HOLST

14 November 2023

CARBON CROSSROADS: AN ANALYSIS OF OPERATIONAL AND EMBODIED CARBON IN MULTIFAMILY HOUSING

ENERGY TRUST OF OREGON RESEARCH FELLOWSHIP REPORT

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This research was completed by the Holst research team as a part of the Energy Trust Net Zero Fellowship. Holst is an architecture firm based in Portland and Minneapolis and devoted to creating meaningful architecture that people love.

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This research would not be possible without the gracious permission of the various building owners. Not only did they allow for the study of their buildings, but they also contributed their efforts in acquiring the energy use data for the project.

- Roundhouse
- Our Just Future
- Transition Projects
- Home Forward
- REACH CDC

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1.0 EXECUTIVE SUMMARY

RESEARCH GOALS

This study of eight multifamily projects in the Pacific Northwest assesses the embodied and operational carbon over their lifespans; in other words, the greenhouse gas emissions associated with operation of the buildings and with the materials used to construct these buildings. Of the studied projects, five projects are located in Portland, Oregon, and three in Boise, Idaho. The eight projects include site-built wood frame, wood frame modular construction, and site-built wood frame over concrete podium construction, as well as both affordable and market-rate projects. The primary goals of this research were:

1) Provide public operational and embodied carbon data for low-rise wood frame and mid-rise wood frame/concrete podium multifamily construction in Oregon.

2) Calculate the predicted life-span balance between operational, embodied, and whole life carbon for low-rise wood frame and mid-rise wood frame/ concrete podium multifamily construction in Oregon.

OPERATIONAL CARBON

Operational carbon emissions are calculated based on the electricity and natural gas usage data from the year 2022, where possible. Where the usage data was unavailable due to permissions or construction timing, operational carbon emissions were calculated based on estimated energy usage data from an energy model of the project.

For the studied projects, the operational carbon per square meter of space ranges from 26.6 kg CO_2eq/m^2/yr to 55.2 kg CO_2eq/m^2 /yr across a range of modeled and actual data. The average, as well as the median, of the operational carbon is 40.1 kg CO_2eq/m^2/yr. For the three projects with actual energy usage data, the operational carbon varied from 31.5 kg CO_2eq/m^2/yr to 46.6 kg CO_2eq/m^2/yr - these three projects all had solar panels that offset their carbon emissions.

This project also analyzes the operational carbon per housing unit, per bedroom, and per occupant. The operational carbon per housing unit varies between a low of 1207 kg CO_2eq/unit/yr for a single residence occupancy (SRO), light wood frame project, to a high of 4441 kg CO_2eq/unit/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per housing unit is 2937 kg CO_2eq/unit/yr.

The operational carbon per residential bedroom varies between a low of 1207 kg CO_2eq/bedroom/yr for a light wood frame project to a high of 4857 kg CO_2eq/occupant/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per occupant is 2161 kg CO_2eq/occupant/yr.

The operational carbon per occupant varies between a low of 865 kg CO_2eq/ occupant/yr for the light wood frame project to a high of 2686 kg CO_2eq/ occupant/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per occupant is 1512 kg CO_2eq/occupant/yr.

Although the SRO project had the highest EUI and operational carbon per square meter, it had the lowest operational carbon per unit and per bedroom. A different light wood frame (affordable housing project) had the lowest operational carbon per occupant, likely due to its multiple bedroom units. This illustrates the importance of looking beyond the per square meter metric when reducing operational carbon emissions of the built environment.

There are many factors that influence the operational carbon of these projects; for further operational carbon discussion refer to section 5.0 Operational Carbon.

EMBODIED CARBON

Embodied carbon emissions were calculated using the software program Tally, which generates a whole building life cycle assessment based on a 3D digital building model. For the studied projects, the initial[2] embodied carbon (base scope of structure, enclosure, and interior walls) varied between 42.8 to 172.2 kg CO_2eq/m^2. The life cycle embodied carbon (base scope) varied between 167.1 kg CO_2eq/m2 and 257.3 kg CO_2eq/m2, with an average of 219.4 kg CO_2eq/m^2. For the full scope (base scope + stairs/railings, ceilings, and doors), the embodied carbon increased by approximately 5% over the

1 20% trimmed mean

2 The embodied carbon from Stage A of life cycle impacts - the embodied carbon emissions that have been generated by the time the building opens for occupancy.

base scope. *Refer to section 6.0 Embodied Carbon for more information.*

The mean[1] embodied carbon per unit, per bedroom, and per occupant respectively is 19,604 kg CO_2eq/unit, 13,965 kg CO_2eq/bedroom and 10,290 kg CO_2eq/occupant. Per year of a 60-year life span, the median embodied carbon is 326 kg CO_2eq/unit/yr, 233 kg CO_2eq/bedroom/yr, and 172 kg CO_2eq/occupant/yr.

For the concrete podium buildings, the concrete materials cause over half of the embodied carbon impacts. For these buildings, over 50% of the embodied carbon impacts occurred in the Life Cycle Stage A (impacts due to manufacture and transport of products).

For the non-podium wood frame buildings, recurring embodied carbon from finishes, windows, and other material replacement contributed a large percentage to the impacts. The end-of-life Stage C impacts (those due to the future demolition or deconstruction of the building) contribute a large portion of the embodied carbon impacts, often more than 50%, due to how biogenic carbon is handled in the Life Cycle Assessment (LCA) software. Across all projects, the calculation method of including biogenic carbon results in a lower overall embodied carbon.

Embodied carbon analysis tools are still inadequate to get a complete picture of a building's embodied carbon. With the current limitations of available data, fire systems, sitework, casework, fixtures, and accessories are not currently included in this embodied carbon assessment. For the comparison of charts that compare operational and embodied carbon, MEP (Mechanical, Electrical, and Plumbing) systems are estimated with an MEP estimate % based on a limited number of MEP embodied carbon studies.

OPERATIONAL VS. EMBODIED CARBON

On the first day of a building's occupation, embodied carbon makes up the entire carbon footprint. Gradually, over the 60-year estimated life span of the building, the operational carbon surpasses the embodied carbon as it uses energy for heating, cooling, lighting and all the other functions that demand power.

In this study, in the light wood frame buildings, the operational carbon surpasses the initial embodied carbon in the first year (or second year if an MEP estimate is included).

1 20% trimmed mean

In the light wood frame over concrete podium buildings, the operational carbon surpasses the embodied carbon in the fourth, fifth, or sixth year depending on whether the embodied carbon includes an additional estimate for MEP systems. The actual year in which operational carbon surpasses embodied carbon is likely to occur later than these estimates because of the multiple construction categories that are not currently available in LCA databases and are thus outside of the scope of our assessment.

As the Operational vs. Embodied Carbon charts illustrate, the natural gas emissions continue to accumulate over the life span, while the electricity grid emissions diminish to zero by 2040, to represent the legislated decarbonization of Oregon's electrical grid. The researchers note that this is a simplification of the future scenario - in reality, the decarbonization rate will be variable rather than a smooth curve. Additionally, even if Oregon's grid has decarbonized, that does not mean that electricity use will truly be 'zero carbon emissions'.

WHOLE LIFE CARBON

At the end of the building's life, including an estimate for MEP systems, the embodied carbon is predicted to make up 25% to 45% of a building's whole life carbon, with a median of 32%. The total whole life carbon ranges from 582 kg CO_2eq/m^2 to 1542 CO_2eq/m^2 across the projects. For all-electric buildings the embodied carbon is predicted to make up a higher percentage of the whole life carbon due to the grid decarbonization.

In this study of operational vs. embodied carbon impacts, the researchers conclude that both types of impacts continue to be important areas of focus. In light wood frame buildings without concrete podiums, the operational carbon impacts quickly overtake the embodied carbon impacts. There is still further operational carbon efficiencies to be found and more embodied carbon research to be undertaken.

2.0 INTRODUCTION

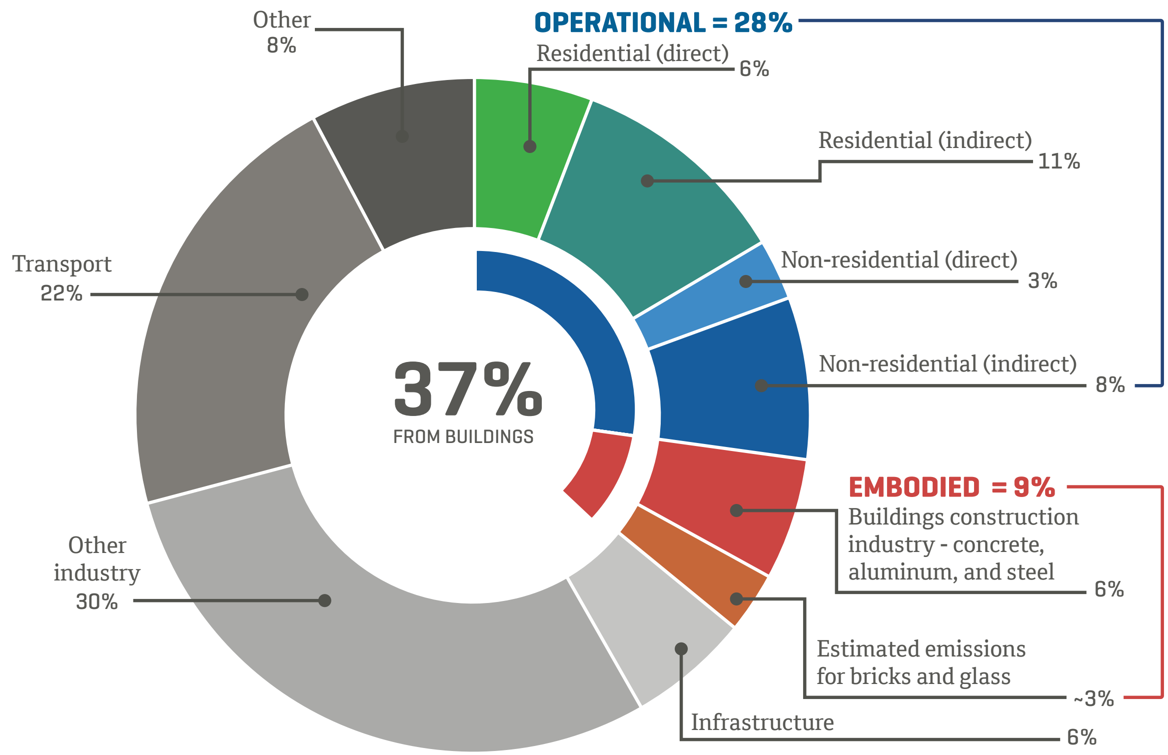
The scope of this research is to analyze the embodied and operational carbon of a range of multifamily housing projects in the Pacific Northwest. Five projects are located in Portland, Oregon, and three in Boise, Idaho. These locations represent the two ASHRAE climate zones (4C Marine and 5B Dry) of Oregon. The eight projects include site-built wood frame, wood framed modular construction, and site-built wood frame over concrete podium construction, as well as both affordable and market-rate projects.

PRIMARY RESEARCH GOALS

1) Provide public operational and embodied carbon data for low-rise wood frame and mid-rise wood frame/concrete podium multifamily construction in Oregon.

2) Calculate the predicted life-span balance between operational, embodied, and whole life carbon for low-rise wood frame and mid-rise wood frame/concrete podium multifamily construction in Oregon.

The results of these assessments will demonstrate the carbon impacts of design decisions and the correlations between embodied and operational carbon, in order to help designers optimize the carbon impacts of future housing projects. The analyzed projects share similar uses, localities, clientele, and design teams. This similarity between the projects should lead to a greater insight into driving factors of operational and embodied carbon within this project type. Ultimately, by looking at both embodied and operational carbon, this research project will help inform efforts to reduce the whole life carbon footprint of future multifamily construction.



Global Carbon Emissions[1]

BACKGROUND

The construction and operation of buildings is a significant contributor to greenhouse gas emissions. According to the International Energy Agency, buildings and construction together were responsible for approximately 37% of global energy-related CO_2 emissions (in 2021).[1] This includes both operational emissions, which result from energy consumption for heating, cooling, lighting, and other building operations, as well as emissions from the production and transportation of construction materials. The need to transition the building and construction industry to net zero carbon is as urgent as ever, yet emissions targets remain unmet.

