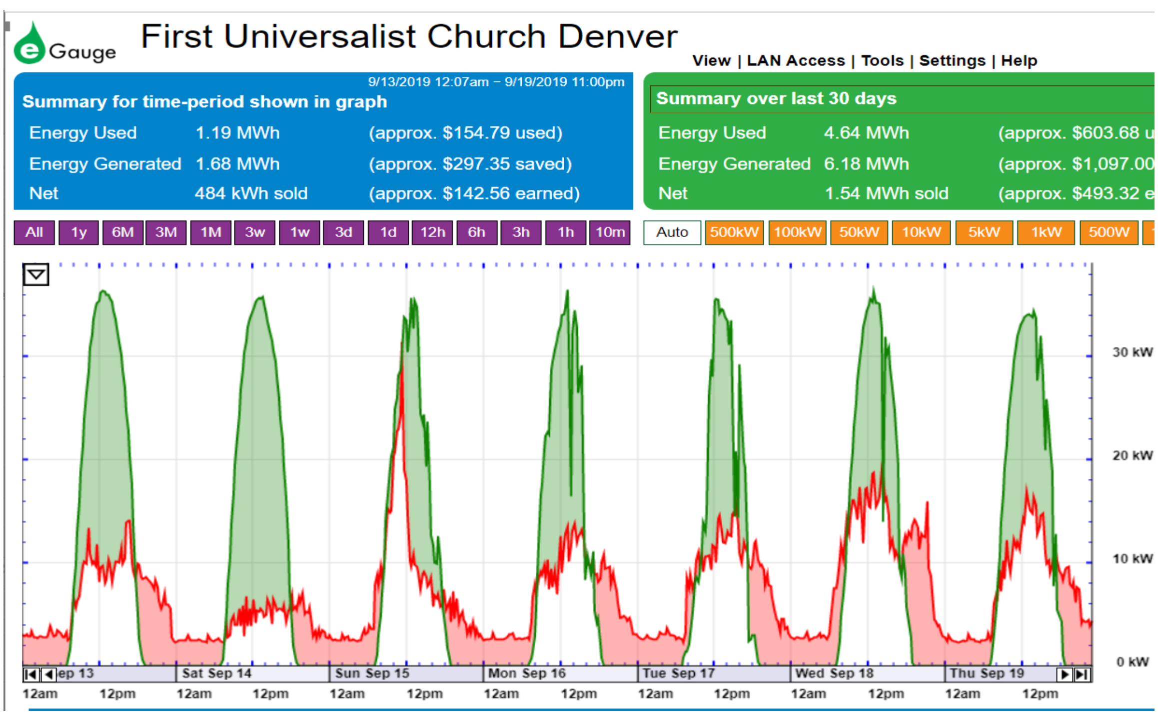


Figure 53 Weather Effect 2019 - Actual Solar Production Data for the Week of 13 Sept to 19 Sept 2019. Production for the Week: 1680 kWh.

Seasonal Variations

To represent the variations over a complete calendar year, four weeks were selected at the beginning of each of the four seasons.

Spring Equinox. The first week displayed in Figure 54 (Mar 15 to Mar 21) includes the spring equinox. The default weather model has four (5) perfect sun days that week. In 2019, based on eGauge data, the actual weather that week had four (4) perfect sunny days. On the perfect sun days, (i.e. when the weather model is not a factor) the peak power output around midday was predicted to be around 42.5 kW; **the measured peak power was almost identical on those days.**

The weekly 'energy generated' predicted by the computer model and measured from the actual solar PV system were nearly identical. The measured value was only 3% less than the predicted.

Summer Solstice. The second week displayed in Figure 54 included the summer solstice (Jun 14 to Jun 20). The measured peak production was around 44 kW. The PVWATTS prediction of peak production was similar to what was measured. The PVWATTS weather model used 4 perfect sun days. The actual weather in 2019 was worse than predicted. There were zero perfect sun days during the week of summer solstice. The actual weekly production was 24% less than predicted the PVWATTS default weather model.

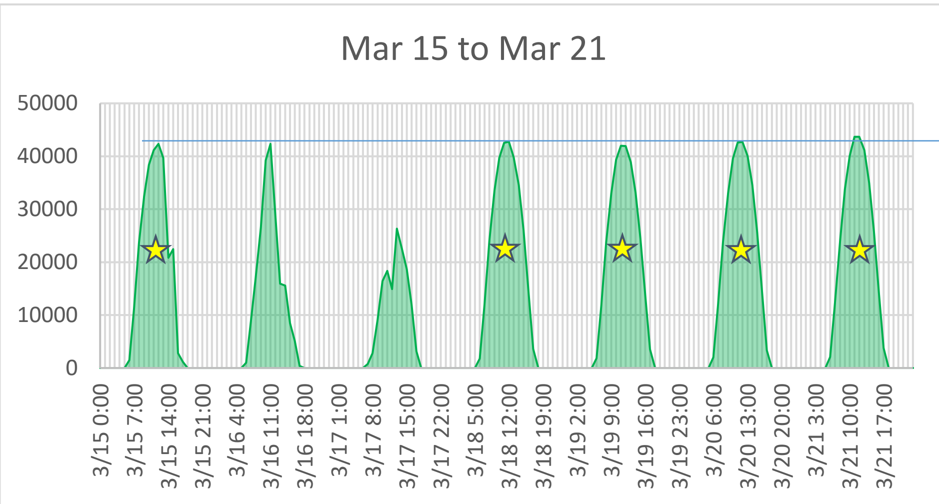
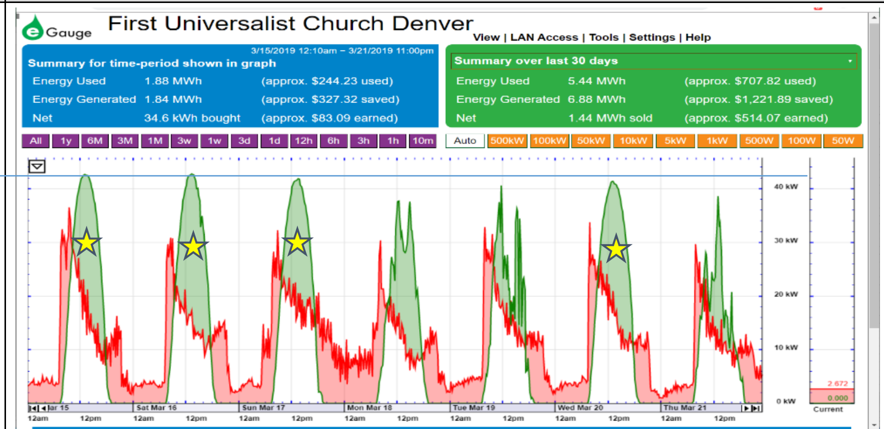
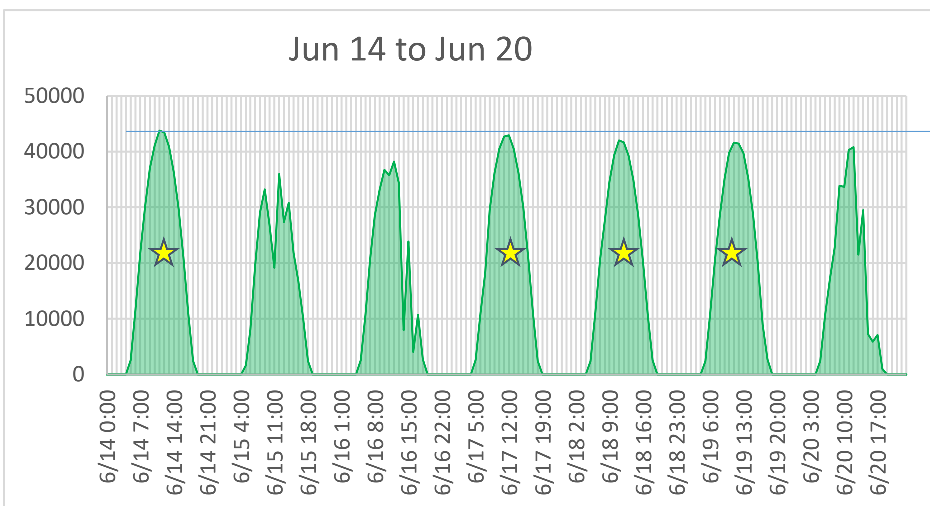
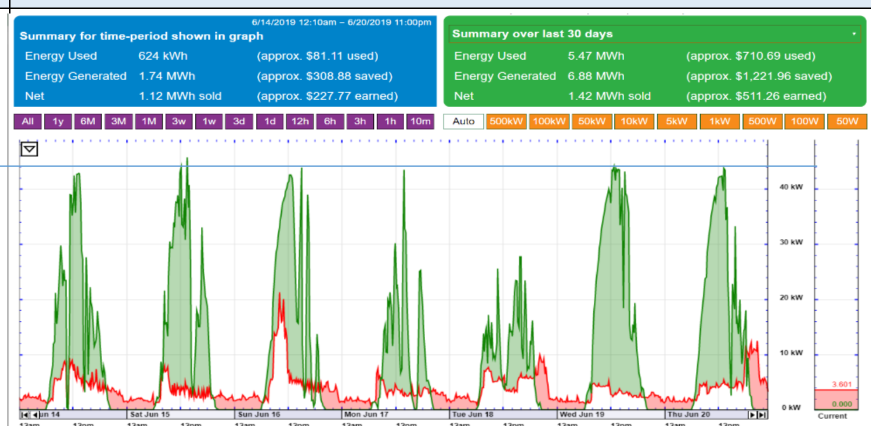
Fall Equinox. The third case was a week around the fall equinox (Sept 20 to Sept 26). There were six (6) perfect sun days in the default weather model; there were actually only three (3) perfect sun days that week in 2019. On a perfect sun day, peak generation was measured to be around 37.5 kW, **10% less than predicted by PVWATTS**. This may be indication there may be a small amount of tree shading occurring. The actual weekly production was less than predicted by 14%.

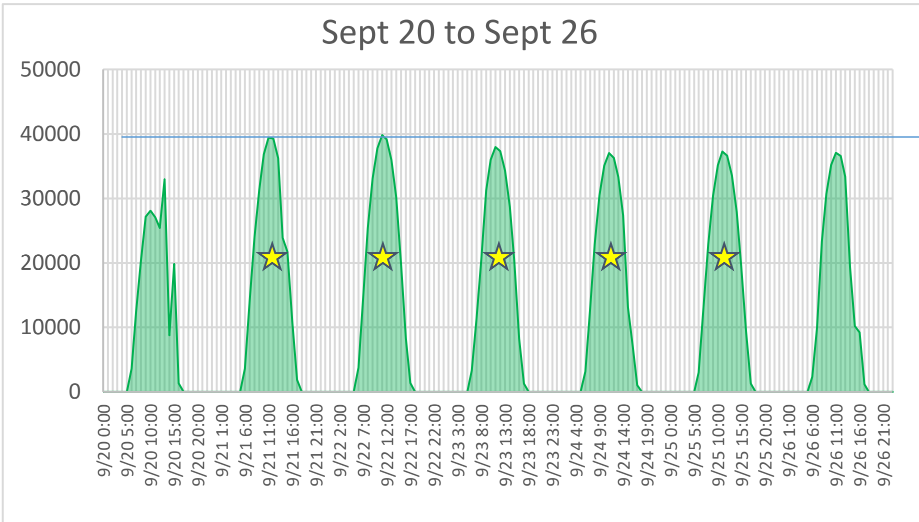
Winter Solstice. The fourth week was around the winter solstice (Dec 13 to Dec 19). The peak production was predicted to be around 32 kW (with 2 perfect sun days) but the actual was around 23.0 kW (with 4 perfect sun days). The measured weekly production was 26% less than predicted by PVWATTS; this is an indication there may be significant shading occurring.

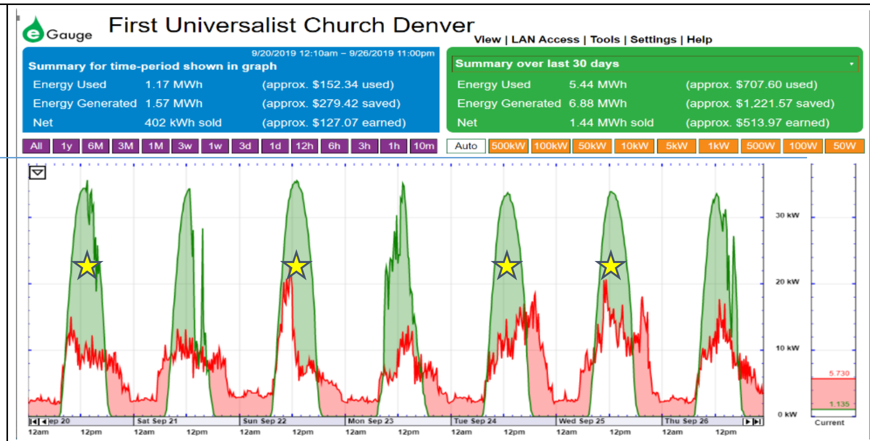
Shading is evaluated and discussed in Appendix M.

DRAFT

Seasonal Comparison of PVWATTS Prediction with Actual Solar PV Performance

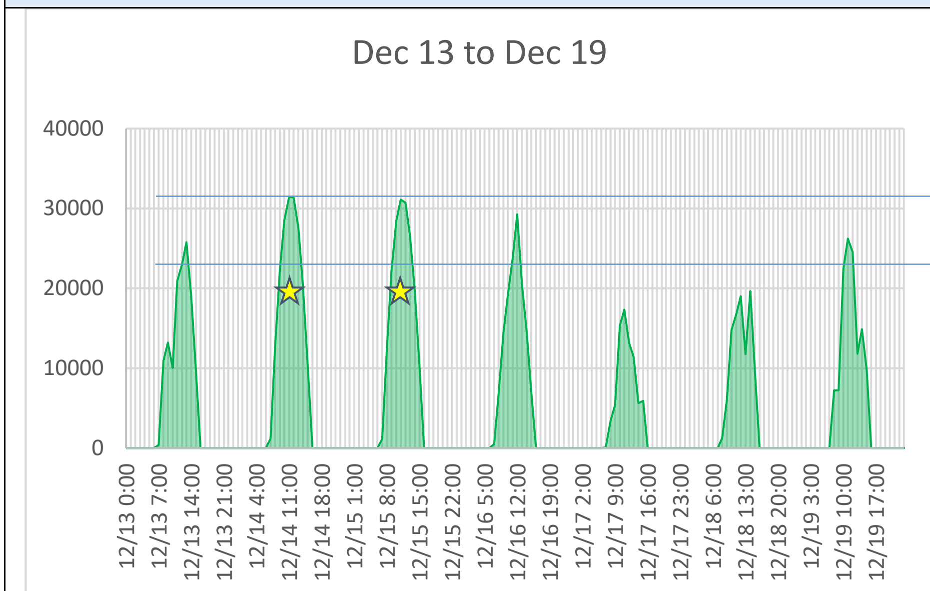
PVWATTS "Hourly" Data	Actual 57 kW Solar PV System (179 Modules)
	 ~ Spring Equinox (Prediction – Actual) = -3%
1888 kWh	1840 kWh
	 ~ Summer Solstice (Prediction – Actual) = -24%
☆ 2294 kWh	1740 kWh

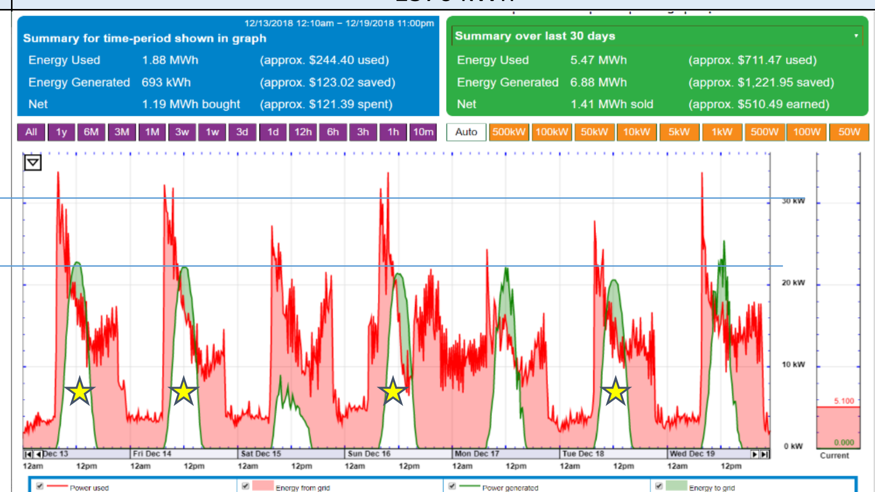




~ Fall Equinox (Prediction – Actual) = -14%

1829 kWh	1570 kWh





~ Winter Solstice (Prediction – Actual) = -26%

937 kWh	693 kWh

As indicated the measured power output was 3-26% less than the PVWATTS model prediction. Peak output appears to be similar except for December.

Figure 54 Seasonal Comparison of PVWATTS Predictions with Actual Solar PV Performance

Conclusion.

On perfectly sunny days, when the weather (clouds, rain, snow, etc.) is not a factor, the PVWATTS predictions and the eGauge measurements are nearly identical. This tends to validate the eGauge measurements and that the system has been properly modeled in PVWATTS **excluding the weather model**. Since shading was not included in the PVWATTS model, the **data indicates that shading is not a dominant factor in explaining the reduced performance of the total system** of 179 modules.

The actual production measured by the Xcel production meter and verified by the FUCD eGauge meter was 68,630 kWh in 2019. The actual production in 2020 was 68,958 kWh.

A daily/weekly comparison of the PVWATTS Calculator results with the actual production measured by the eGauge monitoring system allows us to conclude the following:

Effect of Weather.

Using the default weather model, the measured solar PV system production was nearly 20% lower than predicted by PVWATTS. Using the alternative weather model for the NREL location in Golden, CO, the actual production was still 11% lower than predicted by PVWATTS. The weather model used by PVWATTS has a significant influence on the predicted annual performance of the solar PV system.

Accuracy of the PVWATTS Calculator. NREL provides a range of uncertainty in the PVWATTS Calculator predictions. The actual performance of the FUCD solar PV system was outside this range of uncertainty indicating something else is going on that is not yet being considered.

Note: PVWATTS is not intended to accurately predict daily or even weekly production because of weather variability. Monthly and Annual predictions are expected to be more accurate.

Peak Production on Perfect Sun Days. On perfectly sunny days, when the weather (i.e., clouds, rain, snow, etc.) is not a factor, the PVWATTS predictions and the eGauge measurements of peak power output are nearly identical in the spring and summer. This tends to validate the eGauge measurements and that the geometry, geographical location, tilt angle, etc. of the system were modelled correctly - **excluding the weather model**.

However, in the fall and winter, on perfectly sunny days, even the peak production does appear to less than PVWATTS predicts. This is an indication there may be some tree shading involved.

Number of Perfect Sun Days. The default weather model in PVWATTS used 12 full sun days for the month of June. The eGauge monitoring system indicates there were actually only 3 full sun days in June of 2019. This explains why PVWATTS over predicted production by 17% in June.

It appears the default weather model used by the PVWATTS computer model did not include enough cloudy or snowy days to accurately represent the 2019 and 2020 weather in Denver. As a result, the PVWATTS computer model over-predicts the amount of electrical power expected from the First Universalist solar PV system.

Ironically, to mitigate climate change, First Universalist appears to have unwittingly experienced the local effects of climate change (e.g., it appears the number of cloudy days has increased from the period when the weather model data was derived possibly 5-10 years ago.)

Indication of Tree Shading.

The measured peak power on sunny days in the fall (September) was 10% less than predicted. In the winter (December), the measured peak power was around 26% less than predicted suggesting there may be significant shading involved in addition to weather effects. This observation redirected the investigation to gather more information /data that would quantify the amount of shading that was occurring in the fall & winter months.

Appendix M Assessment of Lower than Expected Power Output Production

Introduction

After the first year of operation (2019), the solar PV system appears to working properly; however, a preliminary assessment of the data indicated the system was producing less energy on an annual basis than expected / predicted. We wanted to understand why.

The Xcel Production Meter and Net Meter data indicated the renovated facility used 98,019 kWh of energy and the solar PV system produced 68,630 kWh in 2019. To achieve Net Zero Energy, solar production would have to increase by 43% to eliminate the 29,389 kWh energy shortfall.

Part of the shortfall was thought to be due to the less-than-expected power output of the solar PV system. The Green First team expected the production would be nominally around 84,128 kWh as predicted by the PVWATTS Calculator. Using the lower end of the uncertainty range for PVWATTS, the 57 kW rated system FUCD installed should have produced at least 79,075 kWh annually.

After the second year (2020), the solar production (68,958 kWh) was basically the same as the first year, but the consumption (66,731 kWh) was reduced due to limited use of the facility in response to the COVID-19 pandemic – so fortuitously there was no energy shortfall in 2020. When the church activities get back to pre-COVID levels, there will be an energy shortfall again. We needed to understand why our solar PV system appeared to be producing less electrical power than expected.

The obvious question was, “Why is the production of the 57 kW rated solar PV system so much less than expected?” The Green First Task Force initiated an investigation to determine why?

Several Hypotheses were proposed:

1) Something is wrong with the solar equipment,
2) Something is wrong with the monitoring equipment,
3) The computer model that predicted the power production was incorrect, and/or
4) Tree shading is reducing the power production.

Each of these possibilities are examined in this section.

Hypothesis 1: Something is wrong with the solar equipment.

Is the solar PV system operating as it was designed or has some hardware element failed?

Response. The solar installer, BriteStreet / City Electric, returned to the site and checked out the equipment; they found it to be working properly when they were on-site.

Nothing appeared to be wrong with the equipment.

Hypothesis 2: Something is wrong with the monitoring equipment.

Did the Xcel Production Meter accurately record the power produced by the system?

Response. Yes. The Xcel Production Meter output was independently verified with the FUCD eGauge Production Meter and found to agree within 1%. Also Xcel changed out their Production Meter and verified it was calibrated correctly.

Nothing was found to be wrong with the production monitoring equipment (i.e. production meters) or the measurement of the total solar PV system power output.

Hypothesis 3 Something is wrong with the computer modeling

Was the predicted power output by the PVWATTS computer model accurate?

Response. Another hypothesis was that the PVWATTS computer model used to predict the output of our 57 kW rated solar PV system over predicted its performance. The weather model used in the PVWATTS model utilizes a multi-year year average of local weather and solar irradiance (the spectral or electromagnetic flux (power) reaching the Earth's surface per unit of area at any instance of time – measured as kW/m^2). The solar irradiance at the Earth's surface will vary as a function of cloud cover, pollution in the atmosphere and the angle through the atmosphere. The computer model takes into account the complex angles between the Sun and a fixed solar module during the day and integrates over time to determine the incident insolation that is the amount of energy received by a surface per unit area – measured as kWh/m^2.

The geometry and sun angles appear to be modeled correctly/ accurately. When we compare the peak power (around solar noon) of spring equinox and summer solstice with the FUCD peak production at noon, the agreement is excellent. This is an indication the model is accurately representing the FUCD solar PV system tilt angle, Sun angles and solar irradiance with no significant shading.

However, the solar insolation (energy received by the solar module) is also a function of the weather / cloud cover that is built into the weather model used by the computer model based on geographical location of the solar equipment. **Appendix L documents a detailed assessment of the PVWATTS weather model used to predict the FUCD solar PV system annual production of electrical energy.**

We found that on a daily basis, the actual number of full "sun"-days (with no significant clouds) as indicated by the power output profile of the FUCD solar PV system, there were 20% fewer full Sun-days than predicted by the PVWATTS weather model. As a result PVWATTS over predicted the power production of the FUCD solar PV system because the actual number of cloudy days in 2019 was greater than weather model predicted.

Hypothesis 4: Tree shading is reducing the power production.

Are the deciduous trees on the south side of the facility shading the system and causing this reduction in annual power production?

After the first year of operation, tree shading was suspected to be causing a reduction in the power output of the solar PV system. However, there was insufficient information/data to quantify the effects of shading and answer that question. A more in-depth trouble-shooting investigation was not possible. The solar PV system did not include instrumentation that records performance data at the subarray or module level.

In March 2020, the Green First Task Force purchased and installed additional instrumentation. It was then possible to monitor the output of each of the six subarrays for further evaluation of the system operation. Several field tests were conducted by members of the Green First Task Force[51]with the new monitoring system on 7 May 2020 to verify its operation and sensitivity. The results are documented below.

Part I (Shading Sensitivity Field Test)

A "Field Test" was conducted soon after the additional eGauge sensors were installed to determine the smallest amount of shading that could be detected by the new monitoring system. Unexpectedly, during this field test, the

[51] John Bringenberg and Milt Hetrick

investigative team determined that the “as built” configuration was different from the “as designed” configuration submitted for permitting purposes. This clarification was critical to understanding the actual performance of the system.

> **Note:** A similar situation occurred when the Green First team installed instrumentation on the geothermal heat pump furnaces. The “as built” geothermal system configuration was different from the “as designed” configuration on the engineering drawings.
> **Lesson Learned:** Request “as built” drawings from major contractors.

Revised System Configuration

Prior to the field tests, the array design layout shown in Figure 55 was being used. Notice that it calls out that three inverters will be used, each inverter converts the DC output of 50 modules into AC power. Each group of 50 modules is divided into 5 strings of 10 modules as denoted in Figure 55.
However, upon field inspection, the “As Built” configuration was found to be completely different as indicated in Figure 56. The assignment of 150 modules to the three inverters is completely different. Also, the five modules on the flat roof with micro inverters are not the ones indicated on the design drawing.

This reinterpretation of the configuration wiring was very important because of the concern about partial shading from the trees on the south side of the building. Partial shading was assumed to affect the southernmost rows of the array. Using the “As Built” configuration, we can now see that shading effects may be observed by reduced output in both Inverter # 1 and Inverter #3.

Based on this new understanding, the modules connected to Inverter #2 are not affected by shading, so the **output from Inverter # 2 can be used as the power output reference or baseline for zero shading.** This is an important observation because any change in the output of inverter #1 or inverter #3 is likely going to be caused by a change in output compared to Inverter #2 (the baseline for zero shading).

Likewise, the subarray, **Oculus(12), is located where there is no possibility of shading**, so it too can become a baseline/reference

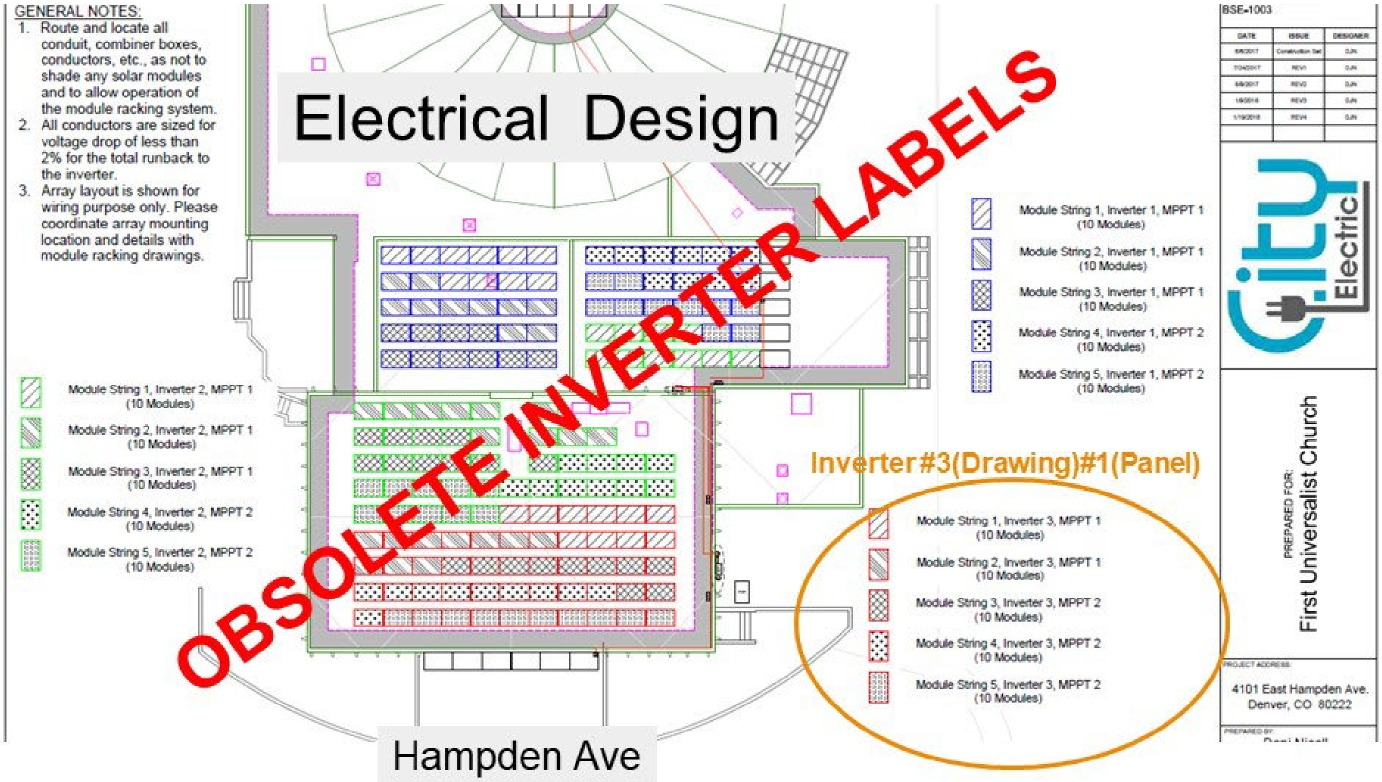


Figure 55 "As Designed" Configuration (Now Obsolete)

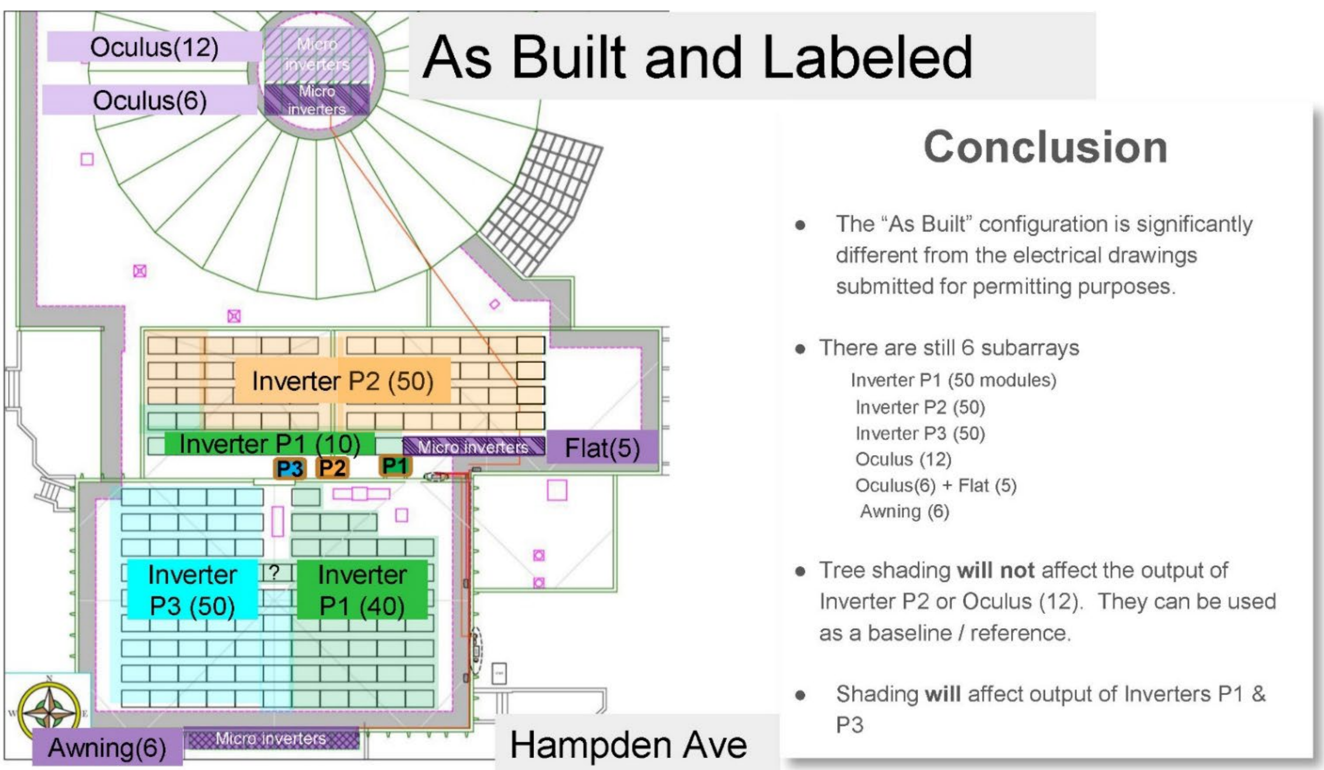


Figure 56 "As Built" Configuration is Significantly Different from the "As Designed" Configuration

Subarray Characteristics

The information in Figure 56 can then be used to construct a table of "Subarray Characteristics" shown in Table 24. Using a more detailed evaluation reduces the expected system performance slightly to 84,859 kWh / year. The two subarrays highlighted in yellow denote they were used as baselines (performance standards) because there was little possibility of these subarrays ever being shaded by trees or structure.

Table 24 First Universalist Solar PV System Subarray Characteristics and Predicted Performance

Subarray	# Modules	Module Rating (W)	Type/ Model/ Inverter	Array Rating (kW)	Tilt (deg)	PVWATTS Performance Factor (kWh/kW)	PVWATTS Annual Production (kWh)	% of Total System Output	% of Array by # of Modules
Oculus (12)	12	300	Silfab 300W Modules w/	3.6	14	1542	5,551	6.5%	6.7%
Oculus (6) + Flat Roof(5)	6	300	Silfab 300W Modules w/	1.8	14	1542	2,776	6.1%	6.1%
	5	320	Jinko Solar 320W Modules	1.6	10	1499	2,398		
Awning(6)	6	300	Silfab 300W Modules w/	1.8	87	1212	2,182	2.6%	3.4%
Inverter#1	50	320	Jinko Solar 320W Modules	16	10	1499	23,984	28.3%	27.9%
Inverter#2	50	320	Jinko Solar 320W Modules (JKM320M-72)	16	10	1499	23,984	28.3%	27.9%
Inverter#3	50	320	Jinko Solar 320W Modules (JKM320M-72)	16	10	1499	23,984	28.3%	27.9%
	179			**56.8**			**84,859**	100.0%	100.0%

Shading Sensitivity Field Tests

It was important to understand how sensitive the eGauge sensors were in detecting partial shading on the array. With the additional sensors, it was now possible to determine which of the six subarrays was being shaded and how much the power output was being reduced. This was adequate to quantify the partial shading effects if the sensitivity was adequate. That was the objective of the field test.

The idea was to cover a portion of one module with something opaque and see I it could be observed by the eGauge meters. Corrugated cardboard was selected. On March 7, 2020, the Green First investigative team went up on the flat roof with sheets of cardboard.

John B started by covering a single module by as little 25%. After waiting several minutes for the data to be recorded and stored in the eGauge offsite database, the amount of shading of the module was increased to 50% and 100%. This same test was conducted on several modules.

As indicated in Figure 57, 7 May 2020 was a good "sun-day" with only slight sporadic clouds around 5 pm. The upper green profile displays the power output of the three inverters. They almost appear as a single line. The lower three curves display the output of the three strings of modules with micro inverters. The lowest curve displays the power output of the 6 "Awning" modules mounted on the south wall of the church that can be seen by traffic on Hampden Ave. At this time of the year, when there are no leaves on the trees, and the sun angles are relatively high so no significant shading can be observed.

According to the eGauge monitoring system, energy production for the day was 386 kWh (See blue box) and usage was around 92 kWh. As a result, 294 kWh of energy was stored on the grid for use in the fall/winter. Peak power production for the day was around 48 kW. (The system rating is 57 kW with full sunlight perpendicular to the module but this requires two axis tracking on each module.)

Figure 57 illustrates that at this time of year, all three inverter outputs are nearly the same and almost appear as a single trace – an indication there is no significant shading. Areas circled in **Red** denote periods when modules were being manually shaded during the field test to determine how sensitive shading could be detected.

