FINAL REPORT

PASSIVELY BUILDING FOR RESILIENCY:

ASSESSING ENERGY EFFICIENCY AND RESILIENT DESIGN IN OREGON BUILDINGS FOR TODAY AND TOMORROW

ENERGY TRUST OF OREGON 2018 NET ZERO FELLOWSHIP RESEARCH

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1 EXECUTIVE SUMMARY

Anyone who designs or constructs buildings understands their performance varies by climate. Even the most energy-efficient building will not have the same energy use patterns or withstand weather conditions to the same extent in Portland, Oregon as it does in Atlanta, Georgia. The cities' climates are entirely different. But what if 40 to 50 years from now—easily within the lifespan of today's buildings—Portland's daily weather forecast looks more like that of Atlanta today? This study involved a close examination of past and future climate conditions in Oregon, the results of which point to exactly that. This raises the question of how we in the design and development community can prepare for this. How do we design and construct buildings now that in half a century will be weathering a very different storm?

It is well known that passive energy conservation strategies result in lower energy use, more reliable comfort, and improved resiliency. However, development teams turn to active (i.e., mechanical) energy conservation measures far more frequently. Why? From a simple energy cost payback perspective, active systems often pencil out to have a more attractive return on investment period than most passive solutions. This simple payback method is arguably inadequate and misses the co-benefits inherent to many passive design elements, such as enhanced comfort and resiliency in the wake of extreme weather events, among others.

To fully prepare building designs and maximize their value for the future, we need an easy way to assess how local, future climate conditions may impact the relative efficacy of passive versus active design solutions on the thermal resiliency and passive survivability of a building. This study created a standardized method, as well as future climate files for two different climate zones (Portland and Bend) that will be available for public use, to assess the resiliency of proposed developments in Oregon. We worked with our design partners, Oh Planning + Design and Portland Public Schools, to specifically research the design of a public middle school.

Future climate conditions will involve warmer temperatures in both winter and summer, reducing the heating demand. The result, when designing for high-performance, is a general shift from a building that is heating-dominated to one that will be cooling-dominated. The research also showed a strong correlation between energy savings achieved through the implementation of passive measures and the resiliency of the building (and communities) as a whole.

Overall, this study revealed the value of expanding our assessment tools to include resiliency metrics, such as passive survivability, to provide a clear picture of the benefits of passive design measures—particularly for our critical infrastructure stock. Envelope decisions should be made to control solar gains and allow for passive cooling with natural ventilation, thermal mass, and solar shading. These same passive measures, along with improved envelope insulation, will help ensure the resiliency of our buildings. Passively designed buildings have been shown to provide better thermal resilience (i.e., provide comfortable conditions during periods of power outage, than their mechanical counterparts). This is even more important for buildings that may one day need to serve as a community refuge during extreme weather events.

2 INTRODUCTION

In an era of changing climate, it is important for building owners and designers to understand design decisions made today determine the performance of buildings in the future. These decisions affect a building's resiliency, not only in terms of its ability to withstand a natural disaster, but also to maintain comfortable conditions in severe weather.

It is well known that passive energy conservation strategies result in energy-efficient, comfortable, and resilient buildings, but development teams often implement *active* energy conservation measures. Yet, beyond comparing energy consumption, how can we know which strategy will be more resilient in the future?

This research explored the design of energy-efficient and resilient buildings for past and future climate conditions in Oregon. Researchers assessed energy performance using end-use energy consumption data from whole-building energy simulation. The team measured thermal resiliency, or passive survivability, based on a building's ability to maintain comfortable conditions for occupants during a simulated power outage.

The project had four main goals:

- Create a standardized method to assess the resiliency of proposed developments in Oregon and provide design teams with a method to evaluate resiliency implications.
- Show value beyond energy savings of passive design strategies for resiliency (e.g., lower maintenance, longer lifespan, improved indoor environment)
- Create future climate weather data files for Portland and Bend for public use with energy modeling software tools.
- Establish guidance for designers to not only achieve net zero energy targets through passive design, but to improve Community Resiliency as well.

3 BACKGROUND AND APPROACH

The building design community has strived for decades to understand and create high-performance designs to help mitigate GHG emissions, and thus climate change. Design teams have rightly focused on reducing energy consumption and carbon emissions as a primary metric for assessing performance. Energy Use Intensity (EUI), a metric for annual energy (kBtu/yr) per gross floor area (ft^2), is a useful way to compare buildings of varying size and function. The downside of this approach is that one kBtu saved is treated the same as another by design teams, rating systems, and incentive programs. This research hypothesizes that a kBtu saved by passive design means is more valuable than a kBtu saved by mechanical design means as it has the added benefit of improved resiliency.

3.1 Passive Survivability & Thermal Resiliency

Resiliency is a term that has a wide range of definitions and applications. This research uses the following definition from the Resilient Design Institute (Resilient Design, 2019):

> "…intentional design of buildings, landscapes, communities, and regions in order to respond to natural and manmade disasters and disturbances - as well as long-term changes resulting from climate change - including sea level rise, increased frequency of heat waves, and regional drought".

This research also considers Energy Trust of Oregon's (Energy Trust, 2019) more specific definition, which includes:

> "… promoting the design of buildings that can maintain temperatures, allow for light, and remain inhabitable for longer periods."

This research study seeks to quantify the passive survivability—and specifically the thermal resiliency—of buildings based on Energy Trust's definition. The concept of passive survivability helps quantify (and thus compare and improve) the resiliency of a built environment. Passive survivability refers to the building's ability to maintain critical life-support conditions in the event of extended loss of power, heating fuel, or water (Wilson, 2005). This concept is being applied more frequently in codes (e.g., City of Toronto Zero Emissions Building Framework (2017)), design guides (e.g., MURB Design Guide (Kesik, et. al, 2019)), and standards (e.g., RELi and LEED Resiliency pilot credits (USGBC, 2019)).

Energy modeling has proven an effective tool to quantify passive survivability and thermal resiliency. By virtually "pulling the plug" on a building, an energy model can track the thermal performance of a space without electricity (i.e., plug and lighting loads and mechanical systems), while maintaining occupancy and passive thermal gains and losses. We tested the thermal resiliency for both the coldest and hottest weeks of the climate file years to understand the upper and lower acceptable thermal limits.

3.2 Design Case Study

This study used a new Portland Public Schools (PPS) project, the Kellogg Middle School, as a representative baseline. It was important to have a building type the community values, is built repeatedly throughout the state, and has long term ownership. It was also important to have a building design tailored to site, local climate, owner goals, and user requirements, rather than a generic building.

Figure 1: Rendering of Kellogg Middle School (image courtesy of Oh Planning + Design)

The owner, PPS, and architects, Oh Planning + Design, joined RWDI to reimagine their original zero net energy performance building as a model to test design strategies for a low-energy and resilient design in the future.

The partnership combined areas of expertise: RWDI focused on energy and climate modeling, Oh Design offered insights on passive design and construction practices, and PPS shared perspectives on operation and maintenance of critical use buildings over the long term.

3.3 Future Climate Files

It is common practice for energy models to use EnergyPlus Weather (EPW) files based on typical meteorological year (TMY) data. This data is both typical (i.e., does not represent climate highs or lows) and historical. The most recent EPW weather files available for Portland and Bend are TMY3 files, representing the time period 1991-2005, as recorded at the respective airport station near each location (Wilcox & Marion, 2008). This is not adequate climate information to make informed decisions on the future energy consumption and resiliency of buildings—that requires future climate files.

It is possible to predict future climate with either statistical or dynamic modeling. To determine a typical meteorological year and provide data for an EPW file that represents future conditions, the data source must:

- Represent weather changes related to future climate changes;
- Cover a sufficient length of time to allow calculation of a TMY (at least 10 years);
- Provide atmospheric parameters required for a TMY calculation and/or an EPW input file; and
- Have sufficient temporal and spatial resolution to be representative of diurnal patterns and local-scale, terrain-induced influences on meteorology.