1 United Nations Environment Programme. *2022 Global Status Report for Buildings and Construction*, 2022. https://www.unep.org/resources/publication/2022-global-status-report-buildings-and-construction, data from International Energy Agency. *Tracking Buildings 2022*. Paris: International Energy Agency. Available at: https://www.iea.org/reports/tracking-buildings-2021

2.1 BACKGROUND

OPERATIONAL CARBON

Since 2006, the 2030 Challenge (issued by Architecture 2030[1]) and the AIA 2030 Commitment have prompted architecture firms to track and meet reduction targets for the operational energy use - with the ultimate goal that all new buildings and major renovations would be net zero by 2030. In 2021, Architecture 2030 accelerated their challenge with a call to make buildings zero carbon today, although the AIA 2030 Commitment continues to target the year 2030. In the 2000s, energy and building codes have required increasing energy efficiency in a building's envelope, HVAC, and lighting systems. On the generation side of operational energy, electricity grids are decarbonizing; the Oregon electricity grid is on track to become carbon neutral by 2040, in alignment with HB 2021.[2] Operational carbon emissions have been the target of many building sustainability efforts, but now there is an increasing recognition of the importance of embodied carbon. As the grid decarbonizes, the relative share of the building industry's emissions attributable to operational carbon decreases, and the relative share of the building industry's emissions attributable to embodied carbon increases.

EMBODIED CARBON

The Architecture 2030 Challenge for Embodied Carbon, originally the 2030 Challenge for Products, set embodied carbon reduction goals for 2030:

1) Reduce embodied carbon emissions 40% below industry average today.

2) Reduce embodied carbon by 45% or better in 2025

3) Reduce embodied carbon by 65% or better in 2030

4) Zero embodied carbon by 2040.

In order to achieve these goals, embodied carbon must first be quantified. Tracking the embodied carbon of a building can be achieved as part of a whole building life cycle assessment (WBLCA), which reports the embodied carbon and environmental impacts associated with a building. Globally, many WBLCA reports have been completed, and many of these reports have been aggregated in a benchmarking report from the Carbon Leadership Forum (CLF). For one to six story multifamily buildings, the lower quartile to upper quartile range for embodied carbon was 259 kg CO_2 eq/m^2 to 741 kg CO_2 eq/m^2 for stage A of WBLCA.[3] However, due to the wide range of building scope and methodology in these multifamily WBLCAs, the CLF researchers could not establish any substantial conclusions about multifamily projects.

OPERATIONAL VS. EMBODIED CARBON

Although Architecture 2030 estimates that embodied carbon will be 72% of the life cycle of global new construction by 2030,[4] with operational carbon making up the remaining 28%, that estimate may not (yet) be true for multifamily projects, which typically have a high energy use due to density of occupants, duration of occupation, and intensity of use. A 2019 study of the Solara Apartments report found that 80% of that building's impacts could be attributed to operational impacts, even with its energy efficient design and positive assumptions about the future decarbonization of the power grid.[5] Ultimately, the ambitious goal should be for buildings that are a net zero whole life carbon - the carbon footprint sum of both embodied and operational carbon.

1 See section 1.2 Abbreviations and Definitions for more info about this organization

2 VanderHart, Dirk. "Oregon Lawmakers Approve Ambitious Carbon-Reduction Goals for State Energy Grid." *OPB. Oregon Public Broadcasting*, June 21, 2021. https://www.opb.org/article/2021/06/26/oregon-lawmakers-carbon-emissions-reduction-goals-state-energy-grid/.

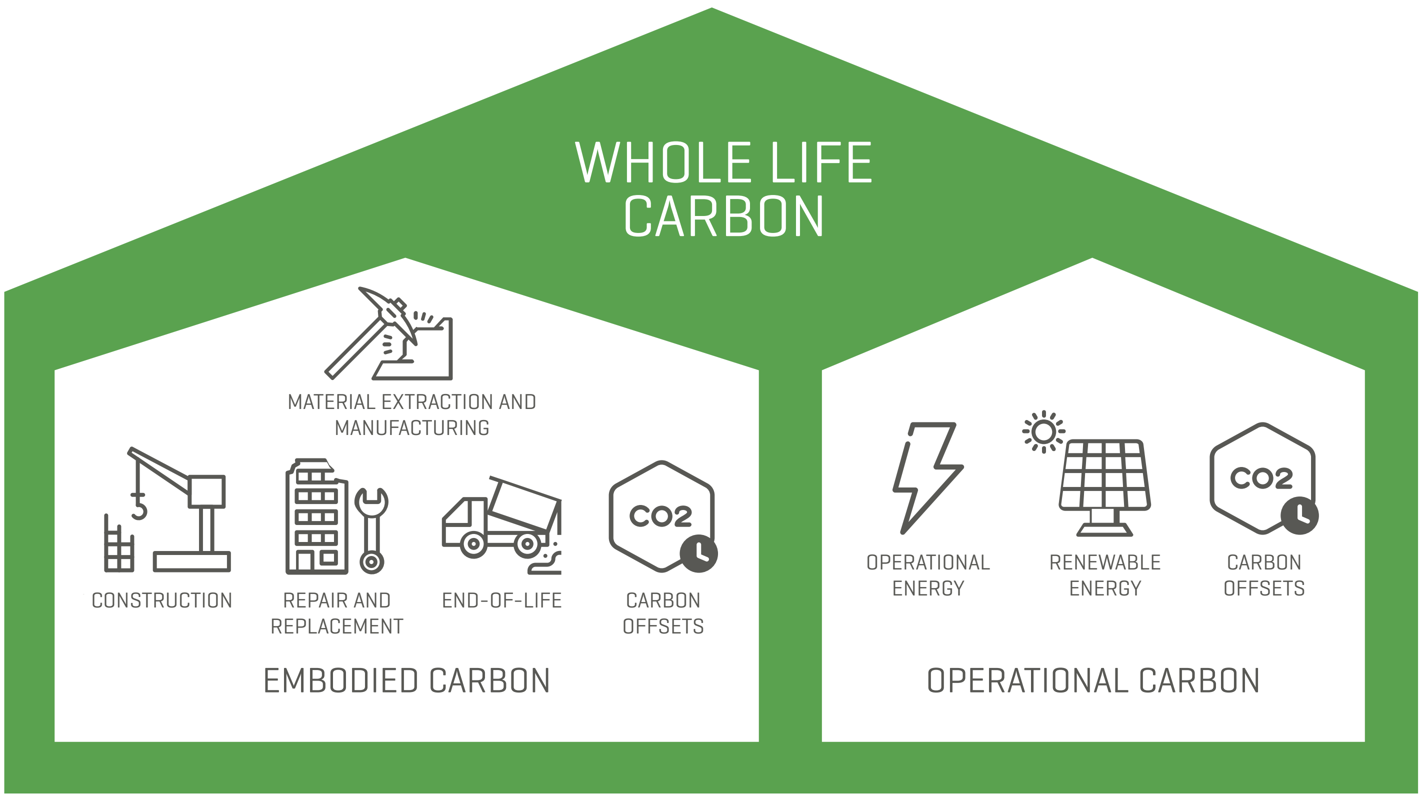
3 Simonen, K., Rodriguez, B., Barrera, S., Huang, M., McDade, E., & Strain, L. *Embodied Carbon Benchmark Study: LCA for Low Carbon Construction*. Carbon Leadership Forum, 2017. https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/38017/CLF%20Embodied%20Carbon%20Benchmark%20Study.pdf?sequence=4&isAllowed=y

4 Architecture 2030. "Carbon Smart Materials Palette – Actions for Reducing Embodied Carbon at Your Fingertips." Accessed September 02, 2023. https://materialspalette.org/.

5 Lamar, Dylan. "Solara Apartments Report 1 - Phase II Life Cycle Assessment," 2020.

WHOLE LIFE CARBON

Whole life carbon refers to the total amount of carbon emissions associated with a building or infrastructure project over its entire lifespan, including the extraction of raw materials, construction, operation, and eventual demolition or disposal. It takes into account both operational carbon emissions (direct and indirect emissions resulting from energy use during the building's operation) and embodied carbon (emissions associated with the production, transportation, and assembly of materials used in construction).



Whole life carbon includes both the operational and embodied carbon of a building.

1.2 ABBREVIATIONS AND DEFINITIONS

ARCHITECTURE 2030

Organization advocating and providing tools to support a dramatic reduction of CO_2 emissions in the built environment, targeting net zero emissions by 2030 and a complete phase-out of fossil fuel CO_2 emissions by 2040. Programs include the 2030 Challenge, the 2030 Challenge for Planning, and the 2030 Challenge for Embodied Carbon.

BIOGENIC CARBON

Carbon removed from the atmosphere due to biological activity and bound in wood or other natural materials.

CO_2e / CO_2eq

Carbon dioxide equivalent. Aggregates impacts of CO_2 emissions with other emissions that cause climate change. *See Global Warming Potential (GWP) definition.*

CONSTRUCTION TYPE

A standard building code convention for defining the fire-resistance of a building. Types range from I to V. Types I and II are constructed with non-combustible materials such as concrete and steel. Types III, IV and V are constructed with combustible materials such as wood with varying levels of protection for those combustible materials. Costs for Types I are generally the highest, Type V are the lowest. Multifamily housing generally is constructed with types III or V. Often the housing is built as a Type III or V building on a concrete podium constructed as Type I. This allows larger and taller buildings with mixed uses.

EMBODIED CARBON

Embodied carbon refers to the greenhouse gas emissions associated with the production, transportation, and disposal of a product or material (or service) throughout its life cycle. It is a measure of the carbon footprint or environmental impact of a product, and is commonly expressed in kg CO_2eq. It is commonly normalized between projects as kgCO_2eq/m^2.

EMISSIONS SCOPE

Operational carbon emissions are classified into three scopes:

- Scope 1: Direct emissions. Impacts due to emissions from directly burning fuel. In the case of this study, this typically is related to the use of natural gas on site.
- Scope 2: Indirect emissions. The carbon impacts due to the utilities' emissions from generation of power.
- Scope 3: Indirect emissions. Transmission of power from the location of generation to the location where it is used involves loss of energy in the form of waste heat.

ENVELOPE UA

A measure of the whole building envelope U-values multiplied by area. In this way the total insulative value of multiple buildings can be compared to one another.

EUI

Energy Use Intensity. The overall annual energy consumption in terms of kBtu divided by building area. Useful for comparing total energy use between buildings and commonly provided in kBtu/ft^2.

1 kBtu = 0.010002387669961 therms = 0.293014534 kWh

GWP

Global Warming Potential. The measure of how much one ton of a particular emissions gas will warm the climate relative to the warming attributed to one ton of CO_2. This study includes CO_2eq (equivalent GWP of other emissions).

One ton of CO_2 = 1
One ton of methane (CH_4) = 28
One ton of nitrous oxide (N_2O) = 373

OPERATIONAL CARBON

Operational carbon refers to the greenhouse gas emissions directly associated with the day-to-day operations of a building, facility, or organization. It includes the greenhouse gas emissions caused by heating, cooling, lighting, transportation, and other operational processes.

1.2 ABBREVIATIONS AND DEFINITIONS CONT.

HDD & CDD
Heating Degree Days & Cooling Degree Days. A comparison tool for the amount of heating or cooling needed in a given climate on an annual basis. The mean temperature for a day 10 degrees warmer or cooler than a reference temperature (usually 65 degrees F) results in 10 HDD or 10 CDD. The heating or cooling degree days for a climate is the sum of all the HDD or CDD for a year. For example, the HDD and CDD (5 year averages) for Portland and Boise indicate that Boise requires both more heating and more cooling than Portland to maintain a comfortable temperature inside a building.

Portland, OR	Boise, ID
HDD = 4282	HDD = 5566
CDD = 766	CDD = 1408

HEATING AND COOLING DESIGN SET POINTS
Refers to the target temperatures at which heating and cooling systems are designed to operate in a building. These set points are typically determined based on factors such as occupant comfort, energy efficiency, and environmental conditions. The heating set point is the desired temperature at which the heating system is activated to warm up the indoor space — typically between 68 to 72 degrees Fahrenheit. The cooling set point is the desired temperature at which the cooling system is activated to cool down the indoor space — typically between 72 to 78 degrees Fahrenheit.

NWPP
Northwest Power Pool. Recently rebranded to the Western Power Pool, NWPP is an association of power utilities serving Washington, Oregon, Idaho, and portions of Montana, Wyoming, Utah, Nevada, and California. These utilities are interconnected and sell power back and forth between them to balance loads. The transmission losses within the NWPP and carbon output due to the fuel mix of individual power sources operated by the constituent utilities (coal, hydro, natural gas, or renewables) is averaged and used to determine the carbon intensity of electricity usage in our study.

