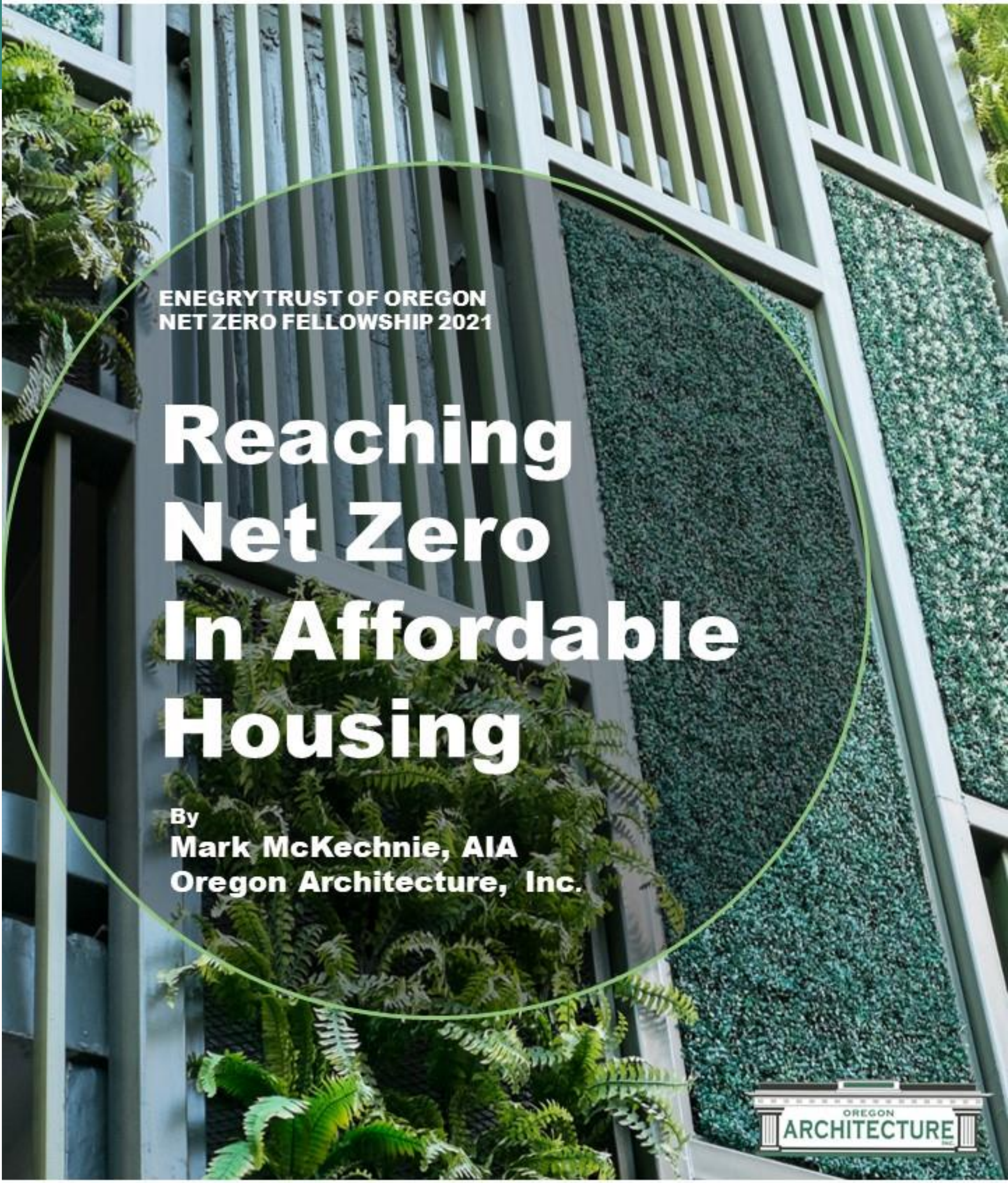

ENEGRY TRUST OF OREGON
NET ZERO FELLOWSHIP 2021

Reaching Net Zero In Affordable Housing

By
Mark McKechnie, AIA
Oregon Architecture, Inc.

OREGON ARCHITECTURE INC.

Table of Content

OBJECTIVES AND GOALS:

- Demonstrate heat/loss gain.
- Show corresponding energy consumption reductions.
- Construction systems employed and materials needed.
- Amount of retraining of workers needed to implement an energy reduction strategy.
- Building Codes implications, if any.
- Applicability to typical market-generated housing construction.

INTRODUCTION:

Oregon Architecture, Inc., and the Energy Trust of Oregon, through the Net Zero Fellowship, aim to address market, technological or policy barriers to net-zero buildings and to grow the community of practitioners advancing Net Zero Energy design and construction practices in Oregon.

The research goal is to increase the industry's knowledge of achieving net-zero energy performance within affordable housing projects in Oregon. The research will be made available to the Oregon Housing and Community Services Office for possible use in modifying rent/utility calculation tables to allow for more energy-efficient construction and to inform local Housing Authorities on how additional energy-efficient construction can be paid for by recapturing a portion of tenant money spent on utilities. This research will also provide information to builders in the conventional market that additional energy-saving strategies can be financed in the same manner. Oregon Architecture, Inc. will evaluate energy consumption reduction options and rate them according to construction cost and return on investment.

Oregon Architecture, Inc. will partner with the Klamath Housing Authority and focus on a segment of the housing population, notably Armed Services Veterans in need of affordable housing, especially in rural areas of this state. As with any government-funded housing agency, the Klamath Housing Authority provides decent, safe, and sanitary housing for individuals and families who meet the certain minimum or maximum criteria. Tenant rent is based on income or ability to pay and is not tied to market conditions, so this is perhaps an ideal population to further investigate and test energy-efficient construction strategies.

Through the use of advanced design and construction practices and technologies, Oregon Architecture, Inc., will demonstrate ways buildings can be more efficient and resilient while meeting the occupants' needs.

Oregon Architecture, Inc. has assigned Mark McKechnie, Owner, and President, to deliver the above research work, supporting other office personnel, including David W. Sommer and Niru Patel. Dianna Otero, Executive Director of the Klamath Housing Authority, will provide energy consumption reports and financing knowledge on federally and state-funded construction bonds. Matt Bogatay, Bogatay Construction, Inc., will provide construction cost data. David Keys, Principal of MEPCon, LLC, will provide heat loss/heat gain consulting on materials and construction systems.

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Architect, Principal at OAI

- University of Oregon
  Bachelor of Architecture, 1972
- University of Minnesota
  Master of Architecture, 1978
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- Bachelor of Architecture
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- Master of Science in Construction Management
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- Universal Technical Institute,
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- Former Director of Facility & Grounds
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RESEARCH BACKGROUND:

The study vehicle to explore ways to move towards net-zero in low-income housing focuses on a specific one-bedroom one-bath unit, designed and constructed for the Klamath Housing Authority for construction in Klamath County, Oregon. To date, the unit has been constructed at two different sites and is currently under construction at a third site. The two previous developments have been operational for 10 years and 3 years, respectively. The first iteration was constructed with two wall-mounted cadet heaters (simple electric resistance heating units) and no air conditioning. The second iteration was constructed with mini-splits, which included air conditioning. Both developments were constructed with units configured as duplexes and were built to meet or exceed Building Code energy requirements at the time of construction. Victory Commons also had a two-bedroom manager's unit.

Regardless of building shell efficiency, the units still require electricity to provide lighting, cooking, and the other functions of daily living. This study will also look at options to bring these uses closer to net zero.

The premise of our study is that savings realized from additional energy efficiency measures can be used to offset the costs of installing those energy efficiency improvements into the unit.

To determine the amount of money available, we first had to determine what the tenants paid for electricity, which is the only franchise utility required to make these units operational. The Housing Authority was able to secure tenant electrical invoices for many of the units, which are typically occupied by single tenants, primarily retired veterans. The following table shows the annual electricity costs per unit, and by extrapolation, what funds would be available to fund the improvements:

Trails View was constructed as four duplexes for a total of 8 one-bedroom, one-bath units of 604 square feet. The actual cost of construction in 2009 was $79,907 per unit. This cost reflected an economy deep in recession, minimal interior finishes and minimal site work.

