Stairstep - A Cost and Energy Comparison of Energy Star, DOE ZERH, and Phius Certification for a Multifamily Building in Climate Zone 6

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ABSTRACT

Developers, utilities, and government planners often lack information regarding the relative performance and costs of well-known energy efficiency certification programs. This research was designed to help fill the gap by investigating and comparing the construction cost and energy savings offered by the following programs for a medium-sized, low-rise multifamily building in climate zone 6:

1) Minnesota standard practice, "code-level" multifamily construction
2) Energy Star Multifamily New Construction (ES MFNC Version 1.1)
3) DOE Zero Energy Ready Home Multifamily (DOE ZERH Multifamily Version 2)[1]
4) Passive certification (Phius CORE 2024)

These programs form a staircase of progressively more challenging energy requirements. The research team used a completed, 3-story, 43-unit multifamily building as a vehicle for testing and construction cost estimates. Based on energy modeling and program requirements, four versions (or steps) of this building were created, each meeting the minimum energy performance of its associated program. A construction cost estimate was then prepared for each version by the building's general contractor. Finally, the research team calculated energy savings, energy costs, and construction cost premiums at each step, as well as the size and expense of an on-site solar array necessary to achieve net zero energy. Site energy savings increased substantially at each step up the staircase, as did construction costs. Total construction cost to achieve net zero energy with on-site solar PV was quite consistent across all building versions (if land costs for additional PV are not included). However, the more energy efficient options provide important additional benefits for residents and utilities that should be considered.
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Introduction

Many developers and utility program managers struggle to understand the benefits and drawbacks of different energy certifications available in the multifamily building market. For example, how does one certification compare to another in terms of energy savings, energy costs, and construction costs? Is there an optimal choice that achieves the greatest energy savings for a minimum additional cost? What specific required items under each program impose the greatest costs for multifamily projects? And if net zero energy is the ultimate goal, what level of building performance should be targeted first? These are important questions this research project is intended to answer, primarily from the perspective of affordable housing developers. However, <u>it's important to recognize that the findings discussed below are most applicable to buildings of</u>

[1] The name of this program was changed to DOE Efficient New Homes in 2025.

similar size and similar climate zone – that is, medium sized, low-rise multifamily buildings (approximately 40 units) in IECC climate zone 6. Finally, although construction costs, energy performance, and utility costs are important considerations for affordable housing developers and residents, they aren't the only significant factors. Additional important implications of these certification programs such as occupant health, safety, and the ability of the utility grid to actually support the different levels of building performance will be discussed as well.

Funding for this research was partially provided by the Minnesota Department of Commerce through its CARD (Conservation Applied Research and Development) research grant program, as well as by the Phius Alliance. Generous in-kind contributions were also provided by Kaas Wilson Architects, Phius, and Frana Companies, providing project management, energy modeling, and cost estimating services respectively. Harty Mechanical and Emanuelson Podas supported design and cost estimating for the high-performance mechanical system options. Precipitate, a local passive building consultant with substantial multifamily experience, also generously supported the project with consulting and energy model review.

Methodology

This project began with an existing, recently completed multifamily building, Carver Oaks. The building was designed and built as affordable housing for 55+ seniors by research project partners including Kaas Wilson Architects and general contractor Frana Construction. Initially, the building was designed and bid to meet DOE ZERH standards. This was later changed to Energy Star, which was required for the project to receive low-income housing tax credits from Minnesota Housing Finance Agency. Having cost data for both Energy Star and DOE ZERH versions of the building already, the team saw an opportunity to create a Phius-certified version of the building and develop an understanding of the full spectrum of energy certifications, cost, and performance. Both Kaas Wilson and Frana were already familiar with Phius certification, having worked together successfully on Verdant Apartments, which was the first Phius-certified multifamily building in St. Paul. The team's familiarity with the building itself and alternate efficiency certification programs helped the team modify the design to meet program requirements and price those versions accurately.

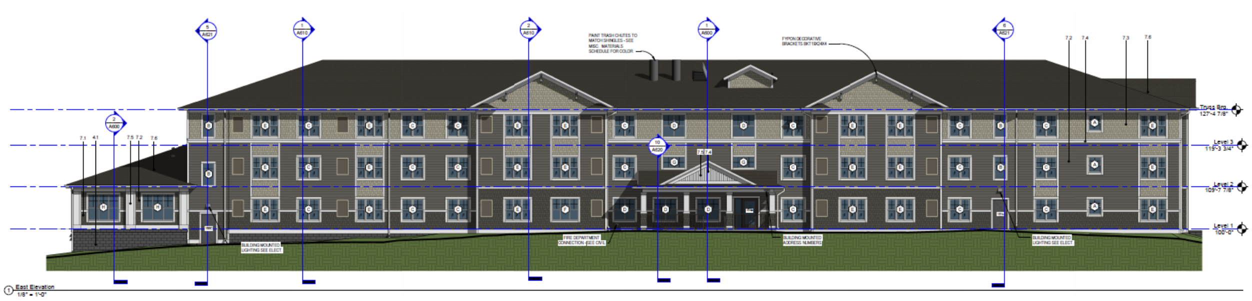

Figure 1 - Carver Oaks east elevation

Carver Oaks is a typical wood-framed, 3 story multifamily building, rectangular in shape with a double-loaded corridor down the center. A truss roof with a ventilated attic creates large, pitched roof areas facing primarily east and west, which can be used easily for roof-top solar. The basement is an insulated, underground parking garage, again typical of multifamily construction in Minnesota. The garage space is not fully conditioned (tempered to 40°F) but is ventilated to control exhaust fumes. This study was primarily focused on evaluating the above-grade building. However, the cost of the garage was included in the construction cost totals and a minor improvement in basement wall R-value was added as an efficiency measure for the certified buildings. In addition, an estimate of garage energy consumption was made using a Phius calculator to provide a rough understanding of the garage's energy use relative to the rest of the building.