SRO
Single room occupancy. A housing type where a resident has a private sleeping space, but kitchen and bathroom facilities are shared with other residents.

WBLCA
Whole building life cycle assessment (LCA) is a comprehensive methodology that assesses the environmental impacts associated with all stages of a building's life cycle, from raw material extraction and manufacturing to construction, repair, maintenance, and eventual demolition or deconstruction. It considers the resource consumption, energy use, emissions, and waste generation associated with each stage, with the goal of identifying and quantifying the environmental burdens and potential improvements for a building lifespan. Embodied carbon is one measure that is typically reported in a WBLCA as GWP. The life cycle of a building is further broken down into several stages:

- LIFE CYCLE STAGE A: Impact due to raw material extraction, processing, manufacture and transport of finished products.
- LIFE CYCLE STAGE B: Impacts during the useful life of the building due to maintenance and replacement of constituent parts.
- LIFE CYCLE STAGE C: End of life impacts due to removal of the building.
- LIFE CYCLE MODULE D: Impacts, generally beneficial, due to avoided emissions from recycling or reusing products at their end-of-life.

A WBLCA may include impacts from operational energy use, but more commonly does not.

WEATHER NORMALIZED USAGE
Total energy use per square foot of a building divided by the total Heating (HDD) and Cooling Degree Days (CDD). This ratio is meant to reveal differences in building energy use due to climate.

WHOLE LIFE CARBON
Whole life carbon refers to the total amount of carbon emissions associated with a building or infrastructure project over its entire lifespan, including the extraction of raw materials, construction, operation, and eventual demolition or disposal. It takes into account both operational carbon emissions (direct and indirect emissions resulting from energy use during the building's operation) and embodied carbon (emissions associated with the production, transportation, and assembly of materials used in construction).

3.0 CONTEXT: CLIMATE & LOCATION

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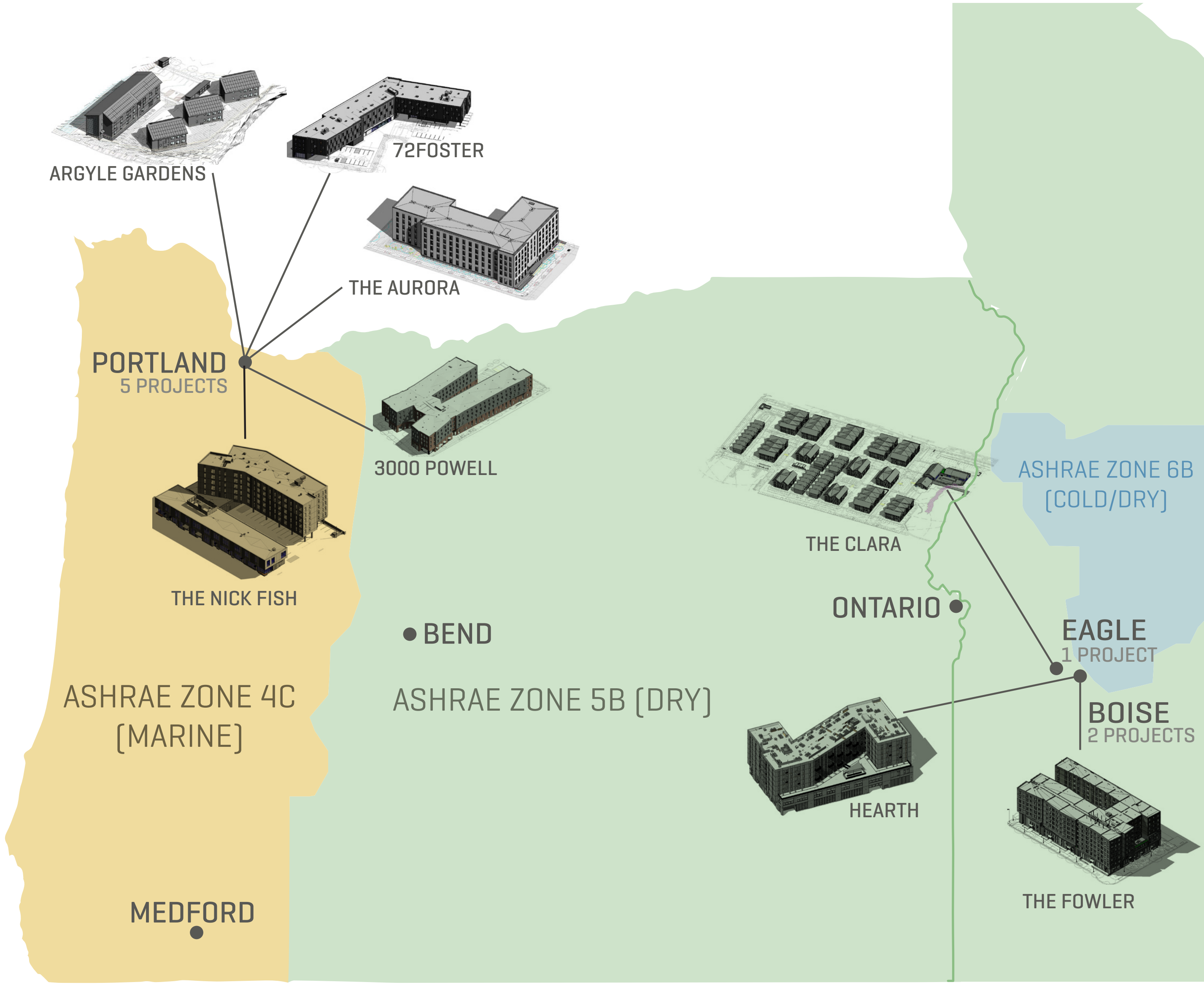
Climate influences a building's design and carbon impact. Oregon has two climate zones as classified by ASHRAE: Zone 4C (Marine) and Zone 5B (Dry). The eight studied projects represent the two main climate zones of Oregon: five projects from the Zone 4C and three projects from the Zone 5B. Although three of the projects are in or near Boise, the climate of Boise is almost identical to Ontario, Oregon and other Eastern Oregon cities.

CLIMATE & ENERGY USE

The average temperature and humidity of a climate is one variable that influences how much heating and cooling is needed. The more heating and cooling a building uses, the higher the energy use intensity (and greenhouse gas emissions).

CLIMATE & MATERIAL USE

Oregon's building code mandates a specific minimum amount of insulation based on climate. Buildings in Zone 5B require more insulation than those in 4C, and this insulation has an up-front embodied carbon cost.



3.0 CONTEXT: CLIMATE & LOCATION

ASHRAE ZONE 4C (MARINE)

PORTLAND, OR

Portland has a temperate oceanic climate with cool, wet winters and warm, dry summers. Moderate winter temperatures allows for less insulation and heating use, and moderate summer temperatures reduce cooling needs compared with the other Oregon locations.

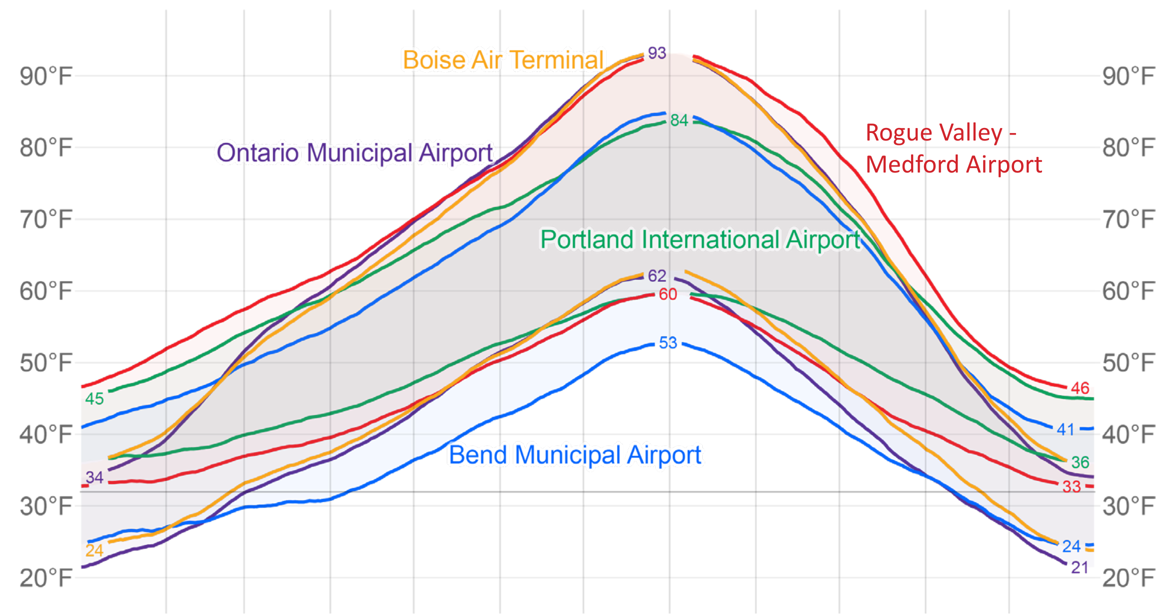
BEND, OR

Bend has a high desert climate characterized by sunny, dry summers and cold winters. Wide temperature fluctuations between day and night necessitate insulation, efficient heating, and cooling systems to maintain indoor comfort throughout the year. Climates with a significant daily temperature fluctuations can use thermal mass to temper fluctuations.

MEDFORD, OR

Medford experiences a Mediterranean climate with hot, dry summers and mild, wet winters. Medford's climate is in the same zone as Portland, but gets hotter in the summer and colder in the winter.

AVERAGE HIGH AND LOW TEMPERATURE



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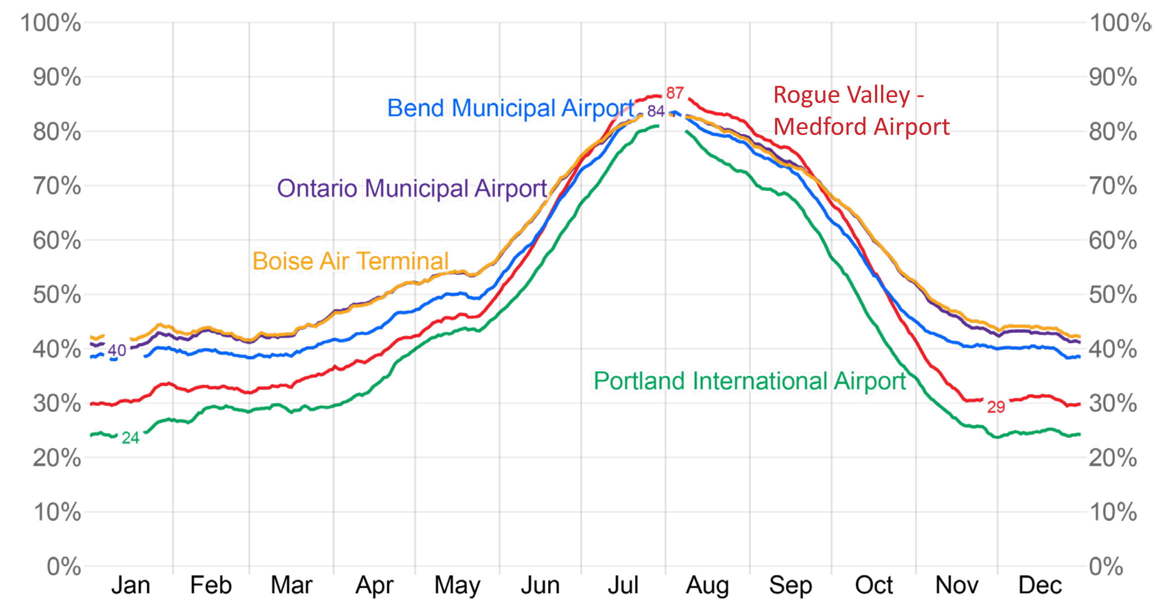
% CHANCE OF CLEAR SKIES



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3.0 CONTEXT: CLIMATE & LOCATION

ASHRAE ZONE 5B (DRY)

ONTARIO, OR

Ontario has a semi-arid climate characterized by hot, dry summers and cold winters. Similar to Bend, there is a high seasonal temperature variation. Compared to the other Oregon locations, there is a greater chance of clearer skies, so solar panels will perform well here.