Victory Commons was constructed as six duplexes, ten one-bedroom, one-bath units of 604 square feet, and one duplex with a two-bedroom, one-bath manager's apartment and a small community room. The actual cost of construction in 2016 was $154,365 per unit. This cost reflected a booming construction economy, added interior amenities (like air conditioning) and additional costs associated with a complex site.

These units are currently being constructed for a third time, with an expected finish date of September 1, 2021. Construction costs are projected to be $150,255 per unit, again reflecting easier site construction.

TABLE: Recent 12 months electric Bill/ Cost analysis without escalation

DATA FROM PACIFIC POWER									
	Victory Commons							Trail's Views	
	1BR Unit						2 BR Unit	1 Bed Unit	
Months	1	2	3	4	5	6	7	1	2
January	106.70	77.84	58.50	71.82	85.92	84.09	109.29	121.68	104.78
February	99.35	66.05	56.55	64.92	67.21	70.54	92.11	122.76	124.48
March	89.01	54.66	47.79	55.33	67.92	55.60	76.80	115.69	107.13
April	93.54	51.50	50.76	52.96	66.99	50.28	83.03	115.06	131.31
May	76.31	35.47	34.14	42.76	53.78	35.86	88.18	66.30	77.35
June	63.08	37.21	28.59	38.16	44.00	30.21	78.90	59.92	66.79
July	61.03	39.79	24.96	40.17	46.64	26.07	90.49	43.42	51.66
August	66.73	42.76	28.77	49.95	43.53	25.24	110.81	39.80	49.72
September	57.81	40.36	29.92	43.82	41.31	22.36	85.49	45.19	37.11
October	57.24	37.13	29.06	41.89	33.67	23.12	86.43	45.68	27.22
November	73.51	46.65	34.17	40.90	42.16	31.58	75.35	60.93	43.78
December	104.30	65.27	55.17	62.00	59.87	54.32	103.73	125.56	110.48
Monthly Avg bill	79.05	49.72	39.87	50.39	54.42	42.44	90.05	80.17	77.65

Properties / Timespan	Victory Commons 1 BR Unit	Victory Commons 2 BR Unit	Trail's View 1 BR Unit
Avg. Per Month	$52.65	$90.05	$78.91
Avg. Per year	$631.77	$1080.61	$946.90
10 Years projection	$6,317.72	$10,806.10	$9,469.00
20 years projection	$12,635.43	$21,612.20	$18,938.00
30 years projection	$18,953.15	$32,418.30	$28,407.00

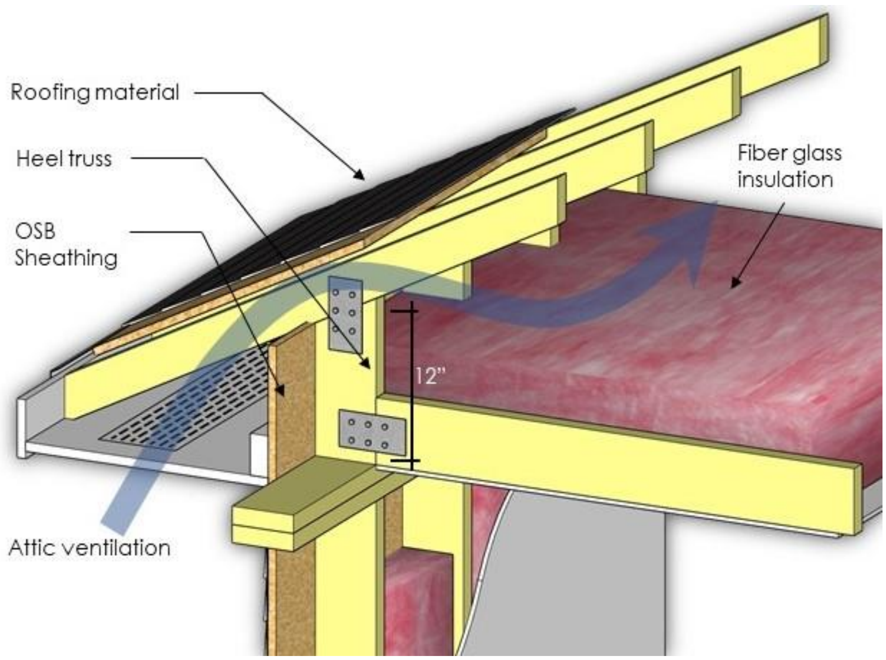
Note: Above 10, 20 and 30-year projections include an escalation rate of 2%, which has been the average rate of escalation for the past 20 years

Housing Authority projects are typically funded through bond sales or other forms of long-term financing that carry a 30-40-year payback schedule. For our study, we utilized the 20 years estimated savings as the amount available to spend on energy efficiency measures, figuring the tenants would benefit from the energy savings from then on.

As standard Oregon Architecture, Inc., office practice, when these units were originally designed, we included two efficient energy strategies that went above the minimum Building Code Energy requirements at the time. They were:

<u>Extended heel roof trusses/energy heel</u>:
This is a simple modification to roof trusses that provides a 14-inch vertical heel at the plate line. This allows the total thickness of roof insulation across the unit ceiling from exterior wall to exterior wall. It is especially effective in units with low-slope trusses.

The raised heel roof truss rests on the wall's top plate just like any other truss. The raised heel now allows the wall sheathing to be attached to the heel of the truss, making a positive connection between the exterior wall stud and the roof truss for added structural rigidity (See detail below). The main advantage of raising the heel end of the truss is to allow for the full depth of uncompressed insulation in the attic with really no additional labor cost and very minimal materials cost.



Simplifies attic ventilation:
By eliminating the need to install blocking and baffles between the roof trusses to provide for ventilation air flow the extended heel allows for infiltration without special equipment. This is an economical method of producing a more resilient building envelope while saving time and resources.

Comfortable interior: A home built with raised-heel trusses is more comfortable living space due to the elimination of cold spots in the ceiling along the top of the exterior walls.

Mechanically vented crawl spaces:
This is a simple change to the traditional way crawl spaces are created. The Building Code requires that heated spaces be insulated from unheated spaces. Typically, in cold climates, the floor above a crawl space is insulated, which means pipe penetrations need to be insulated, with electrical conduits and mechanical ducts compromising that layer of insulation. By insulating the exterior perimeter foundation wall and providing mechanical ventilation of the crawl space to the exterior, the home takes advantage of moderate ground temperatures, requiring less energy to keep the living spaces at a comfortable temperature. This method requires less insulation and it is easier to install. Because the crawl space is ventilated with conditioned air, it is a drier crawl space.

Both of these measures are essentially minimal-cost construction materials options, do not require the retraining of construction workers, and utilize industry-standard construction practices. Extended heel trusses, which were a somewhat revolutionary concept 10 years ago, have become more commonplace in higher-end custom construction.