Table 1 – Carver Oaks building design characteristics

Floors above grade	Living units	Floor area (sf)	Exterior enclosure area (sf)	Window-to-wall area ratio
3	43	61,141	54,613	20%

Having the plans and specs for both Energy Star and DOE ZERH, the team worked backward from Energy Star to a standard multifamily building design that met current Minnesota residential energy code (2012 IECC with Minnesota-specific amendments). Assembly U-values, window performance, mechanical and ventilation system types and efficiency levels, and enclosure airtightness were all adjusted while the basic building design properties (physical geometry, window area, number of living units, etc) were held constant.

Phius then took the plans and specs for these three building versions and modeled them in their energy modeling/certification software, WUFI ® Passive. They also calculated Phius CORE 2024 energy performance targets for the building and climate location, Flying Cloud airport near Minneapolis, Minnesota. Using those energy targets, Phius created a fourth version of the building, modifying assemblies and mechanical equipment to meet the targets and certification requirements of the Phius CORE 2024 standard. Since Phius is not a prescriptive measure-based certification, energy modeling was necessary to determine the needed R-values, U-values, and efficiency levels of the mechanical equipment.

Table 2 – Building enclosure assemblies energy performance characteristics

Component	Standard practice	Baseline - ESMFNC	DOE ZERH	Phius
Attic/roof	R-49	R-49	R-49	R-59
Above grade walls	R-21	R-21 + R-6 CI	R-21 + R-6 CI	R-21 + R-12 CI
Basement ceiling	Uninsulated plank	R-20	R-20	R-28
Basement walls	R-10	R-15	R-15	R-15
Windows	U-0.30, SHGC-0.23	U-0.27, SHGC-0.23	U-0.25, SHGC-0.23	U-0.20, SHGC-0.23
Airtightness	0.30 (0.40)	0.27 (0.36)	0.25 (0.33)	0.06 (0.08)

R-values are center of cavity R-value. Window U-values are whole-window U-values. Airtightness is listed using enclosure surface area as cfm/sf @50Pa and (cfm/sf @75Pa). All units are IP (inch-pound).

In the case of the Phius version, several discussions were held with the architect, general contractor, mechanical contractor, a Phius consultant, and a mechanical engineer to determine the most cost-effective and feasible mechanical system for the building. In Minnesota, Phius multifamily buildings are still a new market niche and a standard mechanical approach for these buildings has yet to be adopted. In the end, a decentralized, ductless cold climate heat pump approach was selected as the best option to meet the super-low heating and cooling loads of the living units, as well as the cost-effectiveness demands of the project. Inexpensive electric baseboard was added to the system for backup during extreme cold periods when heat output might drop below the heating load. A decentralized approach was selected for heat recovery ventilation as well, since local mechanical contractors generally have little experience with large, centralized systems and seem to prefer the redundancy and familiarity of multiple smaller units. Due to program requirements, these same system approaches were used for the DOE ZERH building version, albeit with less efficient and less expensive heat pumps and ERV units that still met minimum efficiency requirements.

For the Energy Star and standard practice building, a unitized gas VTAC (Vertical Terminal Air Conditioning unit) was selected to provide heating and air conditioning to each living unit. This through-wall system is extremely common in the Minnesota multifamily market. The Energy Star version upgraded this equipment to a high efficiency model with 90 AFUE rather than the basic 80 AFUE model which has often been used in market rate buildings. Although these units can provide fresh air to mechanically balance kitchen and bathroom exhaust fans (and therefore meet Minnesota residential energy code), they are very rarely operated in this mode. This is because they lack heat recovery and create severe comfort issues during Minnesota winters. Therefore, both buildings with VTACs were modeled to operate with exhaust-only ventilation.

Table 3 – Building mechanical systems energy performance characteristics

Component	Standard practice	Baseline - ESMFNC	DOE ZERH	Phius
Appliances	standard electric clothes dryers 3.93 CEF	standard electric clothes dryers 3.93 CEF	standard electric clothes dryers 3.93 CEF	ventless heat pump dryers 5.85 CEF
Domestic Water Heater	high efficiency gas boiler, 96% thermal efficiency	high efficiency gas boiler, 96% thermal efficiency	high efficiency gas boiler, 96% thermal efficiency	high efficiency gas boiler, 96% thermal efficiency
Ventilation	direct exhaust only	direct exhaust only	ERV 65% SRE	ERV 84% SRE
Heating & Cooling	gas VTAC 80% AFUE 12 SEER	gas VTAC 90% AFUE 12 SEER	heat pump HSPF 9.5 16 SEER	ductless heat pump COP 1.75 (17F) COP 3.0 (47F) 16 SEER

Phius energy modeling also provided estimates of the energy performance of the 4 building versions, enabling the team to calculate energy consumption (EUI) and energy cost savings. Savings were calculated relative to a baseline building, which was assumed to be the Energy Star version since Energy Star is the minimum performance level allowed for affordable multifamily developments in Minnesota with federal tax credit financing. WUFI Passive does not provide hourly simulation results, but does provide estimates of energy consumption broken down by energy type (electricity and natural gas) and use: heating, cooling, lighting, fans, large appliances, etc. Energy cost estimates were made by multiplying total yearly electricity and natural gas use by standard rates. This provides only a rough estimate of energy costs since it does not include monthly service fees, meter charges, demand charges, or seasonal rate changes. Although the energy costs may not be highly accurate compared to actual energy costs, they likely provide a reasonable relative basis of comparison to measure the impacts of efficiency measures or certification levels from one building version to the next.

Table 4 – Fuel cost rates used for energy cost calculations

Electricity cost rate ($/kWh)	Natural gas cost rate ($/therm)
$0.13	$1.17

After appropriate enclosure performance levels and mechanical systems were determined, reviewed by team members, and verified through energy modeling, the general contractor (Frana Companies) worked to determine the actual products and assembly designs that would be used in each building version. This was done in consultation with the research project team to ensure compliance with any additional certification or performance specifications. Frana then priced each version of the building, getting quotes from additional contractors or equipment suppliers when necessary. Wall assemblies were priced in-house since Frana has its own wall-panelization plant. (Panelization allows Frana to improve airtightness and gain better control over construction quality without major impacts to price.) This research project's scope was purposefully limited to construction costs. Therefore, the costs reported in this project are construction costs only – they do not include development costs, land costs, or certification costs, even though these costs can sometimes play a significant role in development decisions. For example, additional certification and design fees for Passive projects can add tens of thousands of dollars to their total cost, although these fees come with additional benefits such as on-site verification, quality assurance, and testing that non-certified projects typically lack.