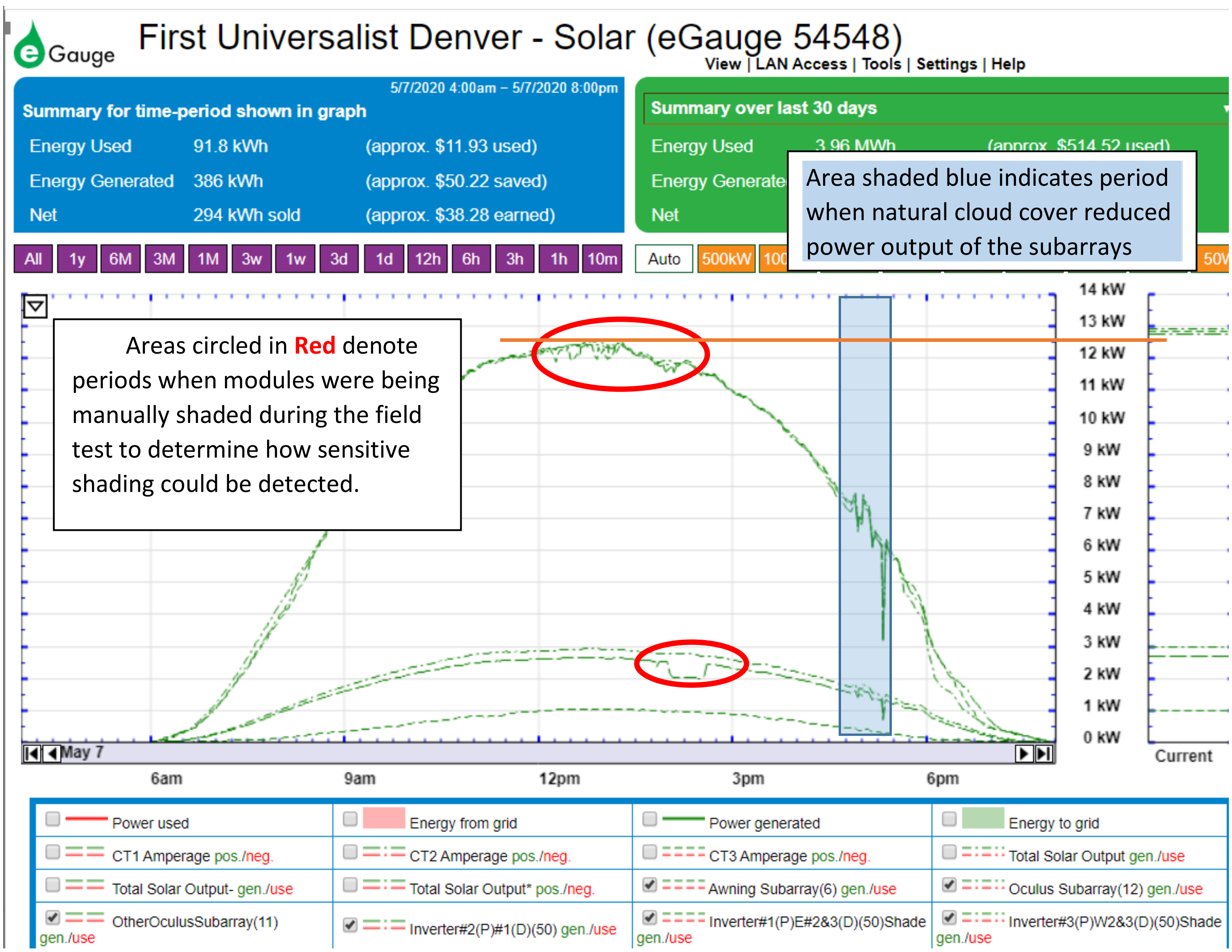


Figure 57 Power profiles for each of the 6 subarrays - 7 May 2020 (See the checked options in the table below the composite plot for identification of each subarray.)

Inverter Subarrays.

The next graphic, Figure 58, illustrates the output from the three(3) subarrays with inverters. Output from each of the three inverters are nearly identical between 9 am and 5 pm. The field tests with simulated shading were conducted between noon and 2:30 pm. The field test created some temporary reductions in the output that will be explained later.

The output of Inverter #1 subarray (the lower dashed curve) drops lower at 1 minute intervals because modules connected to the inverter are being manually covered with cardboard to simulate shading during this field test. The eGauge monitoring system updates the display every minute so there is a 1-2 minute delay between the real-time display on the Inverter LED readout and the eGauge web-based display. Around 12:59, all the cardboard was removed and the output from the three subarrays becomes identical again.

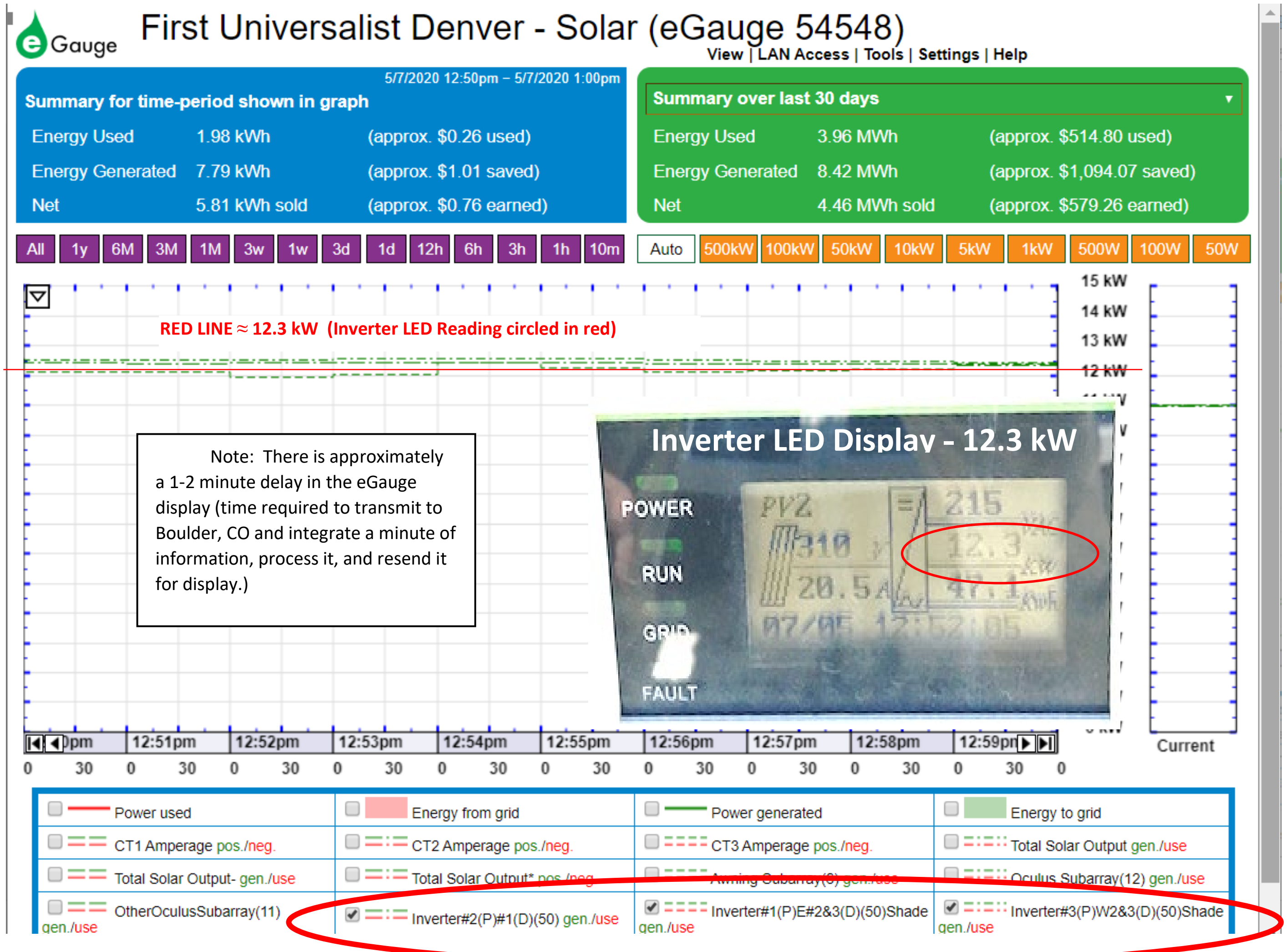


Figure 58 Comparison of eGauge Information with Inverter LED Display @12:52 pm 7 May 2020

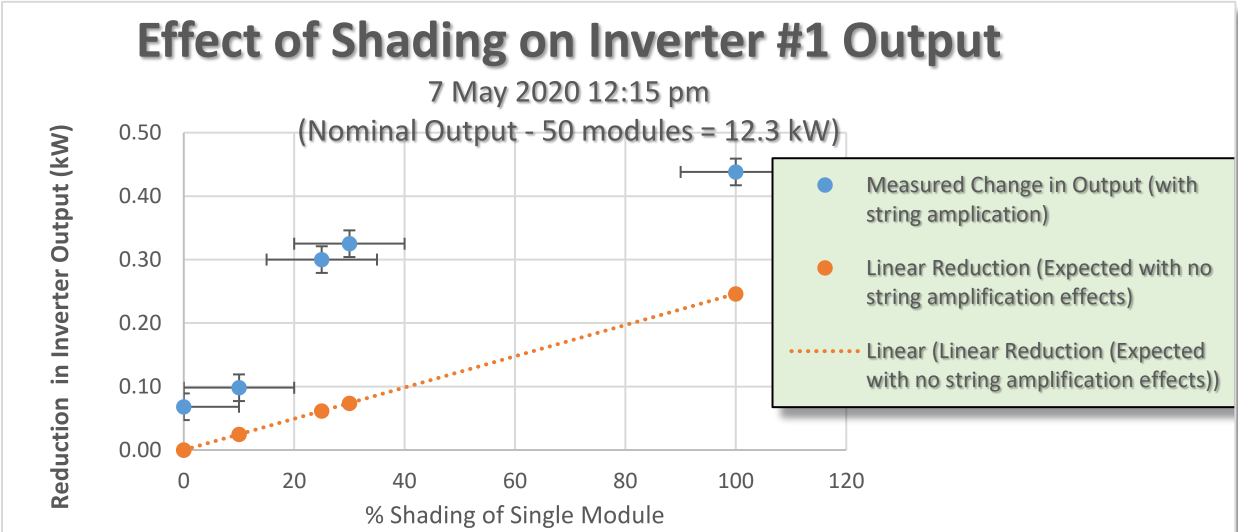


Figure 59 Example of the "amplification" effect when a module in a string of 10 modules without "Power Optimizers" is partially shaded. Adding Power Optimizers or switching to micro inverters would eliminate this amplification effect.

Micro Inverter Subarrays.

A similar field test was conducted on the subarrays with micro inverters. The results are shown in Figure 60. One can easily detect shading on a single module in a string of 11 [(i.e. the Oculus(6) + Flat (5) subarray]; but there does not appear to be any amplification effect. When two modules were shaded, there was a 0.5 kW reduction in the string output (with no string amplification) as expected for the 11 module string that is generating around 2.5 kW prior to shading. [2/11 * 2.5 kW] = 0.45kW, the reduction in output indicated in Figure 60.

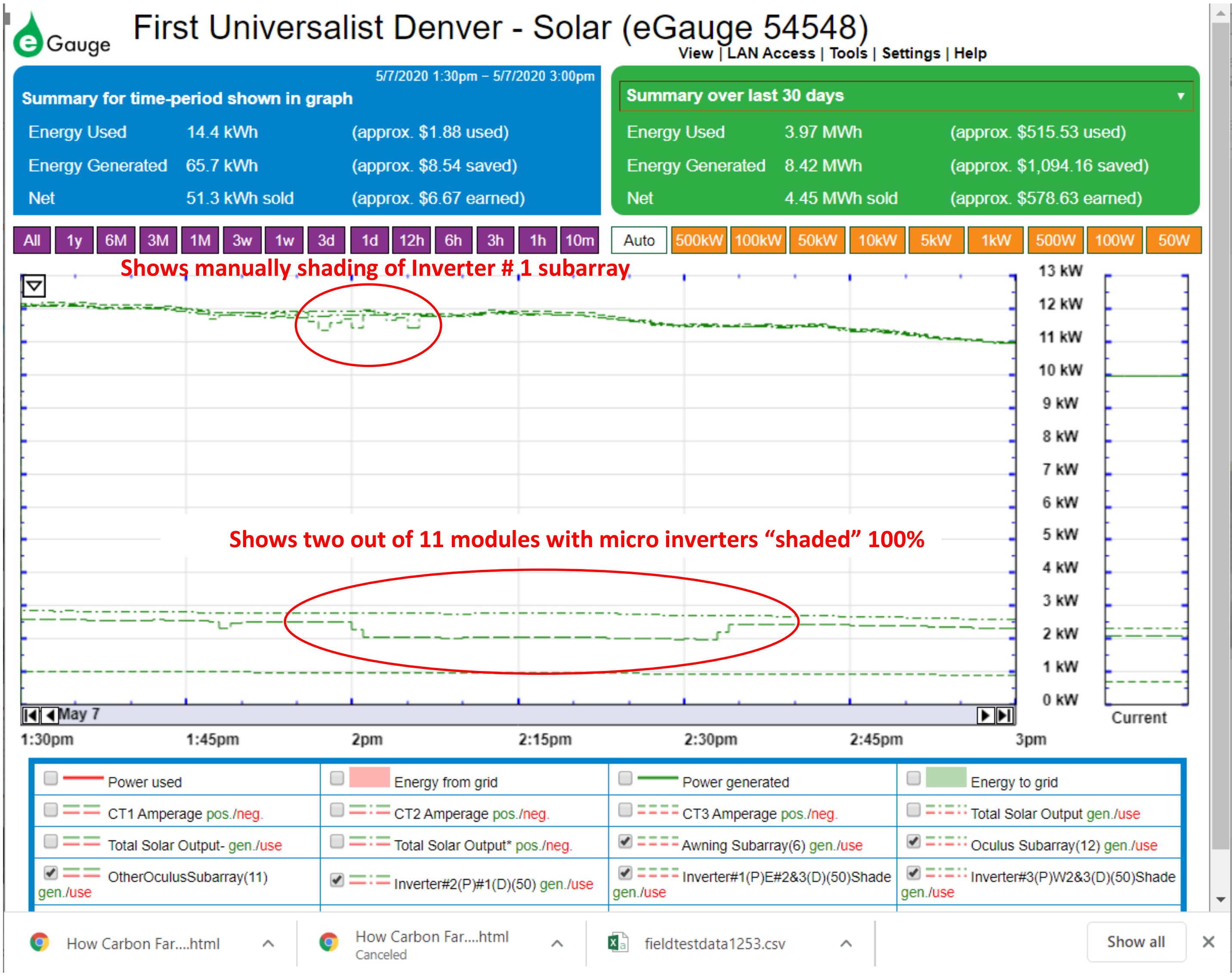


Figure 60 Illustration of output from micro inverter string when two modules are shaded

Summary of Field Test Observations:

This field test was not intended to be a science experiment, but merely an attempt to determine if the new eGauge monitoring sensors could detect small amounts of shading. **The monitoring equipment can detect if even ¼ of one module in a string of 10 modules is being shaded.**

For those solar modules attached to the three inverters, with no power optimizers, there is a string amplification affect that can be observed. For example a 30% shading of a given module should reduce the inverter output by 0.06 kW (on 7 May 12:15 pm); however because it is part of a string of 10 modules, the actual power reduction of the inverter is measured to be 0.33 kW (an amplification of 5.5) The effect does not appear to be linear. When one entire module was shaded, the output should have been reduced by 0.25 kW, but instead a 0.44 kW reduction in output was observed (an amplification of 1.75). Power optimizers would likely reduce the amplification factor to some value closer to 1.0. So the reduction in power due to shading would be equal to the amount of shading (as with the subarrays that use micro inverters). The addition of "power optimizers" would minimize this "string shading amplification" effect, but not eliminate shading.

Shading simulations on modules with micro inverters confirmed there is no string amplification – only the expected linear reduction in output.

Potential Shading Situations that can Reduce Power Output

Table 25 Examples of Shading Situations

<table>
<tr><td>

Figure 61 Minimal Shading from Deciduous Trees with no Leaves. The photo was taken mid-April 2019.</td><td>As indicated in

Figure 61, when there are no leaves 5-6 months of the year (Nov, Dec, Jan, Feb, Mar, Apr), shading of the modules on the roof (labeled "C") by the top thin branches should be minimal.   The trees extend about 20-25 feet above the roof, but in the summer when the Sun angles are high (See

Figure 62 for an example), there is minimal shading except for the "D" array.</td></tr>
<tr><td>

Figure 62   Minimal Shading from Deciduous Trees with Leaves Mid Summer – Local Time ~ 10:00 am.</td><td></td></tr>
</table>

Figure 63 Early Morning Major Shading by Two Deciduous Trees on 6 Awning Modules (with micro inverters). Photo Taken September 16, 2019 at 9:16 Solar Time

When there are leaves on the trees as shown in

Figure 63, the six modules mounted on the vertical south wall (labeled D) are shaded in the early morning and late afternoon.

<table>
<tr><td>
Figure 64</td><td>Looking west.

Example of tree branch shading from leafless deciduous tree on the left (south) in late afternoon December 2020</td></tr>
<tr><td>
Figure 65</td><td>Looking east.

Example of tree branch shading from leafless deciduous tree on the left (south) in late afternoon December 2020</td></tr>
</table>

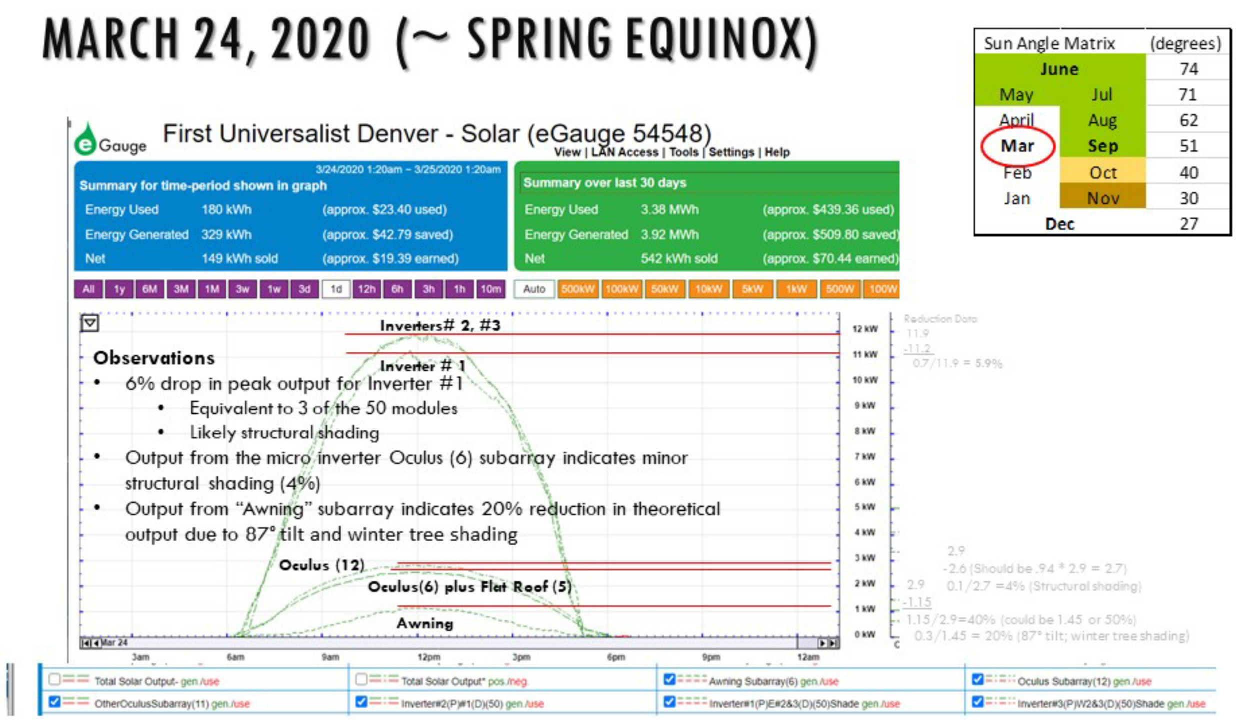
Part II Monthly Subarray Performance for Shading Analysis

This section documents typical performance of each of the six subarrays on a monthly basis. A "good sun-day" was selected near the middle of each month and is displayed in ***Table 26 Year 2020 Representations of Monthly Solar PV System Production for each of the Six (6) Subarrays.***

The output of the subarray "Inverter #2" is used each month as the performance standard for Inverter #1 and Inverter #3 subarrays. The output of "Oculus(12)" subarray can be used after appropriate adjustment for the number of modules in the string, as a performance standard for the two other micro inverter subarrays. Any unexpected deviation from the reference is an indication of either tree shading or structural shading.

Over the course of a year, the Sun's angle above the horizon varies significantly – from 74 degrees at the summer solstice to 27 degrees at the winter solstice. Also, the shading is different for each of the subarrays and the total electrical power/energy generated by the solar PV system varies accordingly.

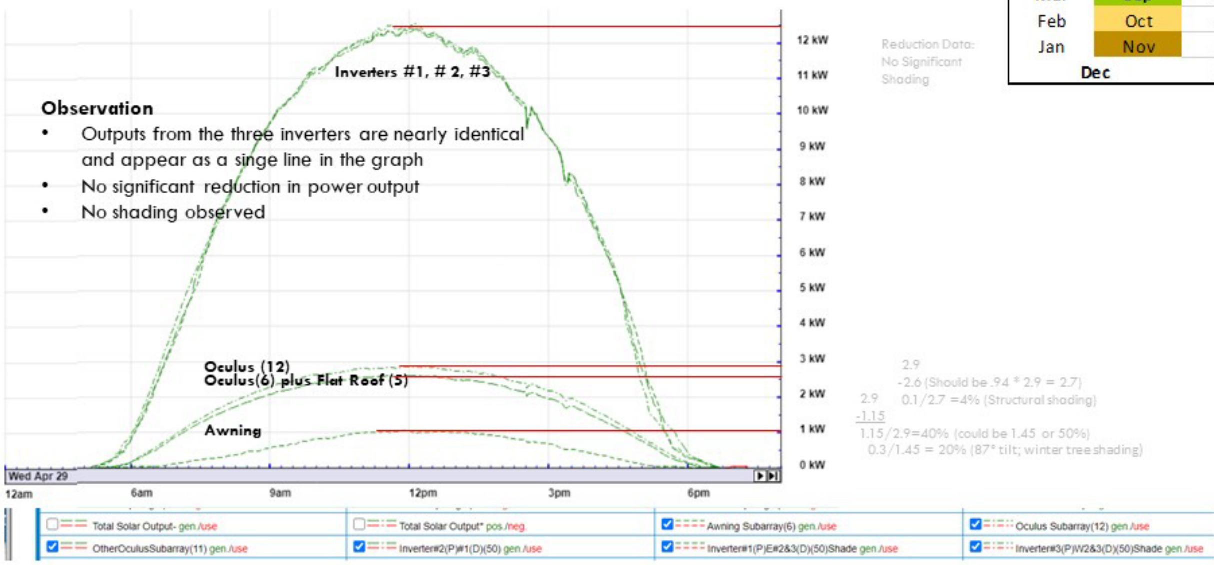
Table 26 Year 2020 Representations of Monthly Solar PV System Production for each of the Six (6) Subarrays



KEY OBSERVATIONS: Shading is apparent for Inverter #1

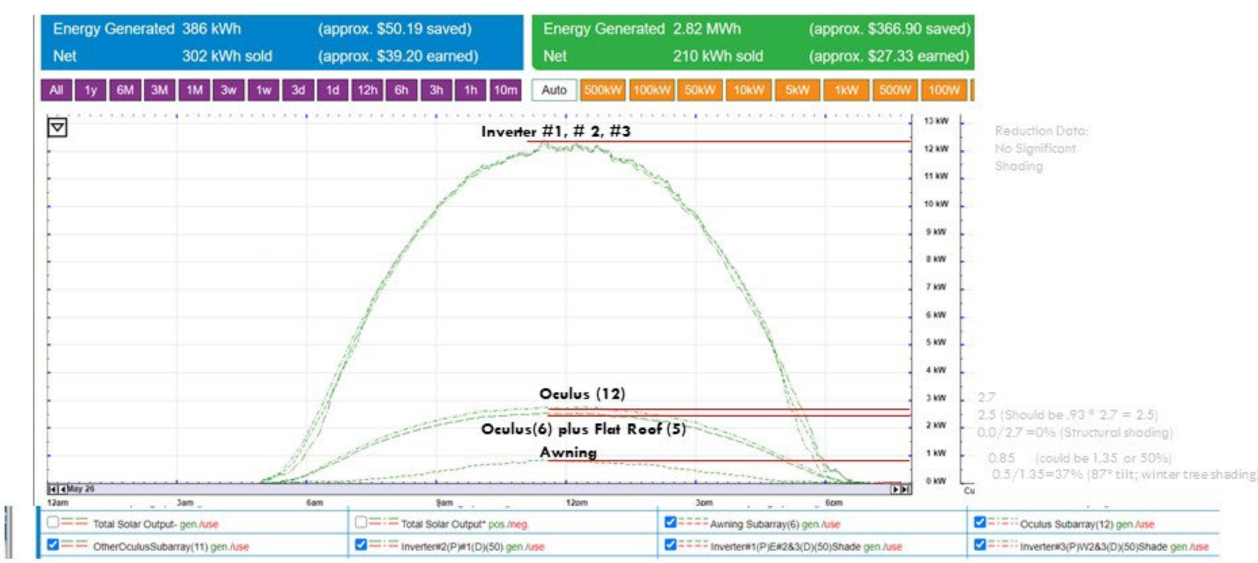
APRIL 29, 2020

Sun Angle Matrix		(degrees)
June		74
May	Jul	71
April	Aug	62
Mar	Sep	51
Feb	Oct	40
Jan	Nov	30
Dec		27



KEY OBSERVATIONS: No shading is observed on any subarray

MAY 26, 2020

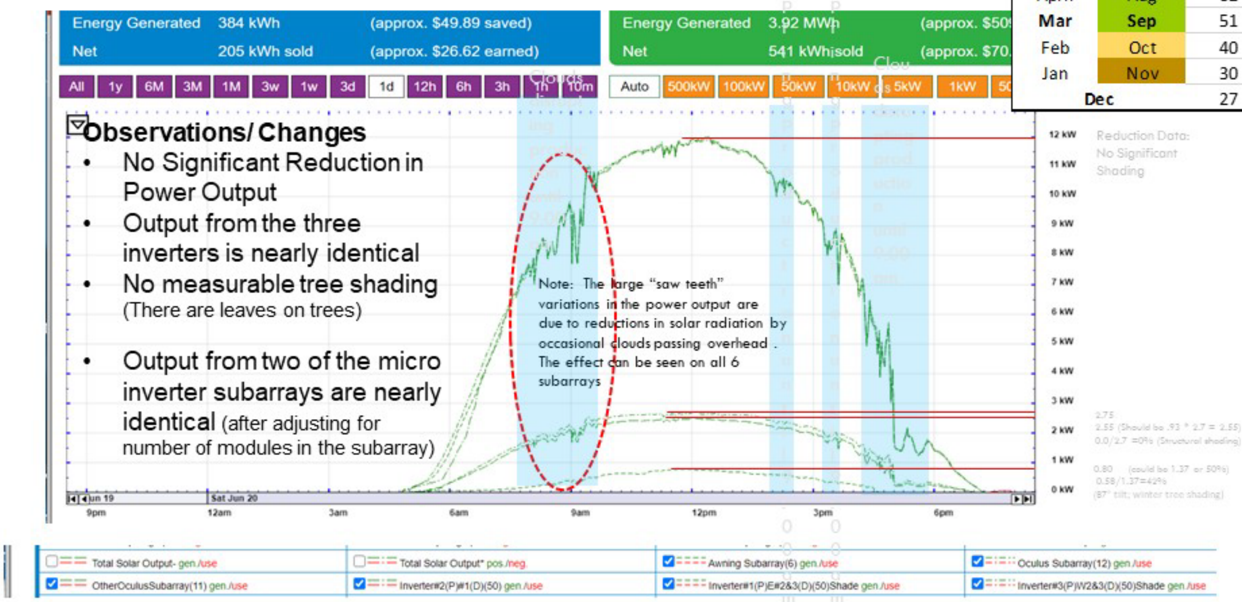


KEY OBSERVATIONS: No shading is observed on any subarray

DRAFT

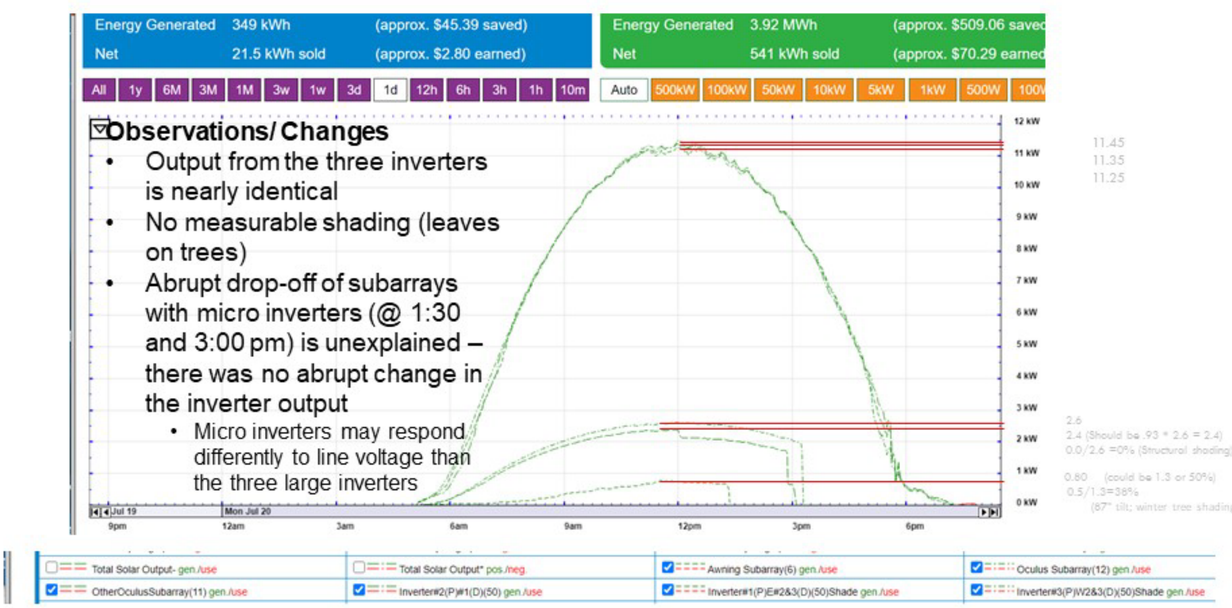
JUNE 20, 2020 (~ SUMMER SOLSTICE)

Sun Angle Matrix		(degrees)
June		74
May	Jul	71
April	Aug	62
Mar	Sep	51
Feb	Oct	40
Jan	Nov	30
Dec		27



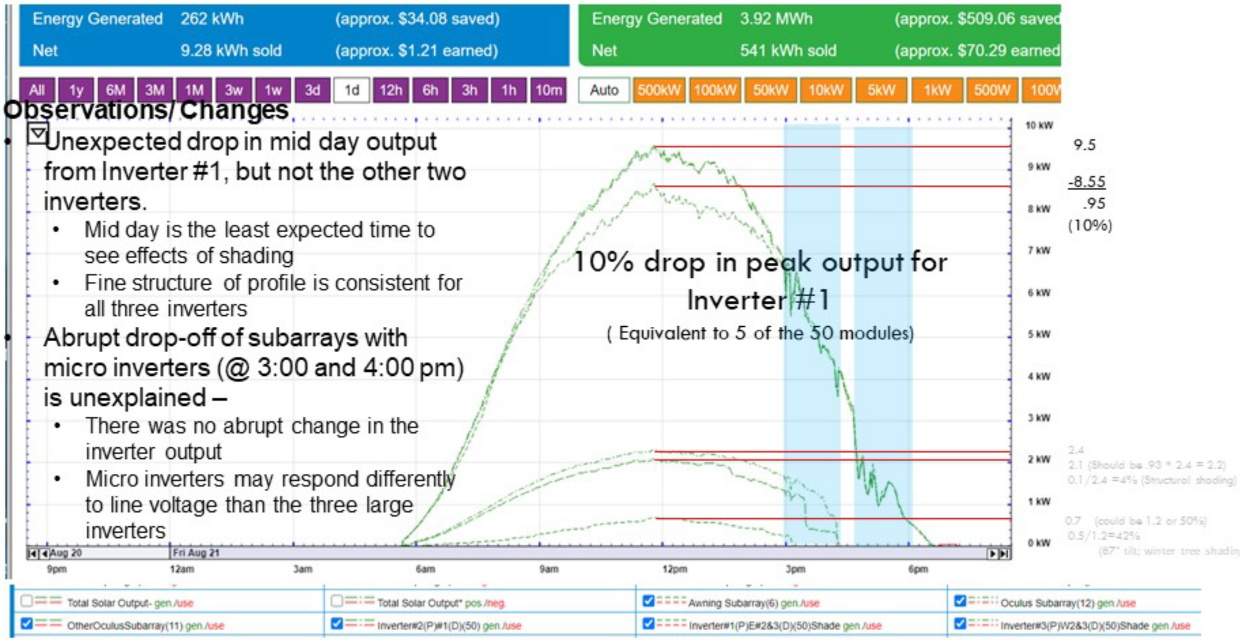
KEY OBSERVATIONS: No shading is observed on any subarray

JULY 20, 2020



KEY OBSERVATIONS: No shading is observed on any subarray

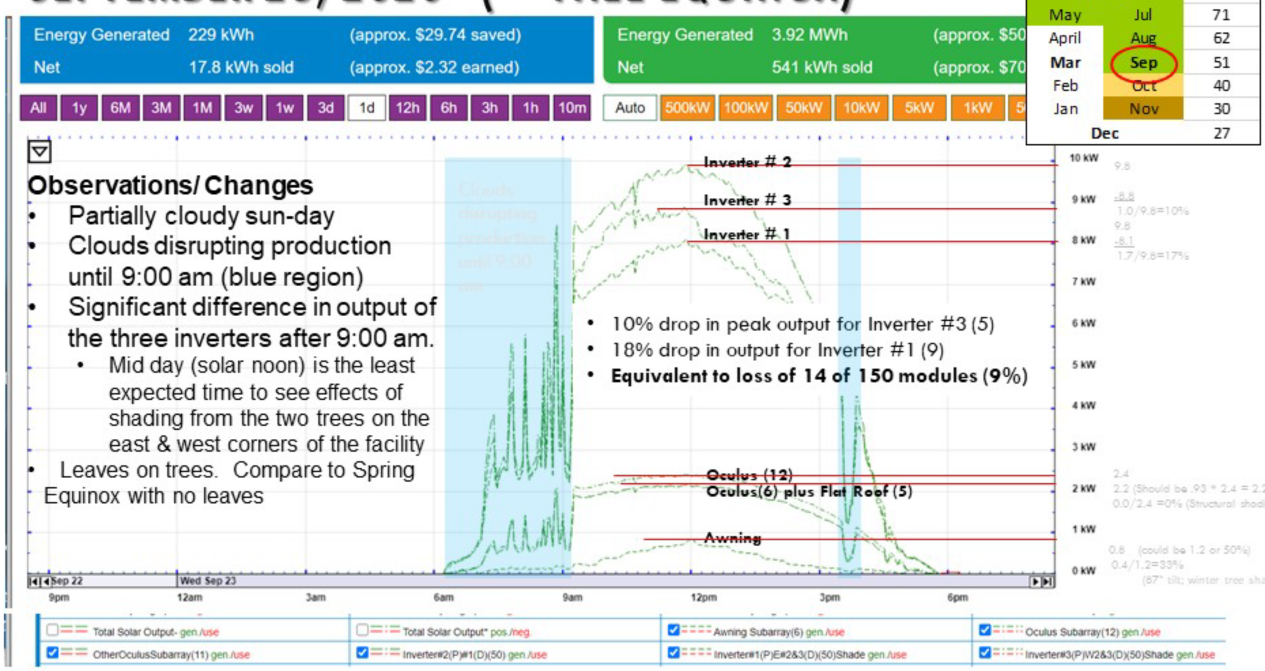
AUGUST 21, 2020



KEY OBSERVATIONS: Shading is observed on Inverter #1

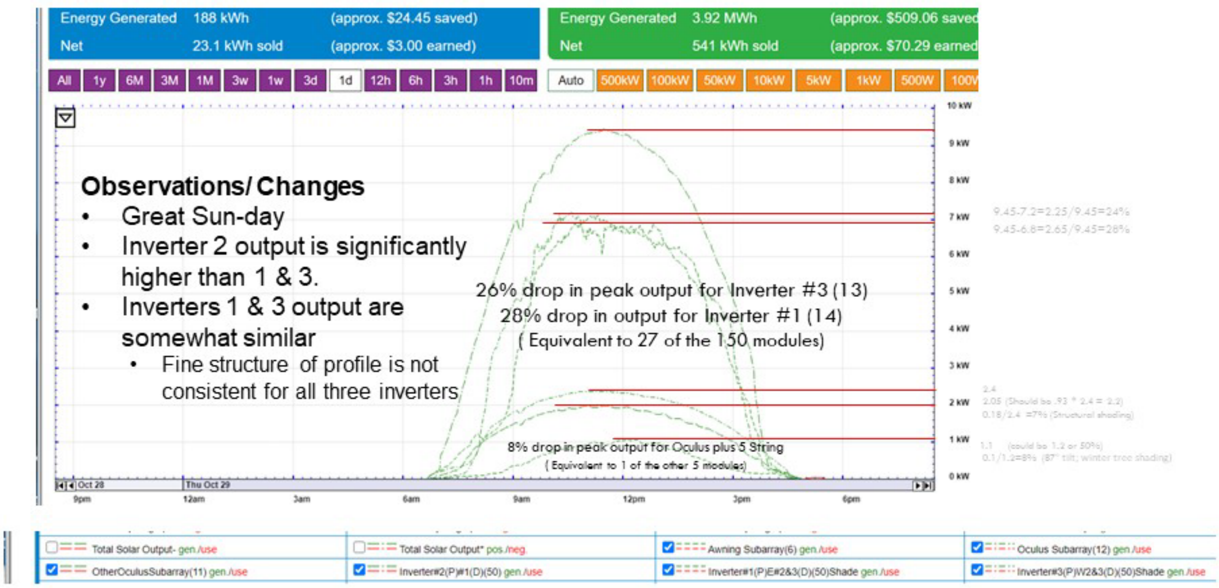
SEPTEMBER 23, 2020 (~ FALL EQUINOX)