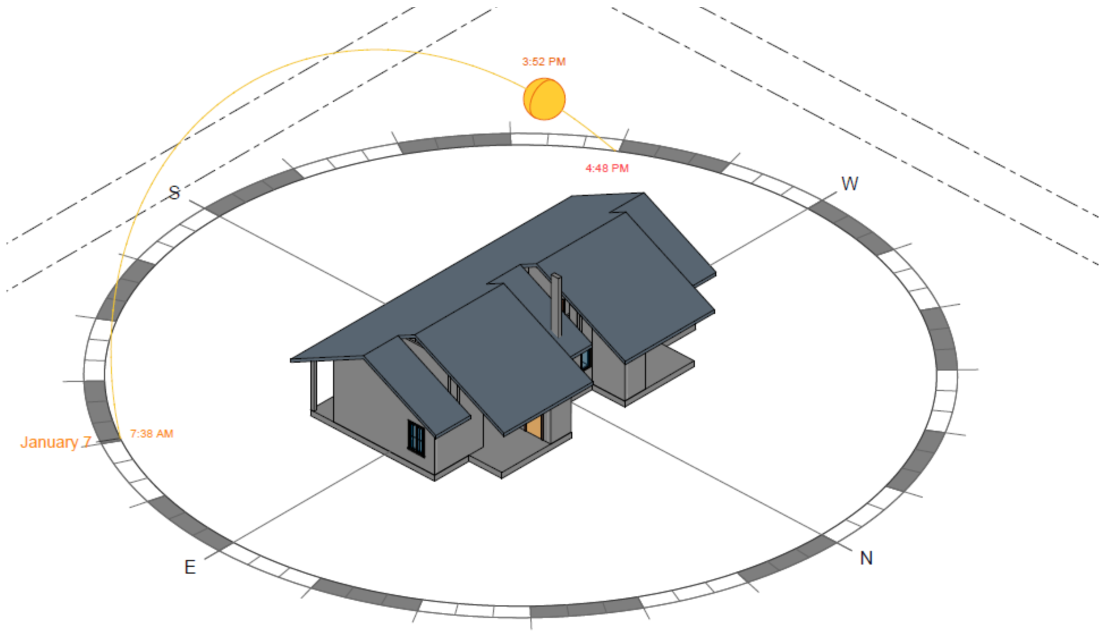
ENERGY SAVINGS STRATEGIES AND BUILDING CHARACTERISTICS FOR DESIGNING NET-ZERO PUBLICLY CONSTRUCTED HOUSING, INCLUDING ENERGY USE BREAKDOWN

Potential energy-saving strategies we studied:

- **Building Orientation**
- **Passive Design Strategies**
- **Reduce Thermal Bridging Using SIPS Panels for Roof & Walls**
- **Addition of an Enhanced Trombe Wall with Heat Recovery/ Heat Dissipation Features**
- **Daylighting Analysis & Artificial Lighting**
- **Weather Seal**
- **Increasing the energy efficiency of windows and doors**
- **Installation of Solar Panel**
- **Installation of Energy Efficient Home Appliances**

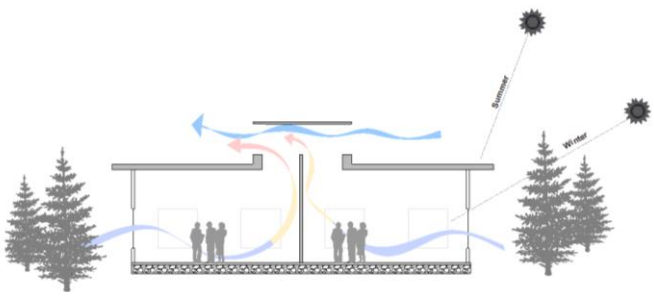
Building Orientation:

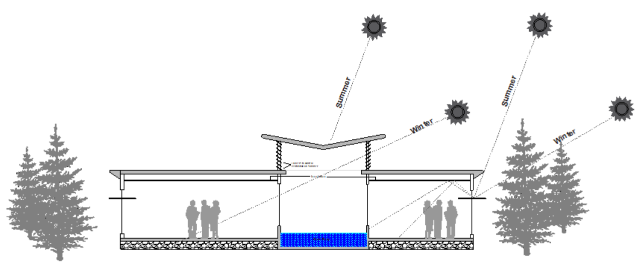
Constructing buildings accounts for almost 30% of global energy consumption and emits 20% of the total greenhouse gas emissions globally. Building orientation is the most crucial factor to consider in constructing energy-efficient buildings. It optimizes efficiency and significantly minimizes the necessity for heating, cooling, and lighting, thus reducing energy consumption.



Passive Design Strategies:

A typical building usually uses more energy in an HVAC system to maintain desirable indoor temperature and relative humidity than any other housing energy use. In this case, passive design strategies can help reduce the energy load on any active system. It can reduce temperature fluctuations and improve indoor air quality by maintaining thermal comfort within the building without any active system, which significantly reduces energy consumption and greenhouse gas emissions.

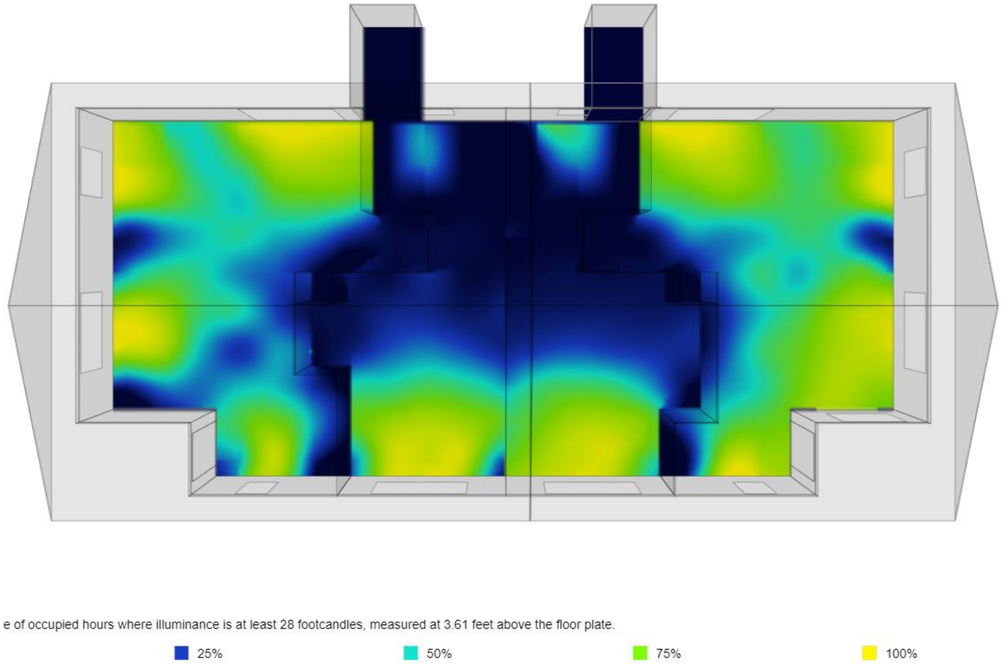




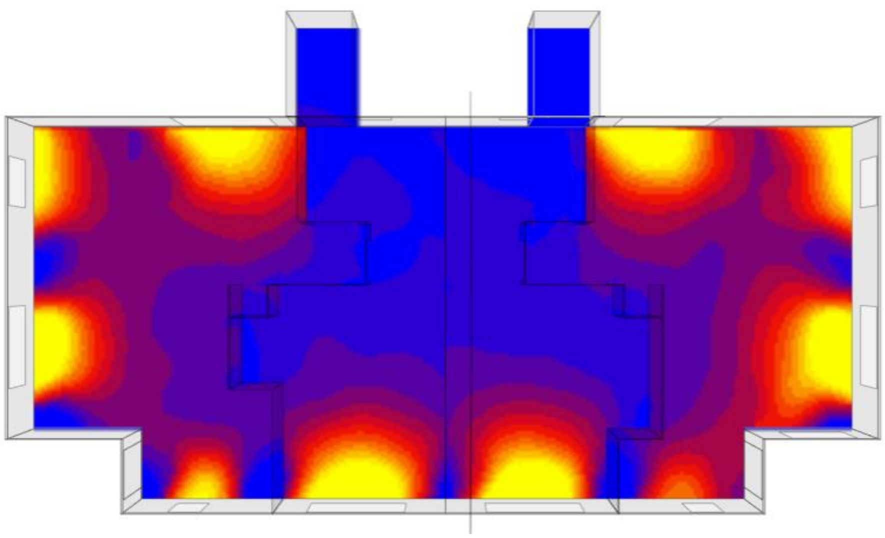
Daylighting Analysis & Artificial Lighting:

Use daylighting analysis to reduce the need for artificial lighting. When artificial lighting is required, create a plan that uses high-efficiency LED bulbs and fixtures. Reduce the amount of ceiling penetrations by using surface-mounted lighting fixtures or make use of soffits to reduce air leakage.