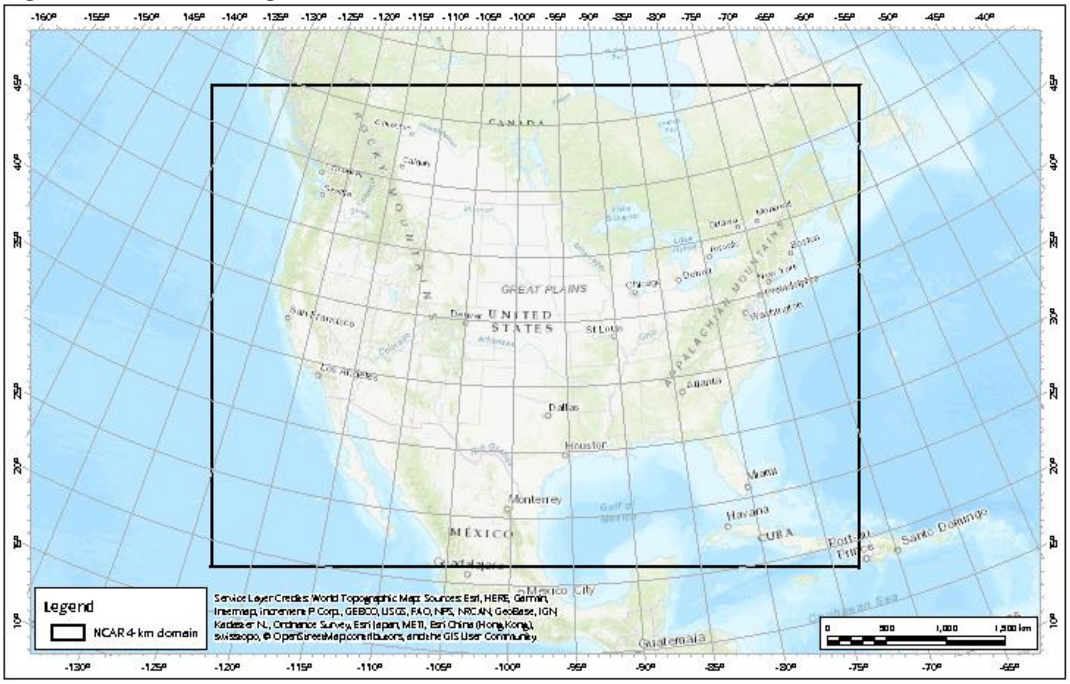
The project used high-resolution, regional climate predictions from the National Center for Atmospheric Research (NCAR) (Rasmussen & Liu, 2017) to fulfil these requirements and provide an estimate of the future weather in Portland and Bend.

The NCAR regional climate model uses a retrospective historical simulation of past weather based on Weather Research and Forecasting Model (WRF). The WRF model (WRF, 2019) is a numerical weather prediction system designed for both atmospheric research and operational forecasting applications. Numerous agencies worldwide use it for multiple applications, including daily weather forecasting, hurricane prediction, historical weather analysis and regional climate prediction.

WRF is a “mesoscale” or “limited area model,” which means that it covers a limited area of the globe, rather than its entirety. Because a WRF model simulation covers only a portion of the globe, it must be influenced on its boundaries by data representing the larger global atmospheric condition. This boundary condition can be derived from historical global weather analyses, or it can be from data that represent a possible future weather condition. The NCAR modeling used WRF to do a regional climate simulation for a historical period and a future climate sensitivity of the same period based on the ensemble average of the results from CMIP5 (Coupled Model Intercomparison Project Phase 5) global circulation model (GCM) experiment.

The NCAR climate model is based on a historical simulation of the period from 2000-2013 that provides hourly snapshots of the state of the atmosphere—including wind, temperature, precipitation and radiation balance—at 4 km (2.5 mi) resolution over all the continental United States and much of Canada and Mexico (see Figure 2).

Figure 2: NCAR WRF Regional Climate Solution Domain

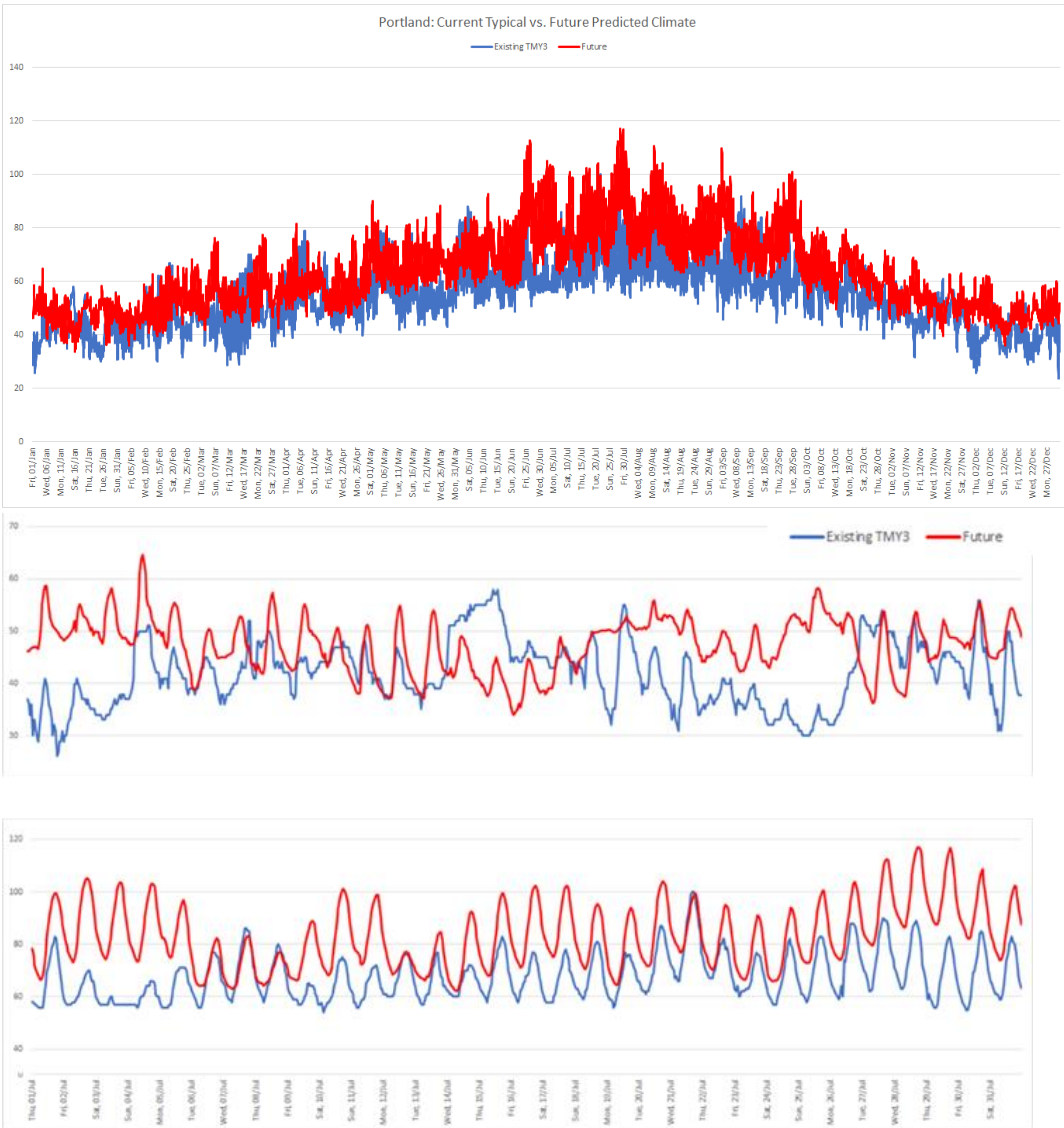


A 'pseudo' or 'implied' future regional climate prediction is then developed from the same model period, but with the model adjusted or 'perturbed' by an increment calculated from explicit predictions of global circulation models (GCMs). This perturbation applied is equivalent to the ensemble average from CMIP5, the future climate GCM results for the rcp8.5 or 'high emissions' scenario over the 2071-2100 future period. In simpler terms, the model represents the estimated effect of the "business as usual" climate scenario for year 2100 over the continental US.

This approach, termed a 'pseudo-global warming' regional climate model, allows for higher temporal and spatial resolution of model predictions than is available from explicit future runs of GCMs. This means that it allows for some important meteorological phenomena, such as cloud formation, precipitation, and terrain induced winds, to be explicitly resolved by the model physics rather than estimated through bulk parameterizations as they typically are in GCMs, thus providing a more accurate estimation of meteorology at any given location.

RWDI climatologists took the 13 years of forecasted, hourly climate data and created a single, annual future climate file representing a typical meteorological year (TMY), following industry standard protocols (Wilcox & Marion, 2008). The results are future climate files, in TMY/EPW format, that will be publicly available for all designers and researchers to use in future work. We also describe our methodology for creating the climate file in detail in a white paper available on the 2018 Net Zero Fellowship Research web page (Energy Trust NZF, 2019).