BOISE, ID

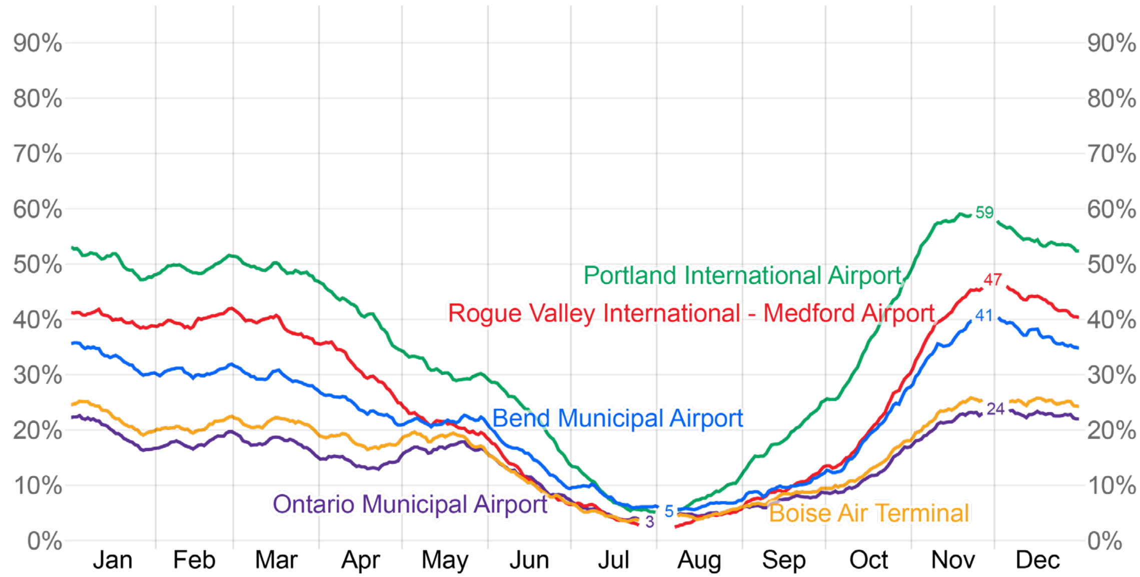
As illustrated by the diagrams, Boise's climate is almost identical to Ontario.

Based on the climate information, an identical code-minimum project would be expected to have the greatest energy use in Ontario/Boise, and the lowest energy use in Portland.

CLIMATE CONSIDERATIONS

Different climates have different opportunities for renewable or passive systems that can reduce operational energy use. Locations with more sunny skies, such as Bend or Ontario, would see a greater benefit from solar panel installations. Locations with higher average wind speeds are better candidates for wind turbines. In the summer, much of Oregon experiences high daily temperature swings which can support passive night cooling.

AVERAGE MONTHLY RAINFALL



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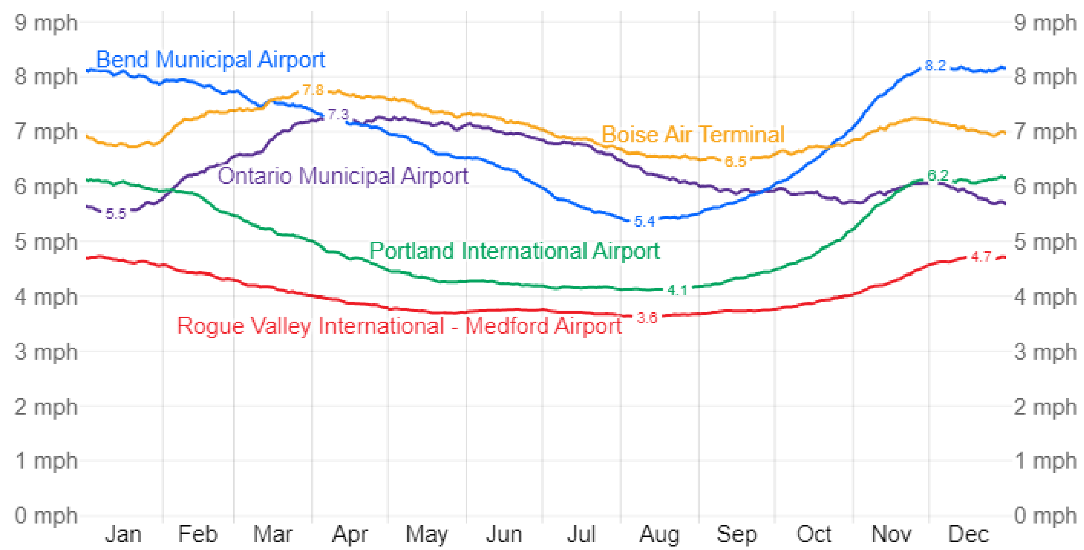
AVERAGE WIND SPEED



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4.0 PROJECT (BUILDING) INFO

72 FOSTER

PORTLAND, OR
COMPLETED: 2019

PROJECT DESCRIPTION
72 Foster contains 101 units of affordable housing tailored to intergenerational families in SE Portland. The intergenerational focus informs the building's close proximity to transit, the mix of dwelling unit types, and the project's sustainability and affordability goals.

CLIMATE
4C Mixed Marine

65° F HEATING DEGREE DAYS
4282 (5 yr avg)
4455 (2022)

65° F COOLING DEGREE DAYS
766 (5 yr avg)
899 (2022)

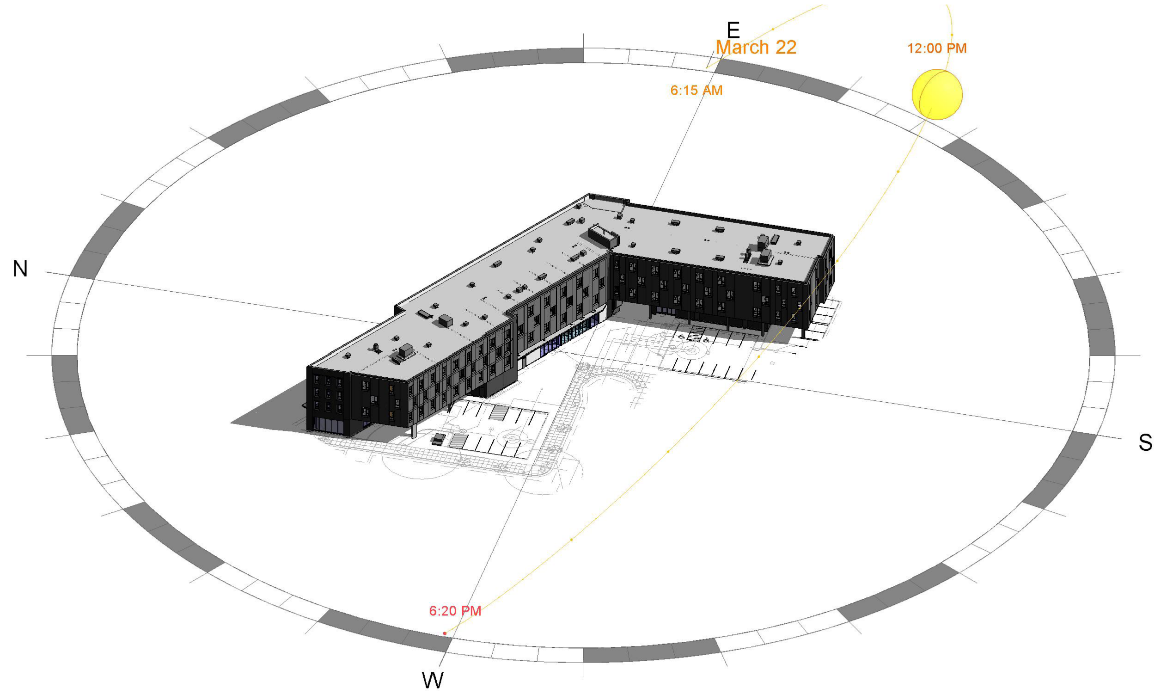
ENERGY CODE
2014 Oregon Energy Efficiency Specialty Code

SITE EUI BASELINE
48 kBtu/sf/yr

SITE EUI - ACTUAL
43.8 kBtu/sf/yr

SITE EUI - ENERGY MODEL
49.4 kBtu/sf/yr

SOLAR - PV ARRAY SIZE
106.5 kW



72Foster

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72 FOSTER

PORTLAND, OR

CONSTRUCTION TYPE
3 floors Type VB over 1 floor
Type 1A construction

BUILDING HEIGHT
48', 4 Floors

FLOOR AREA - CONDITIONED
Residential - 67,805 sf [89%]
Retail - 8,445 sf [11%]
Total - 76,250 sf
**No unconditioned floor area*

UNITS
Studio: 66 units
1-bed: 14 units
2-bed: 12 units
3-bed: 9 units
Total: 101 units

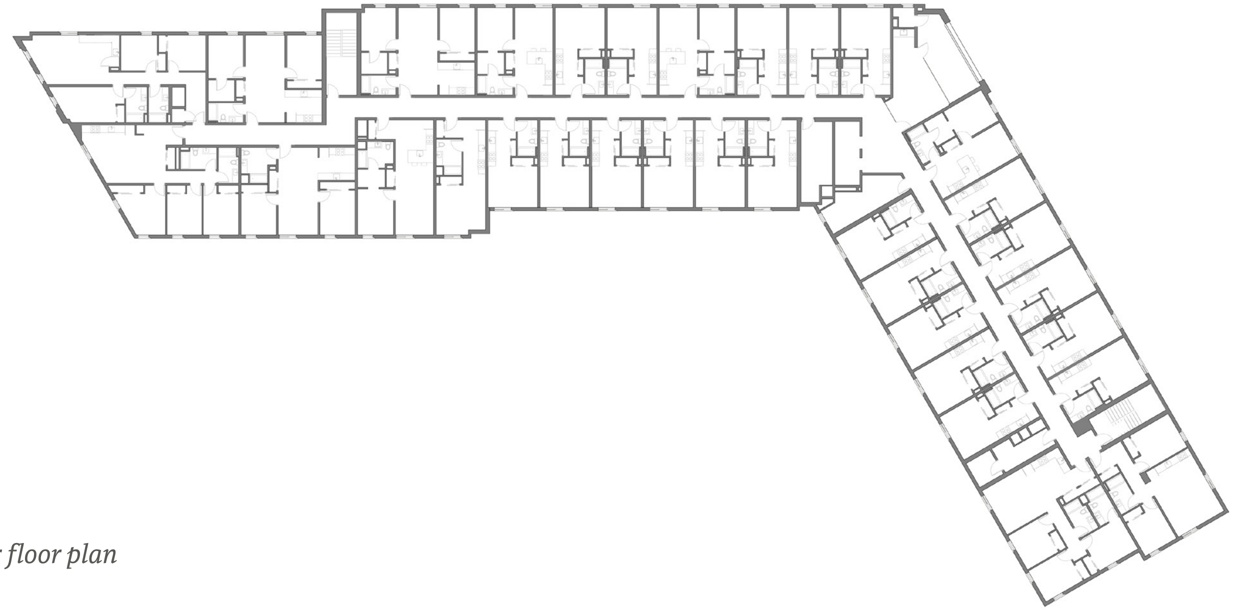
AVERAGE WINDOW/WALL RATIO
22%

WATER HEAT TYPE
Gas

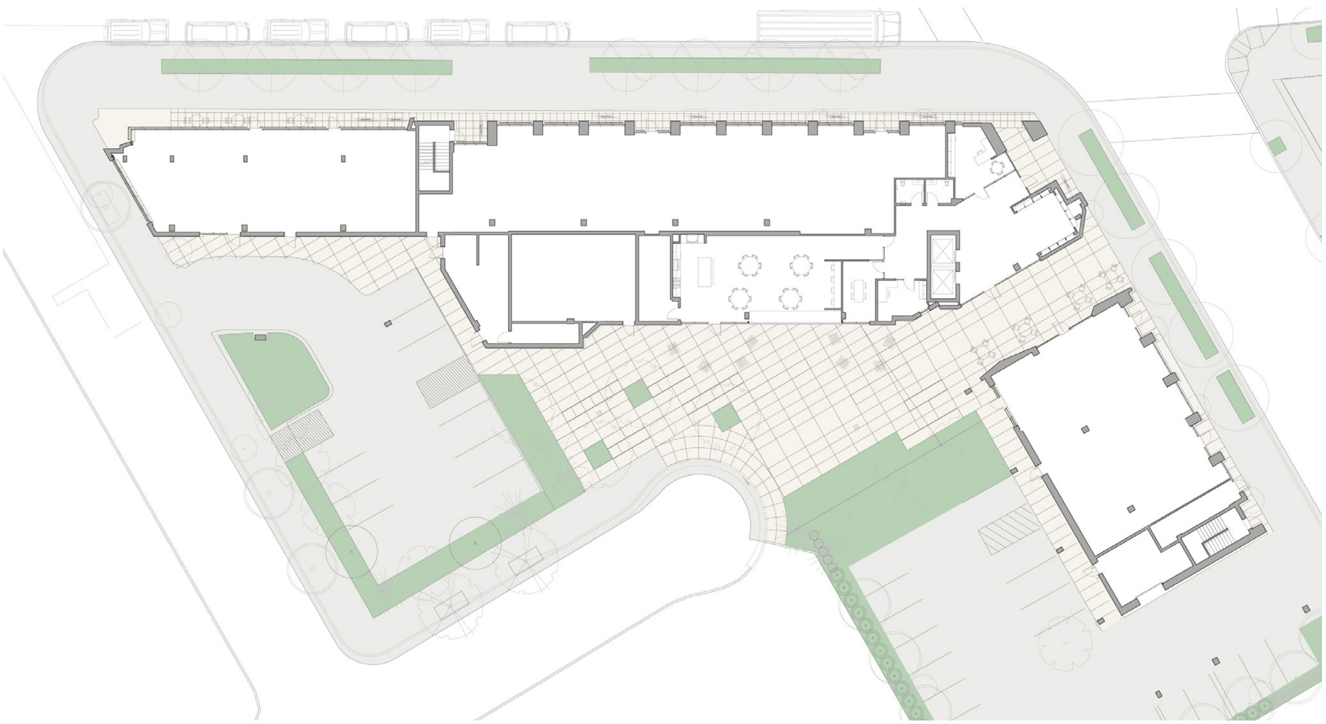
VENTILATION TYPE
100% outside air gas RTU