Daylighting analysis:



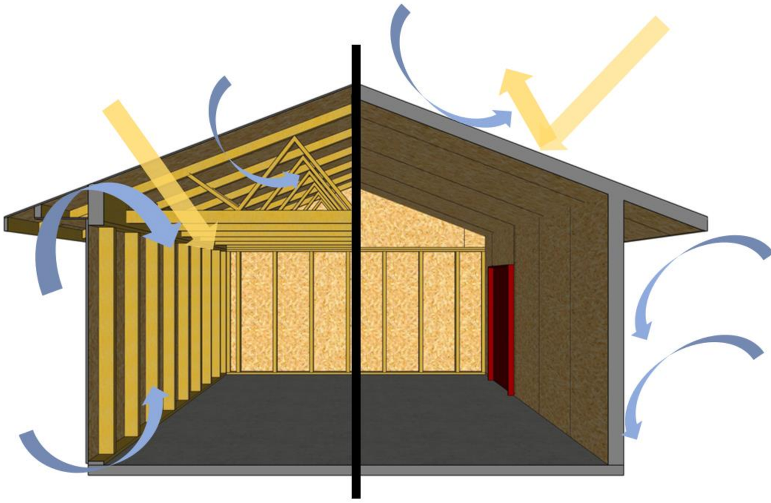
Radiant Temperature:



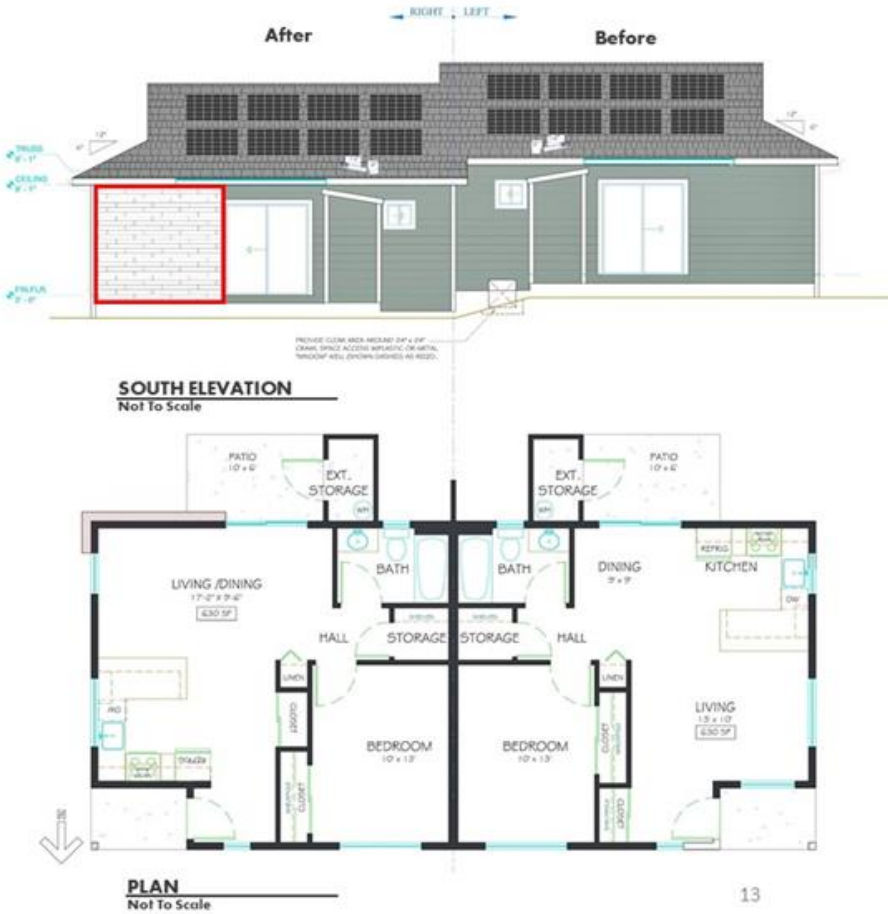
SIPs Panel:

It preventing thermal bridging by making use of available building systems may reduce heat loss from 5 to 20% or more through the building envelope. Structural insulated panels (SIPs), in particular, are able to help reduce thermal bridging in the walls and the roof.

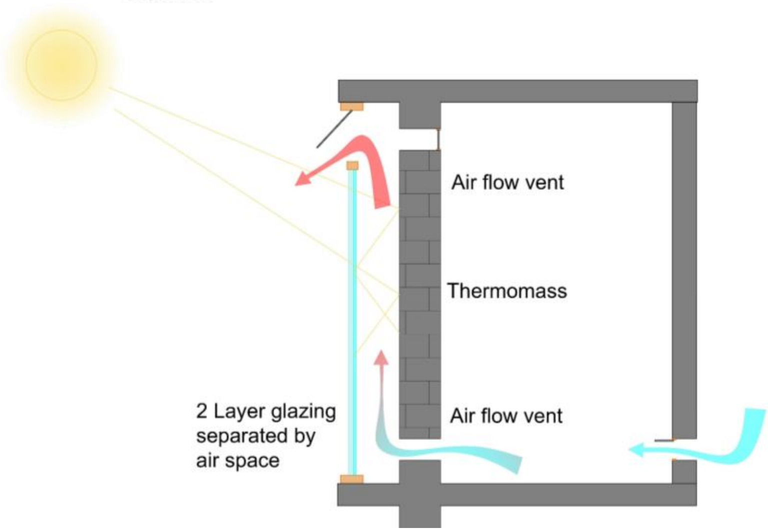
And although not readily accepted in the U.S. construction industry, we may soon see phase change material structural insulated panels (PCMSIPs) that not only prevent thermal bridging but also act as a heat storage medium, flattening the curve in climates with temperature differentials that place an energy need on the home during peak demand for electricity. Most wood-framed homes contain roughly 25% wood studs, leaving 75% for the insulation cavity. Each of the studs acts as a thermal bridge and could reduce an R-50 value to an R-32.



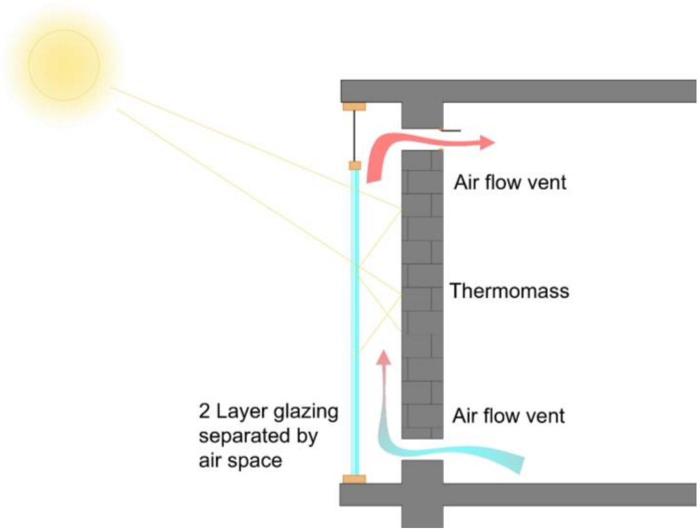
Trombe Wall



A Trombe wall or a thermal storage wall can be utilized to store heat energy from the sun during the day and release the heat back into the home as needed. Any time the heat is not needed, it is directed out of the home and provides a measure of cooling in dry climates. The sun-facing mass wall is usually dark in color to help absorb the lightest light waves in the spectrum and is covered with glass designed to accept the sun's rays but prevent escape between the wall and glass. The system becomes even more efficient when it is linked via ductwork to an additional thermal storage mass located elsewhere in the unit. Trombe walls are ideally suited for locations like Klamath Falls, with big daytime temperature differentials and plenty of room to orient them to south-facing exposures.