Sun Angle Matrix		(degrees)
June		74
May	Jul	71
April	Aug	62
Mar	Sep	51
Feb	Oct	40
Jan	Nov	30
Dec		27



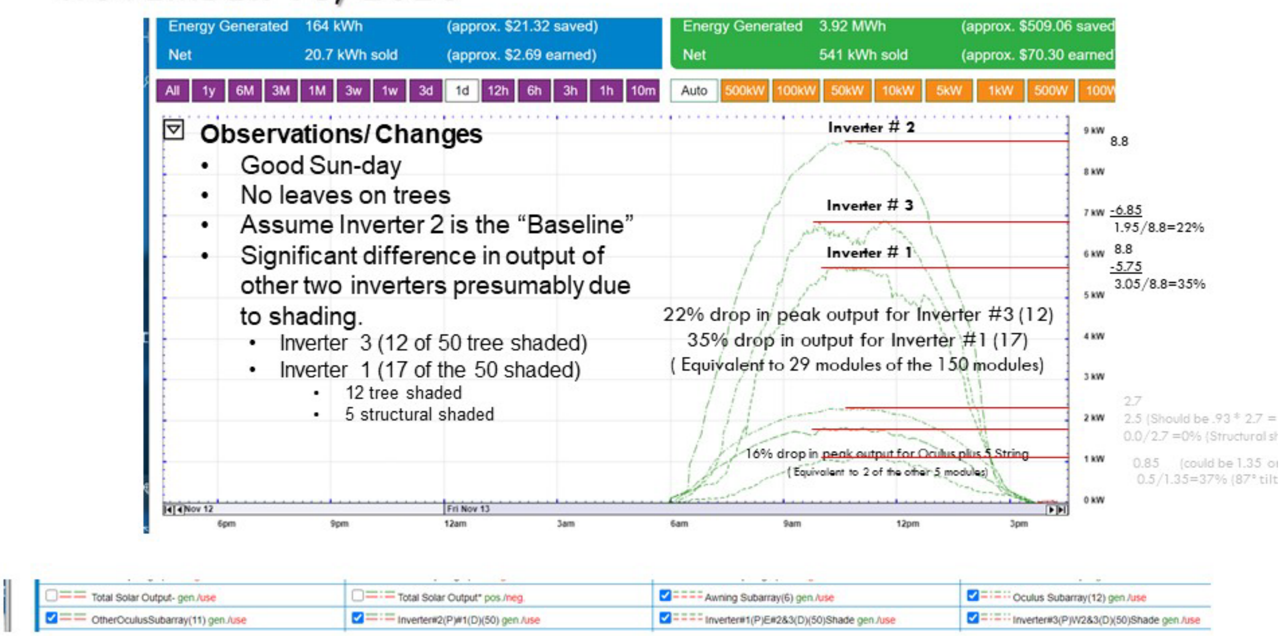
KEY OBSERVATIONS: Shading is observed on Inverter #1 & Inverter #3 subarrays

OCTOBER 29, 2020

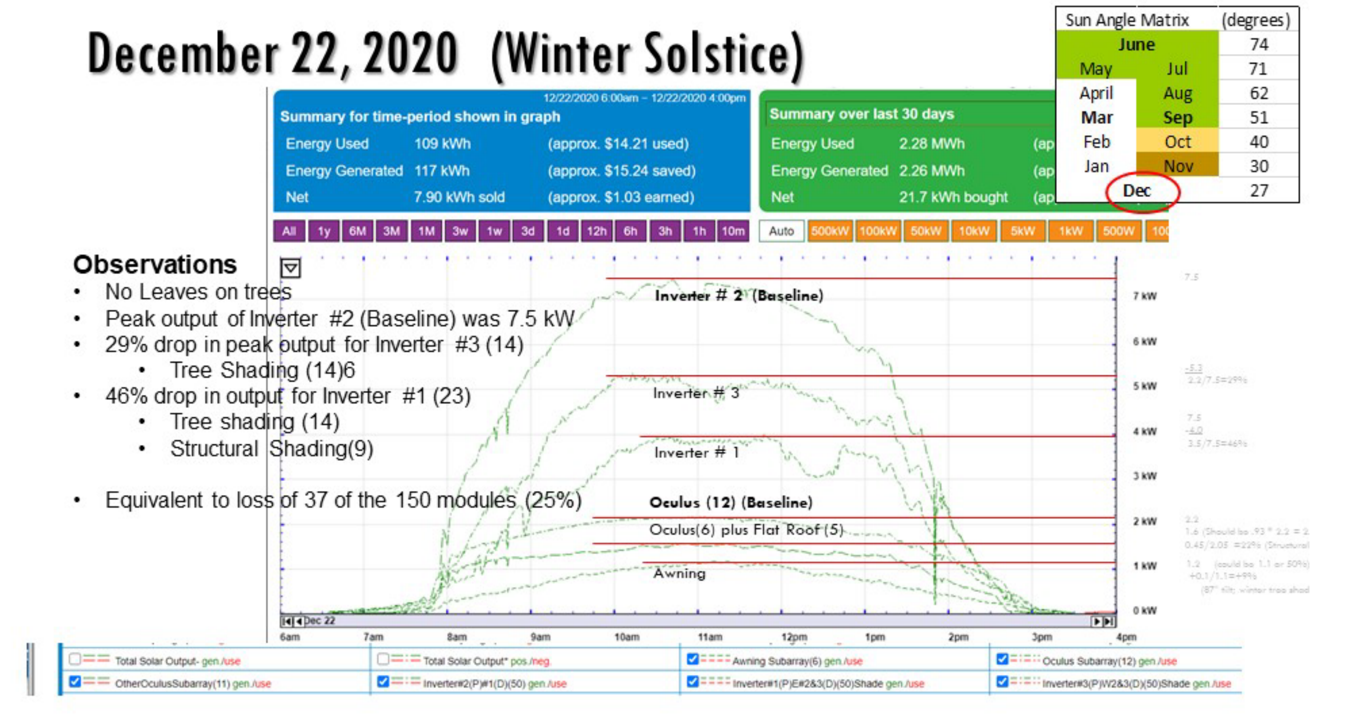


KEY OBSERVATIONS: Shading is observed on Inverter #1 & Inverter #3 subarrays & “Oculus(6) + Flat (5)”

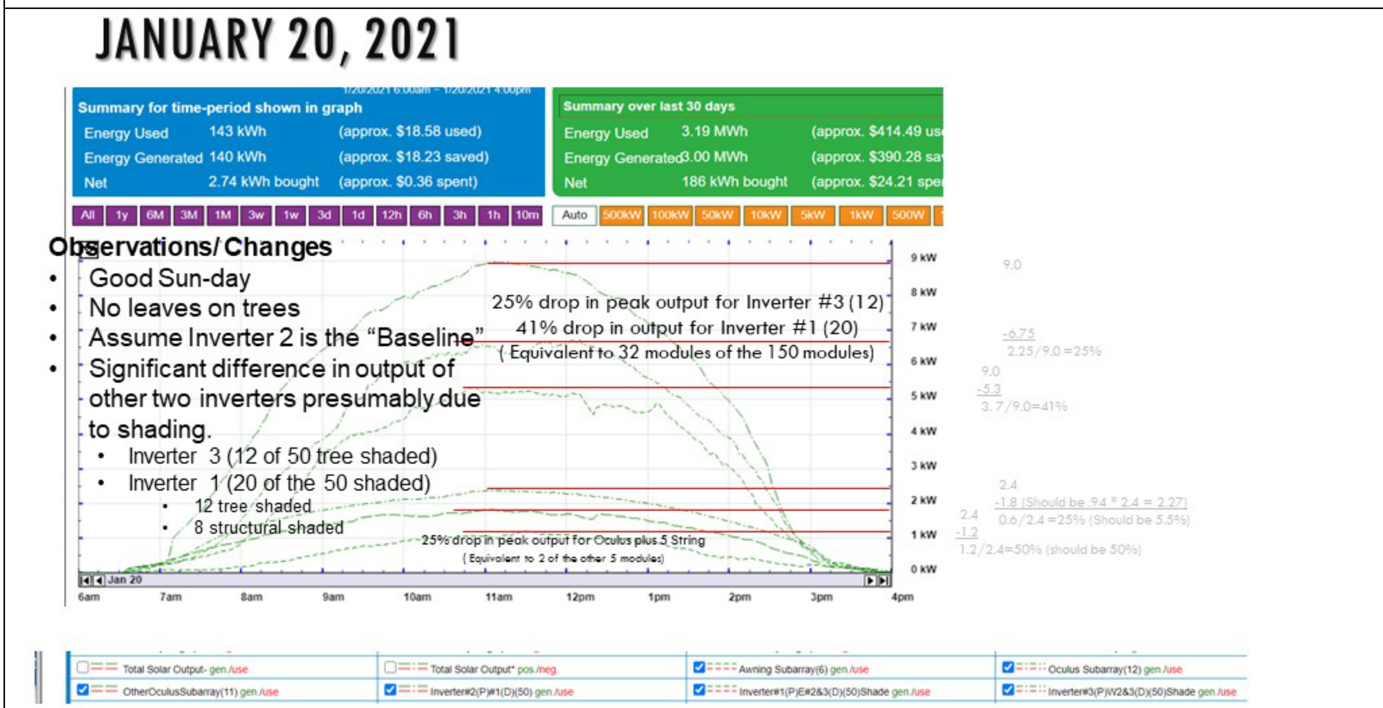
NOVEMBER 13, 2020



KEY OBSERVATIONS: Shading is observed on Inverter #1 & Inverter #3 subarrays & “Oculus(6) + Flat (5)”



KEY OBSERVATIONS: Shading is observed on Inverter #1 & Inverter #3 subarrays & "Oculus(6) + Flat (5)"



KEY OBSERVATIONS: Shading is observed on Inverter #1 & Inverter #3 subarrays & "Oculus(6) + Flat (5)"

END of Table 26 Year 2020 Representations of Monthly Solar PV System Production for each of the Six (6) Subarrays

The representative monthly power profiles shown in Table 26 were then analyzed. The peak power for the representative day was used as a first order approximation to calculate the power produced for that month.

Example: If the peak power (provided in Table 26) for August was reduced 10% from the standard output with no shading (Inverter #2), then it was assumed the power output for month is reduced approximately 10% as shown in Figure 66.

.

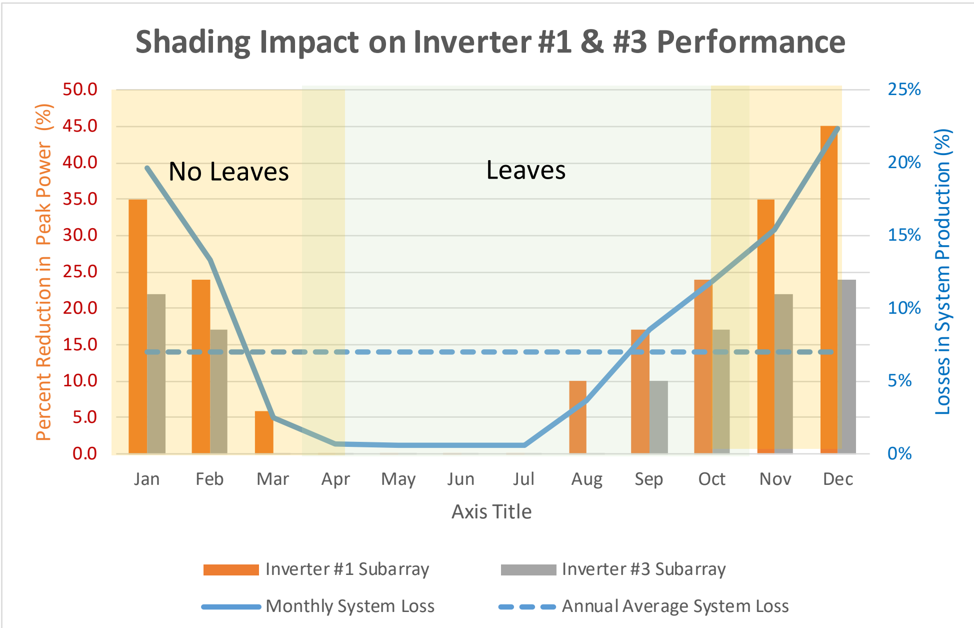
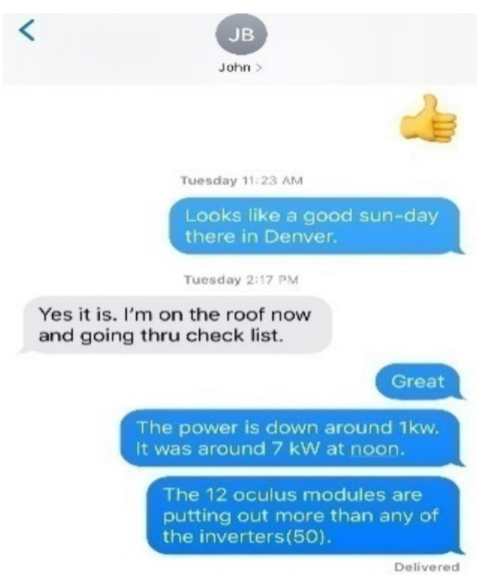


Figure 66 Shading Reduction in Performance – Monthly – Inverter #1 & 3 Subarrays

Part III (Shading Analysis / 3D Modeling)

This section documents the shading analysis and 3D modeling effort. The computer model helps visualize how the shadows move over some of the modules during the low Sun angle winter months. The model verified the tree shading and identified some previously unknown "structural shading" from the parapet walls and elevated Inverter boxes.

Late Afternoon Photos of the FUCD Solar PV System



On Tuesday, December 22, 2020 3:17 MT, John Bringenberg conducted an onsite inspection of the First Universalist Church Denver rooftop solar system. The objective of the inspection was to take some photos of shadows and make some measurements needed to verify a computer model of sun shading that could reduce power output of the system.

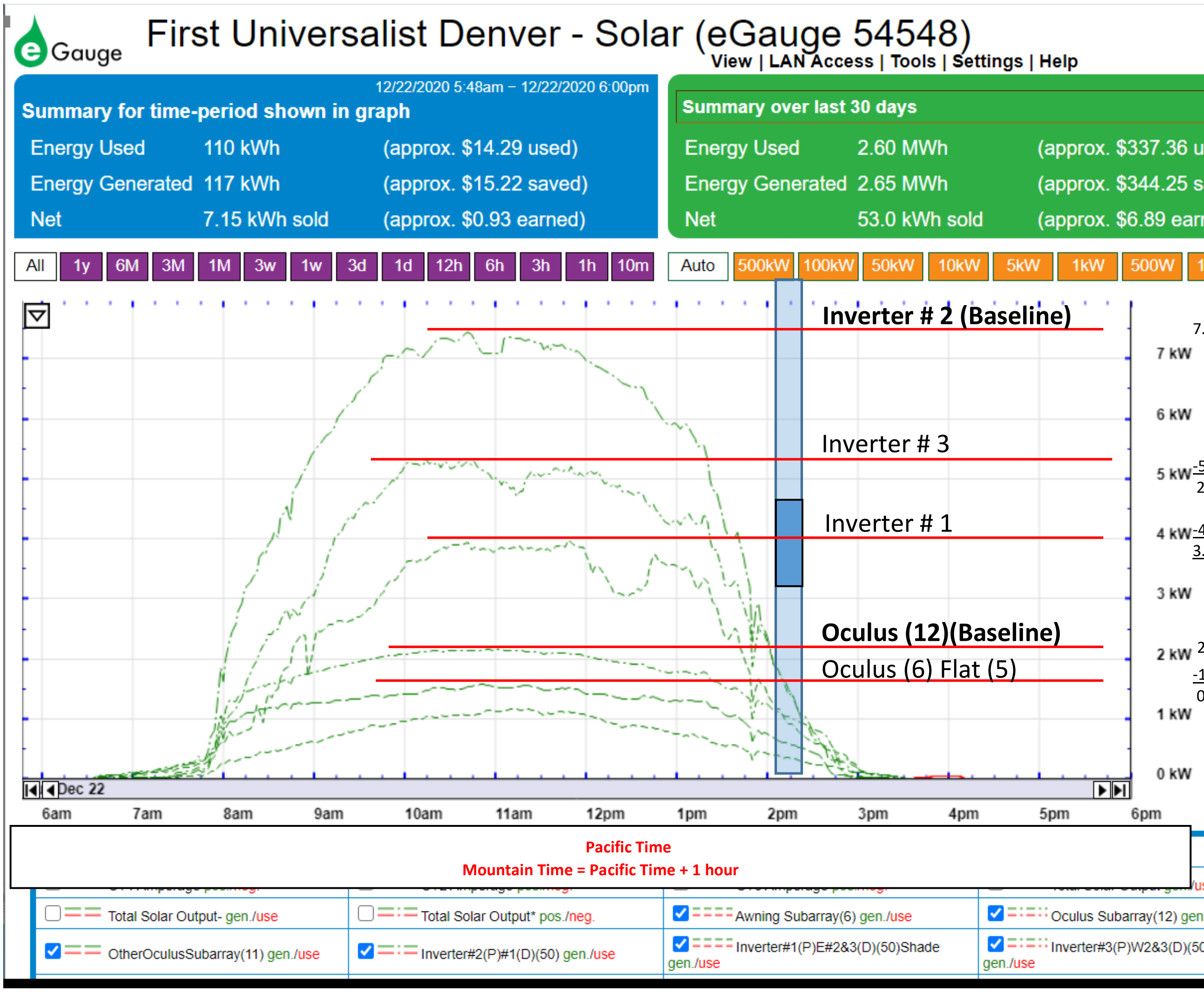


Figure 67 Power Output of Inverters 1, 2 & 3 around the winter solstice

Photos were taken on one late afternoon by John B. for comparison with the 3D modeling result. Amazingly there was good qualitative verification.

4433

12/22/2020 3:21 pm MT

- Shows solar PV equipment attached to the parapet mid-wall.
- Looking east we can see the Inverter #3 (closest), Inverter #2, Inverter #1 two posts, and Combiner Panel casting shadows even onto the second row of modules that is a part of the Inverter #2 subarray.

4432

12/22/2020 3:20 pm MT

- Looking east.
- Inverter #1 is in the center of foreground, then two posts, and Combiner Panel are casting shadows in late afternoon on solar modules
- One module is completely shaded that is connected to the Inverter #1 subarray.

Illustration of SketchUp

- SketchUp is a 3-D computer Modelling Tool that includes a sun shadowing feature as a function day of the year and time of day.
- This computer model was very useful for visualizing the movement of shadows during the day – particularly in the winter months when the Sun angles are low, and shadows are long.
- SketchUp identified some "structural shading" we were not aware of. John took photos to confirm this actually occurs. This was late in the afternoon, so energy production was well down on the power curve.
- The SketchUp computer model was not used to estimate power losses due to shading, although it is theoretically possible to do so with an extension to the program. .

Options to Mitigate Shading Effects.

Trim or remove Trees. Cutting down the trees or even topping them by 10-15 feet will eliminate tree shading. However, at the end of the first year of operation, there was no actual data to quantify the shading effect and justify cutting down the trees. Obviously shading by tree leaves is a natural method of honorably harvesting the Sun's energy that must be treated with due respect. It was possible that eliminating all shading would not solve the energy generation shortfall issue experienced in 2019. It was likely that additional solar modules would still be required even if the trees were removed. At the end of the first year of operation, there was insufficient data to resolve the shading concern.

Add Power Optimizers. One 'shade mitigation' approach would be to add Power Optimizers or micro inverters to modules in the "C" array. Power Optimizers or Micro inverters on each module allow individual modules to be shaded without affecting the performance of an entire string of 10 modules (which may be happening now.)

Adding Power Optimizers or Micro inverters will reduce the system effects of shading and increase production somewhat. There will still be reduced solar insolation each day on some of the modules in the "C" Array during the fall, winter, spring when the shade from trees moves across the array. Tree shading during the summer months with leaves on the trees means the solar irradiance is being absorbed and used by the tree to create biomass; therefore, it is not available to be converted into solar electric.

The six modules mounted at the top of the south-facing wall shown in

Figure 63 ("D" Array) already have micro inverters to minimize the effect of partial shading.

A cost benefit assessment is appropriate to see if makes sense & cents to invest in Power Optimizers because based on the shading identified by the SketchUp 3-D model, over half of the modules assigned to Inverters #1 & #3 are shaded in the winter months by the branches (no leaves) of the two deciduous tree on the side end of the building. Since the tree shading effect appears to be on the order of 4% of the production and Power Optimizers will only regain a portion of the production, this improvement to the solar PV system made have less priority than adding more modules to get to Net Zero Energy.

Appendix N Shading Assessment Recap

Table 27 Shading Summary Table - Analysis Map – File Catalog

Energy Shortfall Evaluations	Word / PDF Documents	PowerPoint Documents	Excel Documents	Sketchup Files
REDUCED PRODUCTION				
Shading Introduction	ShadingIntroduction.docx			
Shading Part I (Shading Sensitivity Field Test)	FirstYearPerformanceReportJan2020H.docx	ShadingPart_I(ShadingSensitivityFieldTest).pptx	FirstYearMasterFile3.xlxs	
Shading Part II (Monthly Production with Shading)	FirstYearPerformanceReportJan2020H.docx	ShadingPart_II(MonthlyProductionWithShading).pptx	FirstYearMasterFile3.xlxs	
Shading Part III (Shading Analysis / 3D Modeling)	FirstYearPerformanceReportJan2020H.docx	ShadingPart_IIvI(ShadingAnalysis3DModeling).pptx	FirstYearMasterFile3.xlxs	CompleteModelWithTrees_SummerFallND.skp CompleteModelWithTrees_WinterSpringND.skp
PVWATTS Weather Modeling Part IV	FirstYearPerformanceReportJan2020H.docx		FirstYearMasterFile3.xlxs	
INCREASED USAGE				
Xcel Net Meter vs eGauge Rope CTs	FirstYearPerformanceReportJan2020H.docx		FirstYearMasterFile3.xlxs	
New Normal Energy Usage	FirstYearPerformanceReportJan2020H.docx		FirstYearMasterFile3.xlxs	

Table 28 Shading Summary Table - Analysis Map -

Energy Shortfall Evaluations	Comments
REDUCED PRODUCTION	
Shading Introduction	
Shading Part I (Shading Sensitivity Field Test)	• Used cardboard covering on modules to simulate various amounts of shading. • Found discrepancies between the "as designed" and "as built" wiring configuration. Updated the wiring diagram. **Conclusion:** Verified that we can detect shading as little as ¼ to ½ of a single module.
Shading Part II (Monthly Production with Shading)	• Power output data exists for each of the six (6) subarrays for the past 9 months. • Daily solar electric output profiles indicate there are few completely sunny days during any week. • A "good Sun-day" was selected for each month to illustrate that there is no shading during the year for two of the six subarrays labeled as "Inverter #2' and the micro inverter string "Oculus (12)". • There is significant **structural shading** of the micro inverter string, "Oculus (6) Flat Roof (5)" subarray for Nov, Dec and probably Jan (TBD). Shading occurs on the five modules mounted on the flat roof behind the parapet wall due to shadows from the wall and Combiner Panel. • There is no shading for the Inverter #3 subarray in April, May, June, July and Aug – with minor **shading** for Mar & Sept - but significant **shading** for Oct, Nov, Dec, Jan, Feb • There is no shading for the Inverter #1 subarray in April, May, June, July and Aug – with minor shading for Mar & Sept - significant **tree & structural shading** for Oct, Nov, Dec, Jan, Feb **Conclusion:**
Shading Part III (Shading Analysis / 3D Modeling)	Information from the monthly graphics was summarized in line graphs indicating: • Data shows the average annual shading (caused by trees plus fixed structure) is around 6%. • A 3D model using Sketchup with a Sun shading feature indicates that in the winter the row of modules behind the parapet wall between the Forum and Friendship Hall (10 modules of Inverter #1; 5 micro inverter modules) are significantly shaded by the shadows of the wall, inverter boxes & combiner Panel. **Conclusion:** • Photos were taken of the structural shading one late afternoon Tuesday, December 22, 2020 @ 3:17 MT and compared to the 3D model. • There was good qualitative agreement. There is a small amount of structural shading occurring in addition to some tree shading in the winter months.
PVWATTS Weather Modeling Part IV	• On a good Sun-day, the peak power predicted by PVWATTS (at noon) agrees well with the output produce by the FUCD solar PV system – an indication that (with no shading and no cloud effect) the geometry and irradiance / insolation were modeled correctly.

	• However the number of "good Sun-days" actually observed in 2019 was significantly less (20%) than the used in the default PVWATTS weather model. With a corresponding difference in system output predicted versus actual **Conclusion:**
INCREASED USAGE	
Xcel Net Meter vs eGauge Rope CTs	• Summarize results of Xcel Net Meter Field Tests with a data logger and the comparison with the eGauge rope CTs • The eGauge split-core CTs agree with the Xcel Production meter to within 1%. **Conclusions:** • The eGauge rope CTs are less accurate than the Xcel Net Meter current sensors. • We will use the Xcel meters to determine the facility's total energy usage by month and by year. • The eGauge split core CTs are accurate for monitoring the energy usage by appliance (e.g. heat pumps, hot water heaters, ERVs, kitchen)
New Normal Energy Usage	• Before the COVID-19 pandemic started, the renovated facility was being utilized more than expected. (e.g. FUCD hosted several new conferences / workshops and accommodated weekday renters in 2019) . As a result, the energy usage was greater than predicted and more than the solar PV was generating – so in the first year after renovation there was an energy shortfall. • While we were trying to quantify and validate the energy shortfall, the church suspended services and went into a reduced mode of operation – less energy was needed to operate. There was no longer an energy shortfall under these operating conditions. So in 2020, the church was operating as a Net Zero facility. • The Xcel rate schedule based on Peak Demand is costing FUCD several thousand dollars per year because of the peak demand on Sunday mornings that exceeds 40 kW – average demand is around 11 kW on an annual basis. Limiting usage on Sundays is not a viable option, investing in some onsite storage (and using mobile storage with V2G technology) is worth exploring to reduce the peak demand charges. • **Conclusion:** Question? What will the new normal be like? How can our energy production respond to a variable energy usage?

Observations

After 9 months of recording subarray performance data, we can begin to quantify the shading hypothesis. Because the variation of the Sun angle geometry is a complex function of a) time of day and b) day of the year, a computer model is appropriate for an accurate assessment. We used an application called Sketchup to create a 3D model of the FUCD rooftop solar PV system. The 3D computer model included a representation of the two trees south of the facility, the parapet walls on the roof and other structure that casts shadows on the solar modules such as the large inverters boxes and a circuit panel that combines the output of the six subarrays. The 3D model was constructed from a Halkin Aerial Services drone photo of the facility taken in the afternoon of April 9, 2019. The shadows in the drone photo were used to "calibrate/verify" the Sketchup Sun shading feature. Preliminary results of the data analysis and shading model indicate the output of the FUCD solar PV system is reduced primarily in the winter months.

Discussion

We observe that even at solar noon when there is no shading from the trees because the azimuth angle of the Sun is 180 degree and in between the trees, there is still a significant amount of "shading" believed due to "structural shading" from the parapet walls, elevated inverter boxes and the combiner panel (circuit panel)

We can estimate that the combined shadowing contributes around a 6-7% annual reduction in the total output of the solar system. Tree shading is likely less than half the shading. Adding power optimizers would not replace the solar radiation blocked by the structure or trees but only eliminate the string amplification effect – at most a fraction of the 6% power reduction.

At this point, it does not appear cost effective to move the several rows of modules that are subject to shading, because of labor cost of rewiring the system to accommodate such a move.

It is time to focus on adding more modules to allow us to get to zero net energy. We might be able to use the COVID-19 pandemic as a means for using the pre-pandemic usage history (and the 30,000 kWh shortfall to justify adding more solar. The additional modules will not fit on the roof so we must consider adding them to the parking lot as car port solar. This will then allow further addition of charging stations – we will apply for a Colorado grant to fund several (around 3 as a minimum) bi-directional charging stations – we will need to write up the grant request and include the idea that the charging stations can be located next to the park and serve the general public – that the cost of the electric will be borne by the church solar. We may be able to figure out a way to donate any surplus solar electric to the community. That will reduce the amount of carbon burned by Xcel.

We can define a system that will produce 30,000 kWh per year with no shading – and put together a revenue neutral proposal. Rather than spend $6000 per year on Xcel electric, we will produce our own.

The idea of community solar is another way to reduce greenhouse emissions, but there is little to no financial gain for the church when it still has available rooftop and parking lot space for solar panels.

A summary of the shading investigation is provided in Figure 68.

Summary of Shading Losses (Based on 2020 Performance Data)

Production - No Shading	**84,098 kWh**	(based on PVWATTS Prediction)	
Losses due to Shading		(based on 2020 observations)	
Tree Shading	3,500 kWh		
Structural Shadi	1,510 kWh		
87° Tilt + Tree S	526 kWh		
Total Shading (	**5,535 kWh**	**6.6%**	
Production with Shading	**78,563 kWh**	(based on 2020 observed shading)	
Other Losses (e.g. weathe	**9,933 kWh**	(Deduced. Attributed to insufficent cloudy days in PVWATTS default weather model)	
Actual Production	**68,630 kWh**	(based on 2019, 2020 performance)	

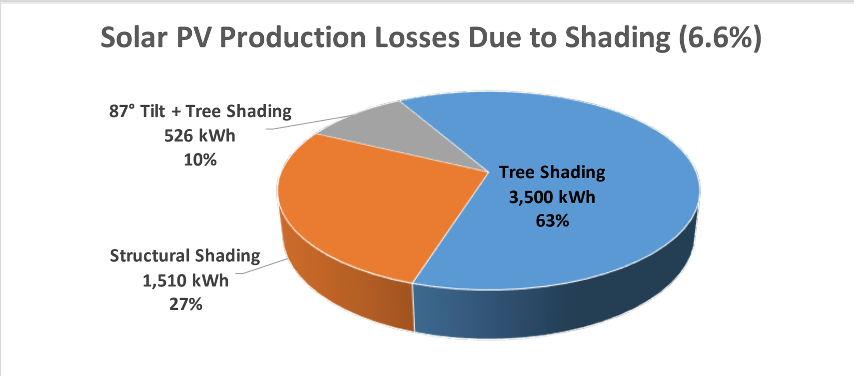


Figure 68 Summary of Shading Losses in 2020.

PVWATTS predicted the 56.8 kW system would produce around 84,098 kWh annually. Using 12 months of subarray production data, it appears that tree shading reduced the system output by about 3,500 kWh, structural shading by 1,150 kWh and tilting 6 modules 87 degrees + tree shading of the "Awning" modules lost 525 kWh. **The total shading losses were around 5,535 kWh or 6.6% of the expected /predict energy production.**

The measured system production for 2019 was 68,630 kWh, so we are deducing that other factors totaling 9,933 kWh were also involved in creating the discrepancy between the PVWATTS predicted performance and the actual production.

Note: Other factors include:

- PVWATTS used a weather model with excessive full sun days compared to the actual observations of 2019. This alone could explain the difference.
- Inspection of the cleanliness of the solar modules after two years on the roof, indicates there is some dust accumulation of portions of some modules,…).

The pie chart graphic in Figure 69 summarizes these observations. An inaccurate weather model for 2019 appears to be the primary source of error in the predicted performance (12%) ; failure to compensate for tree shading accounts for 4% of the discrepancy; and failure to avoid structural shading from parapet walls and inverter box shadows is the source of a 2% loss in production. Installing 6 modules on the south wall of the building tilted 87 degree as an "awning" to indicate the facility uses solar power (instead of mounting these 6 modules on the flat roof at a 10 degree tilt) created only a 1% loss.

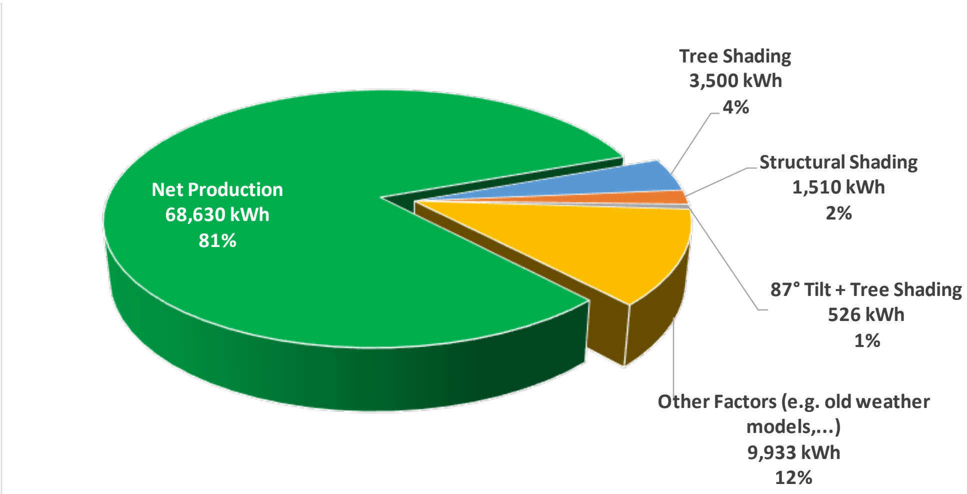


Figure 69 FUCD Solar PV Measured Production and Observed Discrepancies with PVWATTS Predicted Performance using Default Weather Model

Conclusions

After adding another eGauge meter to monitor the solar system at the subarray level, it was possible to sort out and quantify how shading was affecting the total production of the solar system on an annual basis. As this is being written, we have 11 months of data and made assumptions about the 12th month (Feb) based on the symmetry of the sun angles around the winter solstice. We assumed that Feb is similar to October where we have actual performance data. October will over predict the shading because there were some leaves still on the trees in October. An assessment of the situation uncovered the following guidelines.