Figure 3: Sample Outputs from Future Climate Files – Annual (top), Winter Week (middle) & Summer Week (bottom) Dry Bulb Temperatures for Future (red) and Historical (blue) TMY3 Data

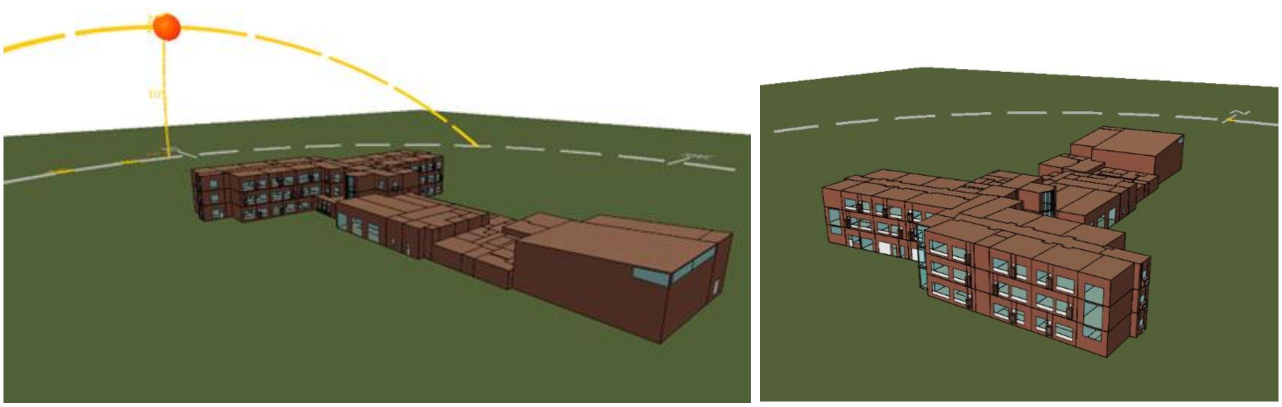


The climate files, procedures, and calculations were peer reviewed by a qualified third-party climate scientist.

3.4 Energy Modeling

We modeled the case study middle school using the whole building energy simulation software IES Virtual Environment (IES VE, 2018).

Figure 4: Renderings of IES VE Energy Model



To understand the effect of future climate on building performance, we developed several iterative energy models. We first created a baseline version of the case study school that would just meet the Oregon Energy Efficiency Specialty Code (OEESC, 2014) requirements for envelope and systems for each climate zone. Then we created a high-performance version of the model that relied predominantly on mechanical (or active) systems for heating and cooling. This version of the model included energy-efficient systems (e.g., high-efficiency pumps and ECM motors, variable refrigerant flow (VRF) heat/cool system, and high efficiency ERV) and lighting with sophisticated controls. Yet, the model building enclosure only met code minimums and passive solar shading was kept at a minimum.

We then built an alternative high-performance version of the building model that relied on passive design strategies. This version included a near Passive House envelope performance, with high insulation, low infiltration, high-performance window systems, and solar shading, as well as low-energy LED lighting and daylight controls. This passive design version used a simple mechanical system (radiant heating, high-efficiency boiler, and ERV).

Both the active and passive cases had a similar modeled EUI. This was intentional as it allowed us to compare relative improvement in energy performance in both cases. Table 1 summarizes the model inputs for each of the three cases in detail.

Table 1: Energy Model Inputs for Oregon Code Baseline, Passive, and Mechanical Design Cases

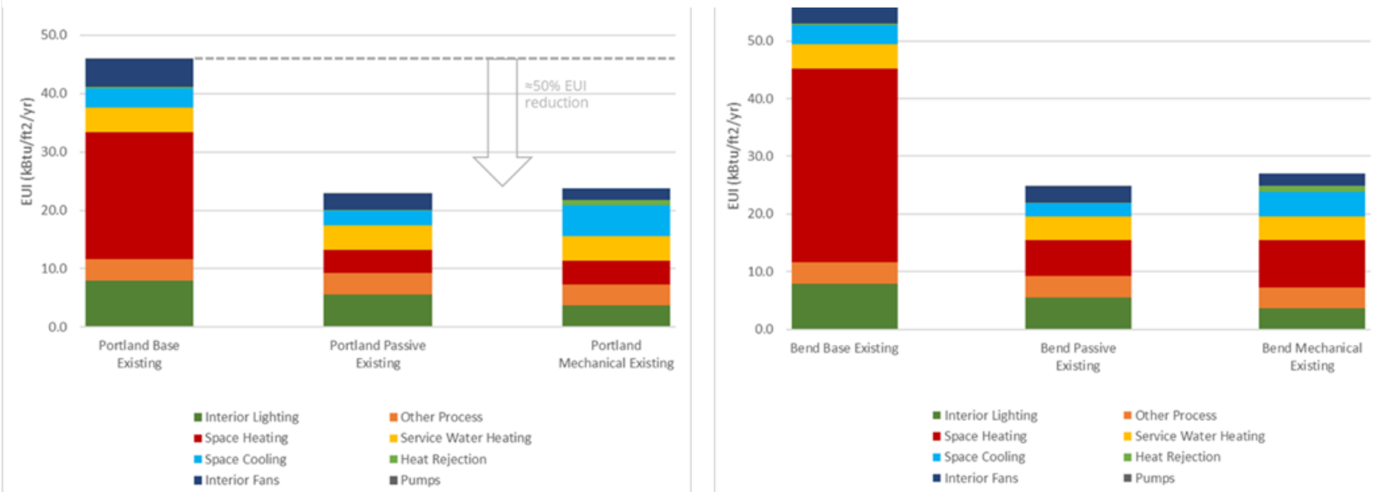
		Baseline Case	Passive Case	Mechanical Case
Envelope				
Typical Exterior Wall		15.0 R-value	35.5 R-value	15.0 R-value
Typical Roof		20.0 R-value	60.0 R-value	20.0 R-value
Gross Window to Wall Ratio		16%	16%	16%
Glazing		U-0.45: All windows	South facing: U-0.14| All other: 0.12	U-0.45: All windows
Glazing (SHGC)		All windows: 0.4	South facing: 0.64 | All other: 0.37	All windows: 0.4
Shading Overhangs		None	1.5" for all windows and orientations	None
System Level				
Main HVAC	System Type	Packaged VAV w/reheat, Mixed Air	Packaged VAV with Reheat, 100% OA, Radiant panels	DOAS, 100% OA, gas furnace | Air source VRF zonal
	System Fans	Total for System: 78.1 kW	Total for System: 52.6 kW	Total for System: 33.5 kW
	Energy Recovery	None	Sensible: 70% | Latent: 65%	Sensible: 90% | Latent: 70%
	Heating	Natural draft hot water boiler	Condensing hot water boiler	System: Gas furnace | Zone: VRF Heat pump
	Cooling	DX Cooling | EER 9.8	DX Cooling | EER 9.8	System: None | Zone: VRF Heat pump
AHU (gym)	System Type	Packaged VAV w/reheat, Mixed Air	Packaged VAV with Reheat, Mixed Air	Packaged VAV with Reheat, Mixed Air
	System Fans	Total for System: 10.8 kW	Total for System: 7.9 kW	Total for System: 11.1 kW
	Energy Recovery	None	Sensible: 70% | Latent: 65%	None
	Heating	Natural draft hot water boiler	Condensing hot water boiler	Heat pump
	Cooling	DX Cooling | EER 9.8	DX Cooling | EER 11.5	None
Plant Level				
Space Heating Efficiency		80.0%	92.0%	Gas Furnace: 80% | VRF: 4.0 COP
DHW Boiler Efficiency		80.0%	80.0%	80.0%
Fixture Flow Rates		Lav: 0.5 gal/min | Shower: 2.5 gal/min	Lav: 0.5 gal/min | Shower: 2.5 gal/min	Lav: 0.5 gal/min | Shower: 2.5 gal/min
Space Level				
Equipment Load		0.5 W/ft2 (classrooms)	0.5 W/ft2 (classrooms)	0.5 W/ft2 (classrooms)
Lighting Power Density		1.23 W/ft2 (classrooms)	0.86 W/ft2 (classrooms)	0.86 W/ft2 (classrooms)
Lighting Occupancy Sensors		Most spaces	Most spaces	Most spaces
Lighting Daylight Sensors		None	None	All perimeter spaces - continuous dimming

To understand the implications of these decisions for Oregon buildings, these three models were simulated using existing TMY3 (typical meteorological year) climate files for two cities representing Oregon's two distinct climate zones: Portland (Zone 4C) and Bend (Zone 5B). The analysis, therefore, consisted of results from 12 unique iterations of the energy model, comparing end-use energy consumption, as well as thermal resiliency.