As a final step, the CSBR calculated the size and cost of the PV array that would be needed to achieve net-zero site energy for each building version. For the purposes of this research project, net zero site energy was achieved by balancing the building's total on-site electricity AND natural gas consumption with renewable energy generation. 1100 kWh of generation per kW of installed PV capacity was assumed (equivalent to an average of 3 sun-hours per day). This represents the average production from the south, west, and east-facing roof area of Carver Oaks, based on calculations from PV Watts. It was also used for the production of ground mount arrays which would likely face south but include more shading. Installation cost was calculated based on $2.50 per watt, without incentives. This value was selected to represent a mix of roof and ground mount PV (ground mount PV being slightly more expensive) since the systems for every building version were too large to fit on the roof area offered by Carver Oaks. This value is a close match to recent prices for on-site PV recorded by the CSBR for multifamily projects going through its Minnesota SB 2030 program, and falls in line with commonly-quoted costs mentioned by solar power suppliers tracking prices for 100kW+ arrays in Minnesota (www.sunwatts.com, accessed 3/9/2026 and www.wolfriverelectric.com, accessed 3/9/2026).

It should be noted that to receive a true Phius net zero energy certification (Phius ZERO 2024, as opposed to Phius CORE 2024), gas combustion is not allowed and the building's natural gas-fired, high efficiency DHW boiler would have to be swapped for an all-electric alternative.

Results and Discussion

Energy

WUFI Passive estimated a steady and significant improvement in building energy efficiency for each step up the certification ladder. In terms of site energy consumption, the standard practice building achieved an EUI of 46.7 kBTU/sf. This dropped to 39.5 kBTU/sf for the Energy Star version, 31.7 kBTU/sf for the DOE ZERH version, and 24.1 kBTU/sf for the Phius version. These values compare well to other modeling results the CSBR has seen for multifamily buildings going through the state's SB 2030 program, including several passive multifamily buildings.

Table 5 – Whole-building modeled energy performance and net-zero energy metrics. Site-to-source energy conversion factors are: 1.1x for natural gas and 2.0x for electricity

	Standard practice	Baseline - ESMFNC	DOE ZERH	Phius
Site EUI (with parking garage)	46.7 (66.4)	39.5 (59.6)	31.7 (52.1)	24.1 (44.9)
2024 Source Energy per Person (with parking garage)	9,084 kWh (14,476 kWh)	7,989 kWh (13,438 kWh)	7,858 kWh (13,310 kWh)	5,816 kWh (11,372 kWh)
PV panel kW needed for netzero site energy (with parking garage)	526 kW (782 kW)	464 kW (701 kW)	373 kW (613 kW)	283 kW (528 kW)

Below grade, semi-conditioned parking garages are common in Minnesota, occupying the basement level of most multifamily buildings. These garages are typically heated to 40-55°F to melt snow from cars, keep surfaces ice-free, and help prevent building water and sewer lines from freezing. For this study, the garage setpoint was assumed to be 40°F. A lower setpoint helps reduce heating energy consumption; however, the garages have high exhaust air requirements and typically still consume a large share of the building's energy. A calculation of the garage's energy consumption was made separately using the Phius Auxiliary Energy Estimator, which allowed garage energy use to be split out from the rest of the building to better understand its impact. Below grade garage walls were upgraded from R-10 to R-15 for the Energy Star, DOE ZERH, and Phius cases, which reduced the garage's energy consumption slightly. However, it still made up 30-50% of the building's total consumption in these cases. Clearly, the energy consumption of underground parking garages is significant and only grows in relative importance as the rest of the building becomes more efficient.

After energy modeling and pricing was completed, it was noted that Phius multifamily buildings with below-grade garages typically require 2-4 inches of sub-slab insulation to reduce garage energy use and enable certification of the complete building (including garage). Indeed, when the parking garage's energy consumption was added, the building no longer met the source energy target for Phius CORE 2024. It must be noted that the additional cost of this sub-slab insulation and resulting garage energy savings were not calculated or incorporated into results.

The size of the PV arrays needed to achieve net zero site energy were all well beyond what could fit on the building rooftop – and especially so if including garage energy consumption. Based on Carver Oak's roof design, its south, west, and east-facing roof area could accommodate roughly 180kW of (unshaded) PV capacity after accounting for necessary setbacks from the roof perimeter and roof ridges. With array sizes between 283kW needed for the Phius building (without garage) up to 782 kW for the standard practice building (including garage), this meant that every building version would require large ground-mount arrays in addition to the roof-top array. Siting 782 – 180 = 602 kW of ground-mounted PV arrays to achieve net zero energy for the standard practice building is likely beyond the scale of what most multifamily development sites could support, especially given the size of typical multifamily sites and/or the cost of additional land. Even for the Phius building without parking garage, 283 – 180 = 103 kW of ground mounted arrays could be difficult or impractical on tight urban sites. Changing the roof design to a flat roof to accommodate more solar panels is one possible design change that could help address this challenge, but would likely increase the cost of the roof. The diagram below shows the approximate area that would be required for each of these ground-mount arrays compared to a scaled image of the Carver Oaks roof.