HEATING
Electric Heat Pumps (ground floor)
Units - Electric Heater

COOLING
Electric Heat Pumps (ground floor)
Units - Ceiling Fan



Upper floor plan



Ground floor plan

N.T.S. **NORTH**

THE NICK FISH

PORTLAND, OR
COMPLETED: 2021

PROJECT DESCRIPTION

The Nick Fish aims to capitalize on the potential of Portland's Gateway Urban Renewal Area with a new standard for quality affordable housing. Its mixed-use program combines studio, one, and two bedroom, and apartments with office space for Our Just Future, ground floor retail, tenant amenities, and parking to create a vibrant community adjacent to the new Gateway Discovery Park. To support equity in the community, the 52 affordable and 23 market rate units are interspersed and designed to the same level of finish.

CLIMATE

4C Mixed Marine

65° F HEATING DEGREE DAYS

4282 (5 yr avg)
4455 (2022)

65° F COOLING DEGREE DAYS

766 (5 yr avg)
899 (2022)

ENERGY CODE

2014 Oregon Energy Efficiency Specialty Code

SITE EUI BASELINE

47 kBtu/sf/yr

SITE EUI TARGET (20% REDUCTION)

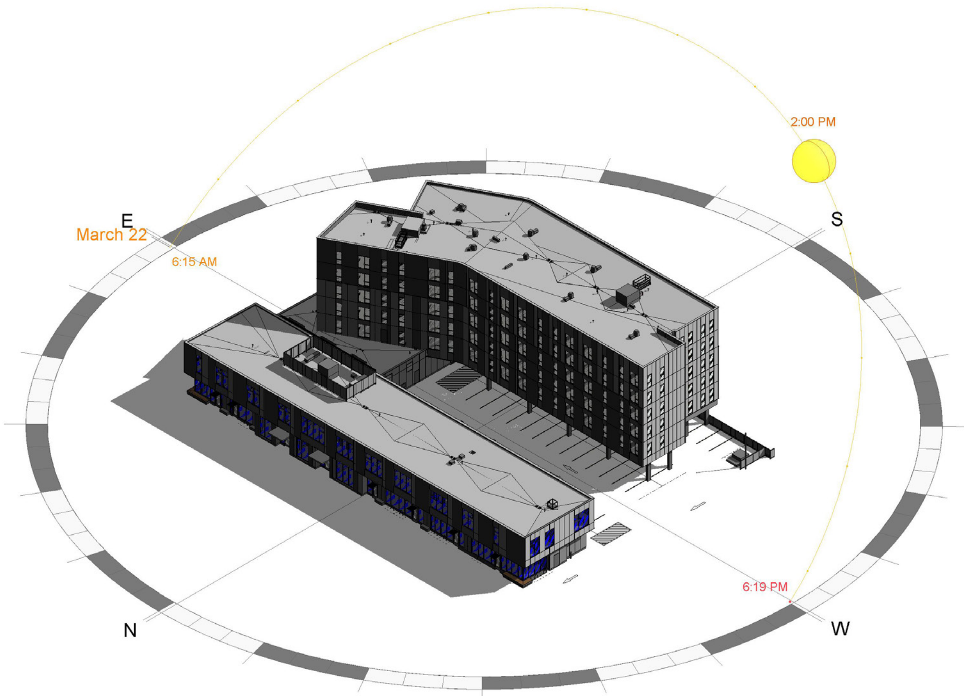
38 kBtu/sf/yr

SITE EUI - ACTUAL

50.5 kBtu/sf/yr

SITE EUI - ENERGY MODEL

61.0 kBtu/sf/yr



The Nick Fish © *Christian Columbres*

THE NICK FISH

PORTLAND, OR

CONSTRUCTION TYPE
5 floors Type VA over
1 floor Type 1A construction

BUILDING HEIGHT
70', 7 Floors

FLOOR AREA
Residential (conditioned) - 60,530 sf
Office (conditioned) - 10,942 sf
Retail (conditioned) - 9,948 sf
Covered parking (unconditioned) - 6,657 sf
Total: 88,077 sf

UNITS
Studio: 20 units
1-bed: 44 units
2-bed: 11 units
Total: 75 units

AVERAGE WINDOW/WALL RATIO
31%

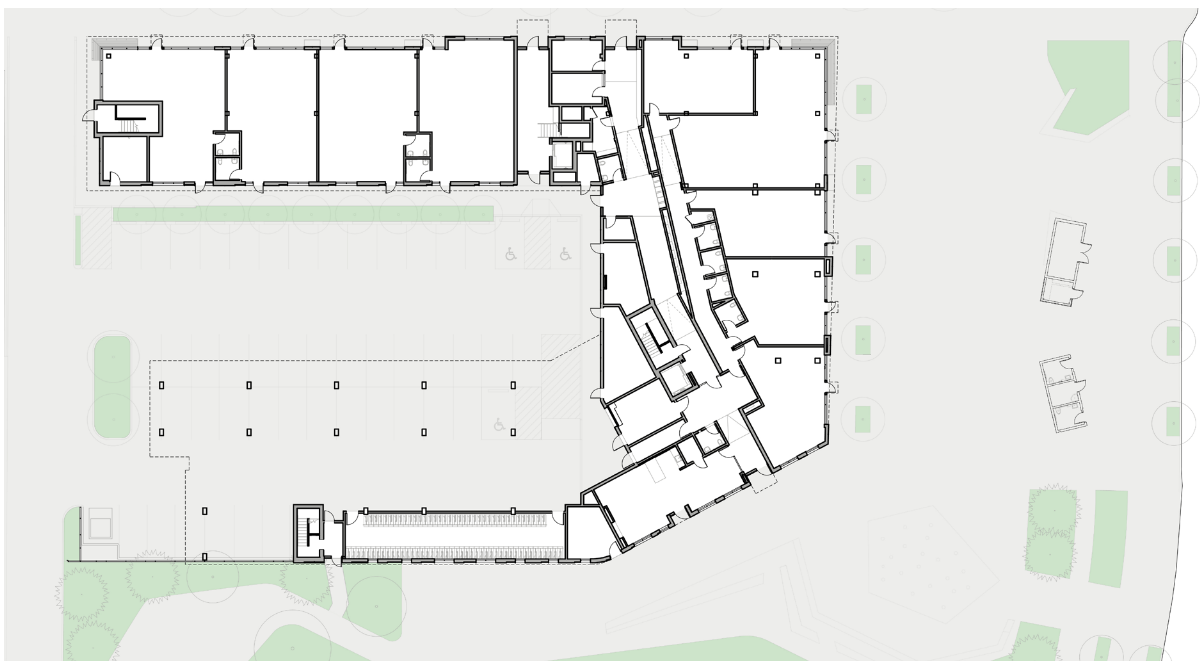
WATER HEAT TYPE
Gas

VENTILATION TYPE
@ Leasing office - heat pump DOAS (dedicated outdoor air supply)
@ Units - gas DOAS

HEATING
Electric VRF & electric resistance

COOLING
Units - Ceiling fan

Upper floor plan

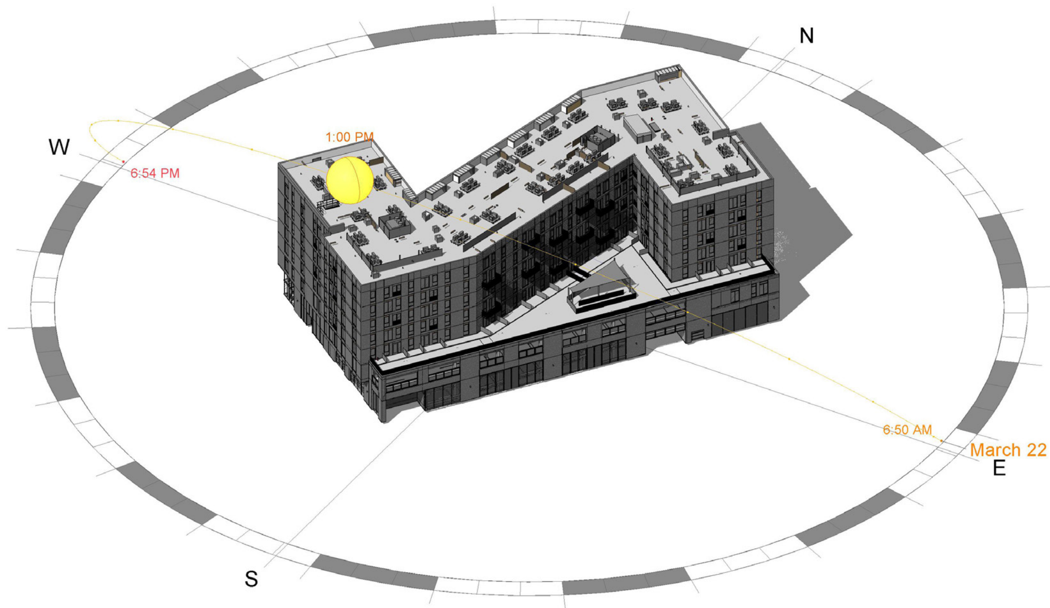


Ground floor plan

N.T.S. **NORTH**

HEARTH

BOISE, ID
COMPLETED: 2021



PROJECT DESCRIPTION

Hearth is an eight-story, mixed-use building in Boise's growing Central Addition. Located just one block from the Fowler apartments, Hearth brings further density and urban amenities to the growing neighborhood. In conjunction with the City of Boise's vision for a lively, mixed-use district, Hearth is a mix of market-rate residential and retail spaces.