1) Month by month, we found specific days that were good sun-days with few if any clouds. Such days eliminated the influence of the weather model on the PVWATTS predications and therefore provided reliable output performance data representing each month.
2) Next we observed there are six subarrays. Three involve Inverters (150 modules) and three utilize micro inverters (29 modules)
    a. Within the Inverter group, Inverter #2 utilizes 50 modules that are positioned so that shading from trees or other roof structure is minimal to zero. We used the Inverter #2 subarray as the "no shading" baseline. Any variation by the two other inverter subarrays is considered the result of shading.
    b. Inverter #3 subarray consists of 50 modules that are subject to tree shading but not structural shading.
    c. Inverter #1 subarray consists of 50 modules. 40 are subject to tree shading similar to Inverter #3 subarray, but 10 are influenced by structural shading from the mod parapet wall, the inverter boxes, the combiner panel, and other roof structure. The Difference between Inverter #3 and Inverter # 1 is probably due to structural shading of the 10 modules in the front row just north of the mid parapet wall.
    d. Within the micro inverter subarray group, there is one subarray, Oculus (12), that is high above the others tilted at 14° and not subject to shading. As a result, Oculus (12) is used as the baseline output for the micro inverter group.

e. The “Awning” subarray consists of 6 panels identical to the oculus subarray by half the number of modules – so theoretically the output should be half that of the baseline subarray Oculus (12). Any difference is due to a combination of the difference in tilt (87°versus 14°) and tree shading.
f. The third micro inverter subarray is labeled Oculus(6)+ Flat Roof(5) because it consists of 6 modules identical to the Oculus (12) subarray, but only 6 plus 5 panels identical to the other 150 on the flat roof. The Oculus (6) modules are next to the Oculus (12) and do not involve any possible shading. So any reduction in the expected output o this subarray must be due to structural shading of the 5 modules in the front row adjacent to the mid parapet wall.

Using these ground rules, we were able to evaluate the monthly output and quantify the effects of shading- we even discovered there were two types of shading that was affecting the system output – tree shading and structural shading.

Appendix O Energy Use/Consumption

Introduction

There are two methods of assessing the total amount of energy **used** by the facility over a 12-month period:
1) using data from the eGauge system and
2) using the information from the two Xcel Meters.

eGauge Meter

An independent monitoring system, an eGauge Meter, also measured solar production.   Figure 70 is a graphical display created by the eGauge monitoring system for a full year of operation.

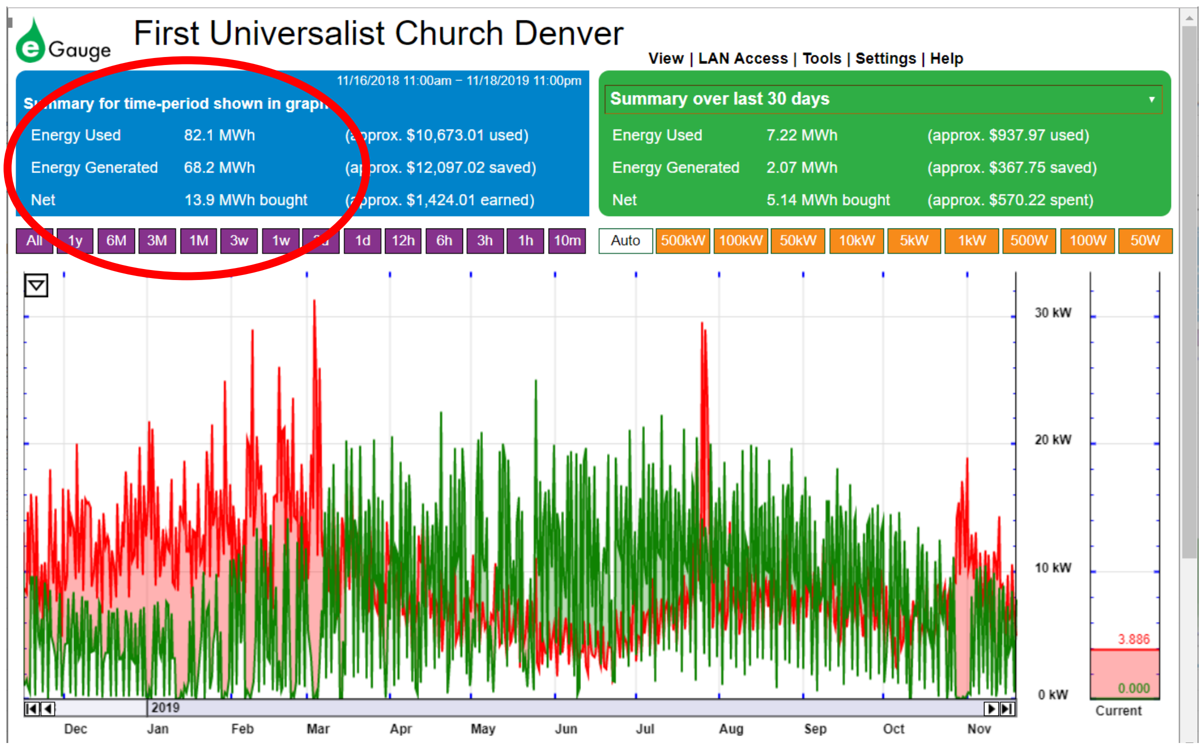


Figure 70 eGauge Measurements (16 Nov 2018 to 18 Nov 2019)   Green profile is Energy Production. Red profile is Energy Consumption.

This graphic shows the power generated in green and the power consumed by the church in red.   As expected in Colorado, peak energy production occurs during the summer months of April-May-June-July-Aug-Sep-Oct and peak energy consumption occurs during the winter months of Nov-Dec-Jan-Feb-Mar.

A summary of the energy generated by the solar PV system and the energy consumed by the facility over this time-period is provided in the blue box.   As indicated in the blue area, according to the eGauge monitoring system, the 'Energy Generated' was approximately 68,200 kWh – approximately 0.6% less than the 68,630 kWh indicated by the

Xcel Production Meter. Although the eGauge equipment is *ANSI C12.20 Revenue Grade Accuracy Compliant,* this is considered more than an adequate agreement between the two independent measurement systems.

As illustrated in Figure 70, there were several high-energy usage days in January, February, and March when heating requirements are the highest. Near the end of July 2019, when the cooling requirements were high, a high usage event occurred when First Universalist Church Denver hosted an extraordinary conference of 200 members of the Association for Unitarian Universalist Music Ministries (AUUMM). Apparently, the sound equipment and A/C for that many people consumed a lot of electricity. Peak demand was around 41 kW on Thursday, Friday & Saturday. It was an honor to have a renovated (solar-powered) facility capable of hosting this large group and support both the AUUMM music ministry and the UU Ministry for Earth (UUMFE).

It is unlikely that a power control system can limit energy use on Sundays and special events to under 25 kW to avoid Xcel's "Demand Charge." If the "Demand Limit" were to be adjusted to 50 kW by Colorado legislation/PUC regulations, then it would be possible to control usage below that limit. This seems like a viable short-term solution for faith-based organizations and small commercial businesses.

As indicated in the blue area of Figure 70, according to the eGauge monitoring system, **the 'Energy Used' from mid-Oct 2018 to mid-Oct 2019 was approximately 82,100 kWh**. Although the eGauge Meter can be compared directly to the Xcel Production Meter and was verified to agree within 0.6%, there is no similar direct comparison with the Xcel Net Meter as discussed below.

In addition to monitoring solar production and the total energy usage of the facility, the eGauge system can provide energy usage information for about 30 individual items as illustrated in the table at the bottom of Figure 71. These items include: 10 heat pump furnaces, 5 ERVs, 4 auxiliary electric heaters within heat pumps, water circulation pump, elevator, hot water heater, kitchen appliances, etc. Only Heat Pump #4 that services the office area is selected in the table for this 24-hour snapshot of 6 June 2019 – a good sunshine day. Heat Pump #4 receives a call for cooling around noon and runs continuously until around 4 pm – an indication it is undersized and struggles to maintain the set temperature.

The green shaded area in Figure 71 shows the energy transferred to the Xcel grid; the red area depicts the energy extracted from the grid.

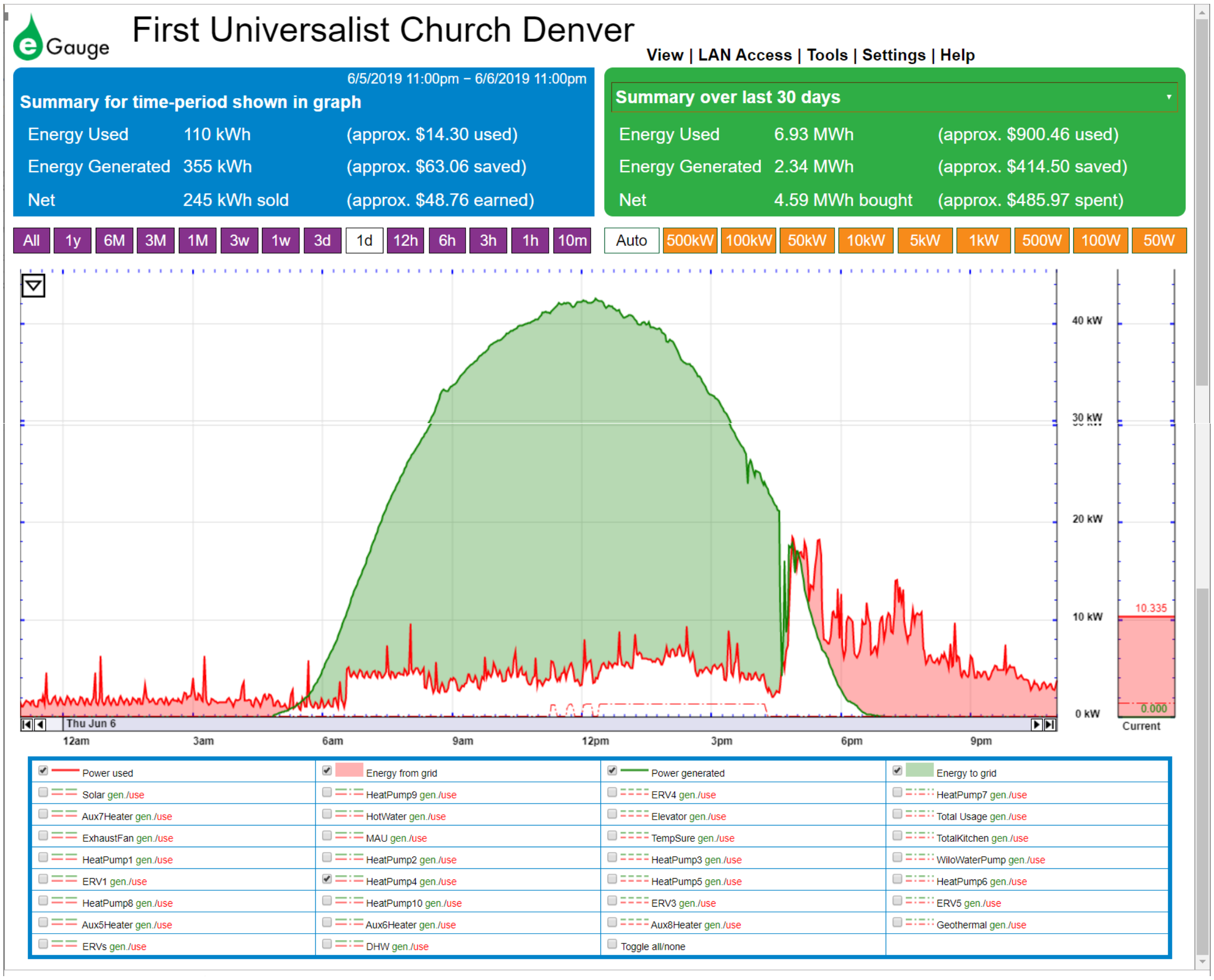


Figure 71 List of Energy-Related Equipment being monitored by the eGauge System

As stated earlier, the eGauge equipment is ANSI C12.20 Revenue Grade Accuracy Compliant; however, it was never intended to be used with revenue-grade accuracy by FUCD. The eGauge monitoring system does provide reasonably accurate performance data at the component level to better manage energy usage within the facility.

Xcel Net Meter & Xcel Production Meter.

A more accurate measure of energy usage /consumption is possible by using data from the two Xcel Meters (found in Table 29 or Table 30).

As depicted in Figure 36, a Net Meter monitors the "net" power transferred into the grid or withdrawn from the grid in 15-minute intervals for the SPVTOU-B rate schedule. A timestamp is added to this information to differentiate between On-Peak and Off-Peak times-of-use. The utility company can then use this information to construct complex rate schedules for billing purposes. Normally, the detailed information of Figure 72 is not made available to the customer on the monthly summary, but it can be found online. The daily 15-minute interval data can be purchased from Xcel for an additional fee.

The information in Figure 72 and Table 29 illustrates the detail information provided by the Xcel Net Meter. It also illustrates the complexity of the Xcel SPVTOU-B rate schedule for commercial customers in the Solar Rewards® Medium Program such as the First Universalist Church Denver.

Last Read Date	Billing Days	Usage	Read Method	Show Details
October 20, 2019	31	-8298	Actual	—

Off Pk Delivered by Xcel: 2930.00 kWh
Total Delivered by Customer: 3065.00 kWh
Off Net Generated by Customer: 5330.00 kWh
Total Delivered by Xcel: 3160.00 kWh
Off Pk Delivered by Customer: 2571.00 kWh
On Pk Delivered by Customer: 494.00 kWh
Billable Demand: 22.00 kW
On Net Generated by Customer: 2968.00 kWh
Total Electric Charges: $286.45
ECA Off-Peak: $8.98
Distribution Dmd: $123.86
RESA FS: $7.02
Srv & Facility: $34.40
Gen & Transm Dmd: $16.54
ECA On-Peak: $0.00
Dem Side Mgmt Cost: $9.18
Renew. Energy Std Adj: $5.32
SPVTOUB OnPk: $0.00
Cooling Degree Days: 0

On Pk Delivered by Xcel: 230.00 kWh
ECA On Pk: 0.00 kWh
Generation&Transmission Demand: 11.00 kW
Off Pk Net Delivered by Xcel: 0.00 kWh
On Pk Net Delivered by Xcel: 0.00 kWh
ECA Off Pk: 999.00 kWh
Demand: 18.00 kW
Electric Charges: $278.11
Total Electric Charges / Day: $9.24
ECA Off-Peak: $14.47
Purch Cap CostAdj: $22.32
GRSA: -$8.09
Gen & Transm Dmd: $16.03
SPVTOUB OffPk: $0.00
ECA On-Peak: $0.00
CACJA: $16.74
Trans Cost Adj: $11.34
Average Temperature: 56 ° F
Heating Degree Days: 0

Figure 72 Xcel Net Meter Monthly Report for SPVTOU-B Commercial Customers (Available on-line)

As indicated in Table 29, determining the monthly "electric bill" requires 40 columns of an Excel spreadsheet (from A to AN) to capture all the "data" used to construct the monthly charge.

Typical criteria used by Xcel to determine the monthly bill include:

Electrical usage, Off Peak Delivered by Xcel, On Peak Delivered by Xcel, Total delivered by Customer, ECA On Peak, Off Net Generated by Customer, etc. Each of these categories is then assigned a cost based on the rate negotiated with the PUC to establish a "Total Electric Charge" that is to be paid by the customer (Column U). Column Q "Billable Demand" is of particular importance because it reflects the 'Peak Demand' observed during any 60 minute period within the 30 day billing period. The 'Peak Demand' during a billing period determines the 'Demand Charges.'

Table 29 Xcel Billing Data Showing 40 Columns of Net Meter "information" (Available On-line)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
3	Customer Nam	FIRST UNIVERSALIST CHURCH																		
4	Account Numb	53-2125618-2																		
5	Account Address																			
6	Premises Numl	3E+08																		
7	Premises Addi	4101 E HAMPDEN AVE DENVER CO 80222-7262																		
8	Premises Statu	CURRENT																		
9	Service	ELECTRIC-1																		
12	Last Read Date	Billing Days	Electrical Usage (kWh)	Read Method	Off Pk Delivered by Xcel (kWh)	On Pk Delivered by Xcel (kWh)	Total Delivered by Customer (kWh)	ECA On Pk (kWh)	Off Net Generated by Customer (kWh)	Generation& Transmission Demand (kW)	Total Delivered by Xcel (kWh)	Off Pk Net Delivered by Xcel (kWh)	Off Pk Delivered by Customer (kWh)	On Pk Net Delivered by Xcel (kWh)	On Pk Delivered by Customer (kWh)	ECA Off Pk (kWh)	Billable Demand (kW)	Demand (kW)	On Net Generated by Customer (kWh)	Electric Charges
13	10/20/2019	31	-8298	Actual	2930	230	3065	0	5330	11	3160	0	2571	0	494	999	22	18	2968	$278.11
14	9/19/2019	30	-8393	Actual	2478	762	3458	0	5689	12	3240	0	1968	0	1490	1192	22	19	2704	$309.57
15	8/20/2019	29	-5175	Actual	2668	1003	3309	0	3199	41	3671	0	1777	0	1532	1502	41	41	1976	$614.05
16	7/22/2019	32	-7344	Actual	1842	381	5024	0	4365	10	2223	0	3060	0	1965	0	22	16	2979	$262.54
17	6/20/2019	30	-4542	Actual	1814	137	5498	0	3147	5	1951	0	3966	0	1532	0	22	18	1395	$242.96
18	5/21/2019	29	-995	Actual	2777	0	3772	0	995	12	2777	0	3772	0	0	230	22	20	0	$261.17
19	4/22/2019	29	777	Actual	3854	0	3077	0	0	13	3854	777	3077	0	0	1899	28	28	0	$383.05
20	3/24/2019	31	5705	Actual	7653	0	1948	1466	0	28	7653	5705	1948	0	0	4239	43	43	0	$780.67
21	2/21/2019	30	8679	Actual	9214	0	535	3720	0	43	9214	8679	535	0	0	4959	43	43	0	$986.57
22	1/22/2019	34	9493	Actual	9780	0	287	3385	0	26	9780	9493	287	0	0	6108	37	37	0	$929.23
23	12/19/2018	33	7052	Actual	7609	0	557	2275	0	21	7609	7052	557	0	0	4777	29	29	0	$715.49
24	11/16/2018	29	3515	Actual	4879	0	1364	814	0	25	4879	3515	1364	0	0	2701	30	30	0	$546.09

T Electric Charges	U Total Electric Charges	V Total Electric Charges / Day	W ECA Off-Peak	X ECA Off-Peak	Y Distribution Dmd	Z Purch Cap CostAdj	AA RESA FS	AB GRSA	AC Srv & Facility	AD Gen & Transm Dmd	AE Gen & Transm Dmd	AF SPVT OUB OffPk	AG ECA On-Peak	AH ECA On-Peak	AI Dem Side Mgmt Cost	AJ CACJA	AK Renew - Energy Std Adj	AL Trans Cost Adj	AM SPVT OUB OnPk	AN Average Temperature (˚F)
$278.11	$286.45	$9.24	$8.98	$14.47	$123.86	$22.32	$7.02	($8.09)	$34.40	$16.03	$16.54	$0.00	$0.00	$0.00	$9.18	$16.74	$5.32	$11.34	$0.00	56
$309.57	$318.86	$10.63	$30.19		$123.86	$23.56	$11.87	($8.80)	$34.40	$49.32		$0.00	$0.00		$9.69	$17.67	$5.84	$11.97	$0.00	72
$614.05	$632.48	$21.81	$38.05		$230.83	$50.84	$13.14	($18.39)	$34.40	$168.51		$0.00	$0.00		$20.91	$38.13	$11.80	$25.83	$0.00	76
$262.54	$270.42	$8.45	$0.00	$0.00	$123.86	$19.84	$14.10	($8.72)	$34.40	$41.10		$0.00	$0.00	$0.00	$2.50	$14.88	$4.89	$10.08	$0.00	72
$242.96	$250.24	$8.34	$0.00		$123.86	$22.32	$11.39	($8.23)	$34.40	$3.89	$13.69	$0.00	$0.00		$9.00	$16.74	$4.56	$11.34	$0.00	61
$261.17	$269.00	$9.28	$5.95		$123.86	$24.80	$6.69	($8.70)	$34.40	$27.96		$0.00	$0.00		$10.00	$18.60	$5.01	$12.60	$0.00	51
$383.05	$394.53	$13.60	$13.79	$37.24	$157.64	$34.72	$6.57	($10.83)	$34.40	$30.29		$14.17	$0.00	$0.00	$14.00	$26.04	$7.38	$17.64	$0.00	49
$780.67	$804.10	$25.94	$127.51		$242.09	$53.32	$6.12	($18.89)	$34.40	$65.24		$104.06	$63.05		$21.50	$39.99	$15.19	$27.09	$0.00	34
$986.57	$1,016.18	$33.87	$149.17		$242.09	$53.32	$3.92	($22.68)	$34.40	$100.19		$156.30	$160.00		$21.50	$39.99	$19.28	$27.09	$0.00	30
$929.23	$957.11	$28.15	$118.88	$64.72	$208.31	$17.50	$3.00	($20.20)	$34.40	$60.58		$173.15	$94.20	$51.28	$8.10	$11.88	$18.16	$6.27	$0.00	35
$715.49	$736.96	$22.33	$143.41		$163.27	$38.86	$4.00	($15.90)	$34.40	$48.93		$128.63	$97.64		$17.98	$26.39	$13.96	$13.92	$0.00	39
$546.09	$562.47	$19.40	$81.08		$168.90	$40.20	$7.14	($13.81)	$34.40	$58.25		$64.11	$34.94		$18.60	$27.30	$10.58	$14.40	$0.00	46

A condensed version of Table 29 is provided in Table 30 below. Only 11 of the 40 columns in the Xcel statement are included in Table 30. Many of the columns have been "hidden" to simplify this discussion.

Column AW (shown in green) was added from the Xcel Production Meter data (Account 53-0012186178-0) provided earlier in Table 29. **Column D was added** to provide information that is not provided by Xcel for customers who install a solar PV system. The missing information is the amount of **Energy Consumed** by the facility – a very important piece of information for customers wishing to manage (and minimize) their energy usage, but strangely not provided directly by the utility company for solar customers.

The **Energy Consumed** by the facility can be calculated using the data from both the Production Meter account and the Net Meter account. The following equation (later validated by Xcel – see Appendix O) was used:

Energy Consumed (Col D) = Energy_Produced (Production Meter, Table 30, Col AW)
– Energy_Delivered_by_Customer (Net Meter, Table 30,Col G)
+ Energy_Delivered_by_Xcel (Net Meter, Table 30,Col K) **[eq. 2a]**

As indicated in Row 21, Col D of Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version), the **Energy Consumed over a 12 month period from 11/17/2018 to 11/19/2019 was 98,019 kWh based on the Xcel meter readings.** This is a significant increase from the 82,100 kWh measured by the eGauge meter.

... the renovated church *facilty used/consumed 98,019 kWh over a 12 month period.* *(11/17/2018 to 11/19/2019)*

DRAFT

Table 30 Xcel Billing Data for a 12-month period from 11/17/2018 to 11/18/2019. (Condensed Version)

	A	C	D	G	H	I	K	L	M	N	O	P	S	AW	AY	AZ
1	Customer Name	FIRST UNIVERSALIST CHURCH			Usage Report		10/29/2019									
2	Account Number	53-2125618-2														
3	Premises Number	3.01E+08														
4	Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262														
6							NET METER DATA							PRODUCTION METER DATA	eGUAGE DATA	
7		I+L+N+S	Consumption = Production - G+K	M+O			E+F									
8	Last Read Date	Electrical Usage (kWh)	Church Consumption (kWh)	Total Delivered by Customer (kWh)	ECA On Pk (kWh)	Off Net Generated by Customer (kWh)	Total Delivered by Xcel (kWh)	Off Pk Net Delivered by Xcel (kWh)	Off Pk Delivered by Customer (kWh)	On Pk Net Delivered by Xcel (kWh)	On Pk Delivered by Customer (kWh)	ECA Off Pk (kWh)	On Net Generated by Customer (kWh)	Production Data (Monthly) using Xcel Bill (kWh)	Raw eGauge Usage Data (See Monthly Snapsots)	Recalibrated eGauge Consumption
9	11/18/2019	-3511	**7920**	**1099**	1452	543	**5886**	0	1099	0	0	3335	2968	**3133**	6610	8092
10	10/20/2019	-8298	**5920**	**3065**	0	5330	**3160**	0	2571	0	494	999	2968	**5825**	4750	6050
11	9/19/2019	-8393	**6993**	**3458**	0	5689	**3240**	0	1968	0	1490	1192	2704	**7211**	5710	7127
12	8/20/2019	-5175	**8095**	**3309**	0	3199	**3671**	0	1777	0	1532	1502	1976	**7733**	6880	8373
13	7/22/2019	-7344	**5893**	**5024**	0	4365	**2223**	0	3060	0	1965	0	2979	**8694**	4570	5843
14	6/20/2019	-4542	**4345**	**5498**	0	3147	**1951**	0	3966	0	1532	0	1395	**7892**	3180	4184
15	5/21/2019	-995	**5732**	**3772**	0	995	**2777**	0	3772	0	0	230	0	**6727**	4390	5634
16	4/22/2019	777	**7069**	**3077**	0	0	**3854**	777	3077	0	0	1899	0	**6292**	5690	7105
17	3/24/2019	5705	**11178**	**1948**	1466	0	**7653**	5705	1948	0	0	4239	0	**5473**	9690	11067
18	2/21/2019	8679	**12189**	**535**	3720	0	**9214**	8679	535	0	0	4959	0	**3510**	10800	12015
19	1/22/2019	9493	**12207**	**287**	3385	0	**9780**	9493	287	0	0	6108	0	**2714**	10700	11932
20	12/19/2018	7052	**10478**	**557**	2275	0	**7609**	7052	557	0	0	4777	0	**3426**	9130	10563
21		**31706**	**98019**	**31629**	**12298**	**23268**	**61018**	**31706**	**24617**	**0**	**7013**	**29240**	**14990**	**68630**	**82100**	**97985**
22		**Generated**	**68630**		41538	38258	29389		**31630**						84%	100%
23		**Shortfall (Purchased)**	**29389**													

Investigating why the monitoring systems do not agree.

Columns AY & AZ (shown in tan) were added to Table 30 from the eGauge monitoring system for comparison with Col D derived from the Xcel Meters. As indicated in the blue box of Figure 70, the unverified eGauge system indicated the "Energy Used" for this 12-month time-period was 82,100 kWh – around 20% lower than the value derived from the Xcel Meter data.

Possible Calibration Error in the eGauge System. Column AZ is the "Recalibrated" eGauge information modified to illustrate a possible 20% error in the calibration of the three rope CTs used to monitor the Total Facility Consumption. Figure 73 compares the Xcel derived energy consumed from equation 2a (shown as the solid blue line) and the raw data from the eGauge system shown as the broken blue line. When a simple linear correction (of approximately 20%) is applied to the eGauge data, the corrected eGauge data (shown as the solid red line) maps closely with the Xcel Meter data.

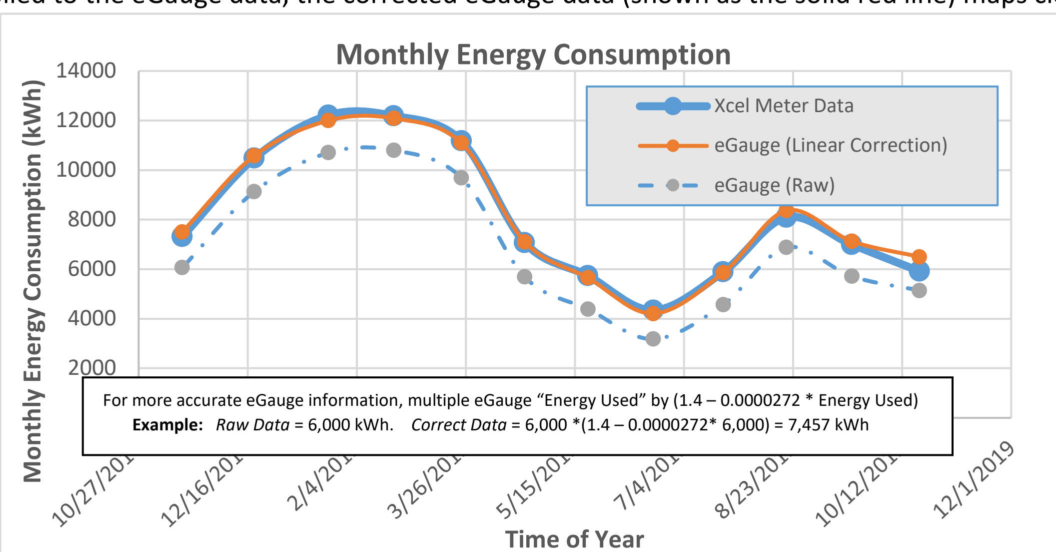


Figure 73 First Universalist Monthly Energy Consumption over the course of one year.

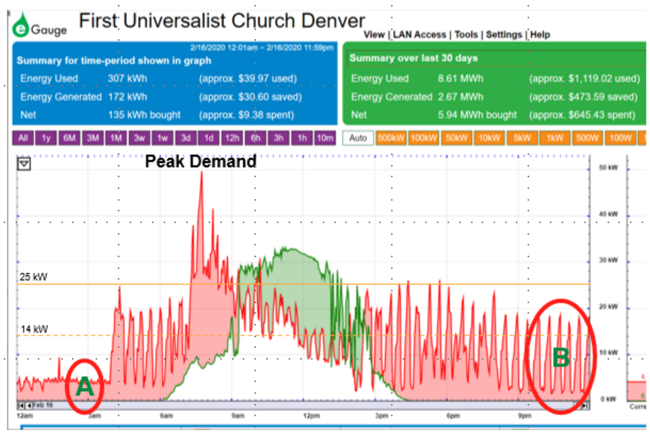
Consultation with the eGauge technical support personnel indicated a 20% error in the calibration of the rope CTs was highly unlikely. **See Appendix B for more details.**

Evaluation & Comparison of Xcel 15 minute interval data with eGauge performance data

The performance of the new sustainable energy system is monitored by two independent measuring systems: 1) two Xcel-owned meters and 2) an FUCD-owned eGauge meter. The two monitoring systems agree on the amount of ‘energy generated’ annually by the solar PV system (68,630 kWh). However, the ‘energy used’ by the church facility annually differs by around 20%. In an effort to help understand the reason for this significant difference, **Xcel provided 15-minute interval data recorded by their meters from 11/30/2019 12:15 AM to 2/20/2020** for further assessments. It was then possible to compare the Xcel meter data with the 1-minute interval eGauge meter data.

We examined one day of the Xcel 15-minute interval data, 2/16/2020, a Sunday, in detail for illustration purposes. A summary of that assessment is provided in the chart below.

Sustainable Energy System Operation - Overview



Red denotes Energy Usage
Green denotes Energy Generation/Solar Production

24 hour perspective – 16 Feb 2020 (Sunday)

- Not a great Sun (Solar) Day
- All 10 Heat Pump furnaces were operating at Peak Demand around 7:45 AM

	Xcel	eGauge	Xcel / eGauge
Energy Used (kWh)	342	307	111%
Energy Generated (kWh)	174	172	101%
Net Energy (kWh)	-168	-135	124%
Peak Demand (kW)	35	42	83%
Daily Average Demand (kW)	14.2	12.8	111%
Average Demand (kW) Time Period “A” (2:00 AM – 4:00 AM)	6.01	4.44	135%
Average Demand (kW) Time Period “B” (9:00 PM – Midnight)	11.2	8.45	133%

The table summarizes the general observations that:

1) The ‘Energy Used’ by the church facility over a given 24-hr period, was measured by the Xcel Net Meter to be around 11% more than that measured by the eGauge monitoring system.
2) The Energy Generated by the solar PV system was around 174 kWh as measured by both monitoring systems.
3) The peak demand using the Xcel 15-minute interval data was 35 kW when all 10 furnaces were operating around 7:45 AM. Using the eGauge data (1-minute interval), the peak demand was 42 kW.
4) The daily average demand was just over 14 kW.
5) The 30-35% difference in meter readings in time zones “A” and “B” when there is no solar production, (when the Net Meter is functioning as a traditional electric meter) is a significant observation that must be explored further. If all the meters are functioning properly, then it would suggest either the Xcel Net Meter or the eGauge rope CTs are not “wired” correctly – are not on the correct wires.

For more details of the Xcel meter and eGauge meter comparison, see Appendix P.

Operation in 2019 Resulted in an Energy Shortfall

Based on the current understanding that the energy production for the past 12 months was 68,630 kWh and the energy usage was 98,019 kWh, **there was a 29,389 kWh shortfall in production.** This energy was purchased from Xcel who generated 72% of it by burning hydrocarbons and dumping 20 metric Tonnes of GHG into the atmosphere. We learned later that the actual amount of **energy purchased from Xcel was 31706 kWh** (see Row 21 Col L of Table 4.)

The reasons for the difference between the current energy production and energy consumption are two-fold.

c. The **energy used** by the facility (98,019 kWh) over the past 12 months **exceeded the amount predicted** by the architect's Annual Energy Usage model (75,349 kWh) by 29%. [See the red circle in Table 31, Col O.] It was anticipated that the electrical usage would increase somewhat due to the replacement of gas furnaces with ground-source heat pumps. Heat pump furnaces have an additional electric motor to operate the heat pump compressor that exchanges free thermal energy with the ground (instead of burning natural gas for thermal energy.)

Rows 32 through 38 were added as part of the energy assessment for this report. Row 36 of Table 31 is the same as Row 31 but combines the electrical **energy required by the geothermal heat pumps for heating & cooling**. The architect's **prediction was 22,657 kWh of electrical energy** would be required to provide 86,777 kBTU (25,426 kWh) of cooling in the summer and 230,268 kBTU (67,469 kWh) of heating in the winter. The **actual annual energy usage** measured by the eGauge system to operate the 10 heat pump furnaces and 5 ERVs was **21,114 kWh – 7% less than expected.**
The geothermal system and ERVs were not the sources of unexpected additional energy usage.

The architect's estimates of the energy required for domestic hot water (DHW) was 131 therms (3825 kWh). Actual usage of the electric hot water heater and the TempSure water heater only 112 kWh for the past 12 months. **DHW was not the source of unexpected additional energy usage.**

The source of unexpected energy usage must be "Receptacle Loads" and "Lighting." The eGauge system does not monitor the outlets throughout the facility, nor the lighting. The combined electrical loads in the new kitchen were monitored and found to be nearly 10,000 kWh (nearly twice that expected for all the "Receptacle Loads." So the source of the unexpected energy usage has not yet been determined, but it appears to be in the "Receptacle" & "Lighting" categories that are not being monitored.[52]

Table 31 Architect's Preconstruction Assessment of Annual Energy Usage Compared to Actual Performance

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
28	Annual Usage (NEW DESIGN - SOLAR/GEOTHERMAL - DMA Model)																
29	System	Receptacle Loads (Solar)		Lighting (Solar)		Cooling EER (BTUh/Watts) = (Solar/Ground-Source Heat Pumps)	14.0	Heating COP= 4.1 (Solar/Ground-Source Heat Pumps)			DHW (Solar/Air-Source Heat Pump)			Total Energy Usage			
30	Name	kBtu	KWh	kBtu	KWh	kBtu	kWh	kBtu	kWh	Therms	kBtu	kWh	Therm	kBtu	[illegible]	Therms	
31	Predictions	*17,983*	5,270	*148,753*	43,597	*21,159*	6,201	*56,147*	16,456	*562*	*13,050*	3,825	*131*	*257,165*	75,349	*692*	Electric - Solar PV
32								230,268	*67,469*	*2,303*				230,268	[illegible]		Heating - Thermal Energy from Earth
33		(RED Denotes Thermal Energy)				86,777	*25,426*							86,777	*25,426*		Cooling - Thermal Energy into Earth
34		(Values in italics are alternate units)												317,045	*92,894*		Total Thermal Energy Exchanged
36	Predictions		5,270		43,597	22657					3825			75349			
37	Actuals	9,953	Kitchen Only	66,235	Other	21114					112			97414			
38		89%	OVER	52%	OVER		-7%		UNDER (includes 10 Heat Pumps & 5 ERVs)			-97%	UNDER		29%	OVER	

[52] A new energu monitoring product, see sense.com may help identified the source of this usage.

d. The **energy generated** by the rooftop solar (68,019 kWh) **was less than predicted** by the Solar PV sizing model PVWATTS using the default weather model (84,460 kWh).[53] (See Appendix L for details)

A number of possible explanations for the difference in actual production versus predicted production are discussed in this report. This issue is still under investigation.

The most probable causes of the shortfall are linked to:
1) partial shading of some modules by two deciduous trees on the south side of the array along Hampden Ave, (shading was not included in the original solar sizing analysis. There is insufficient instrumentation on the various strings of the solar PV system to quantify the power loss due to shading), and

2) the use of the default "weather model" in the PVWATTS computer model that did not reflect the change in climate that has already occurred in the Denver area. The default weather model used average weather conditions from between 5 to 10 years ago. By examining the "hourly" data from PVWATTS with the actual hourly data from last year in Appendix L, it is obvious that last year there was increased cloud cover (and snowfall that temporarily blanketed solar PV panels) from the 5 to 10-year-old weather model – a simple reason why actual production was less than predicted. The difference in hourly data between the PVWATTS prediction and the actual measurements can be quantified and it explains the observed 20% difference in solar electric production (without introducing the effects of partial shading.) See Appendix L for a detailed discussion of the PVWATTS weather model.