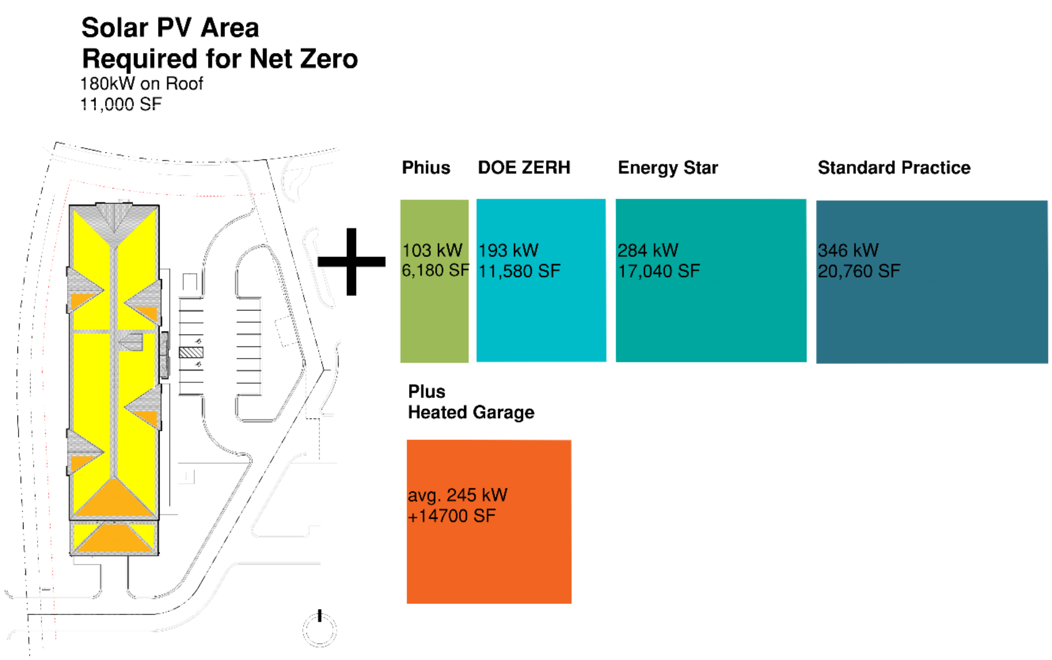

Figure 2 – Carver Oaks site plan and roof area showing required area for ground mount PV arrays (scaled)

WUFI Passive also provided a breakdown in energy consumption between various building loads such as space heating, cooling, and water heating. Although cooling equipment efficiency increased substantially in the DOE ZERH and Phius buildings, only small reductions in cooling energy consumption were achieved. This is likely due in part to the increased R-values and reduced air leakage of those enclosures, which can trap internal heat gains and reduce a building's ability to take advantage of free cooling in the summer and swing seasons.

Much greater energy savings were achieved on the heating side with a combination of the improved enclosure, heat recovery ventilation, and high efficiency heat pumps. Roughly 30% heating energy savings were achieved by the Energy Star building through incremental improvements in window U-value, wall R-value, and furnace efficiency. These savings were increased to 60% in the DOE ZERH case primarily by swapping furnaces for heat pumps and replacing exhaust-only ventilation with balanced heat-recovery ventilation. Heating energy savings were significantly increased again to almost 90% in the Phius building with higher efficiency heat recovery and heat pumps combined with a dramatically improved enclosure. Compared to the standard practice building, above grade wall R-values were improved by 75%, below grade wall R-values by 50%, window R-values by 50%, and enclosure airtightness by 80%.

Overall, the vast majority of energy savings offered by the Phius building came from a reduction in heating energy, with small additional savings offered by higher efficiency cooling equipment and appliances. Ventilation (fan) energy increased slightly for the Phius building (as well as the DOE ZERH building) due to the addition of supply-side fans to balance exhaust. Domestic water heating and lighting systems remained essentially the same in all building versions, as did assumptions about plug load energy use - all resulting in very similar levels of energy consumption for those loads. In reality, both the DOE ZERH and Phius certifications require more efficient plumbing design to deliver hot water as well as lower-flow fixtures to meet the requirements of the WaterSense program. Combined with additional hot water piping insulation in the Phius-building, these upgrades would significantly reduce DHW energy consumption in the DOE ZERH and Phius buildings. However, these specific upgrades cannot be modeled well in WUFI Passive and were not incorporated in the energy results or construction cost analysis.

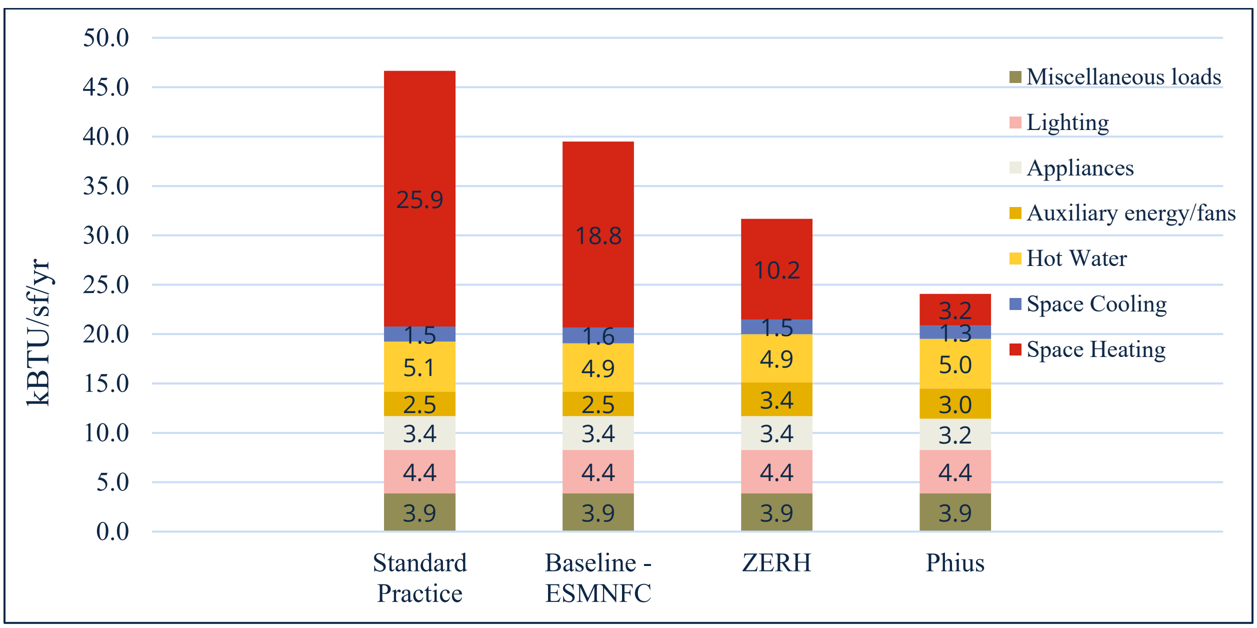

Figure 3 – Yearly energy consumption for major building loads, expressed as kBTU/sf per year.