4 MODELING OUTCOMES

In the Portland Baseline Model (the Code compliant design), the EUI for the existing/historical climate case closely resembles typical Oregon educational building energy performance: approximately 48 kBtu/sf/yr. The results showed that the Code compliant building for the existing/historic climate case is heating-dominated with heating energy making up approximately 50% of the energy end-use breakdown. In that same climate case, our models for both the passive and mechanical designs result in approximately 50% annual energy savings compared to typical PPS schools with an EUI of approximately 24 kBtu/sf/yr (see Figure 5). The selected energy efficiency measures for the two cases—passive and mechanical—dramatically reduced space heating requirements from the baseline. However, space cooling decreases in the passive case, while it increases in the mechanical case.

Figure 5: End-use Energy Consumption for Baseline (code), Passive, and Mechanical Cases for Current Climates in Portland (left) and Bend (right)

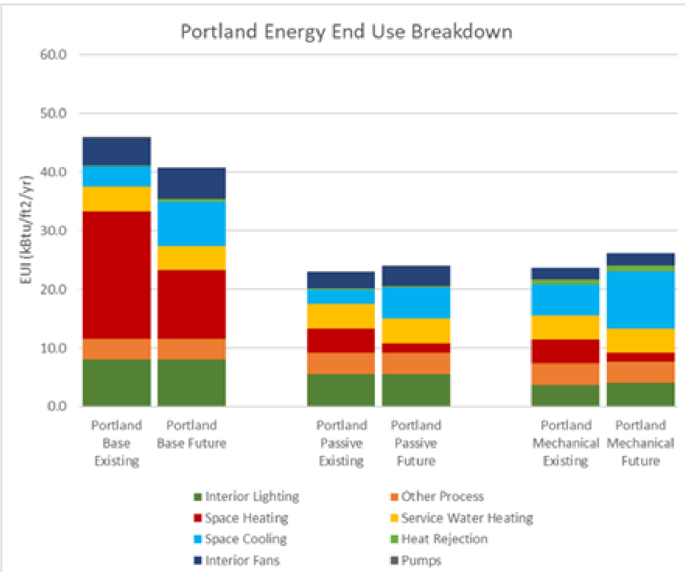


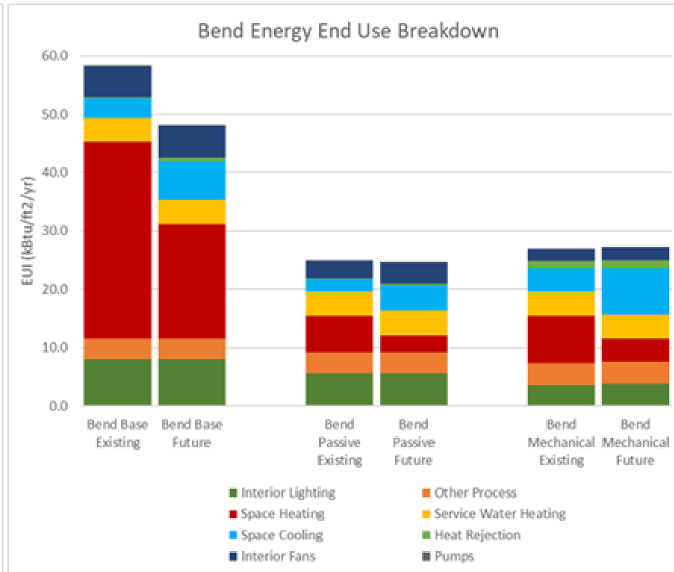
Under future climate conditions, the model shows Bend requires more heating energy than Portland, resulting in increased EUI for the more severe climate. This was more noticeable in the baseline (Oregon code) case than in the energy-efficient passive and mechanical cases.

The same three energy model cases were then run with the warmer, future climate case (Figure 6).

Future climate conditions will have increased winter temperatures in both cities, reducing the heating demand. In addition, future summer temperatures in both cities will result in increased cooling demand, though not to the extent that heating decreases. Future climate conditions will result in a slight increase in energy consumption in both mechanical and passive cases because cooling loads in mechanical cases increase significantly in future climate conditions.

Figure 6: End-use Energy Consumption for Baseline (code), Passive and Mechanical Cases for Current & Future Climates in Portland (left) and Bend (right)





For Bend, future climate shifts energy end use from heating to cooling, but the resulting EUI is approximately the same. The shift from heating-dominated to cooling-dominated could alter fuel use from natural gas to electricity, potentially altering the carbon footprint. This will amplify if we have more renewable energy systems or onsite renewable energy becomes the norm in the future. We predict all other systems will have a similar end-use energy consumption profile to that of Portland projects.

5 RESULTS AND DISCUSSION

5.1 Climate Zone Shift

Climate modeling has shown that the future will result in a climate zone shift for both Portland and Bend. To illustrate this point the Heating Degree Days (HDD) and Cooling Degree Days (CDD) were calculated for over 40 years of historical, measured data (including the TMY3 period), as well as the 13 years of forecasted climate data. It is clear that both cities will show a significant reduction in Heating Degree Days and increase in Cooling Degree Days (Figures 7-8 & 10-11).

Figure 7: Heating Degree Days for 40 years of Measured Weather Data at PDX and 13 Years of NCAR Future Climate Predictions

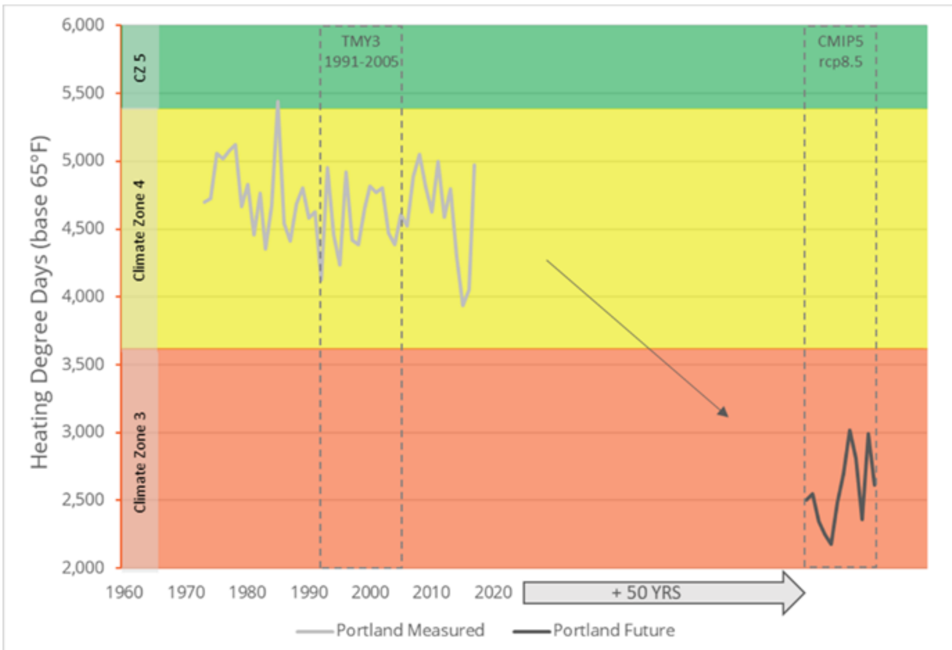
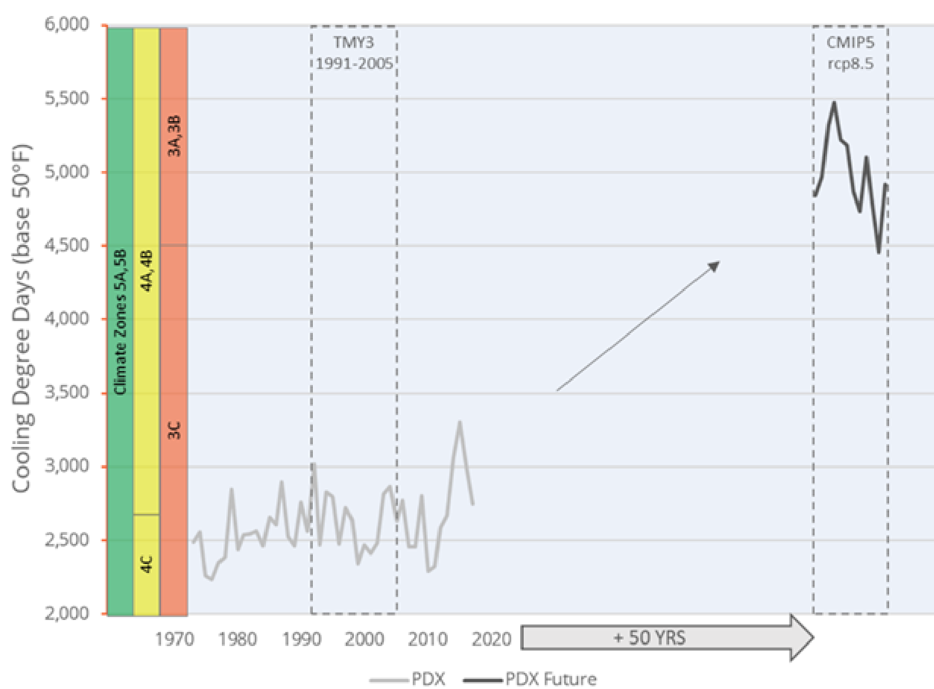
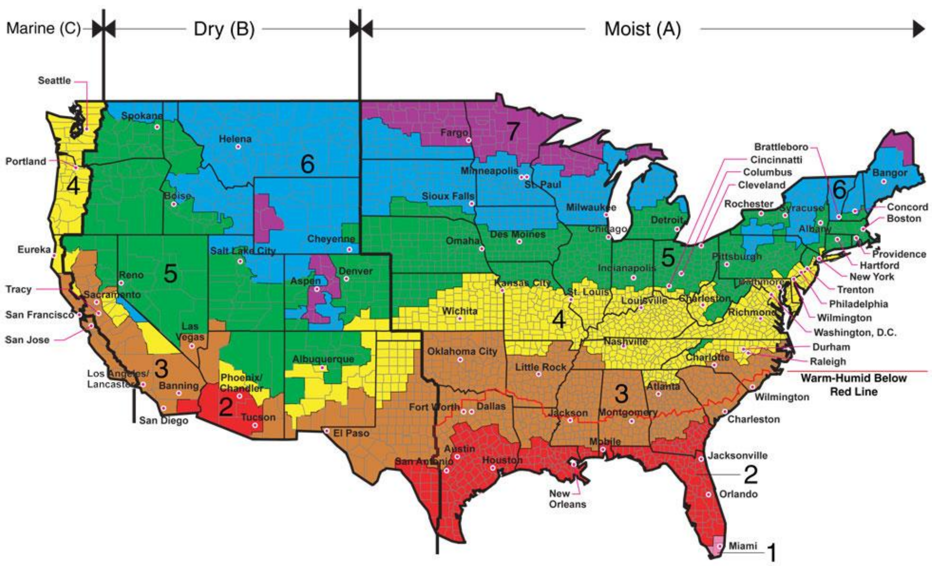