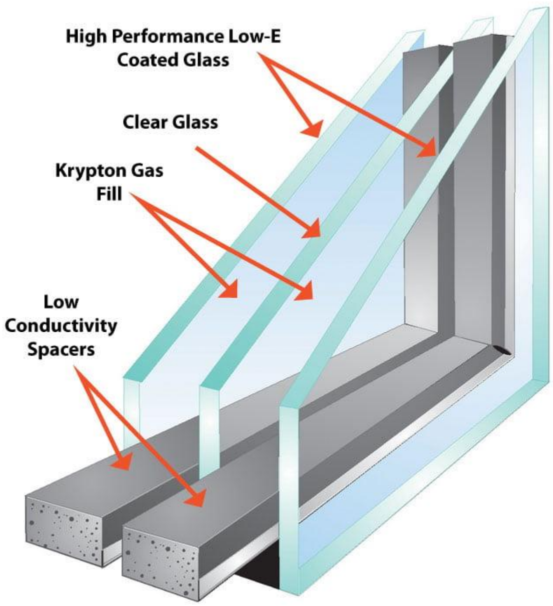


Summer



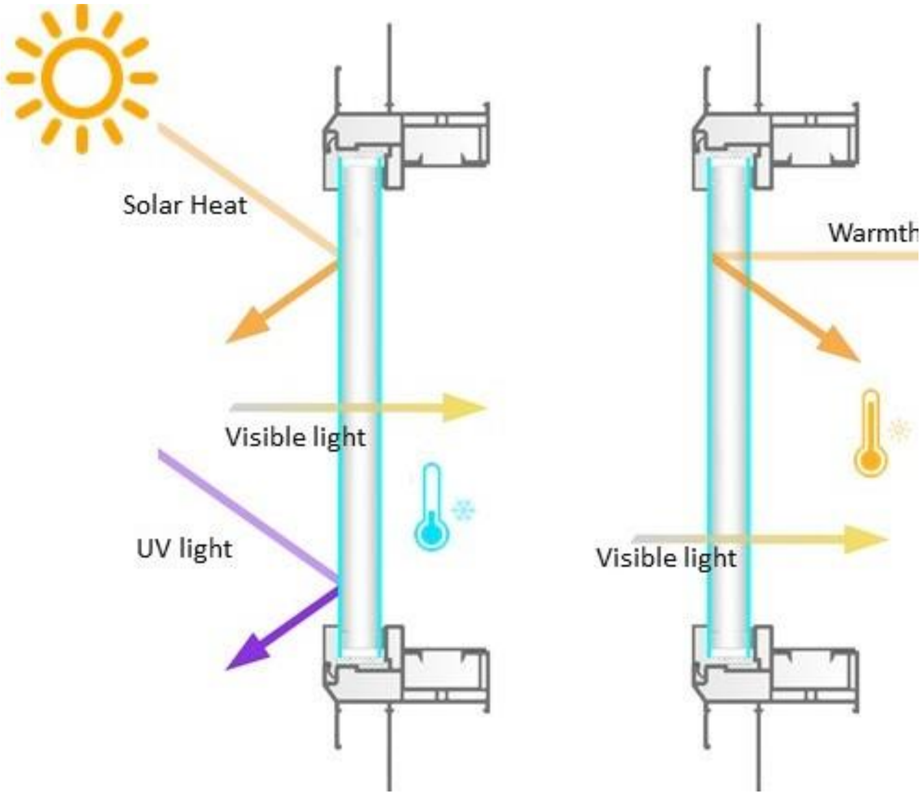
Winter

The increasing energy efficiency of windows and doors:



Any approach to achieving energy savings and the ultimate goal of a sustainable net-zero home starts with the building design and envelope. Minimize the amount of traditionally low R-Value openings in the building envelope, i.e., doors and windows with uninsulated glass. By making use of high-efficiency windows and doors, we can reduce the energy loss in what has in the past been the weakest link in a building envelope.

(Source: Royalty windows, 2020)

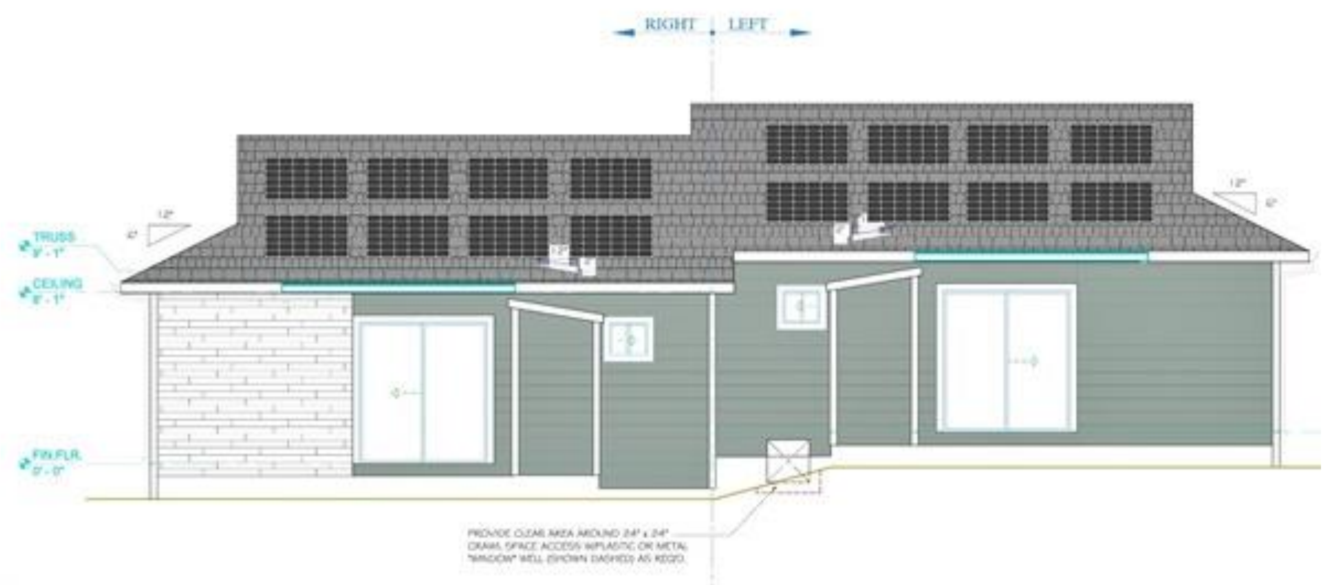


Weather Seal:

Air sealing the home is one cost-effective way to reduce energy use. Air leakage can account for 25 to 40% of the energy used for heating and cooling. By setting an airtightness goal for net-zero construction that is 2.0 ACH50 (Air changes per hour at 50 pascals) or better, we are able to create an energy-efficient, comfortable home. Generally speaking, air sealing costs less than other energy savings approaches. By making use of energy modeling software, we will be able to demonstrate an effective thermal boundary solution while staying within budget.

Installation of solar panels:

Planning for solar panels is an important consideration, and the amount of photovoltaics should be calculated once all other energy-saving measures have been fully utilized. Installing P.V. systems can be costly, but by designing a home with net-zero principles, we can reduce the number of solar panels required to meet a home's needs. Using energy modeling software, we will be able to estimate the energy requirements of the home and match a P.V. system to the home to keep costs down. Although currently on the expensive side, there are government rebates and other tax advantages that make systems more affordable, and they offer the opportunity to sell power back to the grid, should that be an option locally. Again, panel placement is critical for maximum performance.