When broken down by fuel type rather than building loads, it is apparent that electricity consumption goes up for the high performance buildings while natural gas consumption goes down. This is mostly due to switching space heating loads from gas furnaces to electric heat pumps. Since heat pumps are 2-3x more efficient than gas furnaces, overall energy consumption still declines. It is notable that the DOE ZERH-certified building sees quite a large increase in electricity consumption however – almost 70% - and the impact on energy cost could be significant since electricity is currently a more expensive energy type. By comparison, the Phius building sees a much more modest increase in electricity consumption – about 20% - by combining high performance mechanical equipment with a dramatically improved enclosure. This keeps the energy cost impact of switching space heat from natural gas to electricity much more manageable. More discussion on energy costs will be included after the next section.

Table 6 – Yearly energy consumption by fuel type and savings percentage compared to baseline (Energy Star)

	Standard practice	Baseline - ESMFNC	DOE ZERH	Phius
Electricity consumption (kWh)	202,955	204,160	346,294	246,197
Electricity savings (%)	0.6%	NA	(-69.6%)	(-20.6%)
Natural gas consumption (therms)	13,668	10,468	2,161	2,226
Natural gas savings (%)	(-30.6%)	NA	79.4%	78.7%

Construction Cost

Construction costs broken down by component are shown in Table 7 and totaled at the bottom. Again, the Energy Star building was used as the baseline for comparison purposes because it is typically the minimum performance allowed for multifamily affordable housing projects in Minnesota. The “standard practice” building (code-level performance, generally built for most market rate projects) was estimated to cost about 1.9% less than the baseline, while the DOE ZERH and Phius buildings were 2.25% and 4.9% more expensive, respectively. The cost premium for the Phius building was slightly lower compared to Phius multifamily buildings that have been built to date in Minnesota (average 7.5% incremental cost over Energy Star construction (Jacobson, et al, 2026). However, the market for passive multifamily construction in Minnesota is very new and all the completed projects represent first time projects for the development teams. A 5% cost premium for Phius buildings is likely possible as the market matures and teams gain experience with the enclosure and mechanical system upgrades that are needed. As mentioned earlier, this cost study was the 2nd time the general contractor had worked with a Phius multifamily building, which afforded a great deal more confidence, especially pricing enclosure-related items. Other Minnesota contractors working on their second Phius project also report a 5% cost premium (Precipitate, internal communications, spring 2026).

Table 7 – Incremental construction costs for important energy performance features

Component	Standard Practice ***Cost below base bid***	Baseline - ESMFNC ***Base bid***	DOE ZERH ***Cost above base bid***	Phius ***Cost above base bid***
Attic/roof	R-49 blown-in *(-$5000)*	R-49 blown-in *$0*	R-49 blown-in *$0*	R-59 blown-in *$6,115*
Above grade walls	R-21 *(-$31,307)*	R-21 + R-6 CI *$0*	R-21 + R-6 CI *$0*	R-21 + R-12 CI *$23,513*
Basement ceiling	Uninsulated plank *(-$112,233)*	R-20 (3” ccSPF) *$0*	R-20 (3” ccSPF) *$0*	R-28 (4.5” ccSPF) *$32,498*
Basement walls	R-10 rigid foam *(-$19,800)*	R-15 rigid foam *$0*	R-15 rigid foam *$0*	R-15 rigid foam *$0*
Windows	U-0.30 standard vinyl frame, low-e *(-$9,802)*	U-0.27 standard vinyl frame, low-e 272 *$0*	U-0.25 standard vinyl frame, low-e 366 *$5,785*	U-0.20 vinyl frame, 3-glaze, low-e 366 *$51,364*
Airtightness	0.30 (0.40) *$0*	0.27 (0.36) *$0*	0.25 (0.33) *$0*	0.06 (0.08) *$18,810*
Airtightness Testing & Balancing	Standard practice *$0*	Standard practice *$0*	Standard practice *$0*	Phius testing & balancing protocol *$7000*
Appliances	standard electric clothes dryers *$0*	standard electric clothes dryers *$0*	standard electric clothes dryers *$0*	ventless heat pump dryers (5.85 CEF) *$0 net cost since no venting ductwork*
Ventilation	direct exhaust only *$0*	direct exhaust only *$0*	ERV 65% SRE *$129,000*	ERV 84% SRE *$138,000*
Heating & Cooling	gas VTAC 80% AFUE 12 SEER *(-$21,500)*	gas VTAC 90% AFUE 12 SEER *$0*	heat pump HSPF 9.5 16 SEER *$64,500*	ductless heat pump COP 1.75 (17F) COP 3.0 (47F) 16 SEER *$204,250*
Domestic Water Heating	0.96 therm. efficiency central gas boilers *$0*	0.96 therm. efficiency central gas boilers *$0*	0.96 therm. efficiency central gas boilers *$0*	0.96 therm. efficiency central gas boilers *$0*
PV-Ready checklist	NA *$0*	NA *$0*	5 psf additional roof load, vertical chase & conduits, additional electric panels *$7,000*	5 psf additional roof load, vertical chase & conduits, additional electric panels *$7,000*
EV-Ready parking	NA *$0*	NA *$0*	3 EVSE spaces with chargers, 3 EV capable spaces with conduit *$32,400*	3 EVSE spaces with chargers, 3 EV capable spaces with conduit *$32,400*
Total Cost Premium	*(-$199,642)*	*$0*	*$238,685*	*$520,949*
Total Construction Cost	*$10,415,358*	*$10,615,000*	*$10,853,685*	*$11,135,949*
Percentage Premium	*(-1.88%)*	*0%*	*2.25%*	*4.91%*