Conclusions 2019

So, did the facility operate in 2019 at Net-Zero Energy as intended? No. But it can easily be adjusted to be Net Zero Energy.

Based on Xcel Meter data for a 12-month period from 11/17/2018 to 11/18/2019, the new energy system missed the Net Zero Energy goal.

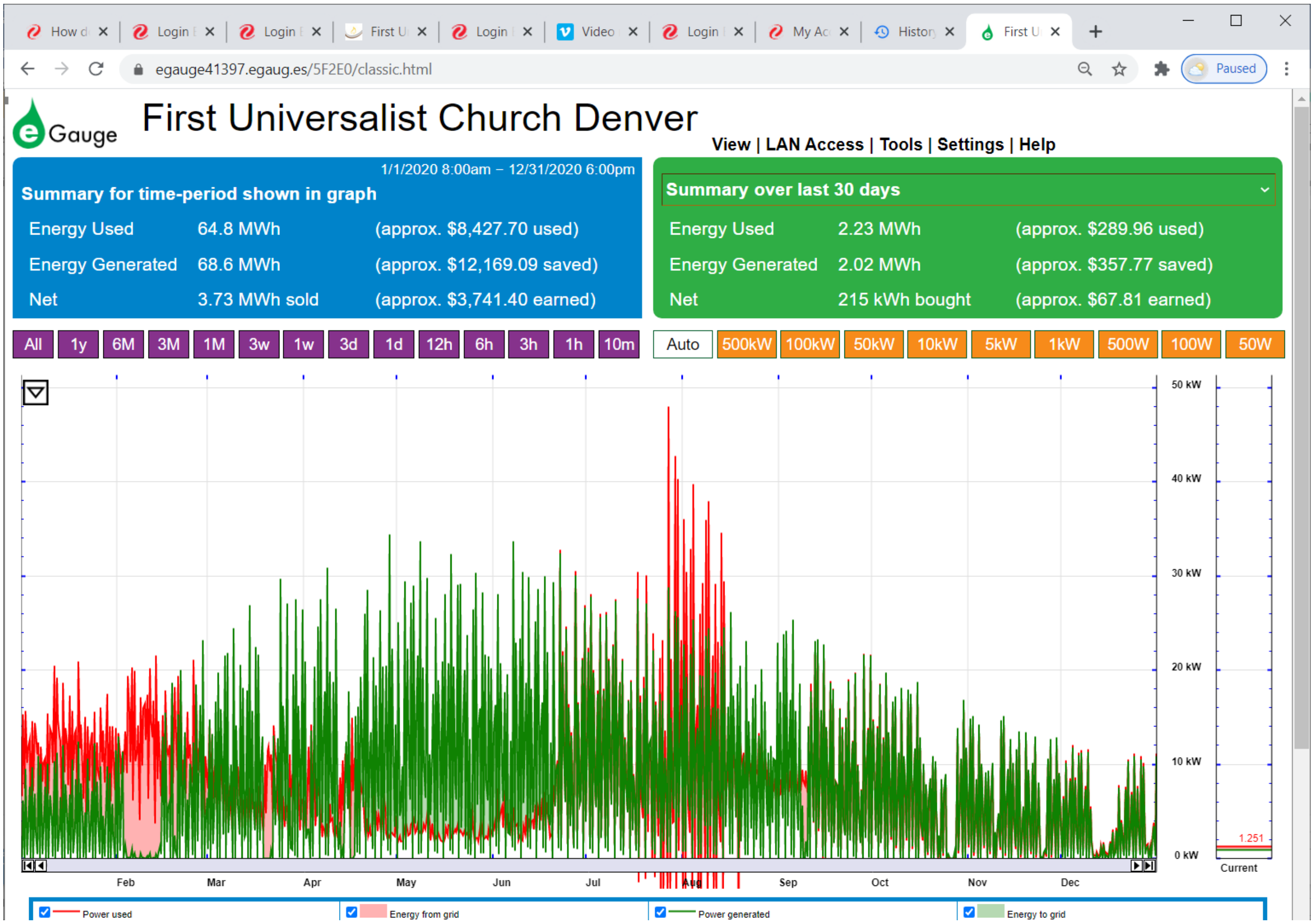
- The actual energy generated by the solar PV system was 68,630 kWh.
- The energy consumed by the facility was 98,019 kWh.
- There was a 29,389 kWh annual shortfall in energy production.

Production must increase by 43% to reach 98,019 kWh and achieve Net Zero Energy.

Recommendations

- Capability for monitoring the performance of the solar PV system at the string level or module level will be added. (The Xcel Production Meter provides monthly data and the eGauge Meter provides hourly system-level production data only.)
- Modifications can be made to the solar PV system to accommodate partial shading by two deciduous trees on the south side of the facility after the extend of shading has been quantified.
- Additional solar PV modules will be installed to make up the shortfall and achieve the goal of net-zero energy.

[53] The PVWATTS computer model (using the default weather model) estimated the FUCD 57 kW solar PV system would produce 84,460 kWh with an uncertainty range of 78,430 to 86,900 kWh. In retrospect, instead of using the PVWATTS default weather model which was for Boulder, CO, a weather model closer to the church (NREL , Golden) would have predicted less production (72,219 kWh), but still more than the 68,630 kWh actually produced.



The energy production of the FUCD solar system for the calendar year 2020 was 68,958 kWh compared to 68,630 kWh for 2019. Essentially the same considering the weather uncertainties. Everything else (number and location of modules, Inverters and micro inverters, shading, etc.) remained the same – only the day-to day weather / cloud cover was of course different. The conclusion is: The weather (cloud cover/rain/snow/fog) was the only variable from 2019 to 2020. 2019 was not an “unusual” year for weather because on an average, 2020 was nearly the same.

Appendix P Comparison of Xcel 15-minute interval data with eGauge performance data

Introduction / Overview

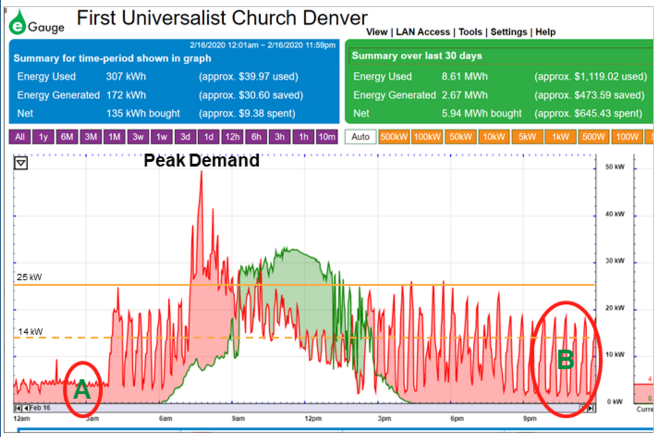
The performance of the new sustainable energy system is monitored by two independent measuring systems: 1) two Xcel-owned meters and 2) an FUCD-owned eGauge meter.

The two monitoring systems agree on the amount of ‘energy generated’ annually by the solar PV system (e.g. 68,630 kWh in 2019). However, the ‘energy used’ by the church facility in 2019 differed by around 20%. In an effort to understand the reason for this significant difference, Xcel provided 15-minute interval data recorded by their meters from 11/30/2019 12:15 AM to 2/20/2020 for further assessments. It was then possible to compare the Xcel meter data with the 1-minute interval eGauge meter data.

The Xcel monitoring system consists of a Production Meter and a Net Meter. The Production Meter (S/N 68537839) measures the amount of energy generated by the solar system. The Net Meter (S/N 81909056) measures the amount of energy drawn from the grid or the amount of energy pushed onto the grid when the solar system is operating. Although readings are recorded in 15-minute intervals, Xcel only provides a monthly summation of the system performance. However, because the Green First team requested verification of the Xcel Net Meter, David Wynkoop, Xcel technical support, provided a spreadsheet of 15-minute interval data to compare with the eGauge data.

We examined one day, 2/16/2020, a Sunday, in detail for illustration purposes. A summary of the assessment is provided in Figure 74.

Sustainable Energy System Operation - Overview



eGauge Measurements (1 min intervals)

- **Red denotes Energy Usage**
- **Green denotes Energy Generation/Solar Production**

24 hour perspective – 16 Feb 2020 (Sunday)

- Not a great Sun (Solar) Day
- All 10 Heat Pump furnaces were operating at Peak Demand around 7:45 AM

	Xcel	eGauge (15 min)	Δ % (Xcel –eGauge)
Energy Used (kWh)	342	307	10%
Energy Generated (kWh)	174	172	1%
Net Energy (kWh)	-168	-135	20%
Peak Demand (kW)	35	42	-20%
Daily Average Demand (kW)	14.2	12.8	10%
Average Demand (kW) Time Period “A” (2:00 AM – 4:00 AM)	6.01	4.44	26%
Average Demand (kW) Time Period “B” (9:00 PM – Midnight)	11.2	8.45	24%

Figure 74 eGauge Record of the Sustainable Energy System Operation for One Day, 2/16/2020

The table in Figure 74 summarizes the general observations that:

1) The ”Energy Generated” by the solar PV system was around 174 kWh as measured by both monitoring systems with only a 1% difference.
2) The ‘Energy Used’ by the church facility over a given 24-hr period, was measured by the Xcel Net Meter to be around 11% more than that measured by the eGauge monitoring system.
3) The Net Energy for the day was a shortfall of 168 kWh according to the Xcel Net Meter. A 135 kwh shortfall was measured by the eGauge system, 20% less.
4) The peak demand using the Xcel 15-minute interval data was 35 kW when all 10 furnaces were operating around 7:00 AM. Using the eGauge data (1-minute interval), the peak demand was 42 kW.
5) The daily average demand (for Sunday, 16 Feb 2020) according to Xcel was just over 14 kW.
6) There is no solar production in the time zones circled and labelled “A” and “B.” The Xcel Net Meter is functioning as a traditional electric meter and measuring the energy consumption of the facility in 15 minute intervals. The eGauge sensors are recording the same usage every minute. But there is a 24-26% difference in meter readings.

Because the difference in energy consumption was significant, a more detailed assessment was initiated.

Detailed Comparison of the Xcel Net Meter readings and the FUCD Total Usage readings.

Observations:

a) the Xcel data uses Central Time whereas the eGauge data uses Mountain Time as indicated in Figure 75. e.g. eGauge 8:00 am = Xcel 9:00 am.

b) the eGauge data was recorded in one-minute intervals. To compare directly with the Xcel data, the eGauge raw data was then averaged over 15-minute intervals.

c) the Xcel & eGauge Energy Generation data (solid green curves) are slightly different, but probably similar enough for our comparison purposes.

d) the Energy Consumption profiles (dashed green lines) are slightly different, but probably similar enough for our purposes.

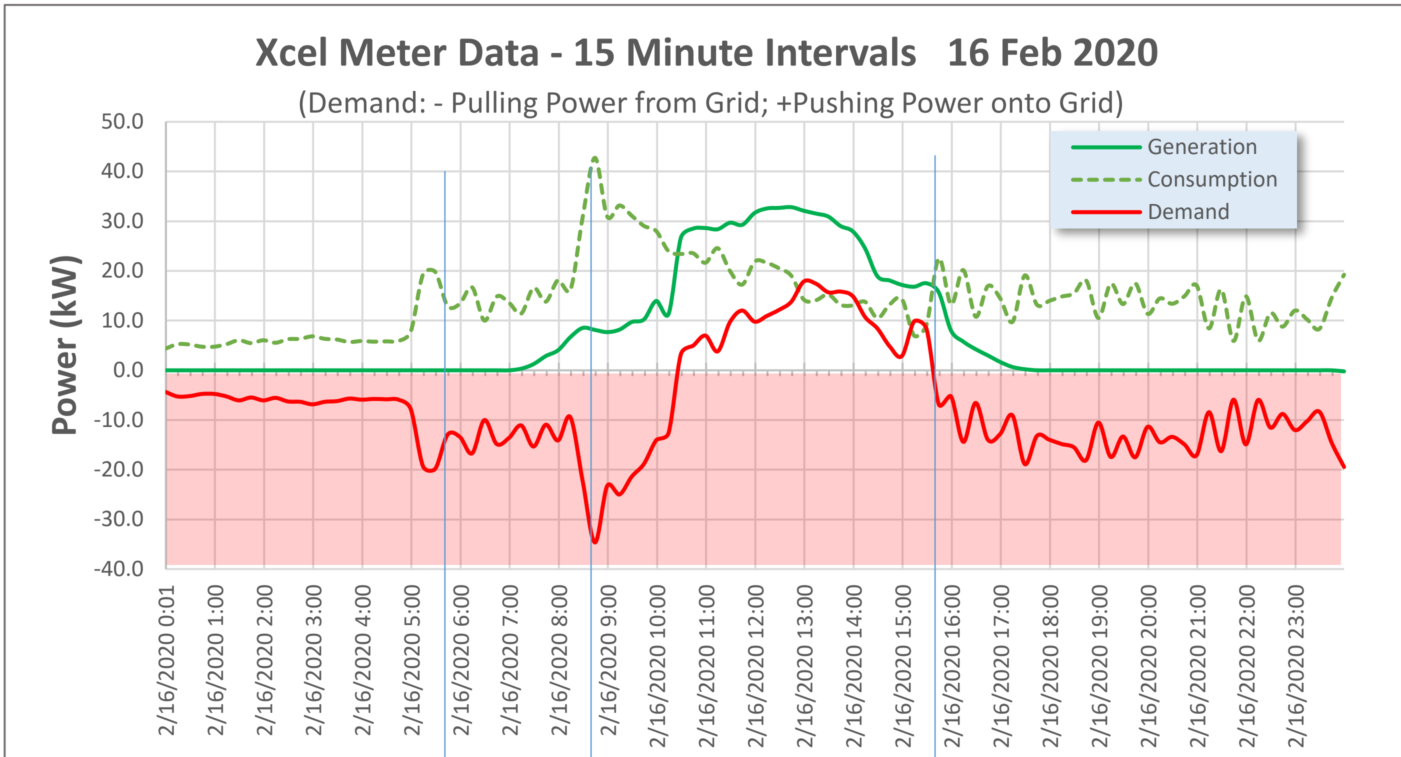
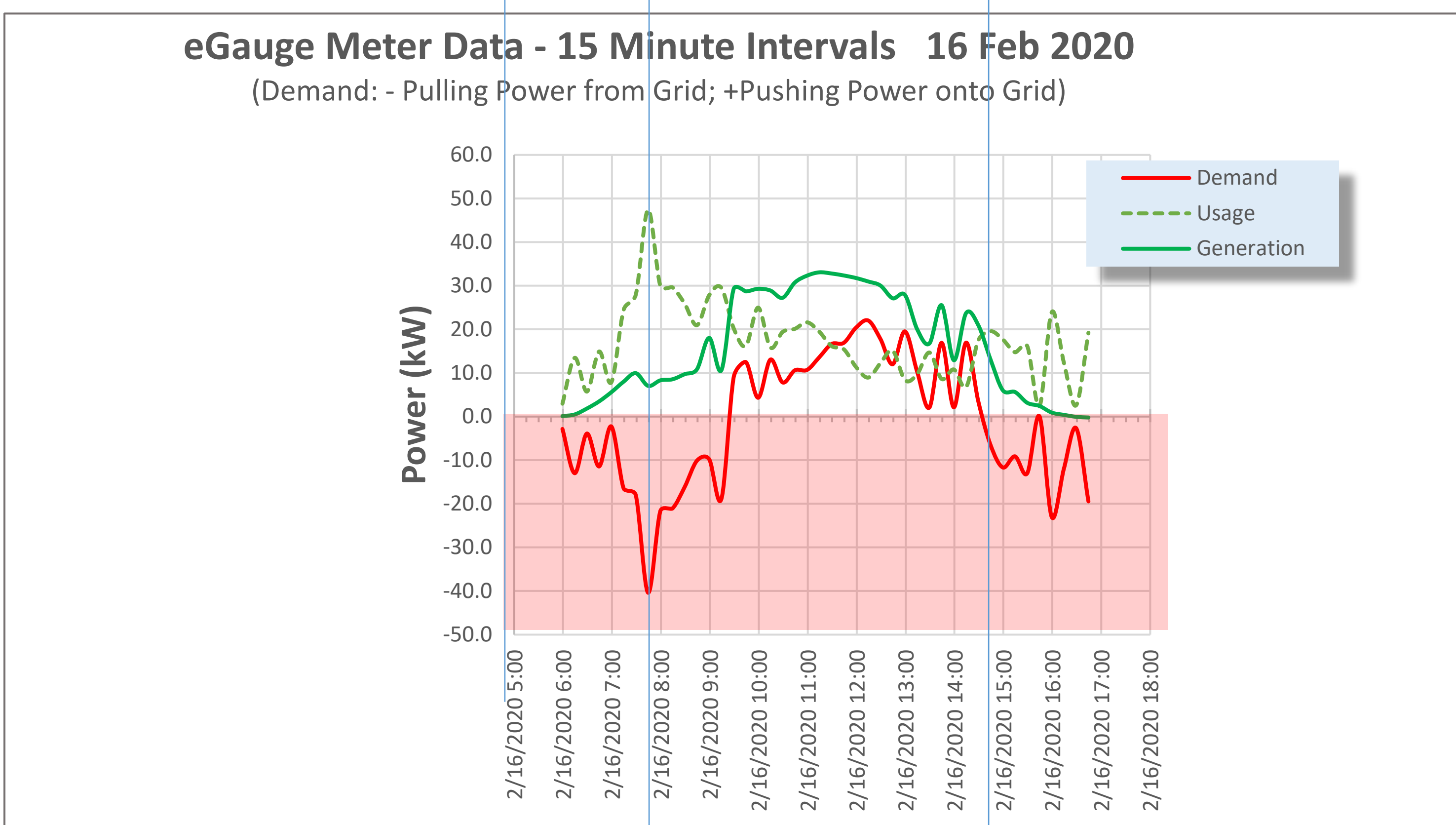


Figure 75 Xcel and eGauge Meter Data - 15 Minute Intervals 16 Feb 2020



Observations

The bidirectional Net Meter operates in the traditional electric meter mode where customers are drawing power from the grid. The Net Meter can also measure the flow of energy into the grid produced by the solar PV system. When in the traditional mode (i.e., the customer is drawing power FROM the grid), the Xcel Net Meter can be compared directly to the eGauge meter; in this mode of operation, the Xcel meter reading was around 30 to 35% higher than the eGauge reading.

To first order, the solar system performance data measured by the Xcel Meters and the eGauge Meter provide similar perspectives. For this specific day, Sunday 16 Feb 2020 we make the following observations:

- The solar electric generation is identical for the two monitoring systems
- Xcel measured electric usage/consumption still exceeds the eGauge on a daily perspective as well as an annual basis.

The Green First Team members contacted both eGauge and Xcel Energy technical support to seek advice on why there was such an unexpected difference between the two monitoring system for the building consumption. The total energy consumption measured by Xcel was particularly unexpected because it was a significantly exceeded the usage estimates of the architect team.

The eGauge technical support personnel maintained their position that the rope CTs were properly installed and setup. Xcel technical support agreed to recheck the calibration on both the Production and Net Meters. They came out and temporarily replaced the two meters with other equipment, took the original meters into their test lab and reran their performance tests. They confirmed that the two meters were functioning properly and returned them to the FUCD site.

The Xcel tech support person provide additional real time data not normally provided to customers – 15 minute interval data used for determining the max demand during one billing period. We were able to compared this data with the eGauge data.

Using the advice of the solar installer, Gabriel Simmons, City Electric, we requested that Xcel install a “data logger” to verify the operation of the Net Meter onsite. Xcel came out to the site and added some additional CTs and a data recorder/logger that provided 15-minute interval data. Xcel install three rope CTs on “high side” of the Net Meter that measured exactly the same line the eGauge rope CTs were monitoring. Xcel also added CTs to the ABB Element output that is connected to the Net Meter, referred to as the “low side” measurement. The induced currents was measured independently and converted to primary current similar to what is done by the Net Meter. The third source of data was the output from the Net Meter itself. Xcel collected data for one month and shared it with FUCD for comparison with the eGauge data.

The following charts illustrate a comparison of some that data.

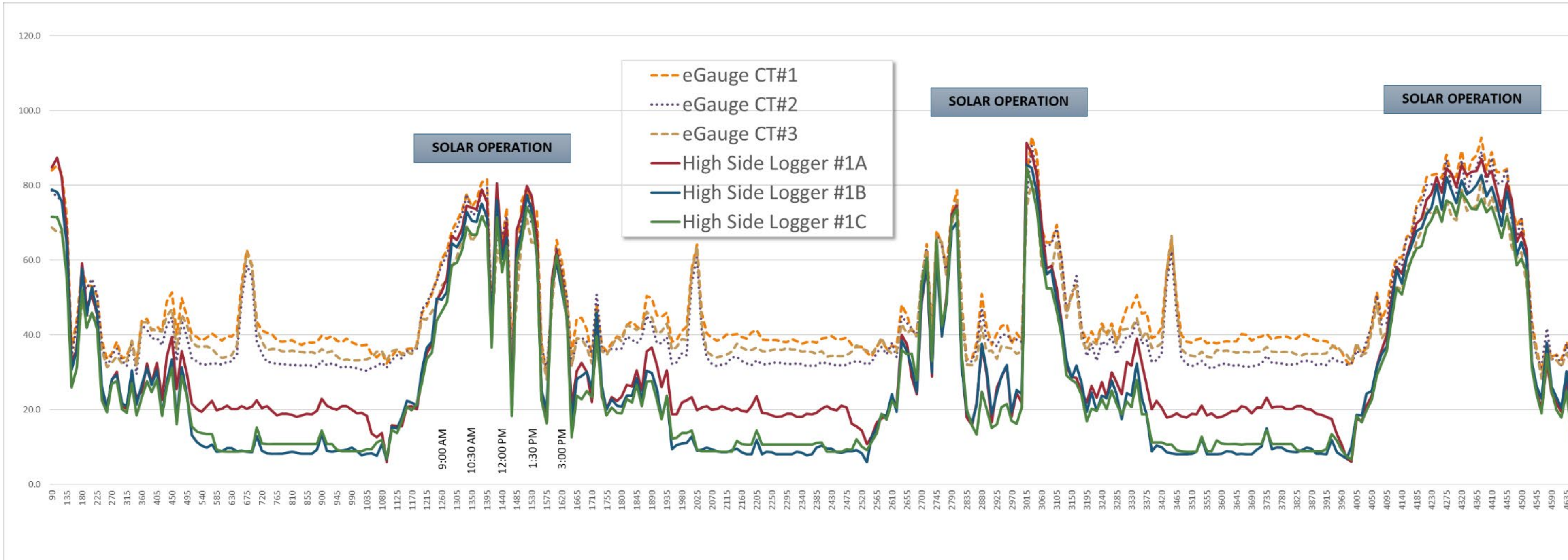
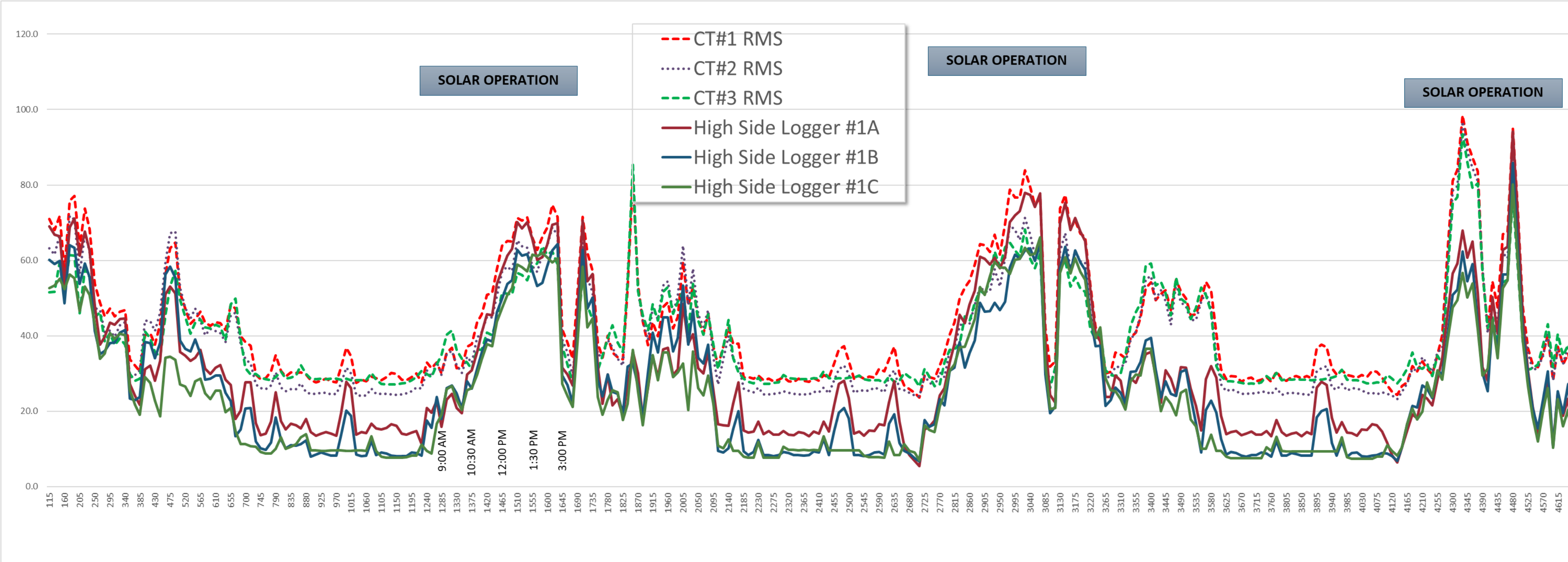


Figure 76   Direct Comparison of Xcel Data Logger and FUCD eGauge CTs

Measurements are consistent at higher power levels (e.g. good agreement @ 80 kW) but differ significantly at lower power levels (factor of 2 difference @ 20 kW)


CT#1 RMS
CT#2 RMS
CT#3 RMS
High Side Logger #1A
High Side Logger #1B
High Side Logger #1C
SOLAR OPERATION
SOLAR OPERATION
SOLAR OPERATION
9:00 AM
10:30 AM
12:00 PM
1:30 PM
3:00 PM
120.0
100.0
80.0
60.0
40.0
20.0
0.0

As indicated, the eGauge measurements (shown as broken lines) generally track the Xcel data (shown as solid lines) for the three phases. At the higher use conditions (e.g. 70-80 amps), the eGauge and Xcel data agree reasonably well; however, as the current drops below 40 amp, the eGauge readings begin to deviate significantly from the Xcel measurements as illustrated in Figure kkk. There is no explanation for this difference at the moment.

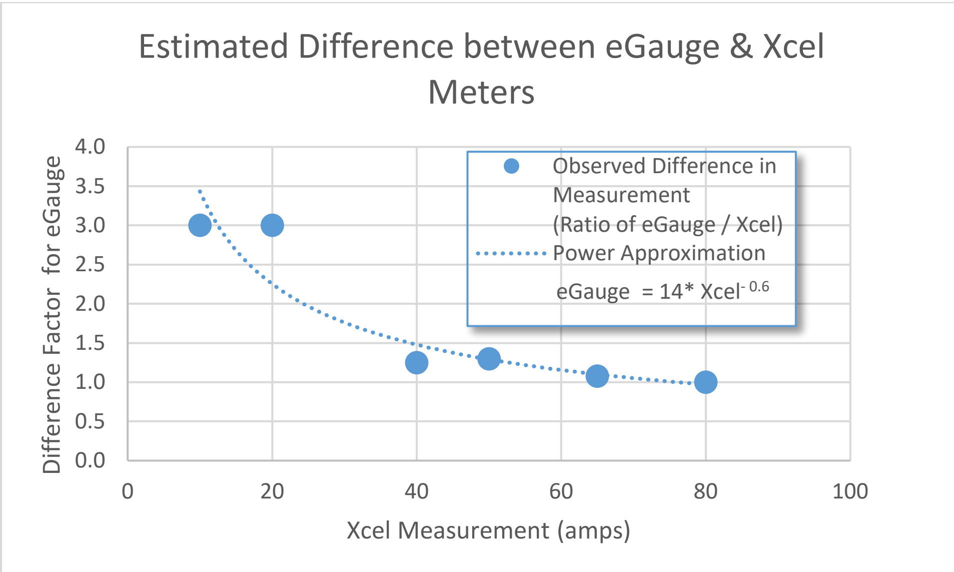


Figure 77 Estimated Difference between eGauge and Xcel Measurements at low usage

David Wynkoop (Xcel) indicates their rope CTs used for the Xcel "high side" measurements were calibrated at 340 amps and found to be have a 1% accuracy; the eGauge rope CTs do not have any similar verification. The eGauge support personnel indicated that typically, rope CTs are not accurate below 25 amps; to achieve better accuracy, they suggest switching to the split core CTs. Unfortunately in our case, this would be require significant redesign of the main panel and significant powered down rework.

Summary.

We have tried to reconcile the measurement differences between the Xcel net and the eGauge meter for the total energy usage of the building. We have a possible explanation for the difference – that the eGauge rope CTs are not accurate enough at low power usage (below 25 amps). In the evening, when the facility is powered down, there is significant time when the eGauge monitoring system for total usage is not as accurate as the Xcel meter – consequently we will accept the Xcel measurements as being more accurate and plan accordingly.

We are now in a position to re-assess the amount of solar needed to get to net zero energy using the Xcel data for energy consumption and current production as provided in

Table 34 Actual - Measured Energy Generation/Production and Usage/Consumption after Renovation

Appendix N1 Energy Usage for the Facility: Pre-Renovation, Predicted, and Present

Was – Energy Related Costs and Usage before Renovation

Table 32 Was – Energy Usage & Related Costs Pre-Renovation

	Annual Cost	Annual Energy Use	Ignored Social Costs (GHG Emissions)
Electric	$12,795[54]	72,040 kWh	**50 tonnes / year**
Natural Gas	$3,830	5196 therms (152,243 kWh)	**55 tonnes / year**
Annualized Equipment Replacement & Maintenance	$3000		
Total Annual Cost	**$19,625** (2.3% of operating budget)	**224,283 kWh**	**105 tonnes / year** **$10,500 / year[55]**

Predicted[56]- Expected Energy Usage/Consumption after Renovation

Table 33 Predicted - Expected Energy Usage/Consumption after Renovation

Annual Usage (NEW DESIGN - SOLAR/GEOTHERMAL - DMA Model; ACTUAL - Feb 2018 to Jan 2019)															
System	**Receptacle Loads (Solar)**		**Lighting (Solar)**		**Cooling EER 14.0 (BTUh/Watts)= (Solar Electric /Ground- Source Heat Pumps)**		**Heating COP= 4.1 (Solar Electric / Ground- Source Heat Pumps)**			**DHW (Solar Electric / Air-Source Heat Pump)**			**Total Energy Usage**		
Name	kBtu	KWh	kBtu	KWh	kBtu	kWh	kBtu	kWh	Therms	kBtu	kWh	Therm	kBtu	kWh	Therms
Predictions	*17,983*	5,270	*148,753*	43,597	*21,159*	6,201	*56,147*	16,456	*0*	*13,050*	3,825	*0*	*257,165*	**75,349**	*0*
							230,268	*67,469*	*2,303*				**230,268**	*67,469*	
	(RED Denotes Thermal Energy)				**86,777**	*25,426*							**86,777**	*25,426*	
													317,045	*92,894*	
Predictions	5,270		43,597		22,657					3,825			75,349		
Actuals	76,188				21,114					112			**97,414**		
	156% **OVER**				-7% UNDER (includes 10 Heat Pumps & 5 ERVs)					-97% UNDER			**29%** **OVER**		
	(Values in italics are alternate units)														

Actual - Measured Energy Generation/Production and Usage/Consumption after Renovation

Table 34 Actual - Measured Energy Generation/Production and Usage/Consumption after Renovation

Actual - Annual Production & Consumption from 17 Nov 2018 to 18 Nov 2019			
	Xcel	eGauge	Xcel / eGauge
Energy Production	68,630[57]	68,200[58]	100.6%
Energy Consumption	98,019[59]	82,100[58]	119.4%
Energy Shortfall	**29,389[59]**	**13,900[58]**	211.4%

[54] By internalizing Externalities. The True Cost according to Epstein, et.al. was two to three times greater – as least $30,000.
[55] This cost is deferred to future generations who will have to capture & sequester this carbon for a habitable planet. Assumes the cost of carbon capture and sequestration (CCS) to remove the GHG (the process has yet to be demonstrated on a large scale) is about $100 / ton.
[56] Table 5, Pg 22
[57] Table 2, pg 15
[58] Figure 5, Pg 16 First Year Report
[59] Table 4, pg 20

The following table presents actual annual energy-related production and consumption

Table 35 ***Annual Consumption - First Year Operation from 17 Nov 2018 to 18 Nov 2019***

Annual Consumption - First Year Operation from 17 Nov 2018 to 18 Nov 2019					
Receptacle Loads (Solar Electric)	**Lighting (Solar Electric)**	**Cooling EER (BTUh/Watts)= 14.0 (Solar/Ground-Source Heat Pumps)**	**Heating COP=4.1 (Solar/Ground-Source Heat Pumps)**	**DHW (Solar/Air-Source Heat Pump)**	**Total Energy Usage**
KWh	KWh	kWh		kWh	kWh
Design Predictions by Architect/Mechanical Engineer					
5,270	**43,597**	**22,657**		**3,825**	**75,349**
Actual Data – eGauge Measurements					
76,429 56% OVER		**21,153**[60] -7% UNDER		**437**[60] -88% UNDER	**98,019** **30% OVER**
Not Measured? **9,969** (kitchen only)[60] 89% OVER	**Not Measured?**	(Monitored 10 Geothermal Heat Pumps & 5 ERVs) 18,090 + 3064		**(**Monitored 80 gallon air-source heat pump augmented electric water heater & the TempSure auxiliary heater)	

Appendix R Xcel Response to Billing Questions

From: Xcel Energy Business Solutions Center <bsc@xcelenergy.com>
Sent: Tuesday, January 14, 2020 2:57 PM
To: john@ .com
Subject: Billing anomaly at our FUCD account

Hello John,
Account: 53-2125618-2
Thank you for contacting Xcel Energy.

We reviewed the document you provided us regarding your concerns about solar billing at the service address. In this email we will go over questions you brought forward to us.

Regarding your interpretation of the Production Meter you asked us to verify if you are viewing the data correctly. **Yes, the total production from 12/19/18 to 11/18/19 appears to be 68,630**. You were also viewing the RECs (Renewable Energy Credits) correctly as well.

Please use the spreadsheet that we provided in this email as a reference as we answer your other questions. We

[60] eGauge data from 10/23/2018 15:45 to 10/23/2019 14:45

highlighted sections of the document to help you find the information we will be referring to.

Last Read Date	Billing Days	Electrical Usage (kWh)	Read Method	ECA On Pk (kWh)	Off Net Generated by Customer (kWh)	Generation& Transmission Demand (kW)	Total Delivered by Xcel (kWh)	On Pk Net Delivered by Xcel (kWh)	Off Pk Delivered by Customer (kWh)	Off Pk Net Delivered by Xcel (kWh)	On Pk Delivered by Customer (kWh)	ECA Off Pk (kWh)	Billable Demand (kW)	On Net Generated by Customer (kWh)	Demand (kW)	On Pk Delivered by Xcel (kWh)	Off Pk Delivered by Xcel (kWh)	Total Delivered by Customer (kWh)	Production Meter (kWh)
11/18/2019	29	-3511	Actual	1452	543	24	5886	0	1099	0	0	3335	32	2968	32	0	5886	1099	3133
10/20/2019	31	-8298	Actual	0	5330	11	3160	0	2571	0	494	999	22	2968	18	230	2930	3065	5825
9/19/2019	30	-8393	Actual	0	5689	12	3240	0	1968	0	1490	1192	22	2704	19	762	2478	3458	7211
8/20/2019	29	-5175	Actual	0	3199	41	3671	0	1777	0	1532	1502	41	1976	41	1003	2668	3309	7733
7/22/2019	32	-7344	Actual	0	4365	10	2223	0	3060	0	1965	0	22	2979	16	381	1842	5024	8694
6/20/2019	30	-4542	Actual	0	3147	5	1951	0	3966	0	1532	0	22	1395	18	137	1814	5498	7892
5/21/2019	29	-995	Actual	0	995	12	2777	0	3772	0	0	230	22	0	20	0	2777	3772	6727
4/22/2019	29	777	Actual	0	0	13	3854	0	3077	777	0	1899	28	0	28	0	3854	3077	6292
3/24/2019	31	5705	Actual	1466	0	28	7653	0	1948	5705	0	4239	43	0	43	0	7653	1948	5473
2/21/2019	30	8679	Actual	3720	0	43	9214	0	535	8679	0	4959	43	0	43	0	9214	535	3510
1/22/2019	34	9493	Actual	3385	0	26	9780	0	287	9493	0	6108	37	0	37	0	9780	287	2714
12/19/2018	33	7052	Actual	2275	0	21	7609	0	557	7052	0	4777	29	0	29	0	7609	557	3426
Total				12298	23268	246	61018	0	24617	31706	7013	29240	363	14990	344	2513	58505	31629	68630

How much energy (kWh) did the church purchase from Xcel over the past 12 months?
The church purchased 31,706 kWh. This number is based on the total Off Peak Net Delivered by Xcel Energy. This also includes On Peak Net Delivered by Xcel Energy but that portion was read at zero.