CLIMATE

5B Cool Dry

65° F HEATING DEGREE DAYS

5566 (5 yr avg)
6124 (2022)

65° F COOLING DEGREE DAYS

1408 (5 yr avg)
1579 (2022)

ENERGY CODE

2015 International Energy Conservation Code

SITE EUI BASELINE

53 kBtu/sf/yr

SITE EUI - ENERGY MODEL

49.4 kBtu/sf/yr

Hearth *© Gabe Border*

HEARTH

BOISE, ID

CONSTRUCTION TYPE
5 floors Type VA over
3 floors Type 1A construction

BUILDING HEIGHT
91', 8 Floors

FLOOR AREA
Residential (conditioned) - 142,009sf
Retail (conditioned) - 5,223 sf
Residential (unconditioned) - 2,933 sf
Covered parking (unconditioned) - 63,963 sf
Total: 214,128 sf

UNITS
Studio: 66 units
Live/Work: 7 units
1-bed: 62 units
2-bed: 55 units
Total: 163 units

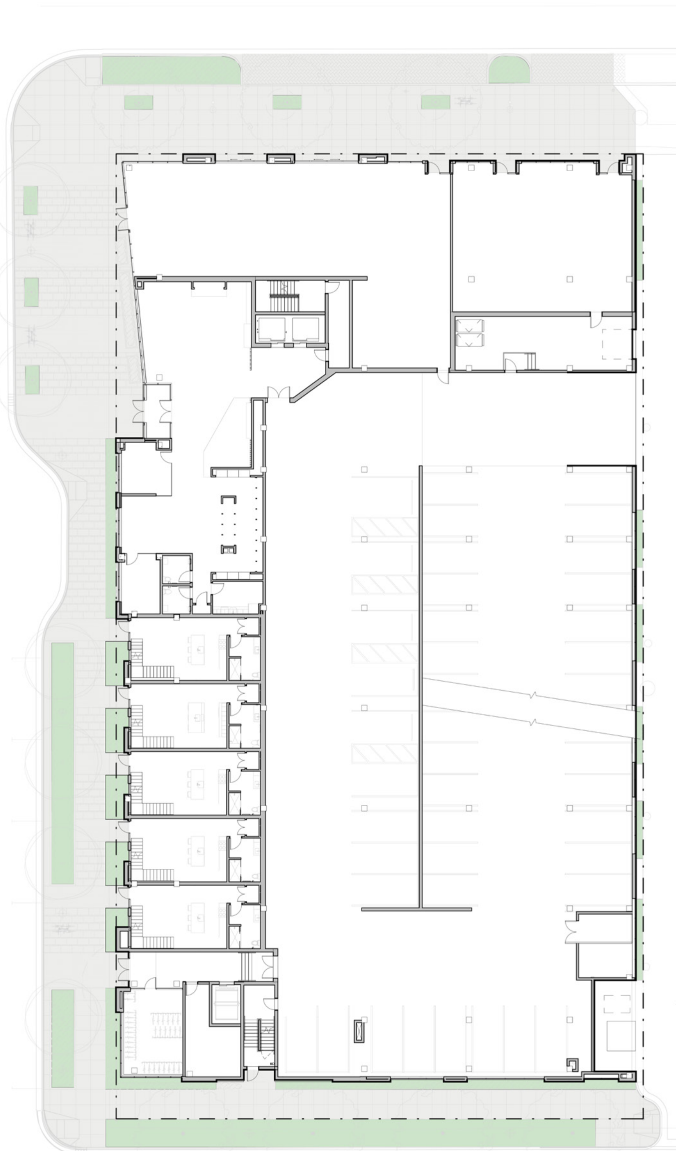
AVERAGE WINDOW/WALL RATIO
30%

WATER HEAT TYPE
Gas

VENTILATION TYPE
ERV/DOAS (dedicated outdoor air supply)

HEATING
Minisplit heat pump & electric heaters

COOLING
Minisplit heat pump & ceiling fan



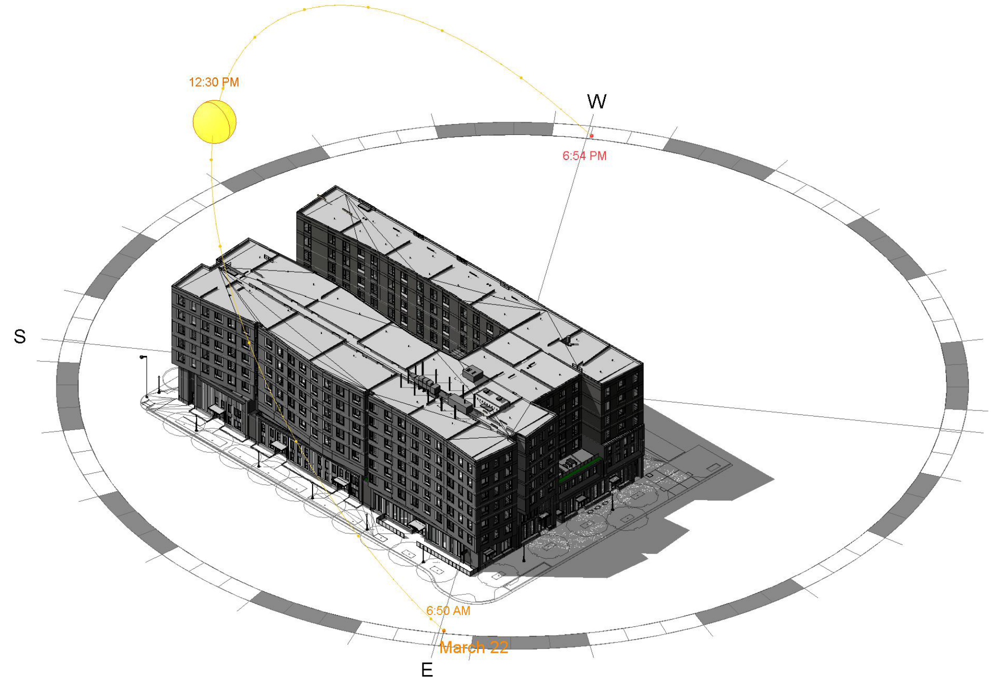
Ground floor plan

Upper floor plan

N.T.S. **NORTH**

THE FOWLER

BOISE, ID
COMPLETED: 2018



PROJECT DESCRIPTION

One of downtown Boise, Idaho's first new multifamily housing projects in decades, the Fowler is a mix of retail, market-rate residential, and live|work spaces, intended to revitalize the area and provide housing units for professionals currently commuting from surrounding suburbs.

CLIMATE

5B Cool Dry

65° F HEATING DEGREE DAYS

5566 (5 yr avg)
6124 (2022)

65° F COOLING DEGREE DAYS

1408 (5 yr avg)
1579 (2022)

ENERGY CODE

2015 International Energy Conservation Code

SITE EUI BASELINE

53 kBtu/sf/yr

SITE EUI - ENERGY MODEL

60.1 kBtu/sf/yr

The Fowler *© Gabe Border*

THE FOWLER

BOISE, ID

CONSTRUCTION TYPE
5 floors Type VA over
2 floors Type 1A construction

BUILDING HEIGHT
83'-6", 7 floors

FLOOR AREA
Residential (conditioned) - 143,096 sf
Retail (conditioned) - 3,993 sf
Residentail (unconditioned) - 508 sf
Covered parking (unconditioned) - 58,166 sf
Total: 205,763 sf

UNITS
Studio: 48 units
Live/Work: 5 units
1-bed: 65 units
2-bed: 45 units
Total: 163 units

AVERAGE WINDOW/WALL RATIO
23%

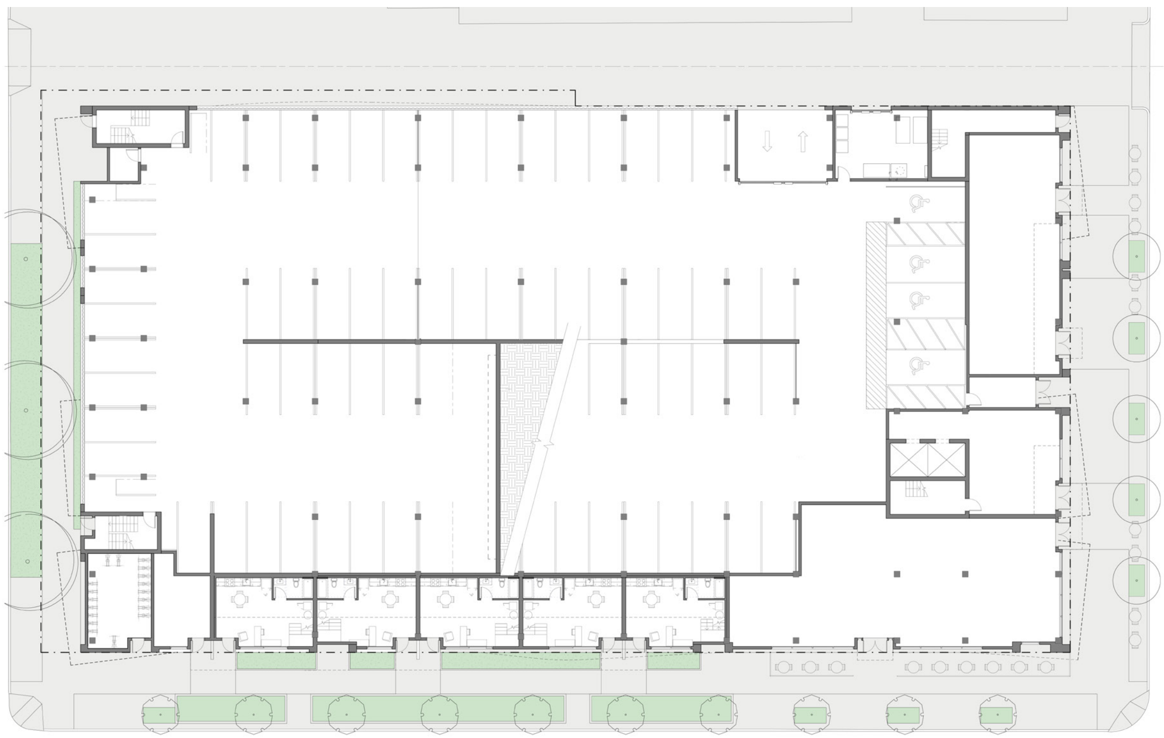
WATER HEAT TYPE
Gas

VENTILATION TYPE
ERV & makeup air

HEATING
Packaged terminal heat pump & electric baseboard

COOLING
Packaged terminal heat pump

Upper floor plan



Ground floor plan

N.T.S. **NORTH**

ARGYLE GARDENS

PORTLAND, OR
COMPLETED: 2020

PROJECT DESCRIPTION
Argyle Gardens is the first buildout of LISAH (Low Income Single Adult Housing), a dignified co-living, permanent supportive housing model designed to accommodate an optimum number of people to share community space and support. The modular system can be configured as formerly homeless, workforce, or student housing, or to house intergenerational families together. Each of three cohousing buildings feature two six-bedroom units with two shared bathrooms and a large kitchen.

CLIMATE
4C Mixed Marine

65° F HEATING DEGREE DAYS
4282 (5 yr avg)
4455 (2022)

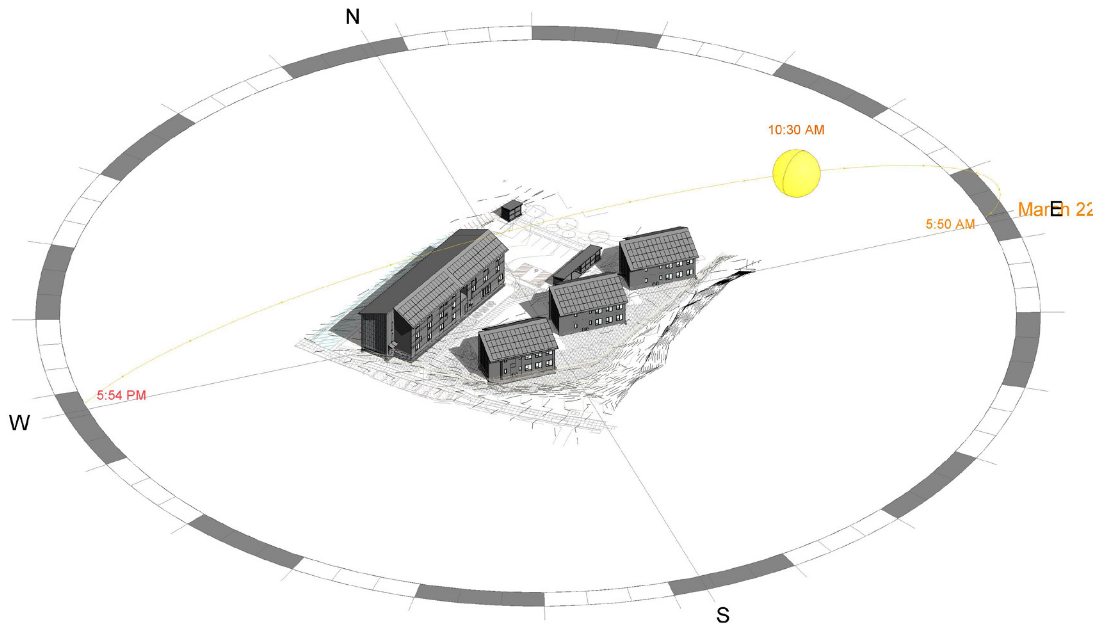
65° F COOLING DEGREE DAYS
766 (5 yr avg)
899 (2022)

ENERGY CODE
2014 Oregon Energy Efficiency Specialty Code

SITE EUI BASELINE
77 kBtu/sf/yr

SITE EUI - ACTUAL
57.3 kBtu/sf/yr

SOLAR - PV ARRAY SIZE
61.28 kW



Argyle Gardens *© Portland Drone*

ARGYLE GARDENS

PORTLAND, OR

CONSTRUCTION TYPE
2 or 3 floors Type VB

BUILDING HEIGHT
35'-2", 3 floor building
25'-3", 2 floor buildings

FLOOR AREA
Residential (conditioned) - 20,066 sf
Residential (unconditioned) - 2,228 sf
Total: 22,294 sf

UNITS
Single Room Occupancy: 36 units
Studio: 35 units
1-bed: 1 unit
Total: 72 units

AVERAGE WINDOW/WALL RATIO
15%

WATER HEAT TYPE
Gas

VENTILATION TYPE
Window trickle vent

HEATING
Minisplit heat pump & electric heater

COOLING
Minisplit heat pump (corridors and community areas) & ceiling fan (units)

Ground floor plan

N.T.S. **NORTH**

3000 POWELL

PORTLAND, OR
COMPLETION: 2024

PROJECT DESCRIPTION
3000 Powell is a 206-unit affordable housing project for families in the Creston-Kenilworth neighborhood of SE Portland. 3000 Powell will offer a wide range of unit sizes and types paired with a robust ground floor program of community rooms, courtyards, playgrounds, services, and spaces for families in need. The transit-oriented development is close to the central city and adjacent to schools, stores, and bus lines.