Table 8 –Summary of incremental costs per unit

	Standard practice	Baseline – ESMFNC	DOE ZERH	Phius
Cost premium per unit	(-$4,643)	$0	$5,551	$12,115
PV cost per unit	$30,719	$27,164	$21,669	$16,474
Total cost per unit (to achieve net zero)	$26,076	$27,164	$27,220	$28,589

Grouping incremental costs by component, it is apparent that most of the increased costs for the DOE ZERH and Phius cases were HVAC-related (space conditioning and ventilation). The Phius building required over $200,000 more for cold-climate ductless air source heat pumps and almost $140,000 more for high efficiency ERVs. This is where the greatest cost compression can still occur as mechanical engineers learn to take advantage of reduced heating and cooling loads with smaller capacity equipment and simplified duct systems, and the local HVAC market begins to provide more high efficiency equipment. Enclosure-related incremental costs were relatively small for the DOE ZERH and Phius buildings. However, stretching back to a standard practice building, it's apparent that much of the additional enclosure cost is incurred in the initial improvements required by Energy Star – most notably garage ceiling insulation (more than $112,000) and exterior insulation for above grade walls (more than $30,000). For experienced project teams, air sealing seems to be a strategy with little impact on construction costs.

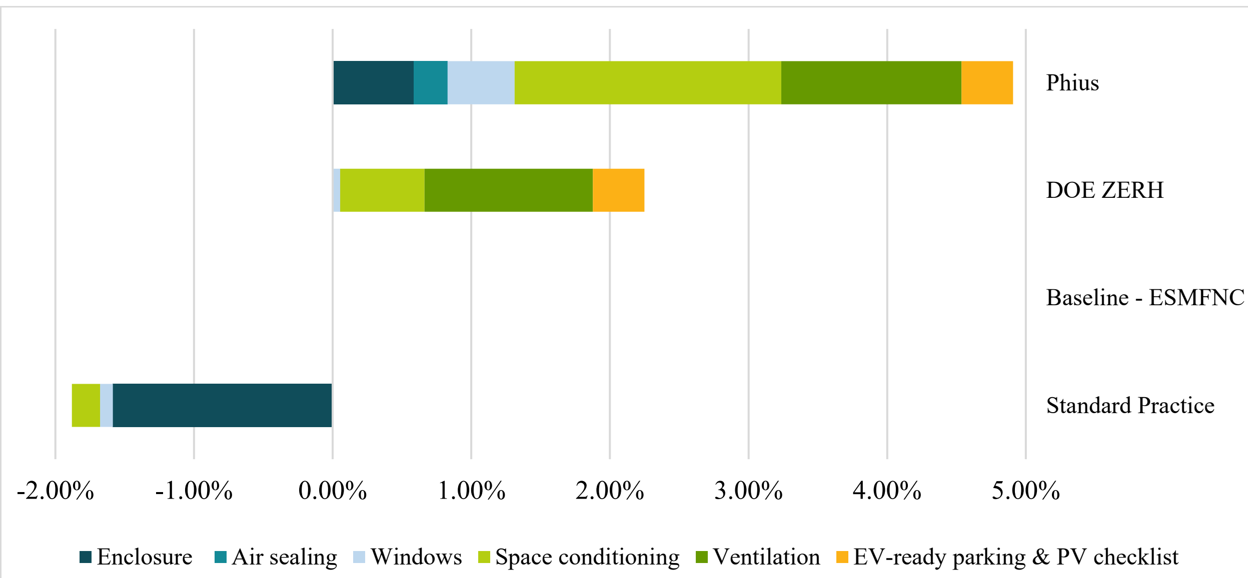

Figure 4 – Total incremental cost to achieve certification as a percentage of construction cost, broken down by component

To achieve net zero site energy, large rooftop and ground-mounted PV arrays were needed in all cases, but the Phius and DOE ZERH buildings significantly reduce the size and expense of such arrays. The PV cost for the Phius-certified building was slightly over $700,000, a roughly 45% reduction compared to the $1,320,000 needed for standard practice construction. However, the total construction cost to achieve net zero energy (for the building plus PV arrays) was surprisingly similar across all four cases. For the Energy Star building to achieve net zero, the incremental cost would be 11%, and all of that expense would go towards PV arrays and associated costs. For the standard practice building to achieve net zero, the overall incremental cost above a basic Energy Star building (without PV) would be slightly less at 10.6%, although the PV arrays would cost significantly more. For both the DOE ZERH and Phius cases, PV costs were reduced, but building construction costs increased, resulting in total incremental costs of 11% and 11.6% over the basic Energy Star building, respectively. To recap, it appears that in this climate and for this particular building design to achieve net zero energy, standard construction with a lot of PV is very similar in construction cost to a Phius or DOE ZERH building with less PV but higher efficiency. However, it is important to keep in mind that although all of these building versions achieve net zero energy, they are not functionally equivalent. This important concept will be discussed in more depth below.