Figure 8: Cooling Degree Days for 40 years of Measured Weather data at PDX and 13 Years of NCAR Future Climate Predictions



Portland is currently categorized as an ASHRAE climate zone 4C, a mixed marine climate. With an anticipated decrease in HDD and an increase in CDD and precipitation it is expected that Portland will transition to zone 3A, a warm humid climate. Current cities that share the 3A classification are Oklahoma City, Oklahoma, Dallas, Texas, Little Rock, Arkansas, Jackson, Mississippi, and Atlanta, Georgia.

Figure 9: ASHRAE Climate Zone Map (left) and HDD/CDD Criteria (right)



Zone Number	Zone Name	Thermal Criteria (I-P Units)
1A and 1B	Very Hot –Humid (1A) Dry (1B)	9000 < CDD50°F
2A and 2B	Hot-Humid (2A) Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm – Humid (3A) Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm – Marine (3C)	CDD50°F ≤ 4500 AND HDD65°F ≤ 3600
4A and 4B	Mixed-Humid (4A) Dry (4B)	CDD50°F ≤ 4500 AND 3600 < HDD65°F ≤ 5400
4C	Mixed – Marine (4C)	3600 < HDD65°F ≤ 5400
5A, 5B, and 5C	Cool-Humid (5A) Dry (5B) Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold – Humid (6A) Dry (6B)	7200 < HDD65°F ≤ 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

Figure 10: Heating Degree Days for 40 years of Measured Weather data at RDM (Bend) and 13 Years of NCAR Future Climate Predictions

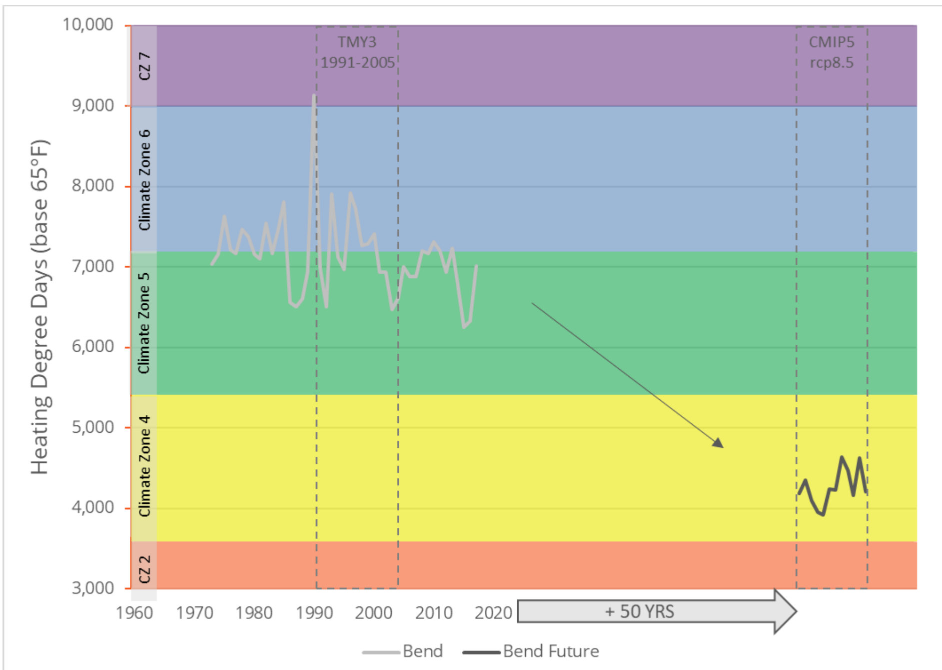
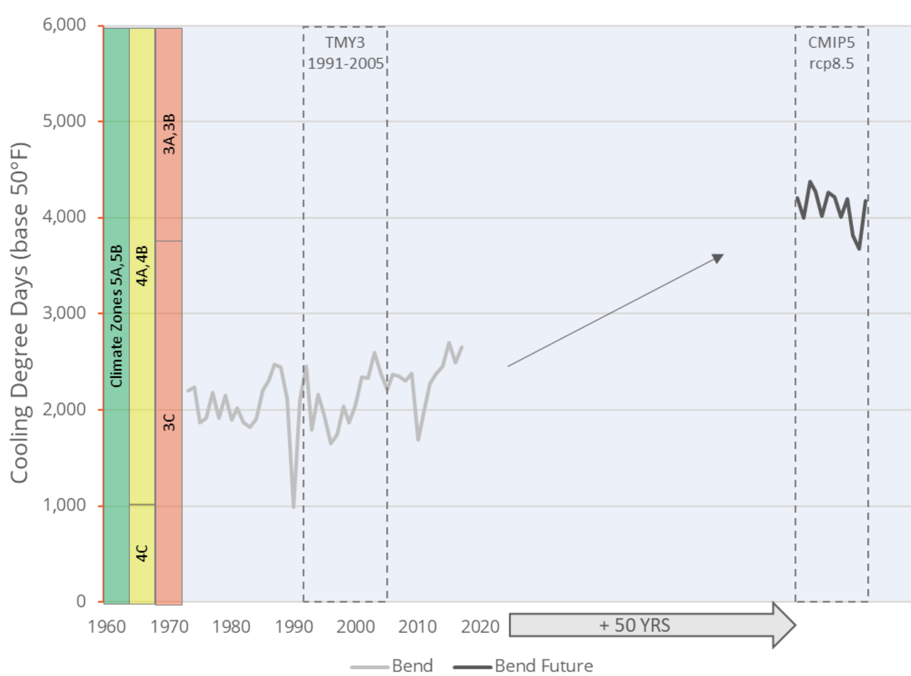


Figure 11: Cooling Degree Days for 40 years of Measured Weather data at RDM (Bend) and 13 yrs of NCAR Future Climate Predictions



Bend is currently classified as an ASHRAE climate zone 5B, a cool dry climate. The future climate file shows a climate zone shift to an anticipated zone 4B, a mixed dry climate. A current city that shares the 4B classification is Albuquerque, New Mexico.