CLIMATE
4C Mixed Marine

65° F HEATING DEGREE DAYS
4282 (5 yr avg)
4455 (2022)

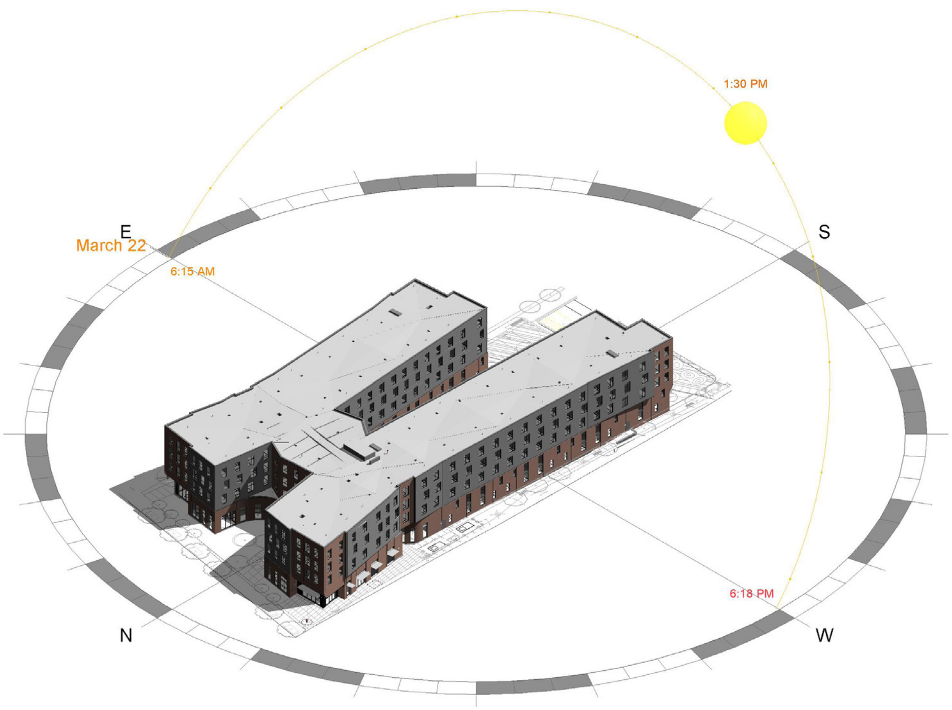
65° F COOLING DEGREE DAYS
766 (5 yr avg)
899 (2022)

ENERGY CODE
2019 Oregon Zero Energy Ready Commercial Code
OZRECC ASHRAE 90.1-2016

SITE EUI BASELINE
48 kBTU/sf/yr

SITE EUI - ENERGY MODEL*
27.7 kBTU/sf/yr

**This was a third-party energy model originally created for Earth Advantage Certification.*



3000 Powell © Holst

3000 POWELL

PORTLAND, OR

CONSTRUCTION TYPE
6 floors Type VA

BUILDING HEIGHT
52'-8", 6 floor building

FLOOR AREA - CONDITIONED
Residential - 130,573 sf
Total: 130,573 sf

UNITS
Studio: 123 units
1-bed: 8 units
2-bed: 59 units
3-bed: 6 units
Total: 196 units

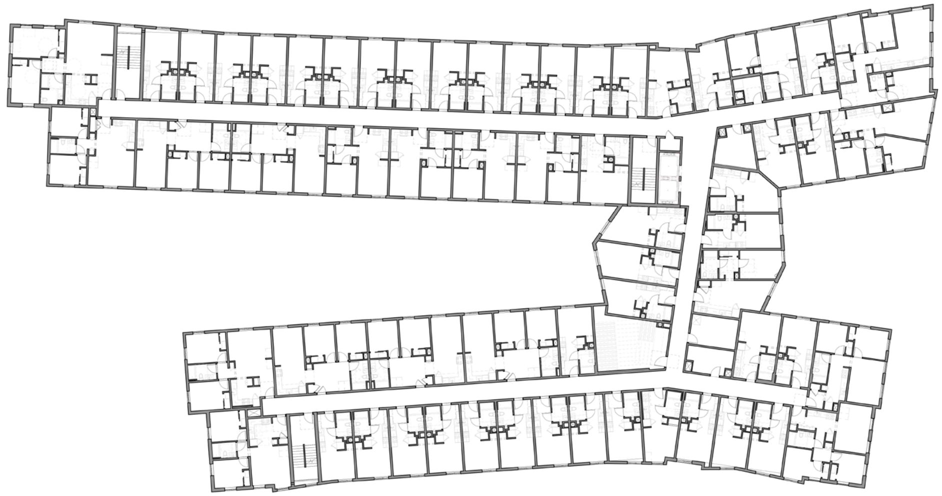
AVERAGE WINDOW/WALL RATIO
24%

WATER HEAT TYPE
Gas

VENTILATION TYPE
ERV/DOAS (dedicated outdoor air supply)

HEATING
Minisplit heat pump & electric heater

COOLING
Minisplit heat pump & ceiling fans



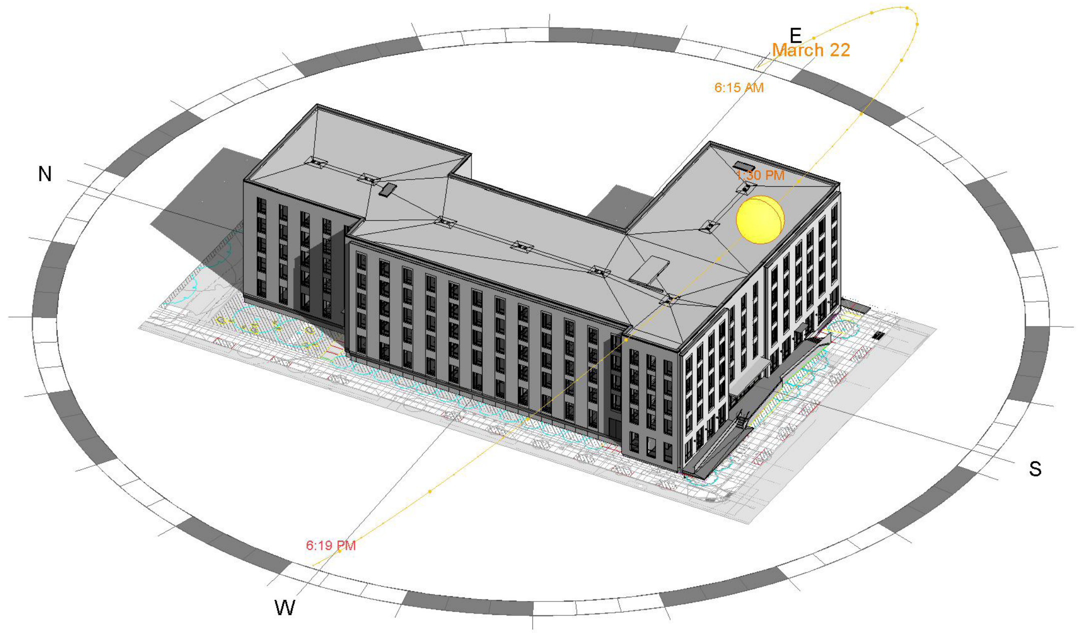
Upper floor plan

Ground floor plan

N.T.S. **NORTH**

THE AURORA

PORTLAND, OR
COMPLETED: 2023



PROJECT DESCRIPTION
Designed for Our Just Future, The Aurora maintains the feel of a residential building while providing a maximum number of family-oriented affordable housing units at SE Stark Street and 160th Street in East Portland.

CLIMATE
4C Mixed Marine

65° F HEATING DEGREE DAYS
4282 (5 yr avg)
4455 (2022)

65° F COOLING DEGREE DAYS
766 (5 yr avg)
899 (2022)

ENERGY CODE
2019 Oregon Zero Energy Ready Commercial Code
OZRECC ASHRAE 90.1-2016

SITE EUI BASELINE
37 kBtu/sf/yr

SITE EUI - ENERGY MODEL
37.7 kBtu/sf/yr

SOLAR - PV ARRAY SIZE
100.8 kW

The Aurora *© Holst*

THE AURORA

PORTLAND, OR

CONSTRUCTION TYPE
5 floors Type IIIB

BUILDING HEIGHT
60’, 5 floor building

FLOOR AREA - CONDITIONED
Residential - 89,280 sf
Total: 89,280 sf

UNITS
1-bed: 47 units
2-bed: 33 units
3-bed: 13 units
Total: 93 units

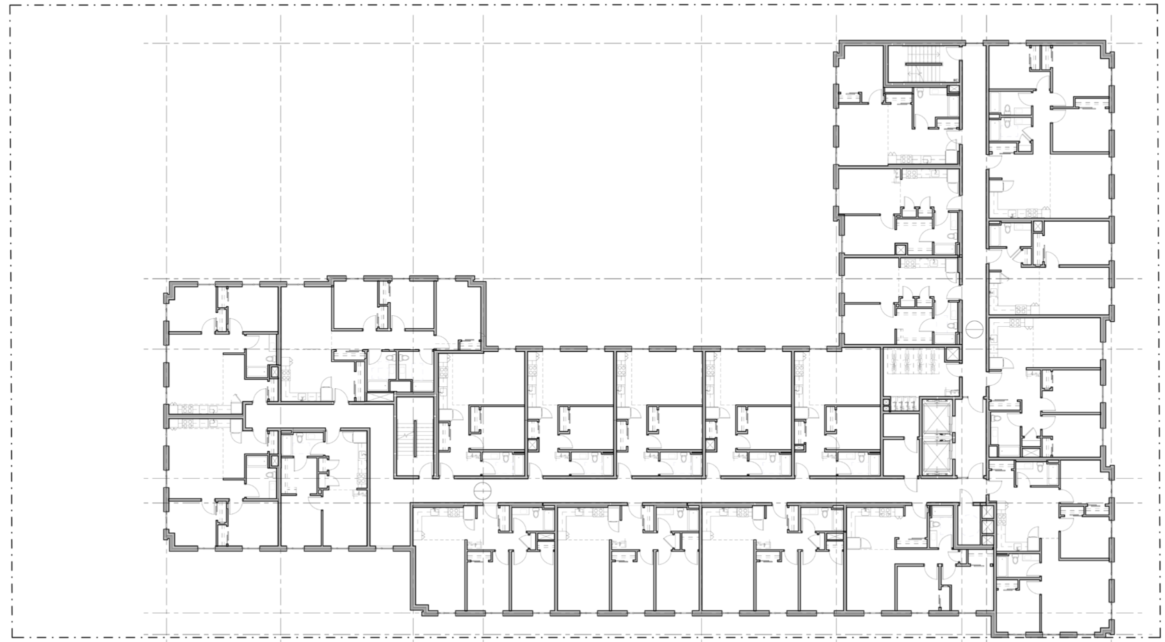
AVERAGE WINDOW/WALL RATIO
25%

WATER HEAT TYPE
Electric heat pump

VENTILATION TYPE
HRV

HEATING
Electric heat pumps (ground floor)
Electric heater (units)

COOLING
Electric heat pumps (ground floor)
Ceiling fan (units)



Upper floor plan

Ground floor plan

N.T.S. **NORTH**

THE CLARA

EAGLE, ID
COMPLETED: 2021

PROJECT DESCRIPTION
The Clara Apartments deliver amenity-filled market-rate multifamily housing to the City of Eagle, Idaho. One of the first garden-style developments in the area, The Clara aims to promote an outdoor lifestyle and encourage community building. There is significant new commercial development in Eagle, which along with proximity to the Boise River and multiple schools, make it an ideal location for a new housing development. The project provides a variety of housing options and amenity spaces.