Table 9 – Summary of PV array costs and total construction costs to achieve net zero

	Standard practice, net zero	ESMFNC, net zero	DOE ZERH, net zero	Phius, net zero
PV cost for net zero energy	$1,320,898	$1,168,051	$931,780	$708,388
Total construction cost (to achieve net zero)	$11,736,256	$11,783,051	$11,785,465	$11,844,337
Percentage Premium (over basic Energy Star building)	10.6%	11.0%	11.0%	11.6%

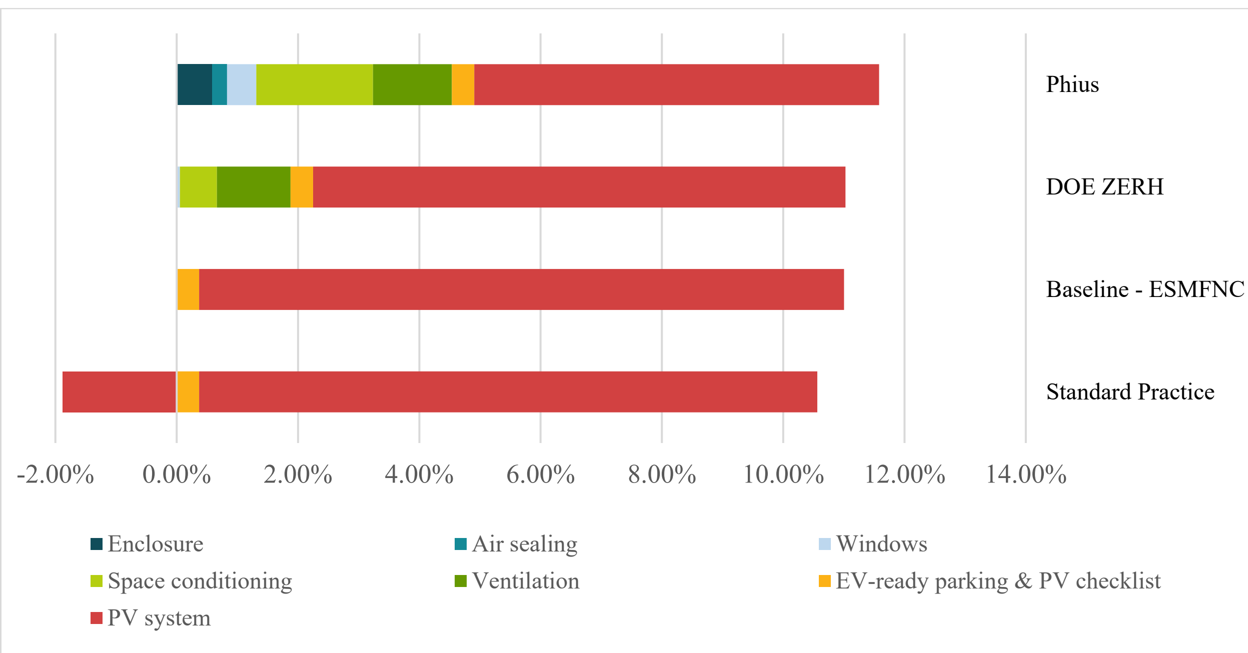

Figure 5 – Total incremental cost to achieve net zero energy as a percentage of construction cost, broken down by component

Energy Cost

Removing PV from consideration, it appears that energy costs could vary widely from one building version to another. No attempt was made to model detailed aspects of utility costs such as seasonal rate changes, demand charges, or special incentive rates for heat pumps. However, it is clear that the standard practice and Energy Star buildings split energy costs between natural gas and electricity, with the Energy Star building cutting natural gas costs significantly (approximately 23.5%) primarily through a combination of incremental enclosure improvements and higher efficiency furnaces. Total utility costs are reduced by 8.5%. The DOE ZERH case demonstrates the energy cost implications of replacing gas equipment with heat pumps before taking stronger steps to reduce energy loads. With only minor improvements to the enclosure and the addition of fairly low-efficiency heat recovery ventilation, electric utility costs rise dramatically, overwhelming the natural gas energy cost savings and driving total utility costs 12% above the standard practice level. This could be unfortunate for developers or building owners if they are anticipating lower utility costs to help pay back the higher upfront costs of DOE ZERH construction.

In comparison, the Phius case shows that even without special electric rates, a transition to heat pumps does not have to increase utility costs. Notably, with a combination of high efficiency mechanical equipment and more aggressive enclosure improvements, electricity cost increases can be moderated while total energy cost still declines – in this case by about 18% compared to standard construction. This does not match the scale of the 48% reduction in energy use offered by the Phius building compared to standard practice, because the Phius case is primarily saving heating energy delivered by natural gas - which is currently the less expensive energy source. Special electric rates for heat pumps could become important here to help reduce this discrepancy and achieve a faster payback. For residents however, there are several immediate utility cost benefits including significantly reduced and stabilized energy bills. Natural gas has historically been much more susceptible to short-term price spikes, which often occur in tandem with abnormally cold weather, doubling up impacts and unpredictably driving utility costs to extreme levels. The more stable monthly costs offered by an all-electric (or mostly electric) Phius-building can be an important benefit for low-income households occupying affordable housing.