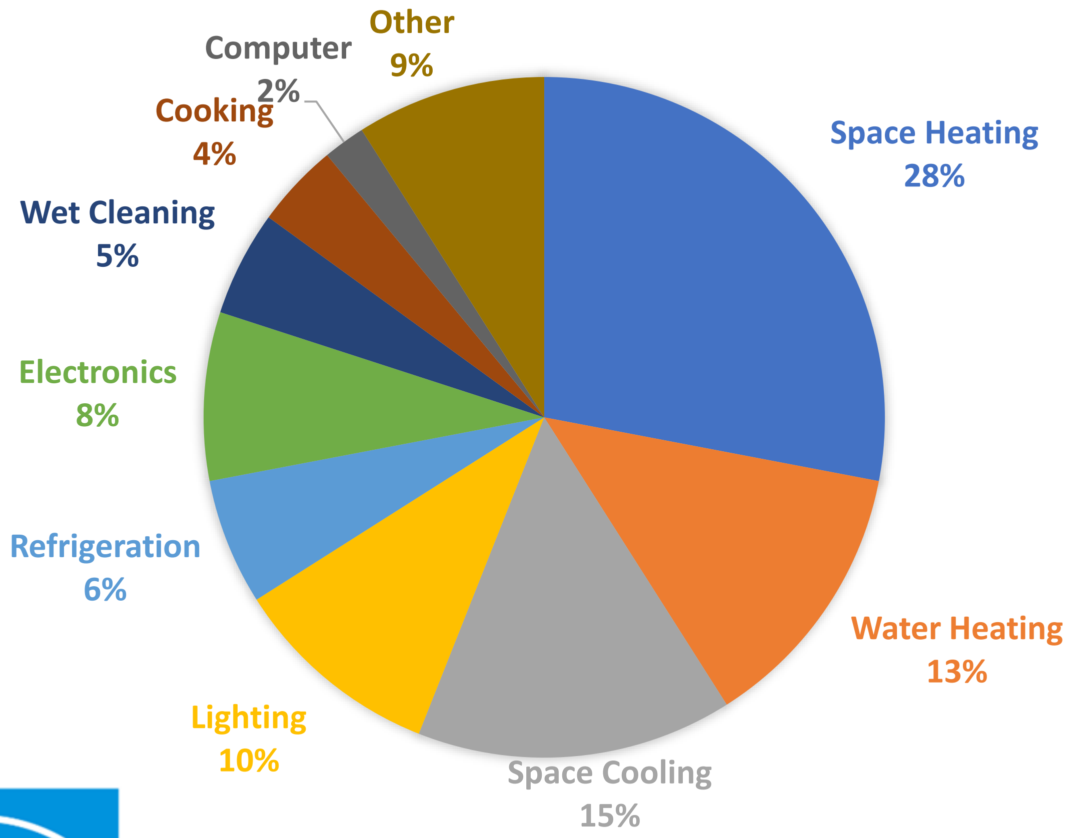


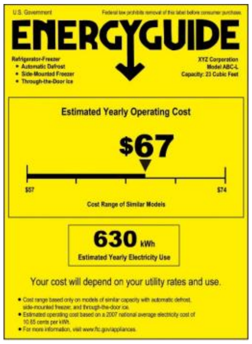
Efficient Appliances:

Home appliances are the 2nd largest energy consumer in a house after the HVAC system. Thus, the employment of energy-efficient appliances is essential to an energy usage reduction scheme. New and improved energy-efficient appliances, for example, refrigerators, dishwashers, and dryers with higher efficiency ratings, can reduce energy consumption up to 50% over conventional models. On-demand or tankless water heaters can be 25% to 35% more energy-efficient than conventional storage-tank water heaters

Residential Building Energy Consumption By End User:

Users





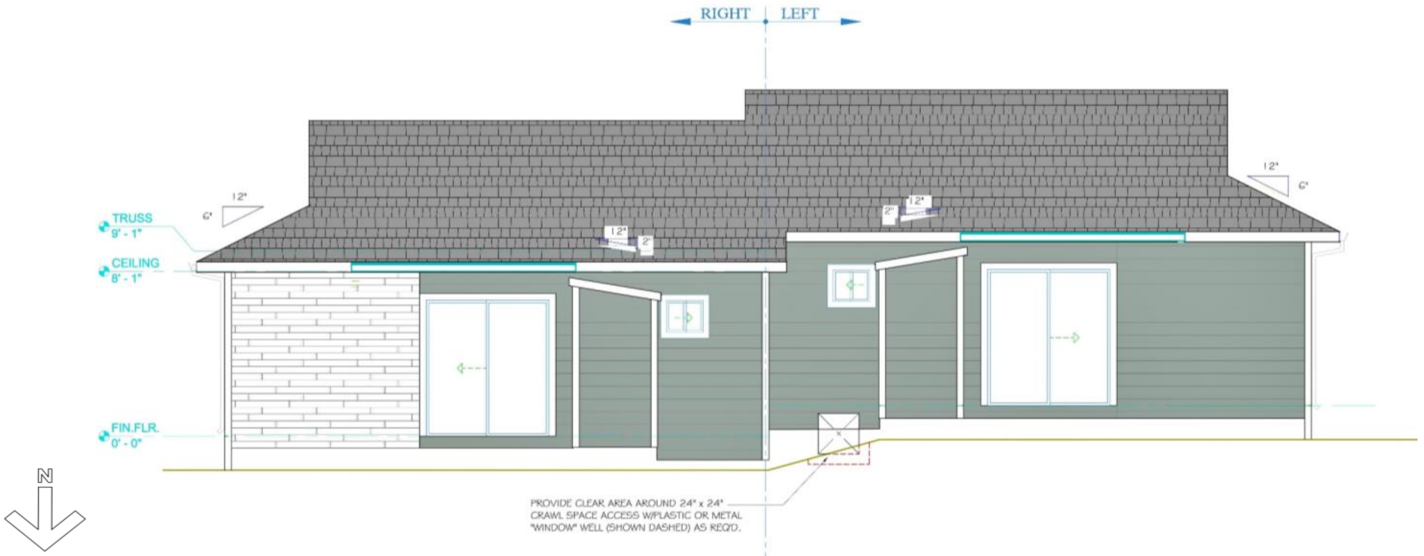
TASK 2 REPORT

ENERGY SAVINGS STRATEGIES AND BUILDING CHARACTERISTICS FOR DESIGNING NET-ZERO PUBLICLY CONSTRUCTED HOUSING, INCLUDING ENERGY USE BREAKDOWN

Energy-saving strategies:

- **Increasing the energy efficiency of windows and doors**
- **Daylighting Analysis & Artificial Lighting**
- **Building Orientation**
- **Passive Design Strategies**
- **Weather Seal**
- **Reduce Thermal Bridging Using SIPS Panels for Roof & Walls**
- **Installation of Solar Panels**
- **Installation of Energy Efficient Home Appliances**

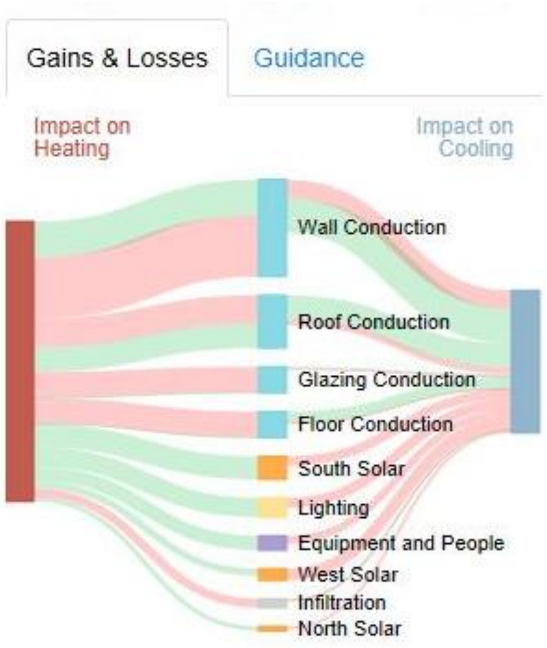
Existing Plan vs Proposed Plan:



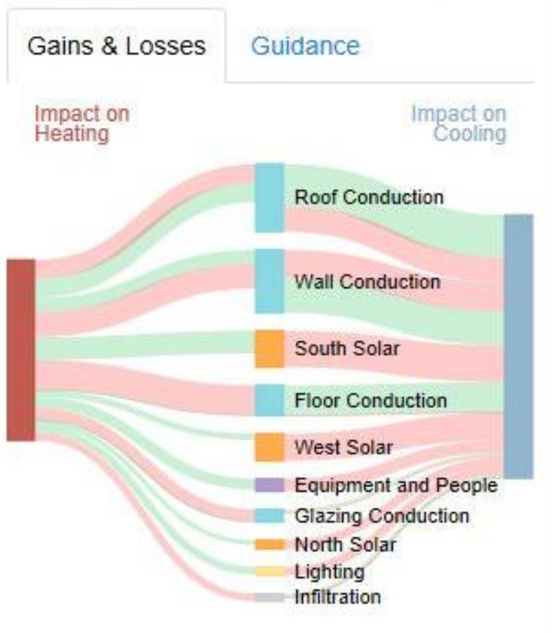
Walls: R-41 SIPs
Windows: U-0.18
Roof: R-41

Walls: R-21
Windows: U-0.35
Roof: R-38

Baseline Gains & Losses

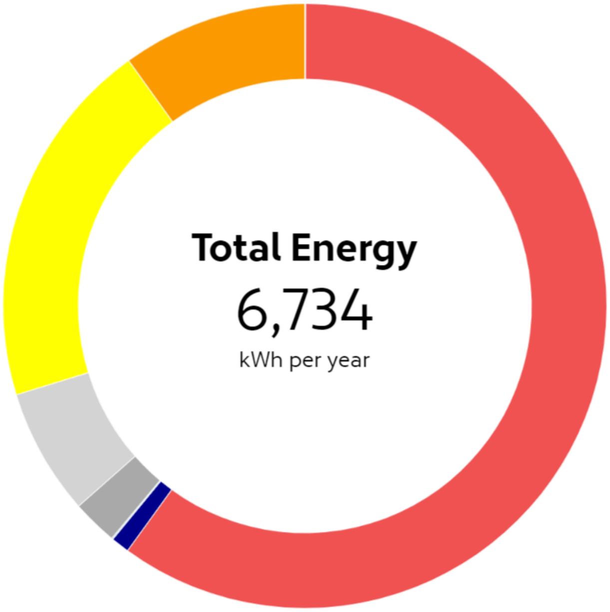


Improved Envelope Gains & Losses



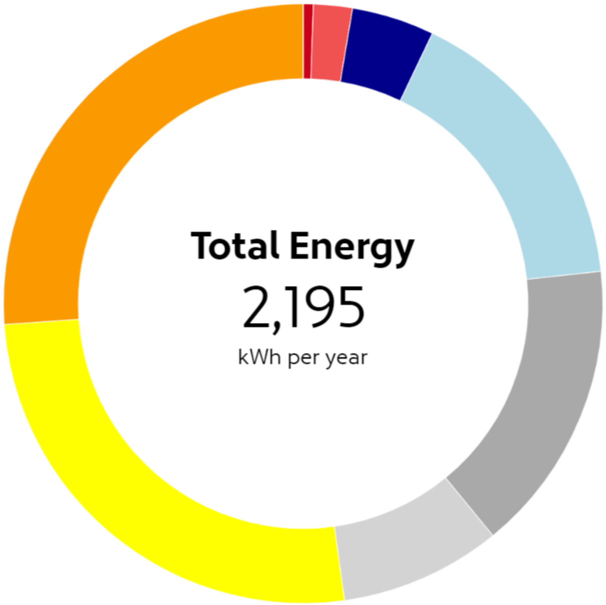
The Gains & Losses diagrams shows which building elements are responsible for heating and cooling loads. Red flows indicate negative (bad) contribution towards either the heating (on the left) or cooling (on the right) loads. Green flows indicate positive contributions towards either heating or cooling loads.

Annual Energy Site Consumption - Baseline Construction:



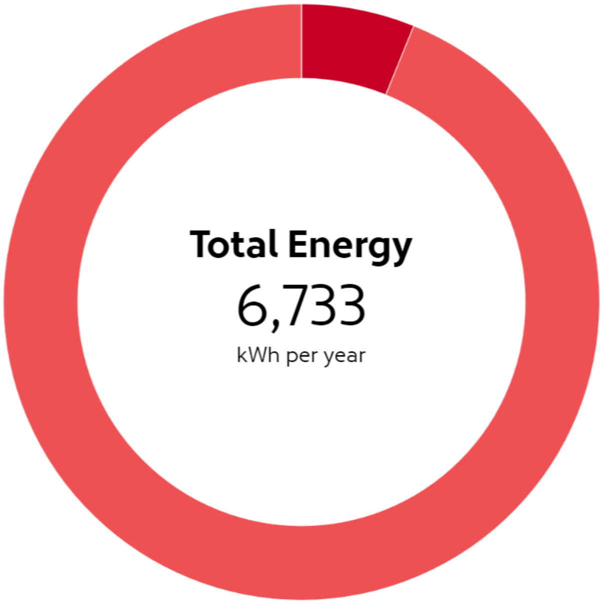
Segment	kWh per year	% of total use
Heating	**4,040**	**60 %**
AHU	3	0 %
Zones	4,037	60 %
Humidification	0	0 %
Cooling	**71**	**1 %**
AHU	66	1 %
Heat Rejection	0	0 %
Zones	5	0 %
Fans	**620**	**9 %**
AHU	164	2 %
Zones	456	7 %
Interior	**2,003**	**30 %**
Lighting	1,335	20 %
Equipment	668	10 %
Pumps	**0**	**0 %**

Annual Energy Site Consumption- NetZero Construction:



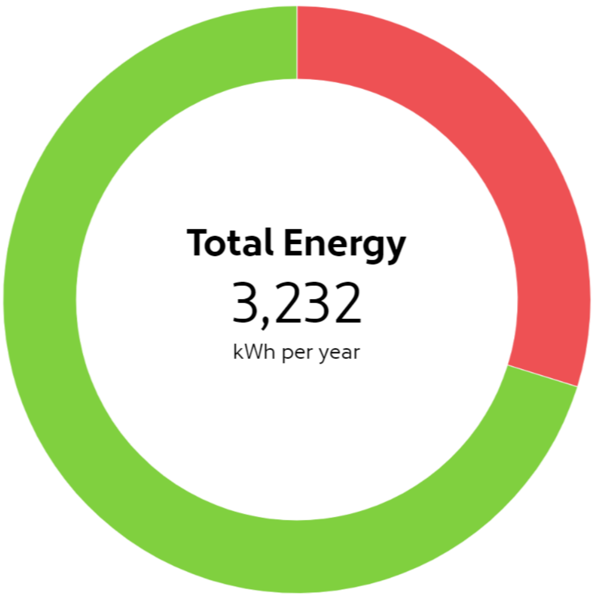
Segment	kWh per year	% of total use
Heating	**58**	**3 %**
AHU	12	1 %
Zones	46	2 %
Humidification	0	0 %
Cooling	**453**	**21 %**
AHU	98	4 %
Heat Rejection	0	0 %
Zones	355	16 %
Fans	**538**	**25 %**
AHU	347	16 %
Zones	191	9 %
Interior	**1,146**	**52 %**
Lighting	573	26 %
Equipment	573	26 %
Pumps	**0**	**0 %**

Annual Energy Demand from source: Baseline Construction



Segment	kWh per year	% of total use
Non-renewable	**6,733**	**100 %**
Gas	414	6 %
Electricity	6,319	94 %
Renewable	**0**	**0 %**
Solar	0	0 %

Annual Energy Demand from a source showing renewable compensation: NetZero Construction



Segment	kWh per year	% of total use
Non-renewable	**963**	**30 %**
Gas	0	0 %
Electricity	963	30 %
Renewable	**2,269**	**70 %**
Solar	2,269	70 %

Cost Estimation Tool

OREGON ARCHITECTURE INC.	Date	Total area of the Building in SF			630
	6/30/2021	Avg cost of Construction			$ 130.00
Trail's View/ Victory Commons		Total cost of project			$ 81,900.0
Klamath Falls, OR		Total cost of project with Net Zero			$ 102,665.7