How much energy did the church facility use/consume over the past 12-months?
The total amount consumed was 98,019 kWh. To acquire this number we took the Total Delivered by Xcel (kWh) then added it to the Production Meter (kWh) and we subtracted the Total Delivered by Customer (kWh).

It should appear as follows:

Total Delivered by Xcel (kWh) + Production Meter (kWh) - Total Delivered by Customer (kWh) = Total Consumption
61,018 + 68,630 - 31,629 = **98,019 kWh**

We also submitted a request to have someone check the electric meter to make sure it is hooked up appropriately and registering correctly. It can take some time to get this order completed but we will notify you of the results.

Thank you for contacting us. I was happy to help.

Sincerely,
John M.
Xcel Energy, Customer Service - Business Solutions Center, Attn: BSC Correspondence P.O. Box 8, Eau Claire, WI 54702
P: 800.481.4700 **F:** 800.311.0050, **E:** bsc@xcelenergy.com

Appendix S Storage and Vehicle-to-Grid (V2G) Capability

Background and FUCD Need for Storage

After a year of operating the new energy sustainable system, the system performance was evaluated from an energy and cost perspective.

There was an unintended annual **energy shortfall** of 29,386 kWh in 2019 at a cost of $6450 – primarily because the activity level and energy usage of the renovated facility was underestimated. This shortfall can be easily and economically remedied by extending the size of the solar PV system. Around 90 more solar modules (equivalent to a 28 kW rating) will eliminate the energy shortfall and allow FUCD to reach its goal of Net Zero Energy.

During the second year of operation with the facility in a reduced mode of operation in response to COVID-19, the solar PV system generated all the electrical energy needed to operate the building. FUCD did not purchase any energy from Xcel. Nevertheless, FUCD paid Xcel Energy over $4228 for "peak demand" charges and other administrative fees even though no energy was purchased. FUCD Peak Demand reached 43 kW on three occasions during 2019 and on one occasion in 2020. Average annual demand was 11 kW in 2019 and 8 kW in 2020.

After two years of operation, we now know how the operational cost of energy is influenced by peak demand charges. Behind the meter (BTM) storage would be able to fatten the demand profile and reduce the monthly peak demand charge.

Consider adding storage for the Energy System of the Future

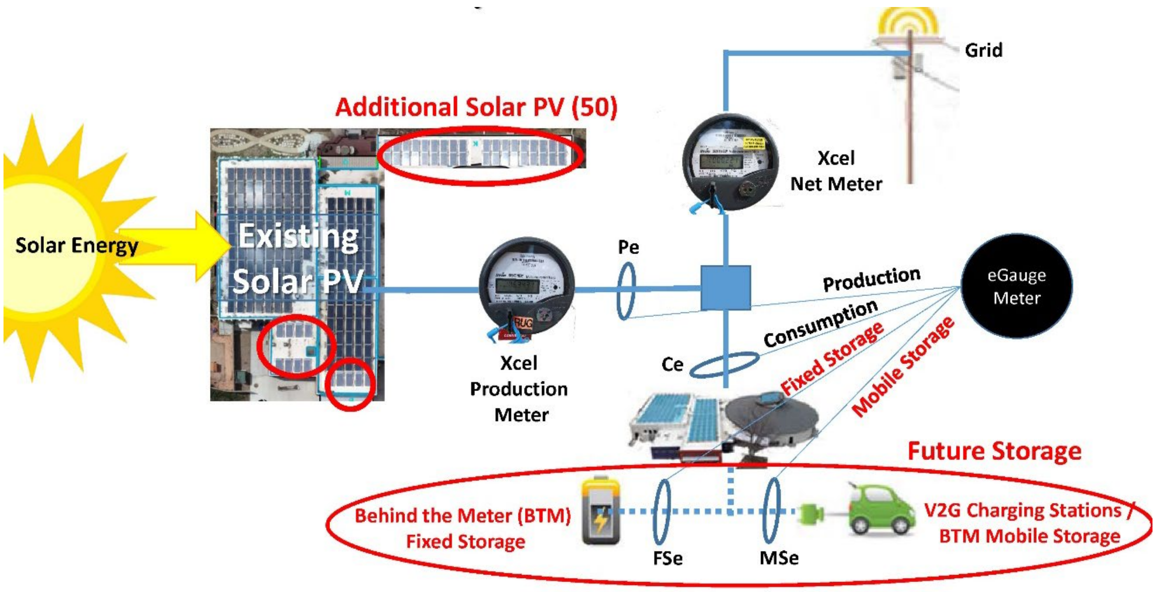


Figure 78 FUCD Energy System Can Include Stationary and Mobile Storage in the Near Future

What is the Rational for this investment?

There are several reasons to consider adding Behind-the-Meter (BTM) Storage.

4) Storage can level the peaks & valleys in the usage profile. When activated, certain electrical equipment (e.g., motors, heater elements) tends to create power spikes on the grid. For example, a 5 kW load for an hour could be supplied from a battery instead of drawing from the grid and contributing to the "Peak Demand."
   It appears that a 20-30 kWh storage capability could reduce the Sunday morning usage profile to below 25 kW.
5) Storage will be required to transition the church's current method of preparing food using a natural gas stove/oven to using an electric stovetop (e.g., induction heating). When a stovetop heating element is activated to a "high" setting it uses around 1.5 kW. Four "burners" turned on to a "high" setting at the same time would create a spike of around 6kW in the usage profile for as long as the heater elements were on (e.g. 30 minutes). The energy used in this case would be 3 kWh. It could be supplied by a battery rather than being drawn from the grid and adding 6 kW to the Peak Demand.
6) Storage and V2G technology could level the usage profile with future bi-directional Charging Stations in the church parking lot.

By adding Behind-the-Meter (BTM) storage, FUCD can reduce its peak demand and even level its usage to possibly 15 to 20 kW (at least below 25 kW). Reducing the peak demand on the grid below 25 kW would allow a return to the Commercial "C" rate schedule with no demand charges. [61]

[61] Mountain View United Methodist in Boulder limits its power usage to under 25 kW using a Brayden Power Control Management system. They have a solar PV system that provides their annual energy and remain on the "C" rate schedule. Their annual usage is larger than FUCD, but their electric bill is around $150, not $6450.

How Much Storage is Required?

Normal Energy Usage. The annual **average** usage of the church facility is around 11 kW. With future electrification to eliminate all natural gas, average usage will increase to 12 or 13 kW. Today, on a typical Sunday, the peak demand can be as much as 45 kW.

Ideal Energy System. A more efficient FUCD Energy System design would include BTM storage and might function like this: Xcel provides up to 20 kW continuously; FUCD provides everything over 20 kW from its solar PV system and storage system (stationary & mobile batteries).

With adequate storage, it should be possible to reduce peak demand on the grid to say 20 kW. To get the demand on the grid down to 20 kW on a Sunday requires drawing 25 kW from a storage system for approximately 2 hrs; then the demand drops off again. The amount of stored energy required for a Sunday morning would be 50 kWh.

Stationary Storage Only. A Tesla PowerWall 2[62] can store around 13.5 kWh of usable energy, so four Powerwall 2 units would be required. However, the maximum continuous power that can be drawn from a PowerWall is 5 kW (for up to 2.7 hours), so to provide 25 kW of power requires five PowerWalls.

Stationary Storage plus Mobile Storage (V2G / V2H). Assume there are two PowerWall 2s that can provide 10 kW of power for 2 hours. Assume on Sunday there are three donor EVs with V2G/V2H technology that provide 5 kW each; that's 15 kW from mobile sources. The combination of stationary and mobile storage would then provide 25 kW for the high demand 2-hour period on Sunday. Mobile storage donors would have to be in the battery class of Nissan LEAFs , Bolt, and Tesla.

> ***Impact on EV battery.*** *Drawing 5 kW from the EV battery is similar to driving 16 miles per hour. If this continues for two hours, it is equivalent to 30-35 miles of driving range.*

The energy donation would be via a bi-directional charging station (See the WallBox Quasar example below). The process of having vehicle storage send back energy to the grid or used to power a building is referred to as Vehicle to Grid (V2G) or Vehicle to Building (V2B) technology. The 2018 Nissan Leaf and newer have V2G capability built in.

Storage and inverter technologies continue to evolve rapidly. Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) technology are growing rapidly in Asia and Europe. A new product from Spain, called Quasar, and ongoing V2G effort by Nissan LEAF are described below briefly.

> *[The U.S. continues to focus on: military technology; maintaining the dying fossil fuel industry on life support; insisting on unsustainable growth in the economy; increasing profits and conducting its internal political ideological war (including climate crisis denial). Meanwhile, the global community is developing new green technology and leaving America in its dust.]*

Wallbox Quasar

"Quasar is a bidirectional DC charger for homes that is expected to retail for around $4,000…it should be in every EV owner's home (in one form or another) in a few short years.

Quasar is about the size of current Level 2 charging …. is infinitely more capable than current level 2 charging boxes …it interfaces with the DC charge port of your EV. The one demonstrated below is CHAdeMO and works only with Nissan Leafs and Mitsubishi Outlanders PHEVs currently, but CCS combo versions are being worked on right now. A Tesla version is also being considered…

Figure 79 Video: https://youtu.be/VgubcvJKw74

[62] The commercial version of the PowerWall is called PowerPack.

… The real value will be the ability to use their car as a backup to their home like a Tesla Powerwall. EV owners typically have 50-100 kWh of power sitting in their car that could be used to power their home during an outage…

Quasar's high voltage bidirectional capability can take power from your car during an outage and send it immediately to your home in the same way a Tesla Powerwall does... A 60 kWh Nissan LEAF could offer the same power as four Tesla Powerwalls.

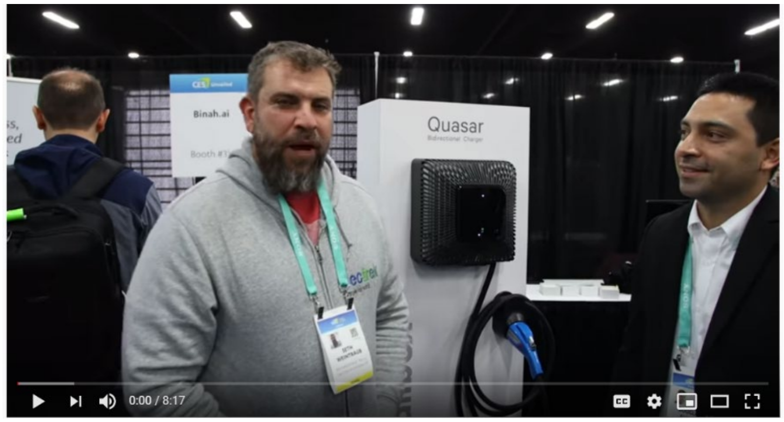


Figure 80 Ref: ***Wallbox Quasar bidirectional home DC charger will turn EVs into a huge Tesla Powerwall**, by* ***Seth Weintraub**, Jan. 6th 2020 1:28 pm ET,* ***@llsethj***

https://electrek.co/2020/01/06/wallbox-quasar-tesla-nissan/?fbclid=IwAR36FZ4JetCG_JkmZk1yikoxPjS38RDHAYBt8g5kjJs0sHswU2wyBw3nYrg

Nissan Demonstrates LEAF Vehicle-to-Grid (V2G)

"Nissan, together with ENEL X and the Energy Sustainability Agency, launched Latin America's first bidirectional vehicle charging system (V2G - Vehicle-to-Grid) in Chile.

The demonstration installation combines the Nissan LEAF electric car, the bidirectional CHAdeMO charger, energy storage system and 3 kW solar panels. The LEAF will then become an auxiliary power source when needed (usually at peak demand or in an emergency).

> **"For the first time in Latin America, the Energy Sustainability Agency's innovative project enables measurement of the bidirectional flow between the electric vehicle's battery and the system's storage unit. During peak hours, when energy costs are higher, the vehicle will contribute as a source of power. The new Nissan LEAF is the only electric car with V2G technology, and we're proud to be part of this important initiative."**
>
> ---- Francisco Medina, electric vehicle manager at Nissan Chile said:

Nissan is trying to popularize V2G and figure out a viable business model for bidirectional charging over the year, but it's not easy until EVs become more popular and the V2G system becomes affordable.

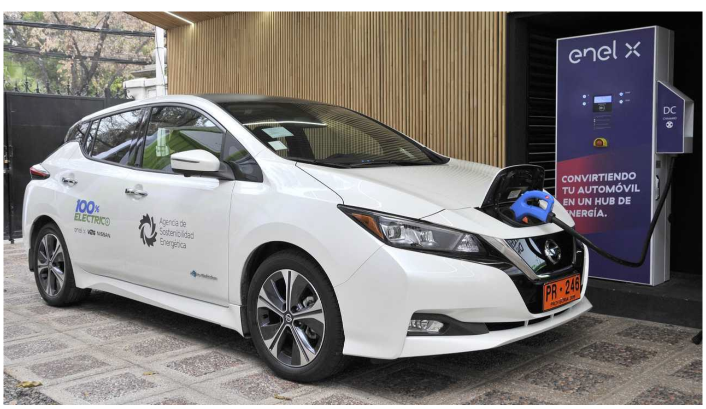


Figure 81 Ref: Nissan Demonstrates LEAF Vehicle-to-Grid (V2G) In Chile, Inside EVs, ***by: Mark Kane, JUL 21, 2019 at 3:27PM,***

https://insideevs.com/news/360948/nissan-demonstrates-vehicle-to-grid-v2g-chile/

The Japanese manufacturer said also that hundreds of thousand LEAFs sold so far have a theoretical combined storage potential of more than 10 GWh. Of course, to tap the potential, all would need to be parked and connected to V2G chargers, which are scarce devices."

Nissan Using Vehicle-To-Grid Technology To Power US Operations

"*CleanTechnica* contributor Maximilian Holland wrote recently about how the **CCS charging standard** seems to be supplanting **CHAdeMO** as the **EV charging technology of choice** for most car companies. While his argument for CCS is cogent, it overlooks one aspect of CHAdeMO that CCS doesn't offer, at least not yet — **using the battery in an electric vehicle as a storage battery for homes and businesses through vehicle to grid technology.**

DRAFT

Figure 82

Nissan is one of the biggest advocates for the CHAdeMO standard and a major supporter of V2G technology. It recently won approval from **German regulators** to trial its V2G system in that country.

Now it says it will use V2G to partially power its factory in Franklin, Tennessee and its design center in San Diego.

"As the only vehicle on the market utilizing bi-directional charging, the Nissan LEAF proves exceptionally useful while on the road and also while parked," says Brian Maragno, director for EV sales and marketing at Nissan North America…

The latest version of the Nissan LEAF is one of the few electric cars on the market that supports vehicle to grid technology.

V2G turns the battery in an electric vehicle into an energy storage device…

… V2G could be perfect for **electric school buses**, which spend most of the day parked and waiting for school children to transport. Think of the energy that could be stored in all those yellow vehicles and how it might be cheaper to tap into it rather than building dedicated fixed battery storage facilities.

Nissan says V2G is ideal for fleet operators. Its "Energy Share pilot program **will continuously monitor a building's electrical loads, looking for opportunities to periodically draw on the LEAF's "lower-cost energy" to provide power to the building during more expensive high-demand periods. This constant monitoring, called demand-charge management, could result in significant electricity savings and could offer the secondary benefit of reducing the burden of peak loads on local utilities."**

…"Nissan Energy will enable our customers to use their electric cars for much more than just driving – now they can be used in nearly every aspect of the customer's lives," says Daniele Schillaci, Nissan's global head of marketing and sales. "Our Nissan Intelligent Mobility vision calls for changing how cars are integrated with society, and Nissan Energy turns that vision into reality."

Figure 84 Ref: Nissan Using Vehicle-To-Grid Technology To Power US Operations, by Steve Hanley, November 29th, 2018, ***https://cleantechnica.com/2018/11/29/nissan-using-vehicle-to-grid-technology-to-power-us-operations/***

Video: https://insideevs.com/news/360948/nissan-demonstrates-vehicle-to-grid-v2g-chile/

More V2G news

Constant monitoring, … arge … esult … icity … the … of … of … ocal … utilities.

Figure 83 Wireless Charging & V2G: An E-Mobility Game Changer?

Figure 85 Renault Starts Piloting V2G Charging Using AC

Assessment of economic potential of Vehicle-to-Home (V2H) in Japan

"As the awareness of environmental issues continues to grow, the market for electric vehicles (EVs), which generate zero emissions during travel, is also surging globally. Great strides have been made to capitalize on the value created by EVs equipped with large-capacity batteries. Among those, the Vehicle to Home (V2H) system, which enables EVs to produce value not only while driving but also while parked, is attracting broad attention.

A two-way electric power supply system whereby power is not only supplied from the home to the vehicle, but also from the vehicle to the home, V2H is a system that enables a diverse array of vehicle applications, such as the use of an EV as a backup emergency power source or for shifting of power use during peak hours to save on residential energy bills. This report summarizes the benefits of a V2H system that users can routinely enjoy, taking into account actual driving habits of Nissan LEAF owners and typical household electricity demand in the Japanese market. The findings confirm that significant advantages can be gained from a V2H system by effectively leveraging surplus solar power generated in the home as well as differences day-night electricity rates."

Ref: "Assessment of economic potential of Vehicle-to-Home (V2H) in Japan with customer driving habits taken into account," Tomoya Nakada1 , Tomoyuki Nakano1 and Hayato Akizuki1, 1Nissan Motor Co., Ltd. , 1-1 Morinosatoaoyama, Atsugi City, Kanagawa 243-0123, Japan, to-nakada@mail.nissan.co.jp , EVS28 KINTEX, Korea, May 3-6, 2015

http://www.evs28.org/event_file/event_file/1/pfile/EVS28_0224_EconomicPotential-V2H-Japan.pdf

Conclusions

BTM Storage should be included on the Roadmap to a sustainable energy system.

It may take a year or two to sort out the charging standards (e.g., CCS vs CHAdeMO.) Tesla has both a residential product (PowerWall 2) and a commercial Product (Power Pack) but they are not yet compatible with say the Nissan CHAdeMO charging standard.

Using the Quasar and PowerWall 2 as an example, the cost of the stationary and mobile storage would be on the order of 3 x $4,000 + 2 x $10,000 = $32,000. The savings in operating cost would be around $3,000 / year in Demand Charges. Payback would be 10 years. Financial gain over 15 years would be $15,000 for an investment of $32,000.

Appendix T Demand Control System Proposal by Brayden Automation Corp.

Mountain View United Methodist in Boulder limits its power usage to under 25 kW using a Brayden Power Control Management system. They have a solar PV system that provides their annual energy and remain on the "C" rate schedule. Their annual electric bill is around $150.

FUCD requested a quotation from Brayden Power Control, but learned subsequently, it would not be possible to reduce their peak demand of 45 kW on Sunday mornings to below 25 kW by selectively limiting the use of specific appliances.

To develop the quotation, assumptions were:

1. Control of loads will be accomplished by Powerline Carrier Control system since hardwiring is not practical due to the location of the main service entrance relative to HP units;
2. Control of 10 Water-to-Air Heat Pump Units, Compressors;
3. Control of 3 Auxiliary Heating Elements on 3 of the 10 Heat Pumps;
4. Control of Dryer Heating Element as the highest priority (last off, first on);
5. Current Transformers (CTs) will be able to be installed "Upstream" (line side) of the solar system tap AND it is possible to have each current transformer get around all conductors on each phase. If not, then the KYZ pulse meter will need to be ordered from Xcel. Current transformers and watt-hour transducer will be deducted from quotation;
6. Savings are difficult to estimate due to abnormally low load factors and PV contributions. 25kW may be possible if normal demands are/were less than 35kW. It is impossible to tell the magnitude of demand reductions until we get the system installed and see how the building responds to demand reductions. I would guess from the data received that we are looking at a 3-year to 4-year payback.

"************

William H. Brayden, President

Brayden Automation Corp./Solid State Instruments
6230 Aviation Circle
Loveland, CO 80538
(970)461-9600 Office, www.brayden.com, www.solidstateinstruments.com

BRAYDEN AUTOMATION

6230 Aviation Circle
Loveland, Colorado 80538
(970)461-9600 fax (970)461-9605
email: sales@brayden.com

Quotation # 2019-140

QUOTATION

Customer

Name	First Universalist Church c/o Milt Hetrick
Address	4101 East Hampton Ave
City	Englewood State: CO ZIP 80222
Phone	(303) 759-2770 Email: mahetrick@msn.com

Date	9/19/2019
Order No.	
Job Name:	First Universalist
FOB	Delivered/Installed

Qty	Description	Unit Price	TOTAL
1	**EnergySentry Model 9388BP Demand Mgmt System** with Pulse input, 16 control points, 20" x 12" x 6" NEMA 3R Enclosure; 120/240VAC Pwr Supply P/N:FG9388B-00GG0PC	[illegible]	[illegible]
1	Model 1020C Powerline Carrier Transmitter ES1020A-00001	$220.00	$220.00
1	Model 9333A Power Transducer - 3phase 120/208Y	$275.00	$275.00
3	Current Transformers, split, 400A 3"x 3" ID P/N: 8420-3066	$195.00	$585.0
10	Model 1022 Powerline Carrier Receiver, 2 chan, 3Amp NC	$171.00	$1,710.0
4	Model 1031 Powerline Carrier Receiver, 1 Chan, 30Amp NC 1 - Dryer control, 3- HP Backup heat strip control	$168.00	$672.0
1	Installation (4 Man Days @ $512 per man-day)	$2,048.00	$2,04
	EnergyAccessConnex Monitoring		
1	Model 9904B WebWabbit 4 Serial to Ethernet adapter	$295.00	$2
1	EnergyAccessConnex server subscription - 3 year	$600.00	
	Leadtime: 1-2 weeks		

SubTot
Shipping & Handling (
Taxes
T

Payment Terms:

- (●) 35% Deposit; Balance upon Completion
- ( ) Net 30 WAC
- ( ) Credit Card (Visa MasterCard

Name ______
CC # ______
CVV ______ Expires ______

Submitted by:

Quotation Good for 30 Days

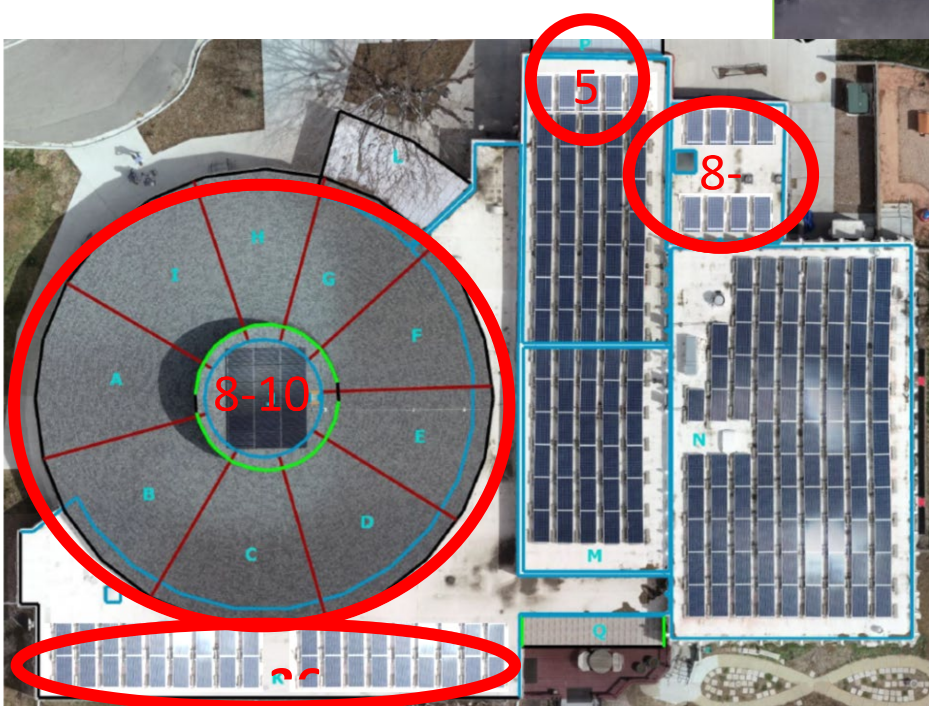
Appendix U Remaining Space on the Flat Roof

After two years of operation, the new energy system is functioning as designed.   However, the “new normal” operation of the renovated facility uses more electrical power than predicted by the architect.   Although on November 6, 2016 the congregation voted unanimously to include a sustainable energy system in the BFF renovation project, the operational data indicates in 2019 there was an energy production shortfall.   In 2019, the facility consumed more than it generated; FUCD purchased 30,000 kWh of energy from Xcel. The production (size) of the solar PV system needs to be adjusted to match the “new normal” consumption.   Additional solar electric production is required to achieve our goal of Net Zero Energy and sustainable operation as authorized by the congregation.   This adjustment can be made without increasing the operating budget of church by simply extending the “revenue neutral” funding model used in 2016.

As illustrated in **Error! Reference source not found.**, there may be space for around 50 additional solar PV modules on the flat roof of the facility.   This assertion is subject to the 2015 INTERNATIONAL FIRE CODE that requires space around the perimeter of the array.   A shading assessment is also needed to determine the effectiveness of the group of 36 modules proposed to be located west of the round sanctuary. The round roof structure may cause significant shading in early morning.

Remediation of the production shortfall will require more than 50 additional solar modules.   It may be possible to add modules to the roof of the round building. Or modules can be installed as carport solar in the parking lot – possibly along Hampden Ave (at a slightly higher cost than roof mounted modules.).

If for some reason, harvesting on-site solar energy is not possible, investing in a community solar garden could be evaluated as an option.



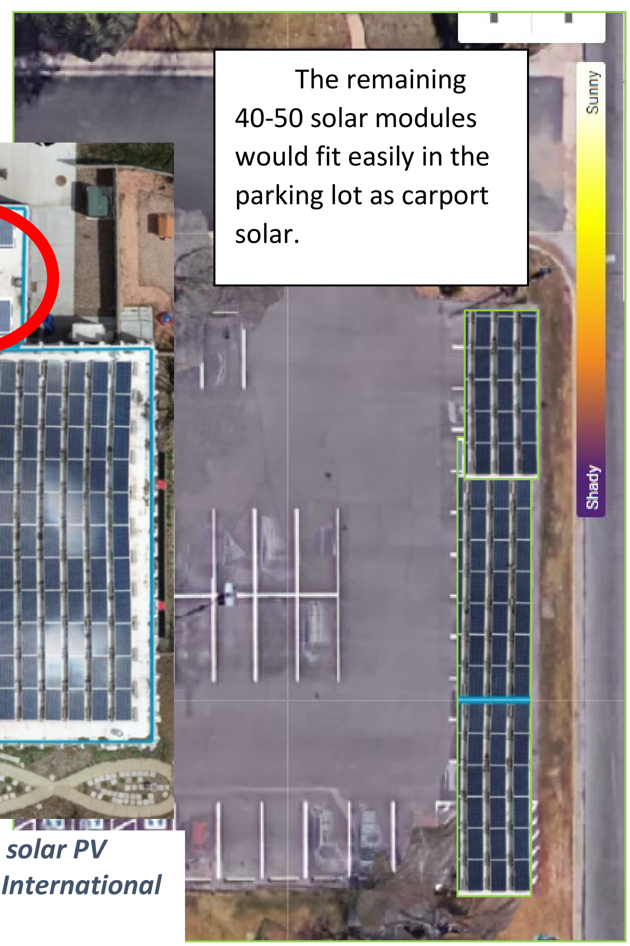


Figure 86 Illustration there may be space for possibly 50 more solar PV modules on the flat roof (subject to interpretation of the 2015 International Fire Code Restrictions.)

Appendix V Steps to Get to Zero Net Energy

The eGauge monitoring system provided subarray data for the Awning modules, the Oculus modules and the "Other Subarray" modules. Module level data for these subarrays is not required. Adding the micro inverter ECU for these modules is a top priority at this point. City Electric indicated that the ECU would not be compatible with future micro inverters anyway.

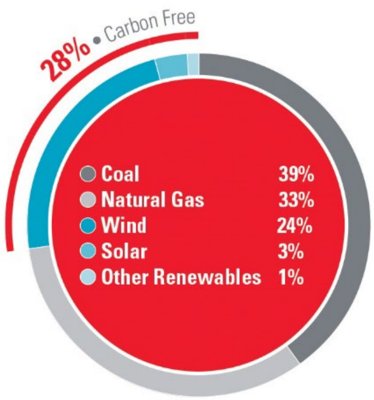
1) Reassess the annual energy shortfall for the "new normal" usage of the renovated facility. Determine the number of additional solar modules required to get to "Net Zero Energy."
2) Discuss and agree on the Green First / UU goals and future objectives:
   a) achieve Net Zero Energy as authorized by the congregation in 2016 (i.e. where the church generates as much energy as it needs for sustainable operations)
   b) use a revenue neutral funding approach as authorized in 2016 (that also results in a financial gain over 20-25 years);
   c) reduce GHG emissions to near zero and stop doing harm to future generations (See 10-year Roadmap);
   d) find a path to transition the kitchen to electric (utilizing some onsite storage);
   e) reduce demand charges (by increasing onsite generation, using on-site and mobile storage – V2G technology);
   f) reduce congregation's carbon footprint by promoting EVs to reduce transportation-related GHG emissions.

Maximizing the solar on roof and decide whether to add solar on-site or buy into community solar

5) Issue a request for a quotation (RFQ) to maximize the number of modules that can be installed on the flat roof. Determine the remainder to get to Net Zero.
6) Solicit an RFQ to install the remainder of the needed modules as carport solar in the parking lot.

   Option. Solicit an RFQ to invest in Community Solar for remaining solar and evaluate the options and make a decision.
7) Assemble a revenue neutral funding approach and line up potential donors/lenders as before.
8) Present to the Board of Trustees as before.

Appendix W Xcel Energy Portfolio - 2018 Colorado



As indicated in the graphic, 28% of Xcel power-generated for Colorado customers was produced from carbon-free energy sources. 72% was generated by burning ancient hydrocarbons (Coal-39%; Natural Gas – 33%.)

With this portfolio, it can be calculated that **the effective greenhouse emissions for Xcel Colorado are 1.55 pounds of $CO_{2\,eq}$/ kWh (assuming 3% methane leakage.)**

https://www.xcelenergy.com/energy_portfolio/electricity/power_generation

Appendix X1 Rope CTs Characteristics in Question - Letter to eGauge for Support

Questions: Can a rope CT measurement uncertainty be as large as 20%? Did we install the rope CT improperly? Did we load in the incorrect information for the rope CTs?

Background:

We are using eGauge equipment to monitor the energy generated by a 57 kW rooftop solar PV system on our facility, First Universalist Church Denver.

Three JD JS 24 mm/0.94” 200 A CTs are used to measure the power/energy generated. Agreement with the Xcel Production Meter appears to be within 1% - more than enough accuracy for our purposes.

We are using three rope CTs (labeled CT1, CT2, and CT3) for monitoring the total power/energy used by our facility. CTs labeled CT4 through CT30 are the typical “clamshell” designs. When the rope CTs were ordered from eGauge, we had requested catalog item: AE-RCT-106-2775 - Self-powered CT coil 2775A/4.2" w/2-pin. However, when the equipment arrived, the rope CTs shipped were Accuenergy RCT16-2500. There was no Accuenergy RCT16-2500 identified in the pulldown menu for “Installation” as shown in Figure 87 below. Your support staff kindly helped with the setup and selected AE RCT 178mm/7.01” 6935A as the appropriate menu item for the RCT16-2500. **This might be the source of what appears to be a 20% error in the rope CT measurements.**

We installed a total of three eGauge meters (eGauge41396, eGauge41397, eGauge41398) and 72 CTs (only three rope CTs) and have found the information provided very useful in managing and minimizing the energy usage of the facility. After a year of operation, we were summarizing our ‘Energy Generated’ and ‘Energy Used.’ We found excellent agreement between eGauge data and the Xcel **Production** meter. However, the **Total Energy Usage based on the Xcel Production and Xcel Net Meter was 20% higher than the eGauge rope CTs measured.**

DRAFT

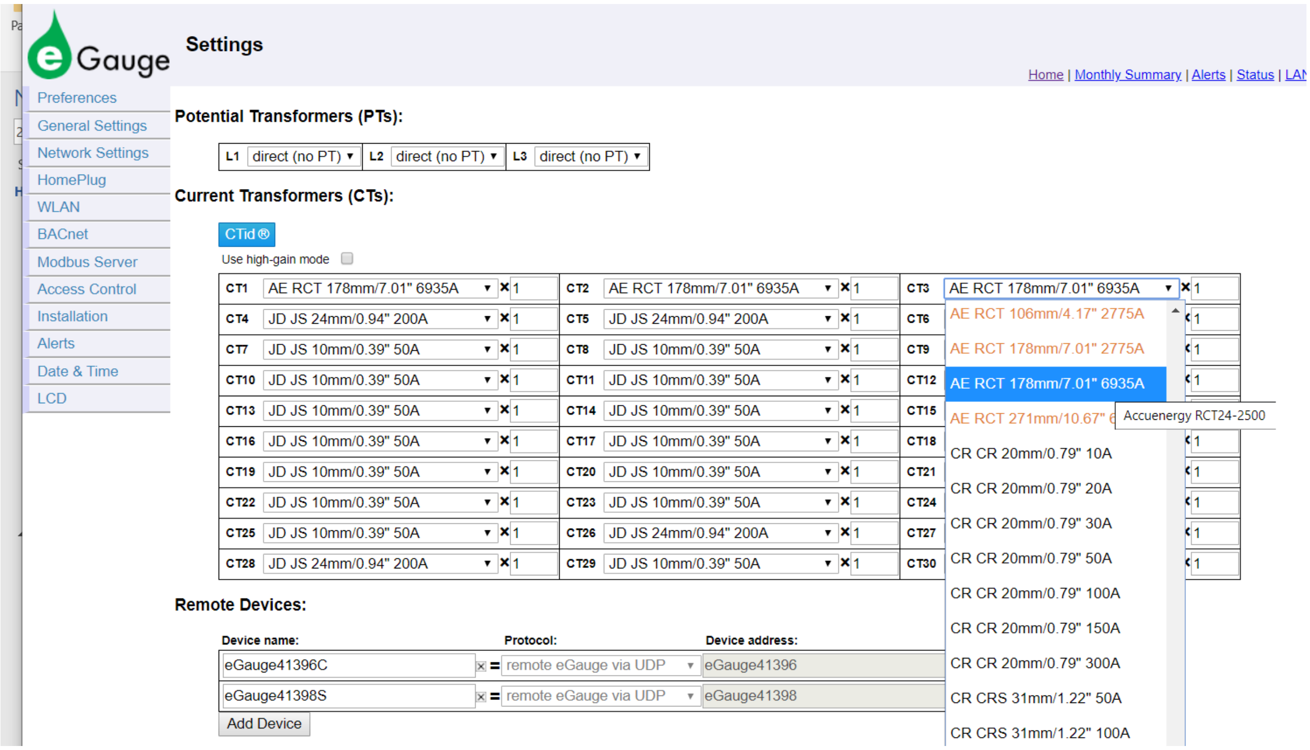
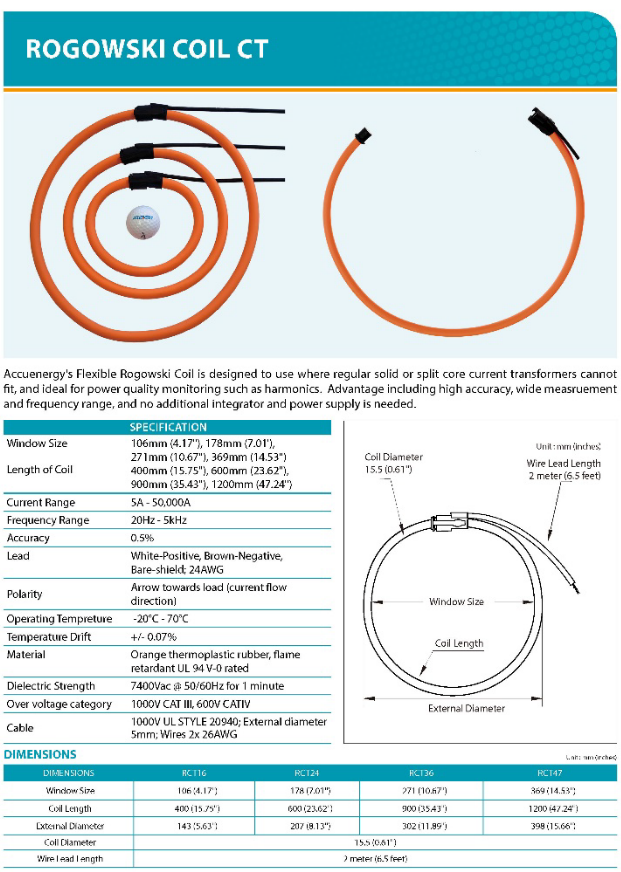


Figure 87 eGauge Settings: Installation: Current Transformer (CTs) setup menu.