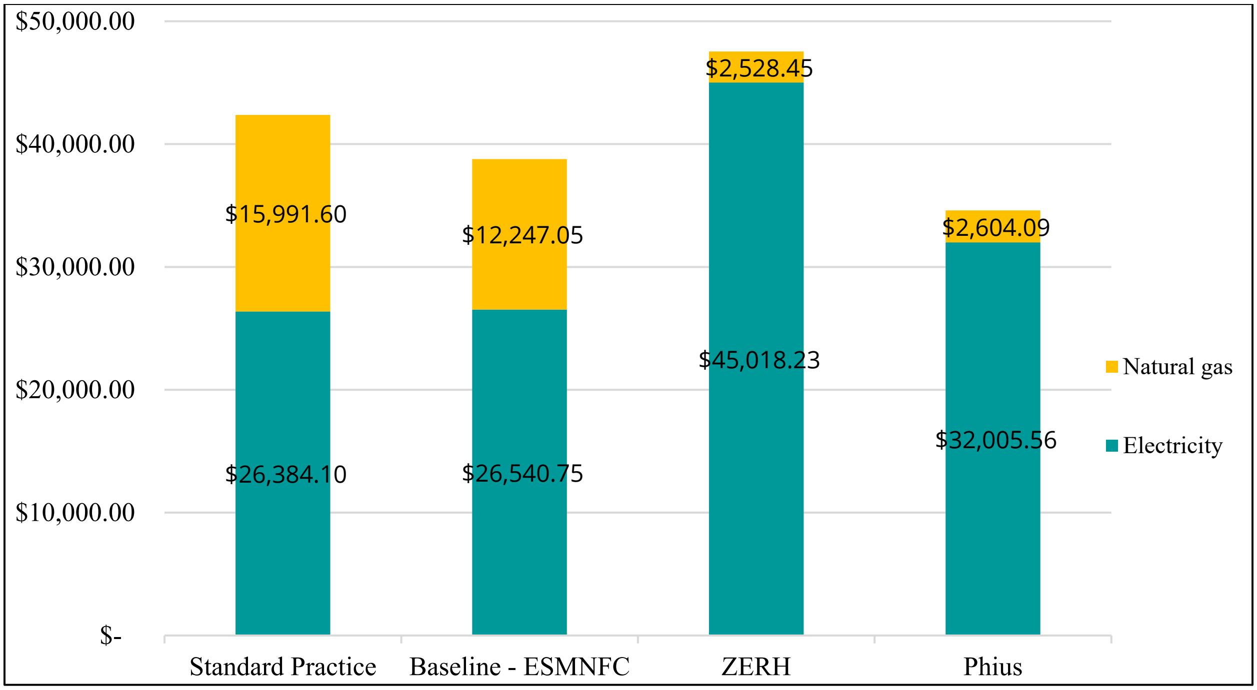

Figure 6 – Total yearly energy cost for the building, by fuel type

Conclusion

In conclusion, Energy Star, DOE ZERH, and Phius appear to offer a consistent, sequential set of steps up the building performance staircase, beginning with Energy Star as the easiest step and ending with Phius as the most aggressive. For this particular multifamily project and climate location, modeled building EUI dropped roughly 7-8 kBTU/sf with each step, beginning around 47 kBTU/sf with the standard practice case and ending at 24 kBTU/sf for the Phius case (not including the parking garage). However, underground parking garages consume a very significant amount of energy, adding around 21 kBTU/sf to the building's total in each case, which would almost double energy consumption for the Phius building. Considering ways to minimize or eliminate underground parking garages could easily offer energy savings equivalent to or greater than that offered by these building certification programs.

Construction costs increased steadily as well with each step in the performance staircase, adding a 2 – 2.5% cost premium with each step. The Phius certification added an estimated 5% incremental cost over Energy Star, which is slightly lower than the average premium calculated from the handful of Phius multifamily projects completed in Minnesota to date (Jacobson, et al, 2026). However, 5% is in line with incremental costs reported in other states with more well-developed Passive markets (NAPHN 2021) (Phius 2022) and reflects an estimate from an architect and contracting team already experienced with Phius certification. While most practitioners assume that high performance enclosure costs such as triple glazing and enhanced air sealing are the most expensive items to cover for Phius buildings, it is apparent that the majority of increased enclosure costs are actually borne in the first step up from standard practice, to Energy Star certification. These costs include garage ceiling insulation, as well as above grade wall exterior insulation. While the triple glazed windows required for Phius certification in Minnesota are still more expensive than double pane from the same manufacturer, high performance window costs appear to be coming down especially for project teams willing to search beyond the big-name manufacturers. When starting from an Energy Star baseline, it appears that high efficiency mechanical systems, rather than enclosure items, are the source of the largest incremental costs for the DOE ZERH and Phius buildings. Fortunately, with a high-performance enclosure, Phius buildings offer the chance for further mechanical system cost compression by optimizing these systems for low loads and smaller, simplified distribution. These savings could be achieved as mechanical engineers, contractors, and suppliers grow more confident with the benefits of high-performance enclosures.

Achieving net zero energy with any of these building versions is possible and surprisingly similar in terms of total construction cost - but stark differences exist in the end products and the benefits they provide. For example, to achieve net zero energy with the standard practice building requires a PV array roughly two times larger than that of the Phius building in terms of output capacity, cost, and space. While the additional expense for PV is balanced out by the lower cost of construction for the standard building, many projects may simply not have the site area or interconnection ability to host such a large array (526kW without including the garage). In addition, such large arrays, if numerous, could strain the capacity of the grid to absorb so much solar energy, as California has experienced. Thus, for developers pursuing net zero energy, DOE ZERH and Phius buildings have fewer site constraints and can be built in more locations. Phius buildings in particular also offer utilities opportunities for electrification and even demand control of major loads such as space heating, without increasing strain on the utility grid (Opinion Dynamics, 2021). For residents, DOE ZERH and Phius buildings offer a host of additional benefits as well. These include safer, more resilient housing in the case of extreme weather and power outages (Franconi, et al, 2023), reduced and stabilized energy bills, and improved indoor air quality and health (Moreno-Rangel, et al, 2020). In essence, while each version of the building (from standard construction through Phius) could achieve net zero energy, they are not functionally equivalent. The higher efficiency buildings offer an array of added benefits to developers, residents, and utilities that are summarized in the chart below.

Table 10 – Summary of benefits offered to residents, developers, and utilities for each net zero energy building case

	Standard practice	Baseline ESMFNC	DOE ZERH	Phius
Resident benefits		improved comfort	improved comfort	improved comfort
			improved IAQ / health	improved IAQ / health
		reduced energy costs		reduced energy costs
			stabilized energy costs	stabilized energy costs
				improved safety & passive survivability
	lower purchase cost			
Developer benefits		potentially higher sale/rent value	potentially higher sale/rent value	potentially higher sale/rent value
			reduced site constraints	reduced site constraints
	lower upfront cost			

Utility benefits		reduced PV over-production	reduced PV over-production	reduced PV over-production
				reduced peak loads
				enable demand control for large building loads such as space heating

While low upfront construction cost has historically driven the production model for multifamily buildings, it is apparent that many other important items could be prioritized for the benefit of developers, utilities and residents alike. When net zero energy is a goal, a Passive-certified building offers many additional benefits for essentially the same total construction cost. Thus, there is a strong justification for helping developers cover some of the upfront costs of high-efficiency buildings to gain those benefits. Larger, better timed, and more impactful incentive programs combined with training and education from utilities and the government could help developers accomplish this beneficial market transformation (Jacobson, et al, 2026).

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