5.2 Energy End-Uses under Future Climate

As described in the previous section, the future climate files show that for both Portland and Bend we can expect a general warming trend, significant to design decisions.

An increase in future winter temperatures will result in reduced heating demand for buildings. This will impact both the sizing and selection of heating system types. With lower heating demands, some internal gain-driven spaces will be able to rely more heavily on passive and low-temperature heating systems.

An increase in future summer dry bulb temperatures will result in an increase in cooling demand for buildings. Passive design measures to control heat gains will be necessary, with an overall increase in reliance on active, mechanical cooling systems.

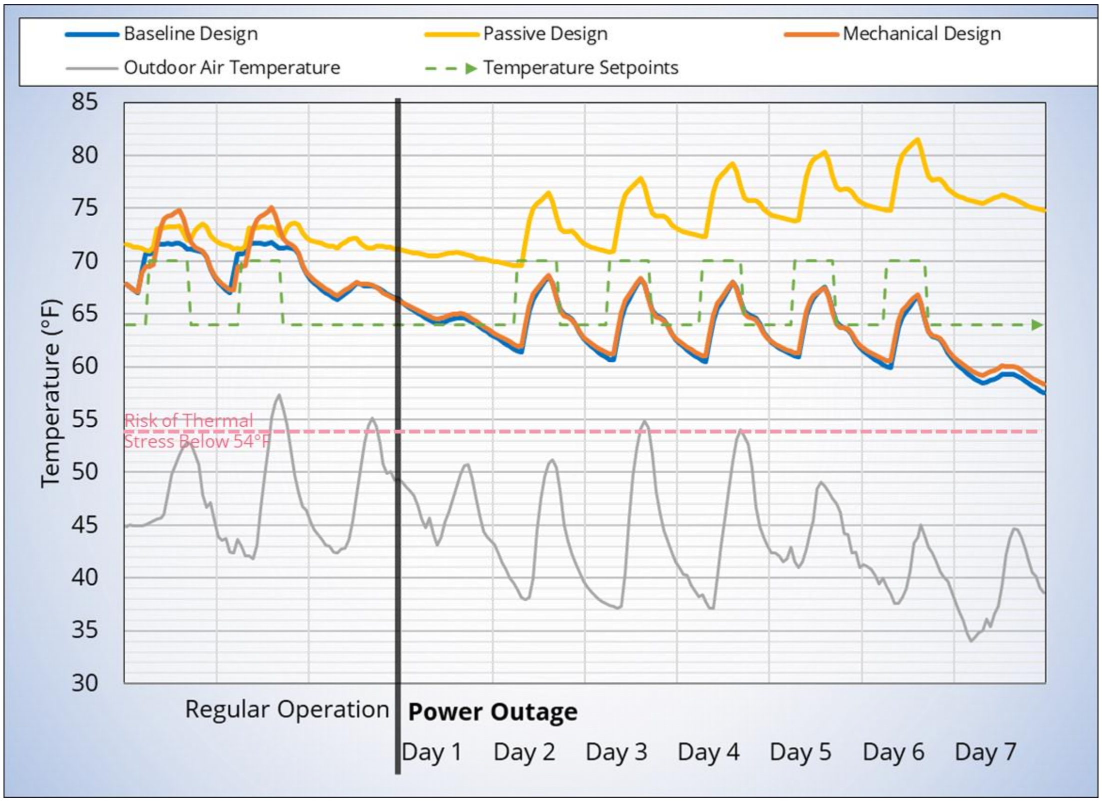
The overall result, when designing for high-performance, is a general shift from a building that is a heating-dominated building to one that will be cooling-dominated. This end-use demand shift could lead to grid supply and peak electricity demand challenges, similar to those seen currently in hotter climate zones.

5.3 Passive Design Improves Thermal Resiliency

We simulated a power outage for the hottest and coldest weeks of the year to test the thermal resiliency of each of the design cases. Without power, mechanical systems, lighting, and plug loads were turned off. Solar gains, occupant gains, and conduction via the envelope were still influencing the thermal balance. Dry bulb temperature for a representative classroom (second floor with northern orientation) has been reported.

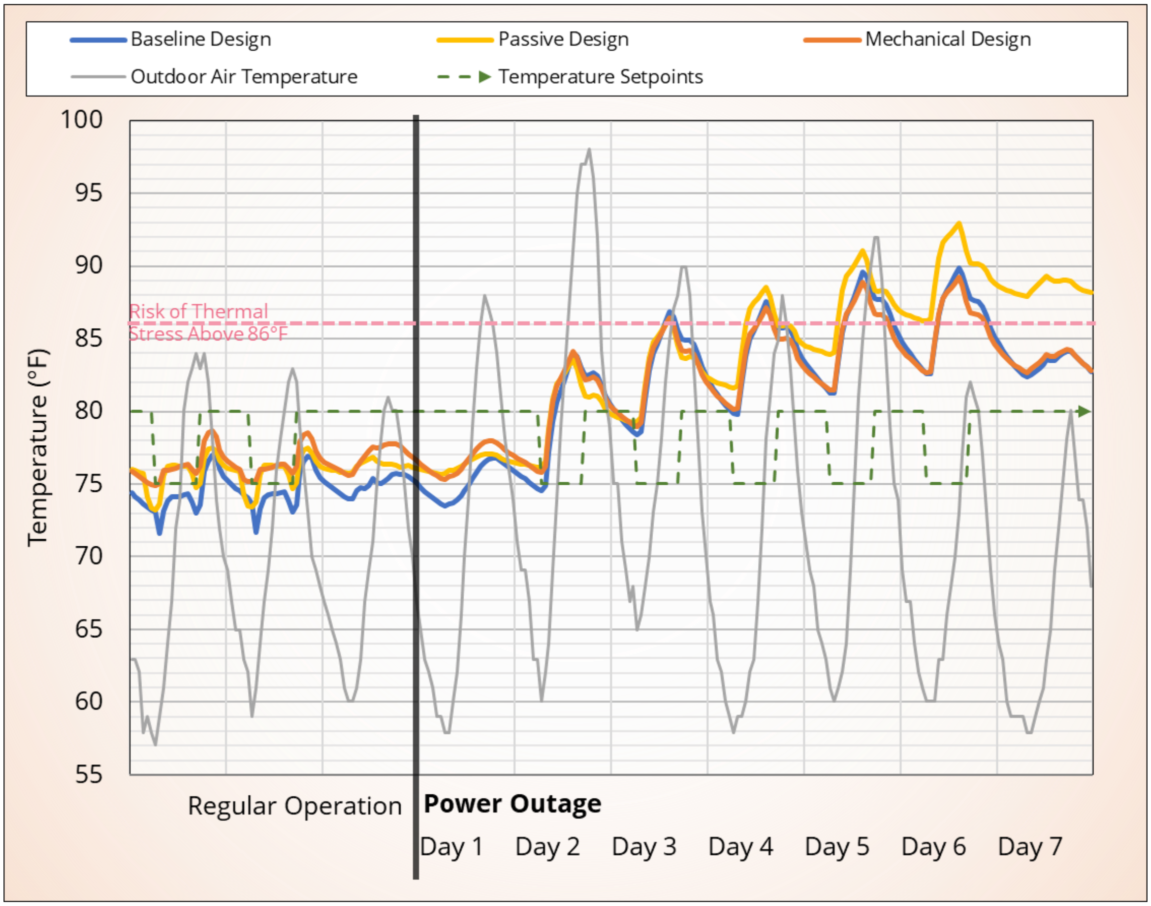
The passive design cases are more resilient to occupant thermal risk in simulated power outages during extreme temperatures. During a cold winter week (Figure 12), the envelope of the passive design case maintains comfortable indoor temperatures, whereas the mechanical design case drops below comfort and safety levels within a few days. The tight, insulated envelope and solar gain control allow the typical indoor setpoint temperatures are maintained, even on the coldest days—enough so that controlled use of operable windows to improve ventilation would be possible in the passive design without sacrificing comfort.

Figure 12: Passive Survivability Test - Portland Existing Climate – Coldest Winter Week



During the hottest summer week (Figure 13), the envelope thermal performance becomes less of an influence on comfort, and both passive and mechanical design cases will require daytime shading and night-time cooling through operable windows to avoid thermal stress for occupants. The slightly lower temperatures maintained by the baseline and mechanical cases can be attributed to the higher infiltration rates, taking advantage of some overnight/off-peak cooling. This could be replicated in the passive design with operable windows to control for this passive cooling effect.