ROGOWSKI COIL CT

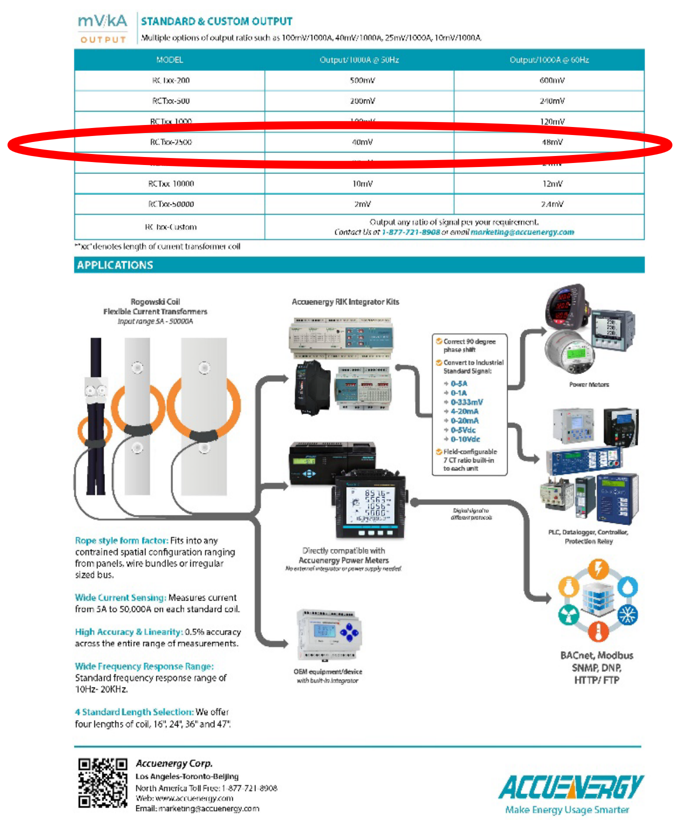
Accuenergy's Flexible Rogowski Coil is designed to use where regular solid or split core current transformers cannot fit, and ideal for power quality monitoring such as harmonics. Advantage including high accuracy, wide measruement and frequency range, and no additional integrator and power supply is needed.

SPECIFICATION	
Window Size Length of Coil	106mm (4.17"), 178mm (7.01"), 271mm (10.67"), 369mm (14.53") 400mm (15.75"), 600mm (23.62"), 900mm (35.43"), 1200mm (47.24")
Current Range	5A - 50,000A
Frequency Range	20Hz - 5kHz
Accuracy	0.5%
Lead	White-Positive, Brown-Negative, Bare-shield; 24AWG
Polarity	Arrow towards load (current flow direction)
Operating Tempreture	-20°C - 70°C
Temperature Drift	+/- 0.07%
Material	Orange thermoplastic rubber, flame retardant UL 94 V-0 rated
Dielectric Strength	7400Vac @ 50/60Hz for 1 minute
Over voltage category	1000V CAT III, 600V CATIV
Cable	1000V UL STYLE 20940; External diameter 5mm; Wires 2x 26AWG

DIMENSIONS

Unit: mm (inches)

DIMENSIONS	RCT16	RCT24	RCT36	RCT47
Window Size	106 (4.17")	178 (7.01")	271 (10.67")	369 (14.53")
Coil Length	400 (15.75")	600 (23.62")	900 (35.43")	1200 (47.24")
External Diameter	143 (5.63")	207 (8.13")	302 (11.89")	398 (15.66")
Coil Diameter	15.5 (0.61")			
Wire Lead Length	2 meter (6.5 feet)			



mV/kA OUTPUT

STANDARD & CUSTOM OUTPUT

Multiple options of output ratio such as 100mV/1000A, 40mV/1000A, 25mV/1000A, 10mV/1000A.

MODEL	Output/1000A @ 50Hz	Output/1000A @ 60Hz
RCTxx-200	500mV	600mV
RCTxx-500	200mV	240mV
RCTxx-1000	[illegible]	120mV
RCTxx-2500	40mV	48mV
[illegible]	[illegible]	[illegible]
RCTxx-10000	10mV	12mV
RCTxx-50000	2mV	2.4mV
RCTxx-Custom	Output any ratio of signal per your requirement. *Contact Us at 1-877-721-8908 or email marketing@accuenergy.com*	

*"xx" denotes length of current transformer coil

APPLICATIONS

Rope style form factor: Fits into any contrained spatial configuration ranging from panels, wire bundles or irregular sized bus.

Wide Current Sensing: Measures current from 5A to 50,000A on each standard coil.

High Accuracy & Linearity: 0.5% accuracy across the entire range of measurements.

Wide Frequency Response Range: Standard frequency response range of 10Hz- 20KHz.

4 Standard Length Selection: We offer four lengths of coil, 16", 24", 36" and 47".

Accuenergy Corp.
Los Angeles-Toronto-Beijing
North America Toll Free: 1-877-721-8908
Web: www.accuenergy.com
Email: marketing@accuenergy.com

Make Energy Usage Smarter

Figure 88 Rope CTs used to monitor the current in the main lines to the facilityappear to be properly installed.

Email exchanges with eGauge personnel indicate that it is highly unlikely the rope CT characteristics can be in error by 20%.

Figure 89 compares the Xcel derived energy consumed from equation 2a (shown as the solid blue line) and the raw data from the eGauge system shown as the broken blue line.   When a simple linear correction (of approximately 20%) is applied to the eGauge data, the 'corrected' eGauge data (shown as the solid red line) maps closely with the Xcel Meter data. There is no explanation for this 20% bias error / difference at this point.

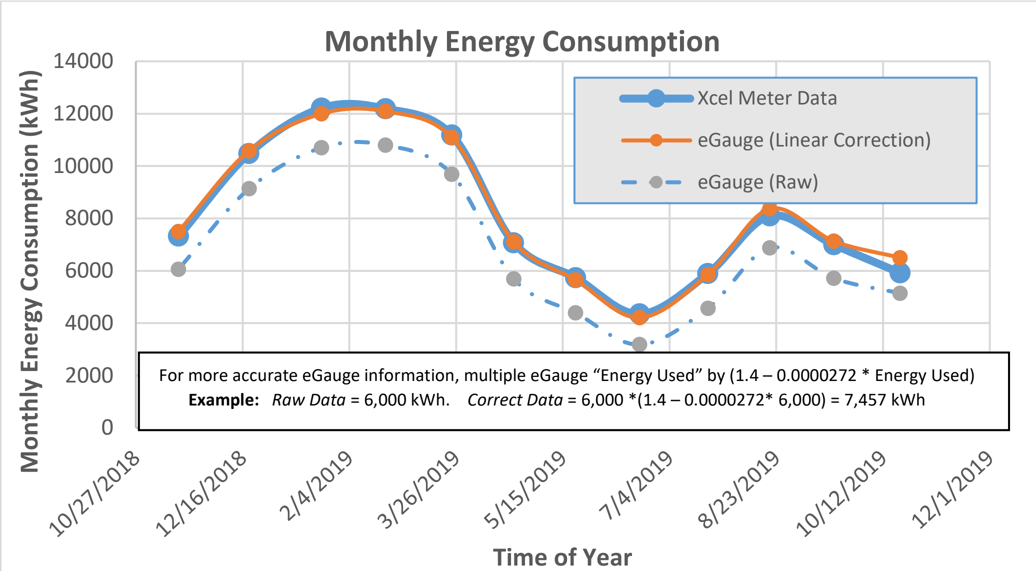


Figure 89 First Universalist Monthly Energy Consumption over the course of one year.

In corresponding with eGauge support personnel, there was the following exchange:

From: eGauge Systems LLC
Sent: Monday, December 16, 2019 10:09 AM
To: mahetrick@msn.com
Cc: john@bringenberg.com
Subject: Re: Questions about the use of Rope CTs for eGauge41397 installation

Milt,

Thank you for providing such a clear and detailed explanation of the situation and problem. Let me address the questions from that PDF in order:

1) Should we expect a 20% uncertainty in the eGauge measurement?

No. A correctly installed, correctly configured eGauge meter should be between .5% and 1% accurate depending on the meter hardware and CT selection. Most utility meters fall into that same range depending on the age and design of the meter. This means it's *theoretically* possible you might see as much as a 2% discrepancy between the eGauge and utility meter (if one meter was reading 1% high and the other 1% low). However, this is unlikely.

2) Did we install the rope CTs improperly?

No, from what I can see the rope CTs are correctly installed. The conductors appear to be clearly identified via color and there's no instance of cross-phasing (conductors on multiple phases passing through the same CT) or similar issues. The CTs are suspended from the conductors in such a way that they're mostly centered (not perfectly centered, but the overall impact this would have on accuracy is negligible - certainly nowhere close to 20%).

3) Did we load in the incorrect information for the rope CTs?

No, eGauge41397 is configured to use the correct CTs *assuming* those CTs are indeed connected to CT port 1, 2, and 3. However, if this wasn't the case I think you would have other noticeable issues, and I'm not seeing anything that points towards those types of problems. In other words, it's a safe assumption that these CTs are configured correctly based on the historical data recorded on this device.

4) If we add a multiplier of 1.2 to the installation setting of CT!, CT2, and CT3 shown in Figure 1, will that adjust/increase the “Energy Used” by 20%.

Unfortunately, it's not that simple. It's almost certain this eGauge is calculating total power used correctly, because the Usage and Generation readings are proportional to one another. This means that the Usage values do not fluctuate in response to changes in Generation. I've included a screenshot from your device which illustrates this below:

The picture can't be displayed.

Looking at these values and based on the information you've provided, we know the Generation readings match your utility readings, so the Generation values are correct. Usage (the solid red line) is calculated by looking at the relationship between Generation and the net flow of power to/from the utility (the "Total Usage" register on your device). "Total Usage" is the aggregate value of CT1-3 (the rope CTs). Right now, an increase or decrease of 100W in production would lead to a corresponding decrease or increase of 100W n the value recorded by the "Total Usage" register - this means these readings are in proportion. If we add a 20% scale to the "Total Usage" register or CTs, a change of 100W in production results in "Total Usage" changing by 120W. This means the Usage and Generation values would no longer be proportional to one another.

I know this may sound a bit confusing, so to summarize - based on this device's current configuration, if Generation values are being measured correctly then the Usage values are being calculated correctly as well. However, there are other things that could cause a discrepancy between the values reported by the eGauge and the utility. These include:

1. Comparison between the wrong values. The solid red line on the eGauge and the values in the summary area show total usage regardless of source, while the utility may be billing based on total power purchased from the utility. In systems with solar, total usage regardless of source is always a higher value than total power purchased from the utility, since you're using some of your solar production locally. For example, you might produce 1000W but consume another 200W from the utility - this means your total usage is 1200W but your power purchased from the utility is only 200W.

2. Failure to measure a load that the utility "sees". The claims I made regarding accuracy are only true if the panel being measured by those rope CTs is the main (and only) panel powering this site. If you have a large building with multiple panels, it's possible to measure a portion of the total building load by capturing a reading from Panel A, while the utility measures the total building load (Panel A + Panel B).

3. Wrong date/time range. This shouldn't lead to a 20% discrepancy by itself, but it may be a contributing factor. Put simply, you need to make sure the utility is looking at the same range of data as the eGauge (within an hour is usually adequate). If you're looking at two different date/time ranges, this will cause varying discrepancies depending on the difference. Also, you need to make sure the utility actually bases their data on real meter reads (some utilities will read once every three months but charge monthly).

4. The utility is wrong. This doesn't happen often, but it's something we've seen before. It could be something like an incorrect meter read, an incorrect meter configuration, a billing/accounting error somewhere in their office, etc. We've even seen

one instance where a utility added the site's total production to their usage (eg, they produced 2000kWh and used 3000kWh from the utility, so their bill was for 5000kWh instead of 3000kWh).

Of these scenarios I think #1 is the most likely.

I hope this information is helpful! If you have any other questions or concerns please let me know.

Thanks,

Andrew Peyronnin, eGauge Systems LLC, 877.342.8431

Appendix X2 Field Tests to Verify Total Energy Consumption

Verification of the RopeCT output using single Split Core CTs – 15 May 2020

Traditional Split Core (clam shell) CTs were installed around one of the two conductors for each of the three phases. The split core CTs were rated at 200 amp and identical to the CTs used successfully to measure the solar production.

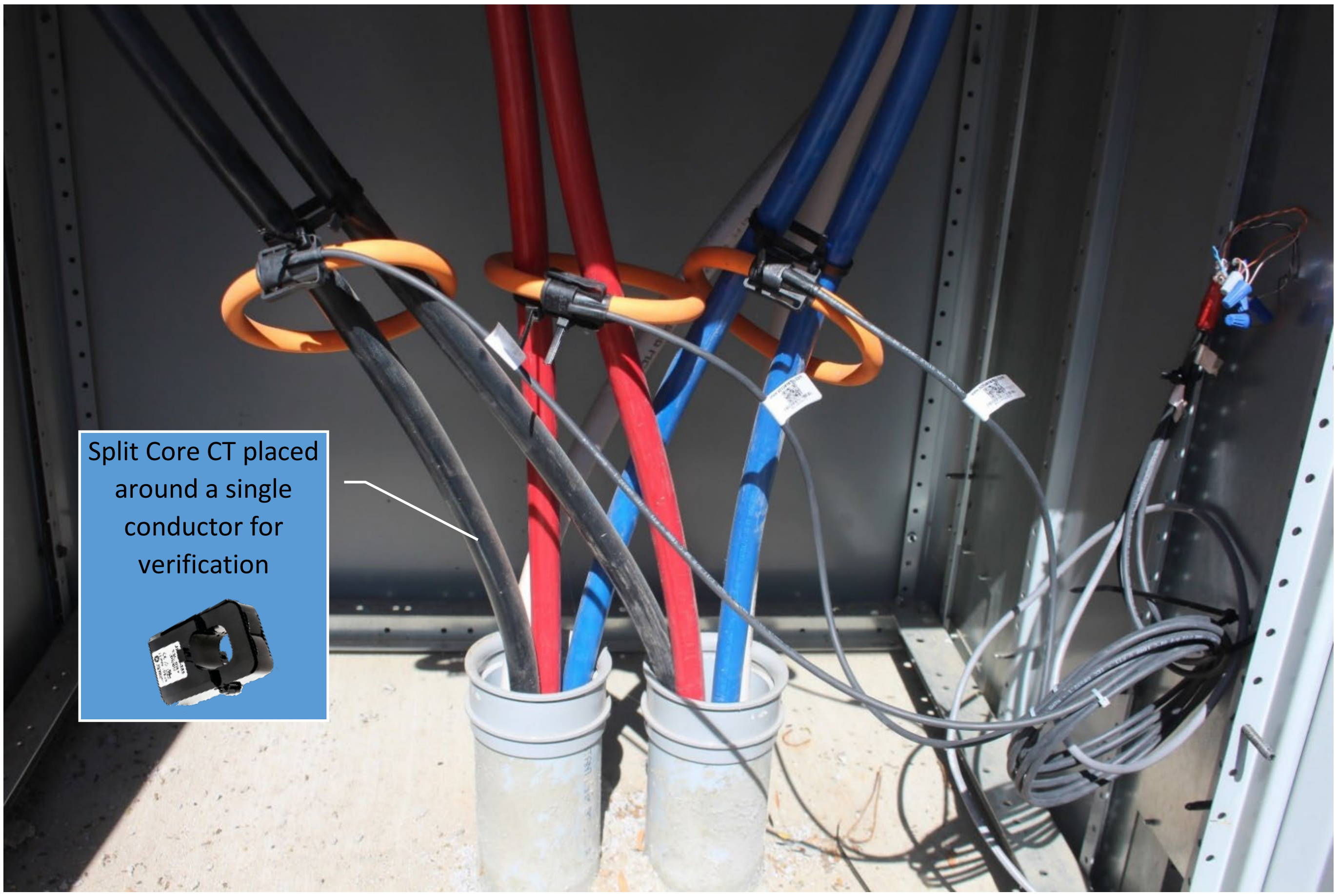


Figure 90 Split Core CTs were also added to individual conductors to verify the output of the Rope CTs

The single split core CTs indicated the same time dependent variation shown in Figure 91. Data from the ropeCTs and the split core CTs was recorded for 10 minutes. **When the split core measurement was adjusted (multiplied by two) to reflect what the ropeCTs were measuring, the two types of sensors agreed to within 2%.**

Conclusion.

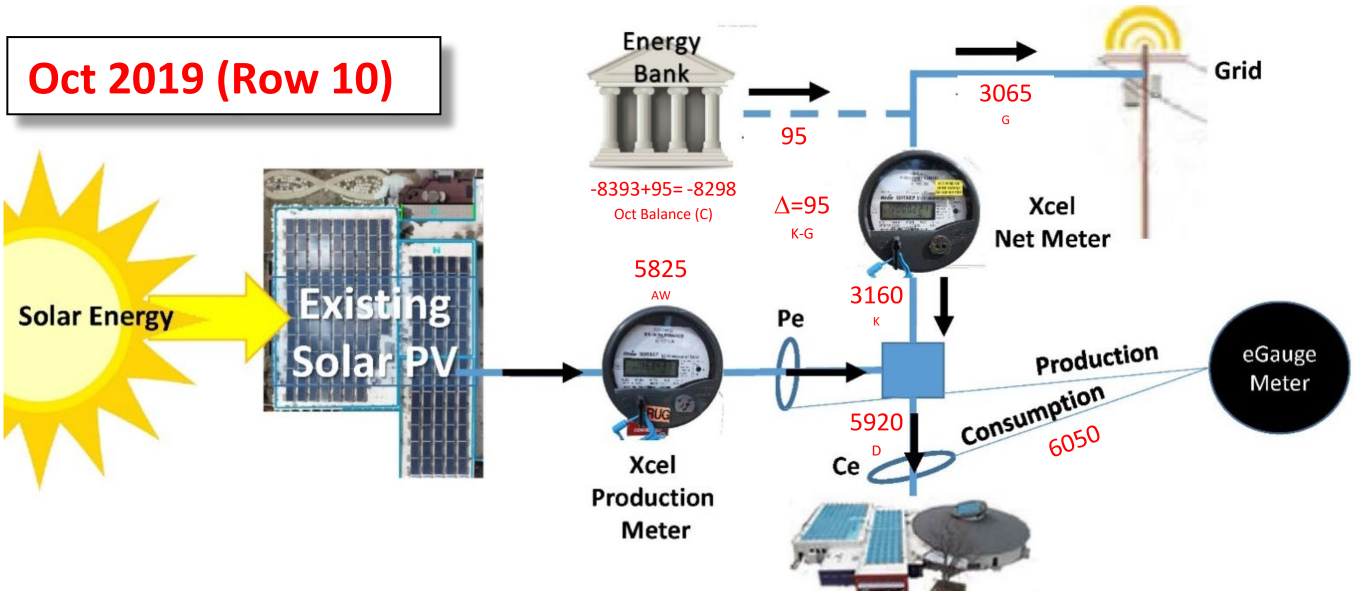
The power measured by the ropeCTs and the split Core CTs is identical (within the experimental error.)

The reason why the Xcel Net Meter and the eGauge sensors are 20% different is still unresolved. The difference is equivalent to an approximate 2000 Watt phantom load that Xcel is measuring but the FUCD ropeCTs are not seeing this load.

Other Possibilities

It is possibly that the Xcel Net Meter is not measurement

Let's also discuss if the rope CTs are attached between the Net Meter and the transformer

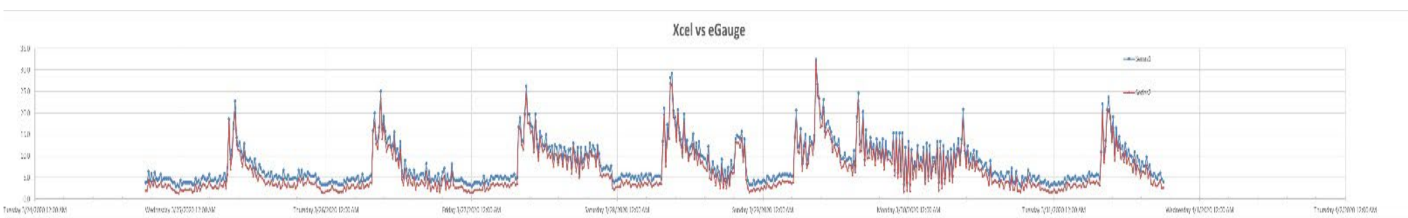


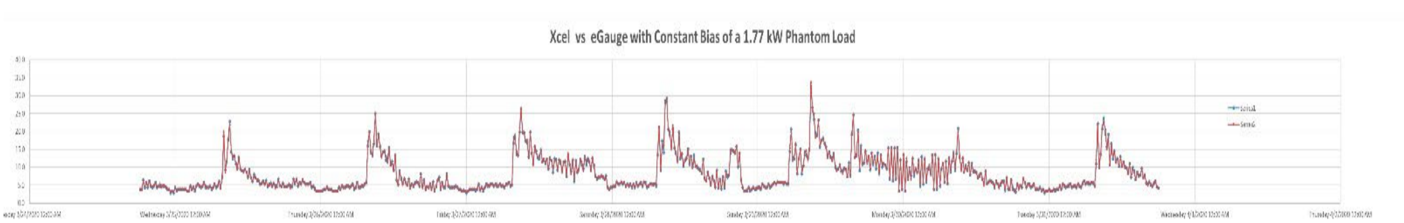
Update

Further Analysis

David Wynkoop, Xcel provided 15 minute interval data for the month of March. We used the Net Meter and Production Meter data to determine the building usage and plotted the results using Excel.

We download the eGauge data for the same time frame and plotted the building usage as well. The eGauge data was recorded for every minute, so we had to collapse the data into 15 minute intervals for direct comparison to the Xcel data.





Another approach may be possible. We could install a traditional clamshell type CT around a single conductor and them multiple the reading by two. - just as a check.

Note to eGauge.

We had identified another circuit we would like to monitor We are currently using a ropeCT because there are two conductors. We want to verify the readings with a second measurement

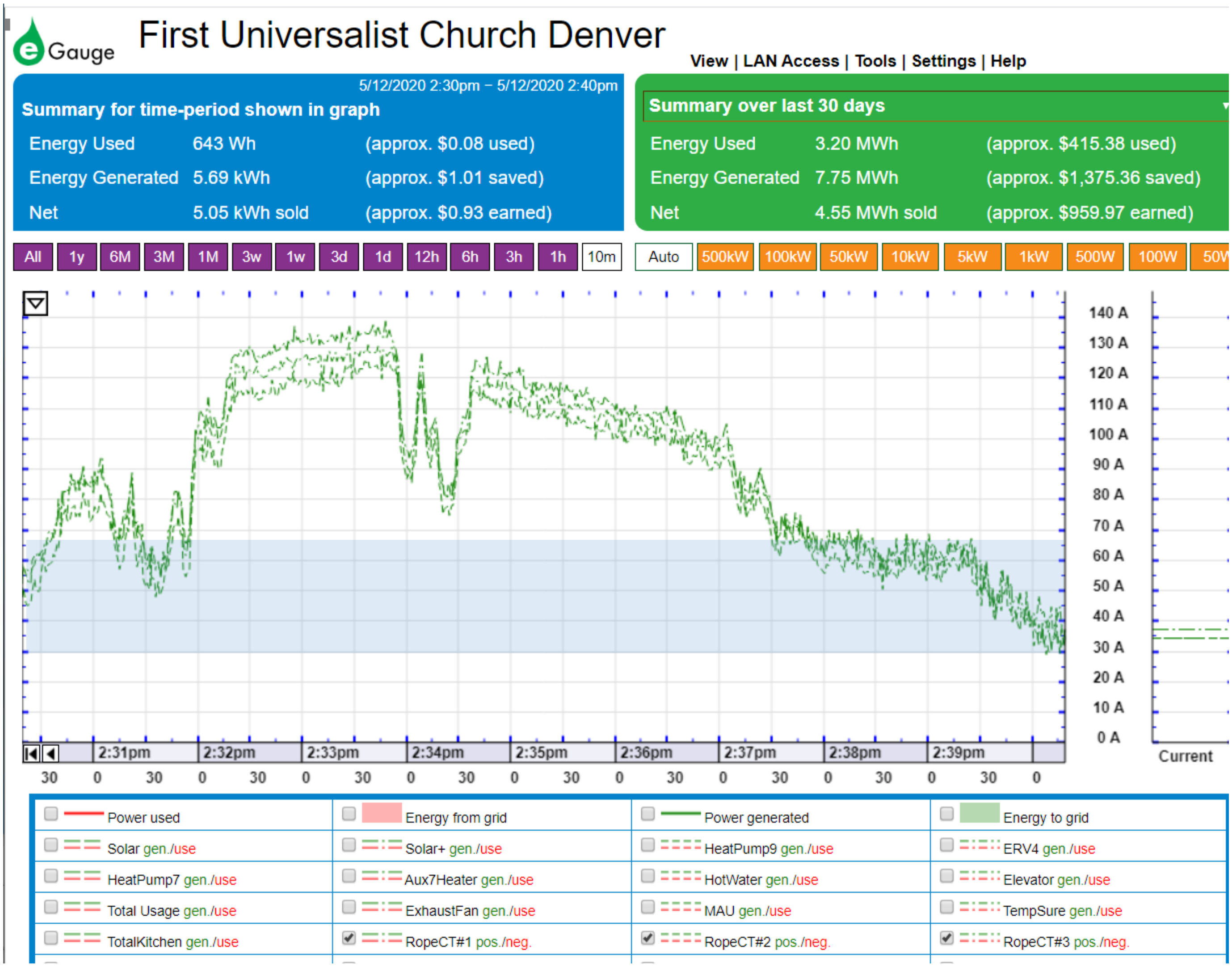


Figure 91 Transient nature of the ropeCT measurements

a) Add the eGauge monitoring system and get Inverter #3 data (for comparison to Inverters #1 & 2 with no shading) to quantify the potential for more output with power optimizers.
    a. What to expect: Each inverter has an equal number of modules (50). With shading, Inverter #3 output will be less than the other two inverters.
    b. A portion of that difference can be recovered by adding Power Optimizers. The shading effect should be most evident early morning and late afternoon. At noon, there should be minimal shading, if any. With no leaves on the trees, the shading effect may be negligible.

c. If the output difference is significant, we can go forward immediately with the proposed addition of Power Optimizers.
d. If the output difference is small, it would seem prudent to monitor the system until the trees have all their leaves and then re-evaluate the effect of shading.
e. Adding 30 optimizers including their gateway/data logger will cost around $3000.

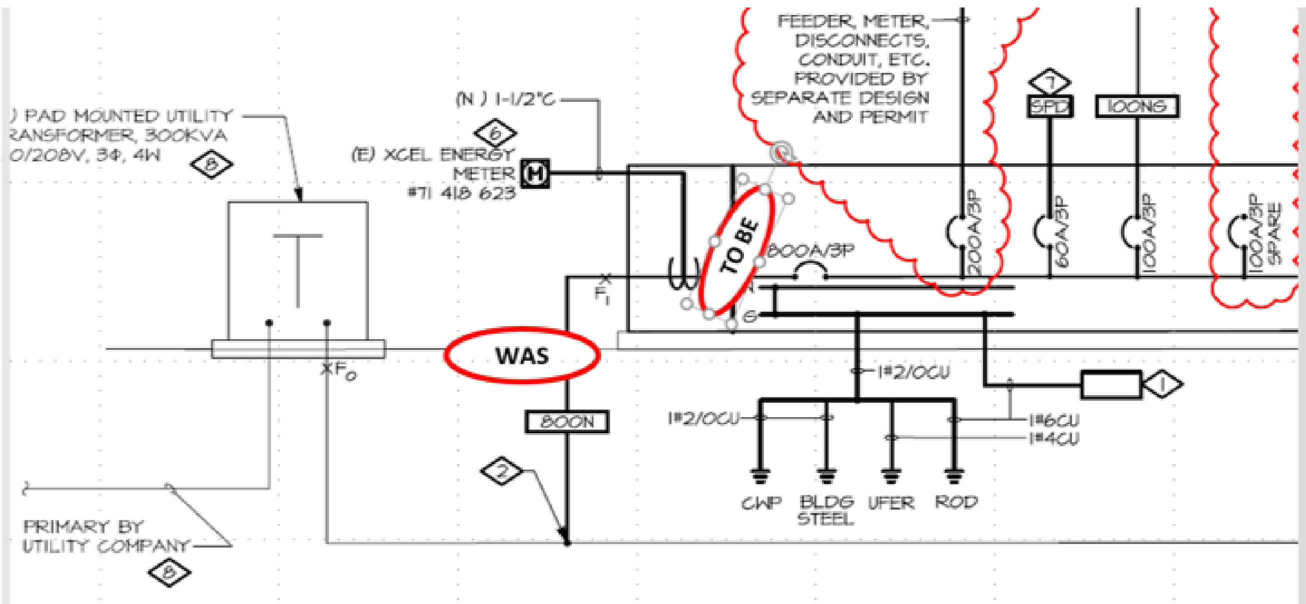
The eGauge will provide subarray data for the Awning modules, the Oculus modules and the “Other Subarray” modules. We do not need module level data for these subarrays. We can forgo adding the micro inverter ECU for these modules. We were told it would not be compatible with future micro inverters anyway.

b) After the Xcel results, reassess the annual energy shortfall. Determine the additional solar modules required to get to “Net Zero Energy.”

Having to remove the three rope CTs from our eGauge monitoring system completely negates our ability to monitor/measure the total energy usage of the church facility. We need to either push back on the Xcel “restriction” or find an alternate location / approach for these CTs.

First Item: In the figure below, I indicated where I think the three rope CT were located before and where we might try to locate them in the future – on our side of the Net Meter between the Net Meter and main service disconnect. I think they was upstream of the Net Meter before.

Figure 92 "One Wire" Electrical Schematic Diagram of FUCD Tie into Grid



This next figure shows the Main Distribution Panel with the Service Disconnect at the top

Figure 93 Main Distribution Panel

This next figure shows the wiring in the panel with the Service Disconnect in the middle

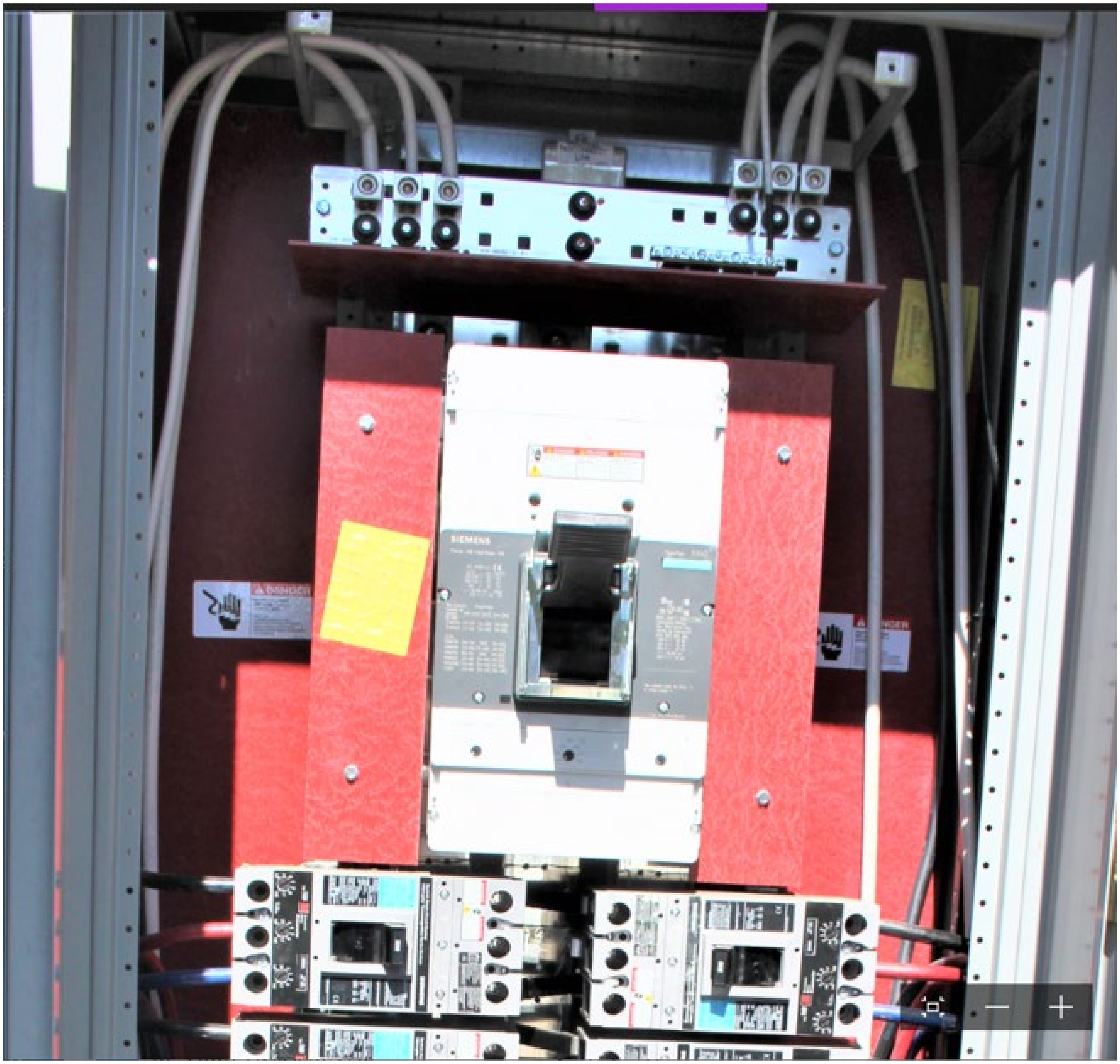


Figure 94   Wiring within the Main Distribution Panel

It's not a good photo and I can't make out any colors, but are the 6 wires coming off the top bringing power into the panel (and on our side of the Net Meter)?   If so, could we add CTS to these wires?   There is probably nowhere in the panel we can bring the dual wires for a given phase together and put the existing rope CTs around the bundle of two wires – if not, we would have to buy three more 800? amp CTs.

Second item: Xcel provided 15 minute interval data for the month of March so we could calculate the amount of energy consumed by the building during the day and compare it to what the eGauge system measured.   The eGauge recorded data every minute, so we had to "manually" sum/average 15 minutes of eGauge data to compare directly to the Xcel data.   The results for one week of operation are shown in the graphics below.   The Xcel data is significantly higher than eGauge data. There appears to be a constant offset/bias of around 1.8 kW that is present 24/7.   Over a year, this is around 15,000 kWh and an added cost of around $3000 to the church.

When a constant "load" of 1770 Watts is added to the eGauge usage data, the Xcel and eGauge results are nearly identical as indicated in the graphic below

Do you have any idea why the eGauge system is not measuring this "phantom load" of 1800 Watts that appears to be on constantly that the Xcel Net Meter is measuring?