	Summery	Avg Cost	Avg Percentage	Net Zero Elements	
1	**DIVISION I**	**$ 16,052.40**	**19.6000%**		
	1.1 Contractor General Conditions/ Soft Costs	$ 8,190.00	10.00%		
	1.1.1 Permits & Fees				
	1.1.2 Impact Fees				
	1.1.3 Water & Sewer Inspection Fees				
	1.1.4 Architecture & Engineering				
	1.2 Overhead	$ 2,457.00	3.00%		
	1.3 Profit	$ 4,095.00	5.00%		
	1.4 CAT Tax	$ 81.90	0.100%		
	1.4 Payments & Performance bond	$ 1,228.50	1.50%		
2	**Site work**	**$ 655.20**	**0.80%**		
3	**Foundations**	**$ 4,914.00**	**6.00%**		
	2.1 Excation, Foundation, Concrete, Retaining wall & backfill	$ 4,750.20	5.80%		
4	**Framing**	**$ 13,513.50**	**16.50%**	**0.00%**	**6.60%**
	3.1 Framing including roof	$ 12,121.20	14.80%		1.00%
	3.2 Trusses	$ 1,228.50	1.50%		0.00%
	3.3 Sheathing	$ 81.90	0.10%		0.30%
	3.4 General Metal and Steel	$ 81.90	0.10%		0.30%
	3.5 Trombe wall			$ 1,638.00	2.00%
	3.6 Sips Panels			$ 2,457.00	3.00%
5	**Exterior Finishes**	**$ 10,647.00**	**13.00%**		
	4.1 Exterior wall finish	$ 5,159.70	6.30%		
	4.2 Roof finish	$ 2,457.00	3.00%		
	4.3 Windows and Doors	$ 3,030.30	3.70%		
	4.5 Triple pane windows (15% addition)			$ 3,484.85	4.26%
6	**MEP**	**$ 10,565.10**	**12.90%**		
	5.1 Plumbing	$ 3,603.60	4.40%		
	5.2 Electrical	$ 3,276.00	4.00%		
	5.3 HVAC	$ 3,685.50	4.50%		
	5.4 Solar Panel			$ 8,190.00	10.00%
	5.5 Heat recovery ventilation			$ 1,638.00	2.00%
	5.6 On-demand hot water			$ 1,228.50	1.50%
7	**Interior Finishes**	**$ 16,707.60**	**20.40%**		
	6.1 Insulation	$ 1,638.00	2.00%		
	6.2 Dry walls	$ 3,439.80	4.20%		
	6.3 Interior trims, door & mirrors	$ 2,702.70	3.30%		
	6.4 Painting	$ 2,293.20	2.80%		
	6.5 Lighting	$ 819.00	1.00%		
	6.6 cabinets and Countertops	$ 1,474.20	1.80%		
	6.7 Appliances	$ 1,064.70	1.30%		
	6.8 Flooring	$ 3,276.00	4.00%		
	6.11 Air sealing			$ 819.00	1.00%
8	**Finish Work**	**$ 4,750.20**	**5.80%**		
	7.1 Landscaping	$ 1,883.70	2.30%		
	7.2 Outdoor Structures (Deck, Patio, Porches)	$ 819.00	1.00%		
	7.3 Driveway	$ 1,392.30	1.70%		
	7.4 Clean Up	$ 655.20	0.80%		
9	**Contingency**	**$ 4,095.00**	**5.00%**		
	Total Cost of Construction	**$ 81,900.00**	**100.00%**	**$ 20,765.75**	**25.36%**
	Total Cost of Net Zero Construction	**$ 20,765.75**			
	Total cost of Project	**$ 102,665.7**			

TASK 3 REPORT

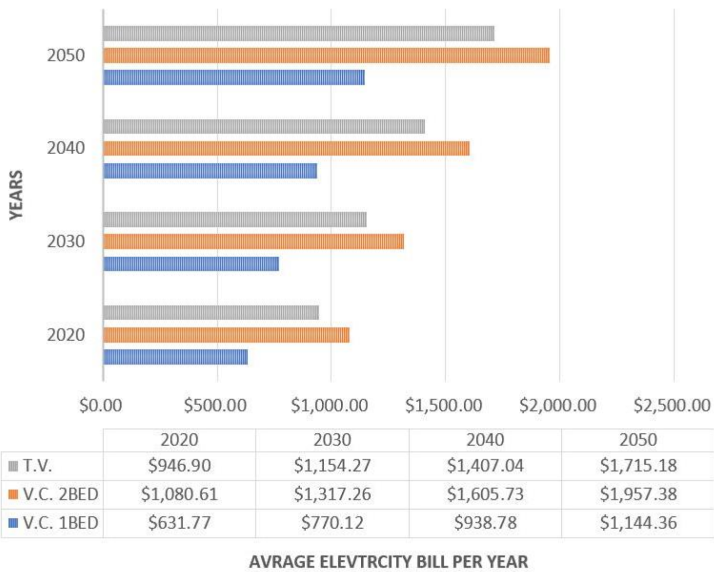
<u>Amount of potential energy saved by employing stated Net Zero strategies:</u>

Prices for electricity, 1913-2021 ($100)

According to the U.S. Bureau of Labor Statistics, prices for electricity were 376.59% higher in 2021 versus 1913 (a $376.59 difference in value).
Between 1913 and 2021: Electricity experienced an average inflation rate of 1.46% per year. In other words, electricity costing $100 in the year 1913 would cost $476.59 in 2021 for an equivalent purchase.

We set our escalation rate at a 2% increase per year rate to capture possible unknown variables.

Properties / Timespan	Victory Commons 1 BR Unit	Victory Commons 2 BR Unit	Trail's View
Avg. Per Month	$52.65	$90.05	$78.91
Avg. Per year	$631.77	$1080.61	$946.90
10 Years projection	$6,917.71	$11,503.90	$10,368.30
20 years projection	$15,350.35	$25,527.00	$23,007.18
30 years projection	$26,774.00	$44,524.30	$40,129.00



Associated construction costs required to compensate for Net Zero:

- There should be minimal labor costs associated with performing energy-efficient methods for building. This is not a specialized skill, so it would not generate an increase in the carpenter's base wage and would not reclassify them (to our best knowledge) for Davis Bacon or BOLI prevailing wage rates.

- Specialized materials may be slightly higher than conventional construction costs, but most of those would be absorbed due to the "in lieu of" instead of "in addition to" nature of the application. For example, if longer eaves are required, this may add a little cost for material lineage but wouldn't necessarily trigger additional labor; or if more expensive air/weather sealing materials are needed, this may generate a materials increase, but labor wouldn't necessarily be affected unless more labor-intensive methods (such as manual caulking of penetrations and seams in excess of current industry standards) are required.

    - More energy-efficient appliances may have a higher material cost, but we don't foresee an increased labor cost associated with this.

Any specialized training:

- With regards to Training, there should be minimal Training required to employ the proposed techniques. If plans and drawings have sufficient details on sequencing for the proposed methods, there isn't much change to standard carpentry practices that would warrant more than potentially a mock-up with the architect of record to ensure the carpenter understands the sequencing and methodology. We estimate a maximum of 4 hours of mock-up and review of the processing time would be needed. None of the proposed methods appear to need specialized skills other than following the details and sequencing as identified on construction plans.
    - Photovoltaic/solar panel usage.
    - Use of SIPS panels would require an estimated 2-hour site training and, depending on the size and weight, a telescoping construction forklift or crane to help position the panels.

Conclusion:

We discovered quickly from this exercise that creating zero energy or near-zero energy building shell is possible with the available technology in the marketplace and within a generally reasonable cost.

However, achieving total zero energy is a bit trickier: we will still need a way to electrically power artificial lighting, refrigeration, cooking, and electrically powered equipment. These tools of modern living are getting more efficient all the time, but no matter how efficient they become, they will still need electric power. At the moment, the only option to provide that energy is through the use of solar panels.

Our study shows it is possible to trade the purchase of energy over time to purchase materials to make a dwelling more energy efficient. Our interactive cost tool provides a way that will allow a person to evaluate the construction cost of an energy upgrade against the amount of energy saved in dollars.