Figure 13: Passive Survivability Test - Portland Existing Climate – Hottest Summer Week



To better understand this night-cooling potential, a naturally-ventilated case was modeled in which the passive design case was scheduled to open windows when outdoor conditions allowed (Figure 14).

Figure 14: Passive Survivability Test - Portland Existing Climate – Fixed Windows (left) vs Passively Ventilated Operable Windows (right)

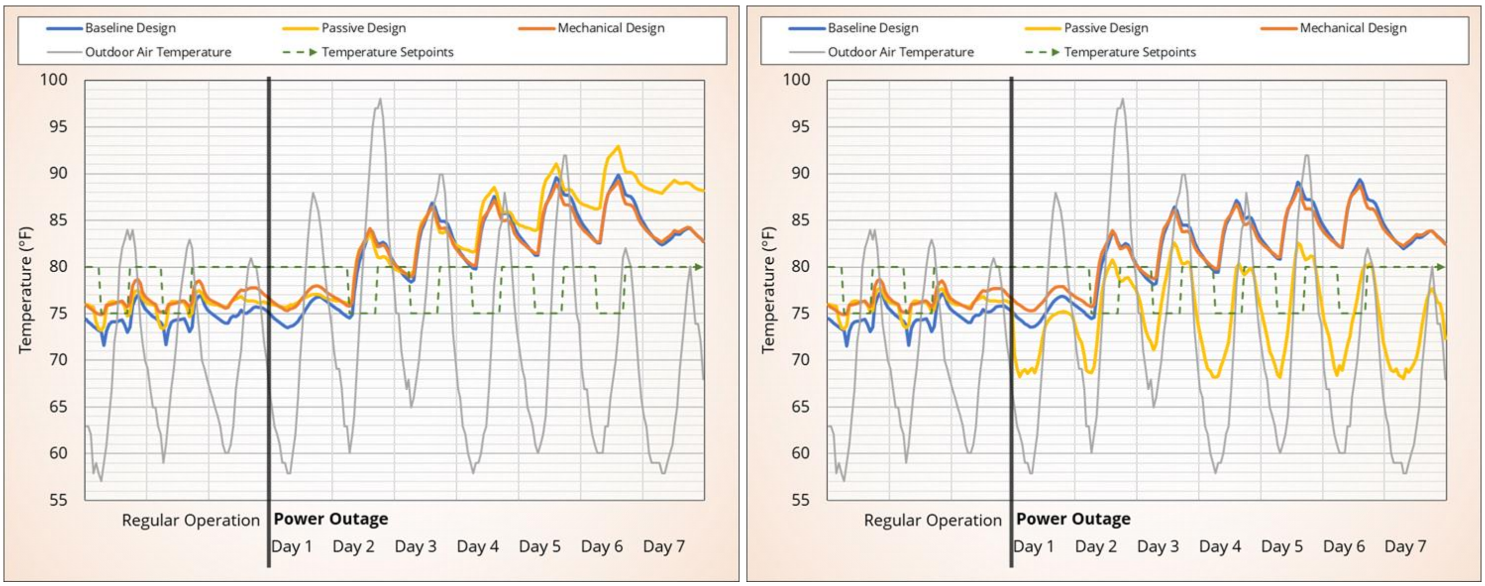
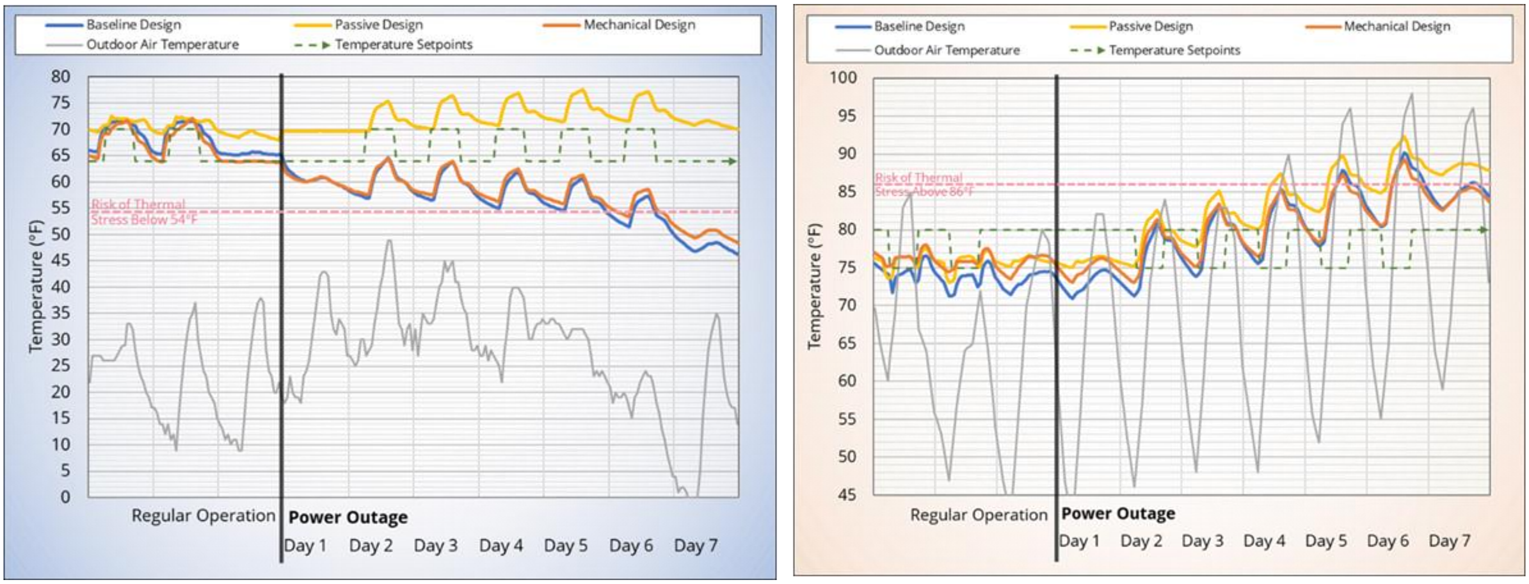


Figure 15 shows the Bend existing/historical climate condition, which demonstrates similar trends in thermal resiliency. The passive case is able to maintain comfortable temperatures during the winter case, while the poor envelope of the mechanical and base cases quickly leads to risky internal temperatures within a few days. The risk of thermal stress conditions is more evident in Bend than in the Portland case due to the colder winter temperatures experienced. The diurnal temperature swings experienced in the desert-like climate allow for some overnight passive cooling shown in the summer case. Natural ventilation would again benefit all cases for avoiding risk of overheating and thermal stress.

Figure 15: Passive Survivability Test - Bend Existing Climate – Coldest Winter (left) & Hottest Summer (right) Weeks



In the future climate scenario, as seen previously when comparing HDD/CDD and climate zones, there is a general warming trend, leading to warmer winter temperatures and hotter summer temperatures in both locations. In Portland (Figure16), the thermal risk in the winter is lower with rising temperatures, lessening the benefit of the passive case, yet still maintaining livable thermal conditions. In the summer, increased overnight temperatures during hot stretches offer little night-cooling potential, relying solely on strict control of solar gains during power outages. The impact is similar in Bend; in the summer case, we do see that the extreme outdoor high temperatures shift the benefit away from a “leaky” façade and stress the importance of passive design measures to reject solar and conduction gains and use the diurnal temperature swings (although lessened from the current case) when possible.