Incidentally, we did conduct a field test and verified the rope CT calibration by comparing it to a 200 amp split core CT. The 200 amp CT was verified by comparison to the Xcel Production Meter. The eGauge rope CTs were not on the same wires as the Xcel Net Meter, so that may be a clue.

Any suggestions would be welcome.

Third Item:

David Wynkoop (Xcel) indicated

The removal of the customer metering equipment located ahead of our revenue metering on an unmetered bus will need to be removed as previously discussed. It is stated in our installation standards per Section 2.8 for Customer-Owned Meter Equipment Restrictions under item 3 that customer equipment shall not be connected to an unmetered bus or conductor. If Xcel Energy encounters customer equipment in violation of our installation standards, we ask for it to be removed and all customers in violation of this standard are treated the same by being requested to remove the equipment to the customer's side of the metering. If you feel you need to file a complaint with the PUC then that is your right as a customer, but in the meantime the equipment will need to be removed as requested.

2.8 <u>CUSTOMER-OWNED METER EQUIPMENT RESTRICTIONS</u>

Under no circumstances shall customers' equipment:

1. Be connected to, or in any way be served from, the secondary terminals of the voltage and/or current metering transformers.
2. Be installed within any metering enclosures including, but not limited to, metering transformer cabinets, transformer compartments, secondary connection cabinets, meter sockets or cold sequence disconnect.
3. Be connected to an unmetered bus or conductor.

Do these restrictions seem applicable to the FUCD situation?

2019	**Total Usage**	**97414**
	Generated	**69297**
	Shortfall (Purchased)	**28117**
		29%
2020	**Total Usage**	**69322**
	Generated	**67762**
	Shortfall (Purchased)	**1560**
		2%

Appendix X3 Obstacles Imposed by the Current Social System

In a civil society that acknowledges the urgency of responding to the existential climate crisis, it would seem that everyone involved in mitigating the root cause of global warming would be helping in every way possible to promote this transition to emission-free energy.

Using what we know today about climate science, **anyone or any organization or any society that continues to burn carbon and release GHG into the atmosphere is committing a crime against humanity – or worse. They are actually perpetuating global ecocide**.[63]

The utility monopoly that serves the church, understandable is not in a hurry to see their customers generate their own GHG emission free energy – this is a loss of revenue (and profit). However, in an existential struggle to prevent a Sixth Mass Extinction caused by current unsustainable human behavior, **we must have "all hands on deck"** – including "for-profit" enterprises – including regulated monopolies such as Xcel Energy.

Items to discuss: Lack of financial support for non-profits
Complex billing
Limit on amount of solar

A close examination of the FUCD monthly bill indicates the utility company is green-washing their operation. Graphics of solar panels and wind turbine grace their website, their publications, and their monthly bills. They begrudgingly comply with Colorado Renewable Energy Standards to have zero emissions related to electric generation in 30 years. There is no mention of how they intend to transition away selling natural gas as an energy source.

Appendix X4 Colorado Legislation House Bill 19-1261

House Bill 19-1261 was passed and signed into law last year with what appear to be "some loopholes." Excerpts are provided below:

(Ix) (A) in addressing greenhouse gas emissions from an energy-intensive, trade-exposed manufacturing source,

*the commission shall require the source to execute an energy and emission **control audit**, according to criteria established by the commission, of the source's operations every five years through at least 2035.*

A qualified third party, as determined by the commission, shall conduct the audit and submit the results to the commission.

If the commission determines that the source currently employs best available emission control technologies for greenhouse gas emissions, and best available energy efficiency practices,

the commission shall not impose a direct non-administrative cost on the source directly associated with at least ninety-five percent of the source's greenhouse gas emissions attributable to manufacturing a good in this state for a period of five years

if the source's emissions are not greater than the emissions associated with use of the best available emission control technologies as determined by the commission.

The commission shall consider how program design as relevant to those sources can further mitigate the cost of reducing emissions for such manufacturers while providing an incentive to improve efficiency and reduce emissions.

Specifically, the commission shall design the program as relevant to those sources such that as the sources are subject to emission reduction requirements, those sources will have, under the program, a pathway to obtain equivalent lower-cost emission reductions at other regulated sources to satisfy their compliance obligations.

[63] A deliberate act, typically as part of a systematic campaign that causes human suffering or death on a large scale. "he was handed over to the International Criminal Court in The Hague to face charges of crimes against humanity" Ecocide is so grotesque, so insane, so obscene there are few words to describe it - let alone a set of laws, standards, regulations, social customs, etc. to discuss it. It is unthinkable that humans as a species could knowingly commit such acts – yet we do every day.

(B) as used in this subsection (1)(e)(ix), "energy-intensive, trade-exposed manufacturing source" means an entity that principally manufactures iron, steel, aluminum, pulp, paper, or cement and that is engaged in the manufacture of goods through one or more emissions-intensive, trade-exposed processes, as determined by the commission.

(X) nothing in this subsection (1)(e) diminishes the existing authority of the commission or the division. Nothing in this subsection (1)(e) alters the regulatory exemptions provided in section 25-7-109 (8)(a).

Nothing authorized in this subsection (1)(e), including the assignment of emission reduction obligations or emission authorizations and excluding program development and administrative costs, implicates state fiscal year spending as defined in section 24-77-102.

Nothing in this subsection (1)(e) alters any requirement to prepare a cost-benefit analysis under section 24-4-103 (2.5) or any requirement to issue a regulatory analysis under section 24-4-103 (4.5).

Nothing in this subsection (1)(e) diminishes the authority of the public utilities commission under the public utilities law, including sections 40-3-101 and 40-3-102.

Appendix X5 Story Abstract / Summary

Are we on the right path? Yes.
Are we there yet? No. But we have a map to get there.
Where is "There"? "There" is a state of global human behavior that no longer burns hydrocarbons as a source of energy – a state where humans have stop adding GHG (e.g. CO_2, Methane,…) to the atmosphere.

When this state is reached, we will know. The Keeling Curve will flatten out. (indicating no further increase in the concentration of carbon in the atmosphere as measured in ppm. We are currently at around 415ppm.) "There" is where human behavior has changed and our society values behavior that is "carbon neutral" meaning zero carbon emissions. "There" is a point in time when society rewards "carbon negative" behavior - activity that extracts carbon from the atmosphere. Both are needed to curtail further global warming/climate change and flatten the Keeling curve.

Do we (FUCD) have a plan? Yes. A proposed plan is provided in this document.
When will we be there? That depends on our congregation. According to the IPCC (global climate scientists), the Laws of the Universe indicate we must by 50% of the way there by 2030; we must arrive at zero emissions before 2040 to prevent the planet from warming more than 1.5 deg C. The proposed roadmap is in compliance with the IPCC goals.

How much will it cost to implement the proposed plan? Actually, over a 10-20 year timeframe there will be a net financial gain for the congregation as well as most individual members.

Appendix X6 Ground-Source Heat Pump HVAC Performance Details

Insert verbal discussion

Insert some photos of ground loop, of valve room, of heat pump furnaces

Of temp sensors o

Of output

Of example plots of temperature

Of eGauge

Of Energy used by HVAC system – compared to old system.

Appendix X7 Kitchen Natural Gas Usage

Table 36 Natural Gas Usage - Kitchen Stove/Oven (2018-2020)

Usage Report	Report Date	01/13/21				
Usage Period	2019-01-13 to 2021-01-13					
Customer Name	**FIRST UNIVERSALIST CHURCH**					
Account Number	**53-2125618-2**					
Account Address						
Premises Number	301360724					
Premises Address	4101 E HAMPDEN AVE DENVER CO 80222-7262					
Premises Status	CURRENT					
Service	**GAS-1**					

Last Read Date	Billing Days	Gas Usage (therms)	Read Method	Gas Charges	Total Gas Charges	Monthly Gas Rate ($/therm)
2020 Natural Gas Usage						
01/04/2021	35	44	Actual	$66.23	$68.22	$1.51
11/30/2020	33	42	Actual	$65.34	$67.30	$1.56
10/28/2020	29	36	Actual	$62.36	$64.23	$1.73
09/29/2020	29	37	Actual	$59.69	$61.48	$1.61
08/31/2020	32	41	Actual	$61.32	$63.16	$1.50
07/30/2020	30	37	Actual	$59.69	$61.48	$1.61
06/30/2020	29	**37**	**(Therms Missing-Calcuatec**	$57.52	$59.24	
06/01/2020	32	**39**	**(Therms Missing-Calcuatec**	$59.29	$61.07	
04/30/2020	29	36	Actual	$57.49	$59.21	$1.60
04/01/2020	29	38	Actual	$59.81	$61.60	$1.57
03/03/2020	8	**10**	**(Therms Missing-Calcuatec**	$15.86	$16.34	
01/23/2020	34	57	Actual	$64.93	$66.88	$1.14
	349	**454**		**$689.53**	**$710.21**	**$1.52**
Prorate for 365 days	**365**	**475**		**$721.14**	**$742.77**	
2019 Natural Gas Usage						
12/20/2019	31	47	Actual	$59.59	$61.37	$1.27
11/19/2019	28	**36**	**(Therms Missing-Calcuatec**	$54.47	$56.10	
10/22/2019	32	**38**	**(Therms Missing-Calcuatec**	$57.83	$59.56	
09/20/2019	30	**36**	**(Therms Missing-Calcuatec**	$55.28	$56.94	
08/21/2019	29	37	Actual	$54.83	$56.47	$1.48
07/23/2019	32	**37**	**(Therms Missing-Calcuatec**	$57.28	$59.00	
06/21/2019	30	38	Actual	$58.68	$60.44	$1.54
05/22/2019	29	39	Actual	$61.09	$62.93	$1.57
04/23/2019	28	38	Actual	$61.47	$63.32	$1.62
03/26/2019	29	40	Actual	$65.52	$67.49	$1.64
02/25/2019	33	41	Actual	$66.15	$68.14	$1.61
01/23/2019	33	43	Actual	$65.54	$67.51	$1.52
	364	**470**		**$717.73**	**$739.27**	**$1.53**
Prorate for 365 days	**365**	**471**		**$719.70**	**$741.30**	
2018 Natural Gas Usage						
12/21/2018	32	40	Actual	$60.78	$62.60	$1.96
11/19/2018	31	42	Actual	$61.74	$63.59	$2.05
10/19/2018	29	38	Actual	$59.91	$61.70	$2.13
9/20/2018	51	64	Actual	$103.88	$107.00	$2.10
7/31/2018	32	53	Actual	$68.71	$70.78	$2.21
6/29/2018	29	87	Actual	$85.94	$88.52	$3.05
5/31/2018	30	100	(Therms Missing-Calcuatec	$105.34	$108.50	
5/1/2018	29	77	Actual	$81.71	$84.16	$2.90
4/2/2018	31	157	Actual	$127.26	$131.07	$4.23
3/2/2018	30	85	Actual	$91.34	$94.08	$3.14
1/31/2018	29	4	Actual	$47.64	$49.07	$1.69
	353	**747**		**$894.25**	**$921.07**	**$25.46**
Prorate for 365 days	**365**	**772**		**$924.65**	**$952.38**	

Externalities associated with Natural Gas (Burning for Heating Purposes)

AS IS - Natural Gas - Externalites

CO2 Production / Addition to the Atmosphere

For this exercise, we will only consider two externalities: 1) Burning natural gas in a furance results in the production of CO2. This CO2 is vented/dumped into the atmosphere.
2) The drilling/fracking/collection/transportation of natural gas results in leakage of methane into the atmosphere. Methane has a GWP of 86 averaged over 20 years compared to CO2. Although leakage rates have been measured in actual gas producing fields to be 6% - 17%, the oil and gas industry often self-reports a level of 3% leakage to the EPA. That's what we will use for illustration.

Amount of CO2 produced from burning natural gas				
Amount consumed annually	470	therms / year		$705.00
CO2 per therm				
1therm =	0.005302	metric tons CO2		http://www.eia.gov/environment/emissions/co2_vol_mass.cfm
CO2	2.5	metric tons CO2 / year		
Cost to capture & sequester CO2	$60	/tonne		
Externality - no leakage	**$150**	/year	Note: this natural gas is currrently sold for $1.50 / therm	
CO2 Equivalent with Leakage				
Leakage	3.0%	See cell "B23" to input different value		
Muliplier	1.93			
CO2	**5**	metric tons CO2 / year with methane leage		
Externality - with leakage	**$289.28**			
Operation	**20**	**years**		
CO2 produced using natural gas (tonnes)	**96**			
Cost to capture & sequester CO2	**$5,786**	No escalation due to inflation, etc.		

Appendix X8 Hydrogen as a Fuel

Liquid Hydrogen--the Fuel of Choice for Space Exploration

Despite criticism and early technical failures, the taming of liquid hydrogen proved to be one of NASA's most significant technical accomplishments. . . . Hydrogen -- a light and extremely powerful rocket propellant -- has the lowest molecular weight of any known substance and burns with extreme intensity (5,500°F). In combination with an oxidizer such as liquid oxygen, liquid hydrogen yields the highest specific impulse, or efficiency in relation to the amount of propellant consumed, of any known rocket propellant.

Figure 95 Centaur is raised into the "J" Tower for testing at Point Loma, early 1960s. Credit: Lockheed Martin

Because liquid oxygen and liquid hydrogen are both cryogenic -- gases that can be liquefied only at extremely low temperatures -- they pose enormous technical challenges. Liquid hydrogen must be stored at minus 423°F and handled with extreme care. To keep it from evaporating or boiling off, rockets fuelled with liquid hydrogen must be carefully insulated from all sources of heat, such as rocket engine exhaust and air friction during flight through the atmosphere. Once the vehicle reaches space, it must be protected from the radiant heat of the Sun. When liquid hydrogen absorbs heat, it expands rapidly; thus, venting is necessary to prevent the tank from exploding. Metals exposed to the extreme cold of liquid hydrogen become brittle. Moreover, liquid hydrogen can leak through minute pores in welded seams. **Solving all these problems required an enormous amount of technical expertise in rocket and aircraft fuels cultivated over a decade by researchers at the National Advisory Committee for Aeronautics (NACA) Lewis Flight Propulsion Laboratory in Cleveland.**

Today, liquid hydrogen is the signature fuel of the American space program and is used by other countries in the business of launching satellites. In addition to the Atlas, Boeing's Delta III and Delta IV now have liquid-oxygen/liquid-hydrogen upper stages. This propellant combination is also burned in the main engine of the Space Shuttle. One of the significant challenges for the European Space Agency was to develop a liquid-hydrogen stage for the Ariane rocket in the 1970s. The Soviet Union did not even test a liquid-hydrogen upper stage until the mid-1980s. The Russians are now designing their Angara launch vehicle family with liquid-hydrogen upper stages. Lack of Soviet liquid-hydrogen technology proved a serious handicap in the race of the two superpowers to the Moon.4 Taming liquid hydrogen is one of the significant technical achievements of twentieth century American rocketry.

The above excerpt is from the Introduction to Taming Liquid Hydrogen: the Centaur Upper Stage Rocket, 1958-2002 →. This report details why the Centaur was so important in NASA history as an upper stage rocket -- the critical link between its booster stage (Atlas or Titan) and the mission's payload (satellite or spacecraft).

See also Liquid Hydrogen as a Propulsion Fuel, 1945-1959, (http://history.nasa.gov/SP-4404/ch8-1.htm) the NASA History Office's detailed account of liquid hydrogen as a propulsion fuel in the early days of space flight.

https://www.nasa.gov/topics/technology/hydrogen/hydrogen_fuel_of_choice.html

XTRA

Shading effects were not included in the original sizing analysis.

The initial sizing of the solar PV system did not attempt to compensate for possible shading from the two deciduous trees south of the array.

Installation of Additional Instrumentation / Monitoring Capability for the Solar PV System

"In the Western tradition there is a recognized hierarchy of beings, with, of course, the human being on top—the pinnacle of evolution, the darling of Creation—and the plants at the bottom. But in Native ways of knowing, human people are often referred to as "the younger brothers of Creation." We say that humans have the least experience with how to live and thus the most to learn—we must look to our teachers among the other species for guidance. Their wisdom is apparent in the way that they live. They teach us by example. They've been on the earth far longer than we have been, and have had time to figure things out."
— Robin Wall Kimmerer, Braiding Sweetgrass: Indigenous Wisdom

"Knowing that you love the earth changes you, activates you to defend and protect and celebrate. But when you feel that the earth loves you in return, that feeling transforms the relationship from a one-way street into a sacred bond."
— Robin Wall Kimmerer, Braiding Sweetgrass: Indigenous Wisdom

There were more questions than answers.

It was recognized the only data available was the total system output. Xcel provided a monthly summary, and the eGauge monitoring system provided total system output every minute. But the total monthly output was not sufficient to trouble shoot or evaluate the health of the system or to quantify the amount of partial shading on the array. There was a lack of performance information so an evaluation of the system health was very limited. Options were explored. City Electric proposed some additional monitoring approaches, including adding Power Optimizers (or micro inverters) to some of the modules

Additional monitoring equipment was added. More data was obtained. 3D modeling helped envision the issues. A new perspective emerged.

The reduced output is now seen as a combination of several factors

There were more cloudy days in 2019 than used in the PVWATTS weather model – as a result PVWATTS appears to have over predicted the system output by between 13 to 25%. There is no significant shading during spring and summer months. However there is measurable tree shading as well as structural shading during the fall and winter months. The leaves are on the trees when the sun angle are lower in the sky. Around winter solstice, the sun angle is do low, shadows from the middle parapet wall, inverter boxes and even the combiner panel box can cast a shadow on the front row (southern most row) of modules on Friendship Hall.

By developing a 3D model of the rooftop geometry including the deciduous trees and the some key structural elements mounted on the roof, we discovered another source of shading we refer to as structural shading.

Looking ahead to the 2021, as the church members are vaccinated, church usage is expected to increase and if 2019 represented a normal usage, we will again be using more energy we produce. Additional solar modules will be needed.

Role of GF – limited perspective – later began to appreciate the tie to transportation – bi directional charging stations – need for storage – tie to community – near a park – grants for charging stations – tie with peak demand – incentives to add to car port solar

Utilize parking area

The report goes on to envision the energy system of the near future – next few years – next decade.

This is followed by conclusions and recommendations and a plan to go forward in reducing the carbon footprint of FUCD facility

There are numerous appendices providing technical details for those who might be interested in the basis for the report.

There are many lessons learned along the way – we often stop and try to point out these

May want to write a grant proposal for some charging stations – not sure how to justify them if they are not bi directional and can help for reducing the peak demand on the grid.

We need to know this information so we can resize the solar PV system to generate an equal amount of emission-free energy on an annual basis. The church membership wishes to be responsible global citizens and stop contributing to the climate crisis. Further discussion of how the current social system supports the transition from burning fossil fuels to harvesting renewable energy can be found in Appendix L1.

Since the output from the eGauge monitoring system had not been verified, it was decided to use the official Xcel billing data from the Xcel Production Meter and the Xcel Net Meter as the definitive performance measurement system. Sensing that there was a shortfall, and it would be necessary to reclama the application to Xcel for a permit to install more solar modules, in such a situation, the Xcel Meter data would be used instead of the unverified eGauge data.

The decision to use Xcel data became problematic because the Xcel rate schedule was changed around Sep - Oct 2018 to SPVTOU-B. So it wasn't until October 2019 that 12 months of consistent billing data were available.

We had no idea how difficult using the Xcel billing data was going to be.

> For example, during much of 2019, the facility was used by a third party renter on the week days. Also during the year, FUCD hosted a half-dozen unexpected events and numerous tours of the building because the renovated facility is not only aesthetically pleasing, but it is a positive example of what can be done to be in 'right relationship' with the environment when so motivated (e.g. by our UU Seventh Principle, "Respect for/reverence of the interdependent web of life.")

"I want you to act as if our house is on fire. Because it is."

--- Greta Thunberg

Do we (FUCD) have a plan to get there?

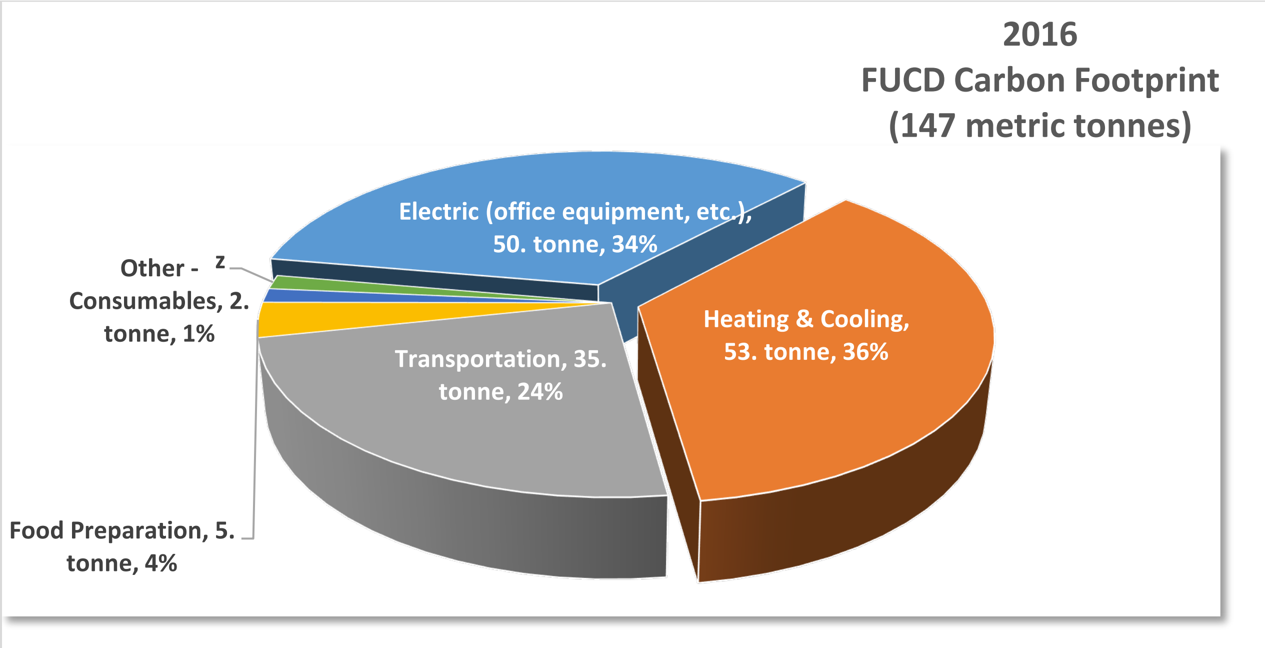
No. Only a sense of direction. There were more question to answer before an actionable plan could be developed. A proposed roadmap/plan is provided in this document.

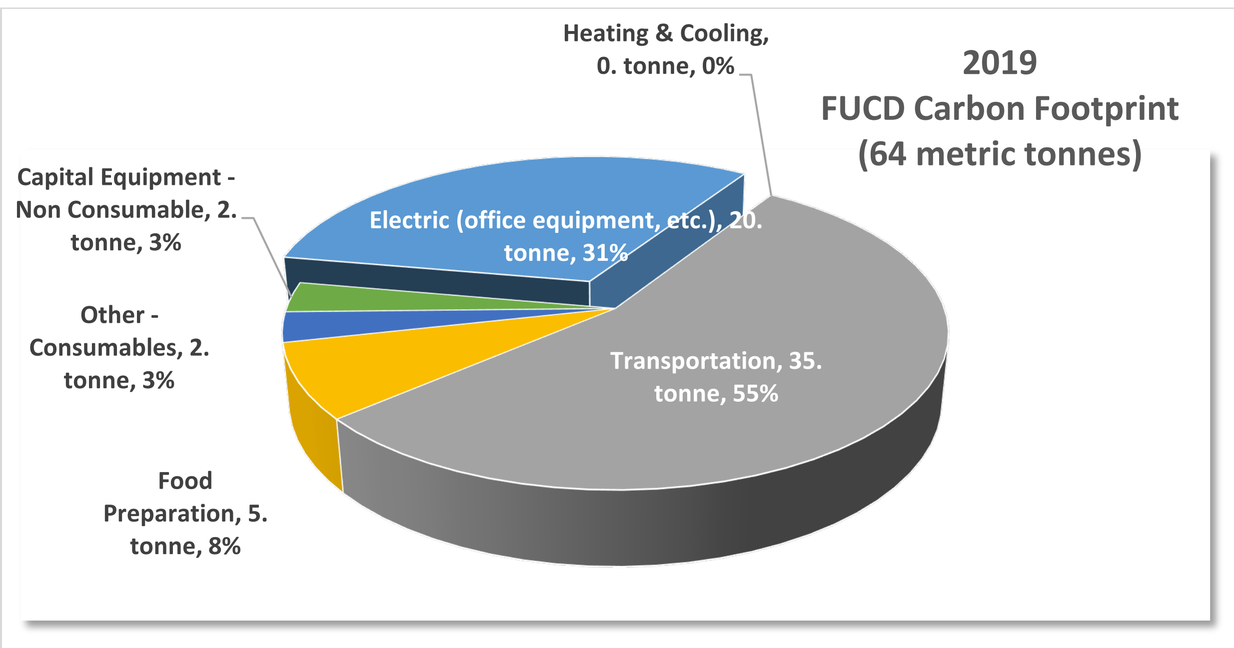
How much will it cost to implement the proposed plan?

From past experience, we know that cost or money is not the issue or the concern – we know that transitioning to renewable energy is always a profitable endeavor from a global perspective – it is always less expensive to prevent the problem than to fix the problem at a system level. But nevertheless we have to apply classical economics to show it is profitable to change behavior as well as the right thing to do from a moral/ethical perspective – we worship the economic gods and use their rules to make many of our life choices --- hopefully these rules are going to change soon or humans will be cause primary cause of the sixth mass extinction that has already been initiated

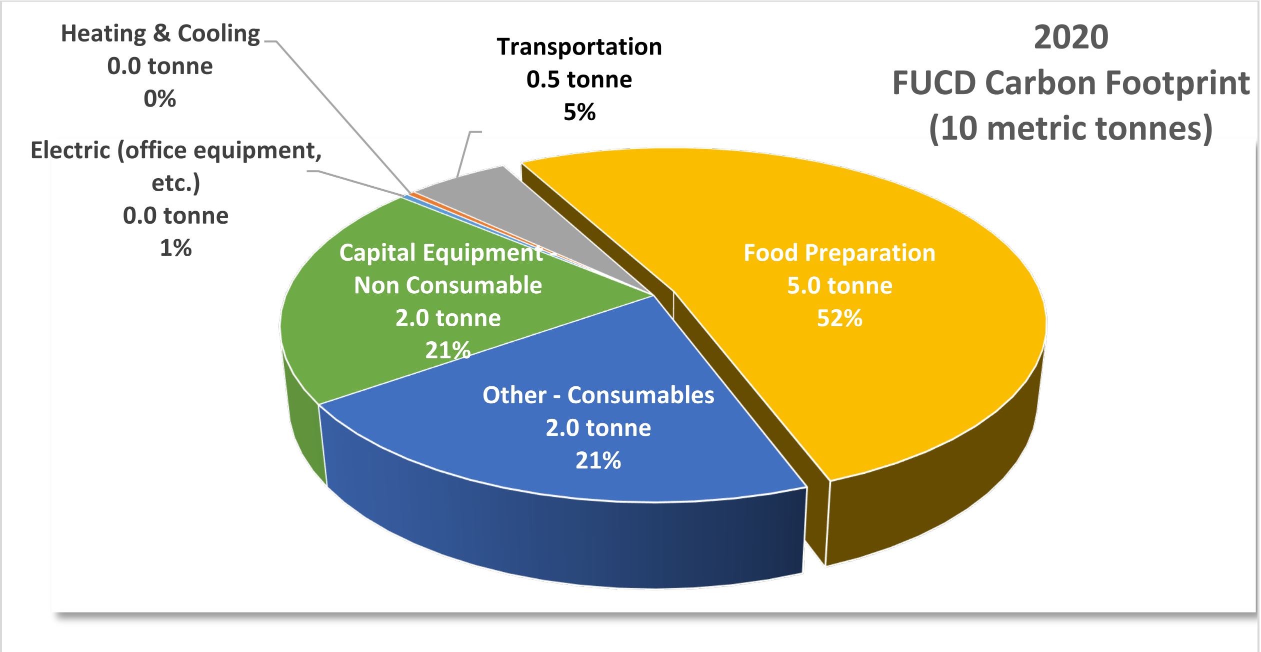
At the end of the first year, we still needed more quantitative information about the new energy system to develop a cost estimate.

Nevertheless, we did have confidence that the changes to the energy system needed over the coming decade would result in a **net financial gain** for the congregation. Generating power onsite is less expensive than buying & importing energy from a 'for-profit' utility company. So it is expected FUCD will move closer to the Revenue Neutral operational goal as well. For example, adding more solar modules to our existing array to generate all of our electrical needs can actually be a "money-maker."


2016
FUCD Carbon Footprint
(147 metric tonnes)
Electric (office equipment, etc.), 50. tonne, 34%
Heating & Cooling, 53. tonne, 36%
Transportation, 35. tonne, 24%
Other - z
Consumables, 2. tonne, 1%
Food Preparation, 5. tonne, 4%


2019
FUCD Carbon Footprint
(64 metric tonnes)
Heating & Cooling, 0. tonne, 0%
Capital Equipment - Non Consumable, 2. tonne, 3%
Electric (office equipment, etc.), 20. tonne, 31%
Other - Consumables, 2. tonne, 3%
Transportation, 35. tonne, 55%
Food Preparation, 5. tonne, 8%

DRAFT



NOTE: *In March 2020, an additional eGauge meter was installed along with 15 CTs to monitor the performance of the solar system at the subarray level. Monitoring is still ongoing, but an interim report on shading is documented in this report.*

A field test was conducted in May that identified the as built system was wired differently than indicated on the engineering drawings

Continued to monitor data during the year and attempt to understand

Compared the Xcel data logger data with the eGauge meter data on an hourly basis – concluded the Xcel Net Meter was nmore accurate than the FUCD rope CT sensors – hence we revert to using theXcel Net Meter data rather than the FUCG eGauge info for the total usage measurement of the building

Updated the annual production and usage table for the calendar year 2020

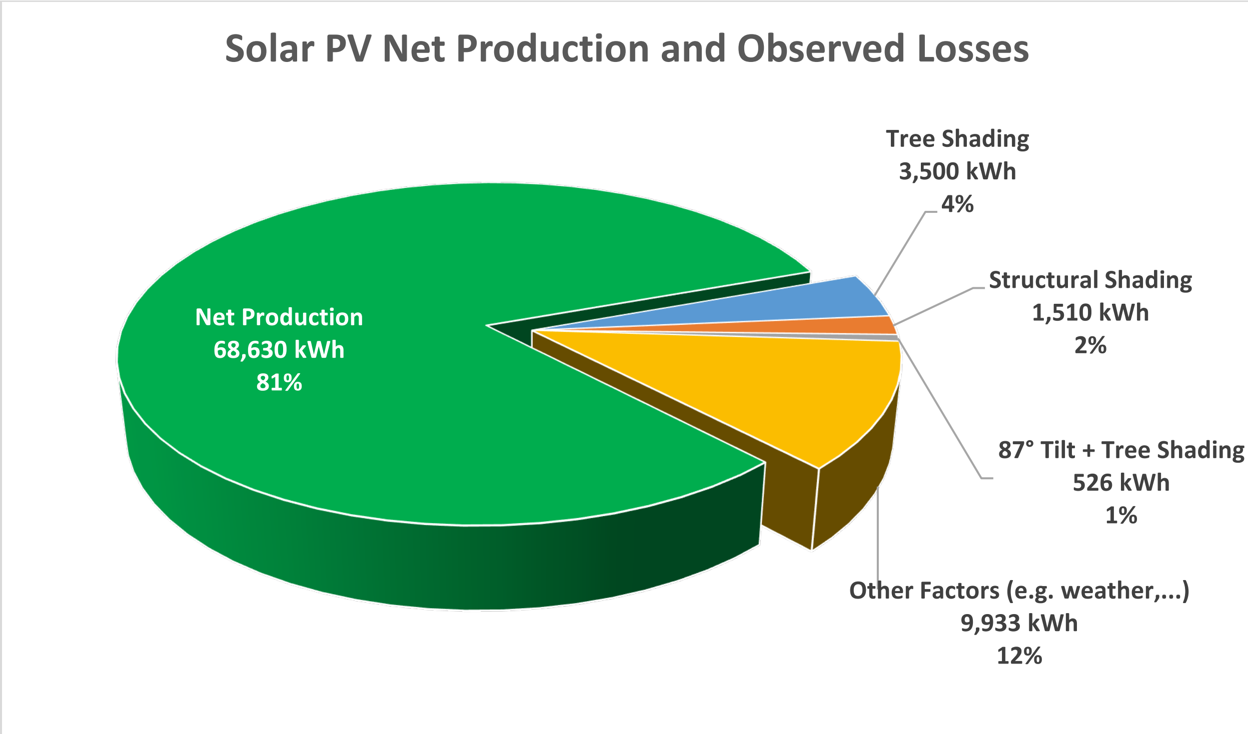
Found it to be Net Zero Energy

Developed a 3D Sketchup model of the roof with tree and structural shading

> *"Verified/ clarified" tree shading – can envision how extensive the winter shade moves across the array of 100 modules*
>
> *Identified another source of shading during Nov, Dec, and Jan – structural shading from the inverter boxes and the Exhaust air furnace housing.*

Concluded that it may not cost effective to added power optimizers to 75 to 100 modules in an effort to mitigate "strung effects" during the 3 winter months when significant tree and structural occur.

Continued to revise Roadmap to Zero GHG Emissions.



This reduced mode of operation may be good for the planet, but it severely restricts the mission of our church. As our church membership and local community becomes vaccinated for the corona virus, and operations return to a new normal. When we do, we will again be using more energy than we produce unless we increase the size of our solar PV system accordingly. This includes the transition to electric or hydrogen powered cars for transportation to church functions.

Energy usage in 2019 turned out to be 25% more than the architects predicted and more than the solar system produced. As a result, there was an energy production shortfall. The Net Zero Energy goal was not met. Power was purchased from Xcel to make up the energy shortfall. The additional energy expense meant the Revenue Neutral goal was not met. FUCD paid $1820 [64] more for sustainable energy in 2019 than for fossil-fuel based energy in 2016 (prior to the renovation.) In 2019, FUCD did not meet their Zero GHG Emission goal because they used energy generated by Xcel. Xcel still burns fossil fuel to generate 72% of the power they sell and they dumped around 20 metric tonnes of CO_2 in the atmosphere with FUCD's name on it. (See Appendix U Xcel Energy Portfolio for details)

This report describes several possible explanations for the unexpected amount of energy used in 2019 including:

1) the architect's energy analysis may have underestimated energy usage for 'normal' operations, and/or
2) the activity level of the renovated facility in 2019 was more than expected (possibly because the BFF project was so successful in enlarging the facility, making it more aligned with the UU ethical & spiritual values, and making it more esthetically pleasing.)

But 2020, the second year of operation was different. Energy usage in 2020 was 30% less than in 2019 due to reduced operations in response to the COVID-19 pandemic. As a result, FUCD met their Net Zero Energy, Revenue Neutral and Zero GHG Emissions goals in 2020. In fact, they ended the 2020 calendar year with a small surplus of energy (+3% of the total). They "banked" around 2,230 kWh of energy credits. The cost of energy related utilities in 2020 was around $420 less than in 2016 (prior to transitioning to renewable energy.)

The new energy equipment that has already been installed demonstrated we can comply with our Zero GHG Emission goal. None of the new equipment (i.e., solar PV modules, heat pump furnaces, energy recovery ventilators (ERVs), energy efficient windows, insulation, etc.) burns hydrocarbons or net greenhouse gas emissions that harm life on the planet.

Insights from evaluating the first year of operation of the new sustainable energy system were used to define additional data that was needed to quantify adjustments to the initial system. We discovered that just measuring the 'total energy system production' was insufficient to recommend changes. We recognized additional instrumentation/monitoring equipment was needed to record more detailed information about the system performance. For example, after the first year of operation, we realized that 'tree shading' was likely reducing the power output of the system. But there was insufficient data to quantify how much shading was occurring, or what could be done to mitigate/minimize these effects. The Green First Task Force funded and installed additional eGauge monitoring equipment in March 2020.

PATH TO ZERO GHG EMISSIONS

FIRST UNIVERSALIST CHURCH DENVER CARBON FOOTPRINT

[64] This slight increase in operating expense is 0.2% of the annual operation budget of the church

DRAFT

Respect/Revere the interdependent web of life