Figure 16: Passive Survivability Test – Portland Future Climate – Coldest Winter (left) & Hottest Summer (right) Weeks

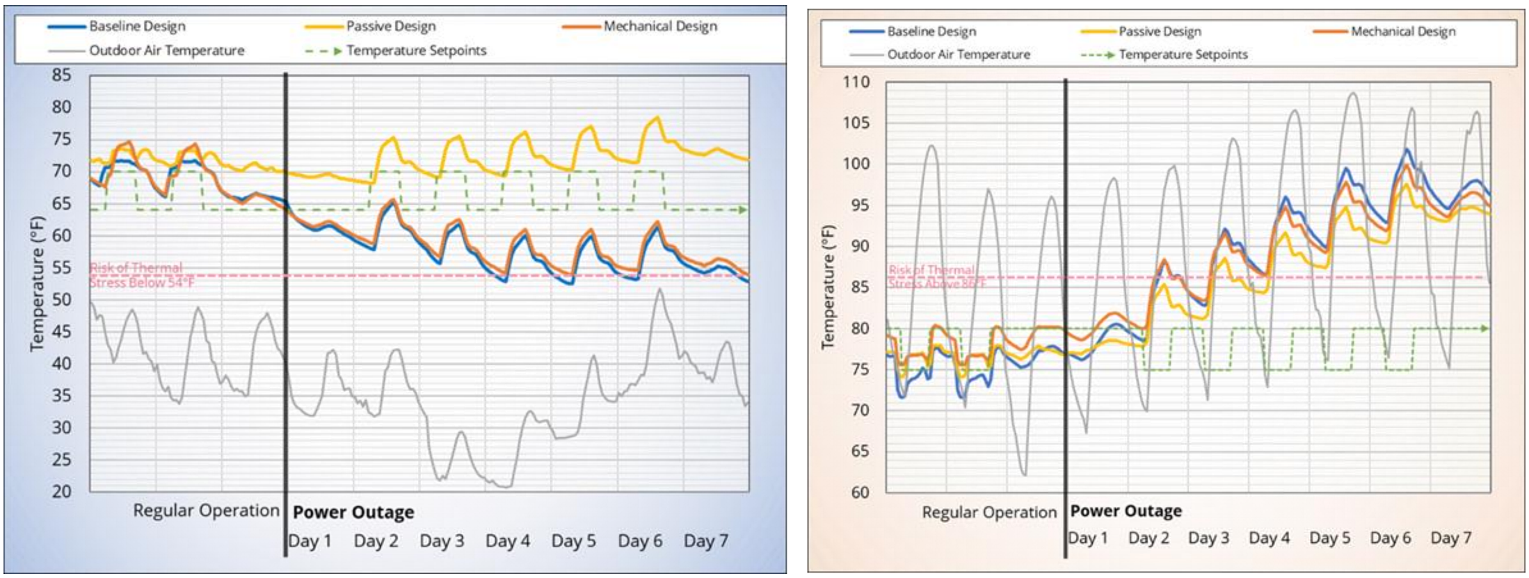
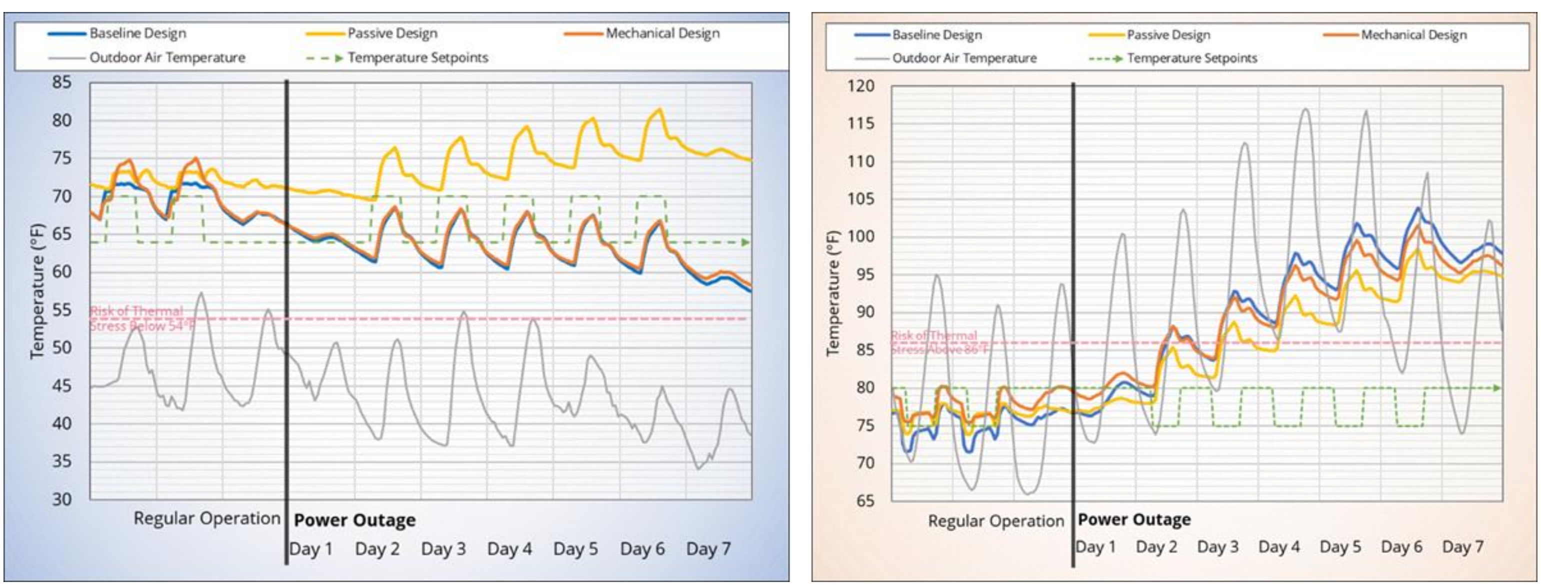


Figure 17: Passive Survivability Test – Bend Future Climate – Coldest Winter (left) & Hottest Summer (right) Weeks



5.4 Shift in Design Decisions

In addition to having to account for the comfort and energy implications of a shifting climate, local designers will no longer be able to rely on local "rules of thumb" and guidelines for making enclosure and design decisions. A shift in design will be necessary to accompany anticipated climate shifts.

The transition from a historically heating-dominated climate to a future cooling-dominated climate will require a shift in designing the building envelope. Windows that formerly were designed to allow winter solar gains for heating will be required to provide solar control to maintain thermal comfort and minimize cooling demand. Lower solar heat gain coefficients (SHGCs) will be necessary, shifting from the recommended 0.6 range to values more suitable for hot climates (i.e., below 0.3). Similarly, controlling heat gains with solar shading, thermal mass, and a tight envelope will be necessary for greater energy savings and comfort conditions during hot stretches. During shoulder seasons, passive ventilation via operable windows will be beneficial, and during warm periods, night flushing with thermal mass will reduce overall cooling demand.

6 CONCLUSIONS AND RECOMMENDATIONS

The methodology proposed for this research study proved successful in assessing building energy and thermal resiliency for past and future climates. The climate modeling shows that the design industry should prepare for a shift in the way buildings are designed in Oregon. Future climate modeling shows that within the lifespan of a building built today we should expect Portland to shift from a mixed marine climate zone 4C to a warm and dry climate zone 3A. Bend will also jump climate zones from 5B to 4B.

What does this mean for owners and design teams today?
We need to acknowledge that Oregon buildings should be designed for a cooling-dominated climate where design decisions made today can also be optimal in the future. This points to the importance of promoting and designing buildings that maximize both energy efficiency with passive strategies and onsite renewable power for resilient, low-energy use buildings.

Building envelope decisions should control solar gains and allow for passive cooling with natural ventilation, thermal mass, and solar shading. These same passive strategies, along with improved envelope insulation, will also contribute positively to the resiliency of our buildings. Passively designed buildings have been shown to provide better thermal resilience (i.e., provide comfortable conditions during periods of power outage) than their mechanical counterparts. This is even more important for buildings that will provide refuge during extreme weather events. Overall, designers should place a priority on passive design strategies for the building enclosure now, as the building envelopes that we design today will surely face the climate changes predicted within their lifespan.

7 FUTURE RESEARCH

The research agenda for the Net Zero Fellowship allowed for the creation of future climate files and a comparative analysis of energy and resiliency performance. Several avenues of future research would be beneficial to expand the understanding and implications of this line of research.

Future climate files for Portland and Bend have now been made available to the general public to use. This research also began comparing the climate changes (by HDD, CDD, and climate zone) and testing the impact on design decisions through the lens of EUI and passive resiliency. Further study on the impact of future climate on design days, HVAC system selection and sizing, and hygrothermal impacts on design would be very valuable.

Using energy and resiliency metrics to compare passive and mechanical design performance in changing climates was also informative but adding a cost analysis and payback calculations would add further value. The additional benefits of resiliency through thermal comfort, reduced downtime, increased usability could also be considered.

A number of passive design measures were highlighted as being thermally beneficial by this study (e.g., natural ventilation, thermal mass, solar control glazing properties). A significant unknown for resilient buildings is how to provide adequate ventilation, particularly during periods when power outages may coincide with periods of poor air quality, such as wildfires that have been an increasing concern in Oregon. Further research in this area would be very useful to the design and development community.

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