CLIMATE
5B Cool Dry

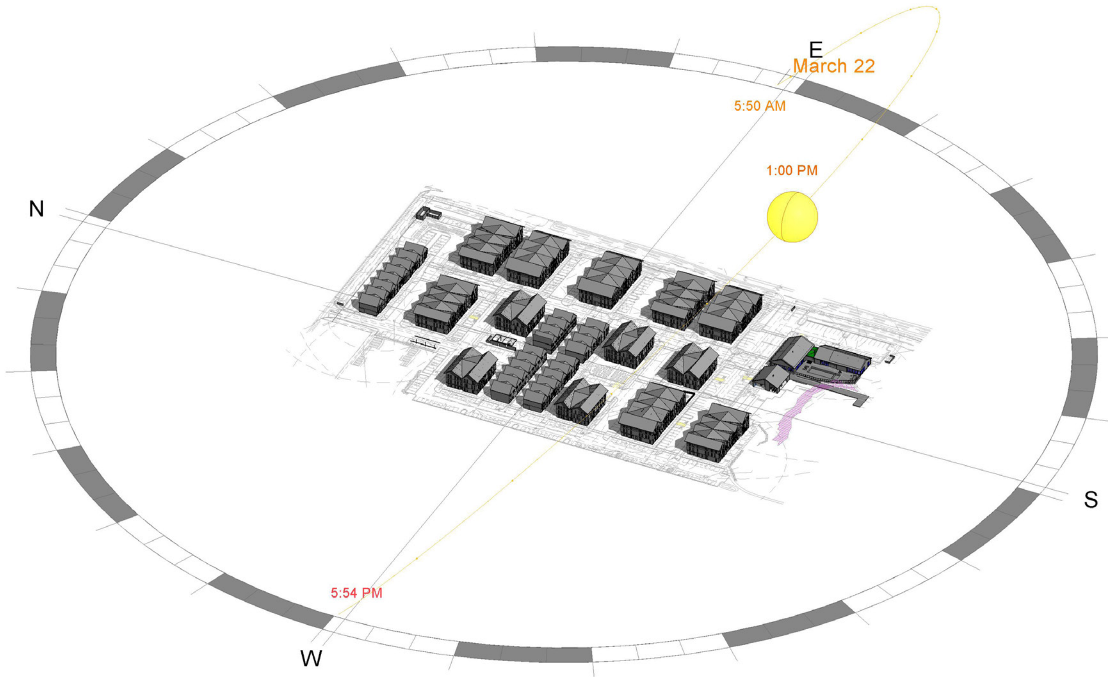
65° F HEATING DEGREE DAYS
5566 (5 yr avg)
6124 (2022)

65° F COOLING DEGREE DAYS
1408 (5 yr avg)
1579 (2022)

ENERGY CODE
2015 International Energy Conservation Code

SITE EUI BASELINE
50 kBtu/sf/yr

SITE EUI - ENERGY MODEL
48.2 kBtu/sf/yr



The Clara © *Gabe Border*

THE CLARA

EAGLE, ID

CONSTRUCTION TYPE
2 to 3 floors, Type VB

BUILDING HEIGHT
83’-6”, 7 floors

FLOOR AREA - CONDITIONED
Residential - 306,550 sf
Total: 306,550 sf

UNITS
1-bed: 72 units
2-bed: 144 units
3-bed: 64 units
Total: 280 units

AVERAGE WINDOW/WALL RATIO
24%

WATER HEAT TYPE
Electric resistance

VENTILATION TYPE
VTAC (vertical terminal air conditioner)

HEATING
VTAC

COOLING
VTAC

Site plan

N.T.S. **NORTH**

5.0 OPERATIONAL CARBON

DATA COLLECTION

When possible, for projects that were completed and in use, a year's worth of electrical and gas energy data was obtained from building owners. Ultimately, the received energy use data for the three Boise projects was limited to common areas and commercial spaces, but did not include the use of the occupied dwelling units. Idaho Power, the energy provider for Boise and much of the rest of the state, has strict customer privacy policies in place that prevented the sharing of all units. None of these buildings had a "master meter" which would have assisted in understanding the full building's energy consumption.

For these projects and the Portland projects that were under construction at the time of the study, a year's worth of energy use data was estimated using a detailed energy model created with Revit[1] Insight. Revit Insight energy models were also created for projects with complete actual energy usage data. This extra step was taken to help validate the projects without actual energy usage data. See the following page for information about this comparison.

Actual and predicted energy data was assembled into an Excel spreadsheet for comparison and analysis. Carbon intensity factors were assigned to electricity and natural gas usage amounts, in order to determine the yearly operational carbon footprint associated with each project. The general formula for the operational carbon calculations is as follows:

Operational Energy x Energy Source Carbon Intensity = Operational Carbon

example: **1 kWh/yr x 10 kgCO_2eq/kWh = 10 kgCO_2eq**

1 The building information modeling platform was Revit, version 2022.

The entirety of Oregon and Idaho are part of the Northwest Power Pool (NWPP), a subregion within the nationwide power grid (recently renamed to the Western Power Pool). While individual utilities have power generation resources (coal, hydro, wind, solar, gas) with unique carbon intensities per unit of energy delivered, utilities within the NWPP commonly buy and sell energy to each other to more efficiently match supply and demand and create a more resilient grid.

Using the NWPP regional numbers was determined to be beneficial for the purposes of this study because it eliminated a variable in carbon intensity of a project due to the energy provider. Therefore, differences in the operational carbon footprint between projects is due to climate, occupant use, and design factors, not the source of the energy.

Electrical Grid Contribution: CO_2eq = 289.6 kg/MWh

It is important to note that this value is a snapshot in time, and that as the electrical utilities transition to cleaner methods of generating power, and more on-site renewables are deployed, the quantity of CO_2eq will decrease. Oregon HB 2021 requires that utilities provide 100% renewable energy by the year 2040, which would significantly reduce overall carbon intensity of the NWPP and thereby reduce the carbon emissions of the buildings in this study.

Since Natural Gas is used on site (Scope 1 emission), carbon intensity can be determined by a simple multiplication of the quantity burned by the quantity of CO_2eq released per unit of gas. A source factor of 1.05 was also applied to account for transmission loss through leakage.

Natural Gas Contribution: CO_2eq = 5.3 kg/therm

In contrast with electricity as an energy source, there are very limited opportunities to decarbonize natural gas beyond reducing wastage and leaks in the distribution network.

The total yearly carbon emissions for each project were normalized for comparison with each other. Calculated metrics include CO_2eq emissions per square meter, CO_2eq emissions per dwelling unit, and CO_2eq emissions per occupant.

5.0 OPERATIONAL CARBON METHODOLOGY

NOTES & LIMITATIONS

BUILDING ENVELOPE COMPARISONS

Comparisons between building envelope insulation values was completed by calculating each building's UA, a strategy employed by the International Energy Conservation Code to determine compliance with energy efficiency standards for new buildings. While the UA factor of each building does take into account the overall insulation values of walls, floors, roofs, windows, slab edges and the like, it is not able to take complex or three dimensional thermal bridging into account. It also does not account for building square footage or volume.

ENERGY MODELING INFORMATION

Where possible, actual natural gas and electricity usage from the most recent year (2022) was obtained from building owners. Where that was unavailable due to incomplete data, privacy limitations or the lack of operational history, the team used predictive energy modeling to estimate usage.

The energy models were created in Revit using the Insight feature, which uses EnergyPlus as its underlying energy simulation engine. This feature creates a building energy model using the building's geometry, materials, and user-defined settings.

An Insight energy model considers the building's geometric properties, including its shape, size, orientation, and fenestration (window) areas. Spatial analysis helps determine how natural lighting and shading affect energy usage. Users can define various energy analysis parameters, such as location, climate data, occupancy schedules, and operational settings.

Insight simulates heat transfer within the building envelope, including walls, roofs, floors, and windows. It calculates thermal properties like U-values, solar heat gain coefficients (SHGC), and thermal bridging effects.

Insight calculates the building's energy consumption patterns, including heating, cooling, lighting, and plug loads. The results include visualizations, reports, and graphs to present the analysis results. Users can identify areas of high energy usage, compare design alternatives, and explore energy-saving strategies.

INSIGHT LIMITATIONS

1. Insight limits the user to select from a preset range of options for heating and cooling systems.

2. No option exists for buildings using a hybrid HVAC system, i.e. Mini-splits in the common areas, and PTACs in the units.

3. Insight limits the user to select from a preset range for PV coverage and efficiency, envelope tightness, lighting power density, and plug load.

4. Insight, in general, has a learning curve and complexity that may make it difficult for users to quickly get useful information.

ENERGY MODELING VS. ACTUAL DATA

Insight energy models were completed for two projects where complete usage data was available to help establish a correlation between modeled and actual data.

72 Foster

EUI (actual) = 43.8 kBtu/sf/yr

EUI (Revit Insight) = 49.4 kBtu/sf/yr (+12.8%)

The Nick Fish

EUI (actual) = 50.5 kBtu/sf/yr

EUI (Revit Insight) = 61.0 kBtu/sf/yr (+20.7%)

EUI (Trane Trace 700)[1] = 61.0 kBtu/sf/yr (+20.7%)

The energy modeling results were significantly higher than actual measured use in both buildings. This could be attributable to several factors, including underestimation of vacant retail space or dwelling units, assumption of a higher energy use intensity for retail and office spaces than actually occurred. The Nick Fish, in particular, experienced unusual vacancy in 2022 in the retail spaces, as well as reduced occupancy in the offices due to the lingering work-from-home effects of the COVID-19 pandemic which may explain why the modeled predictions are more than 20% higher than the actual usage.

This comparison suggests that energy models may show energy use intensities greater than the actual energy usage, especially during high vacancy periods such as a pandemic. However, they are still a good starting point and tool to aid in building optimization.

1 These results were from an energy model created prior to this study, which somewhat surprisingly had the same results as our Revit Insight model.

5.0 OPERATIONAL CARBON METHODOLOGY

U-VALUES AND ENCLOSURE

CALCULATIONS

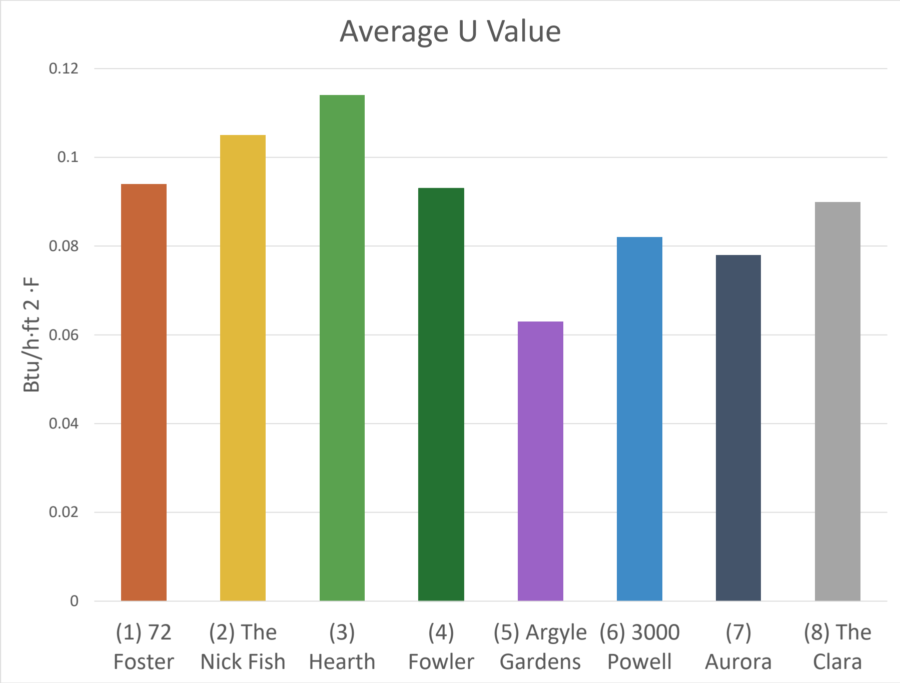
The efficiency and insulation of each building's enclosure was calculated using a spreadsheet based on the 2018 International Energy Conservation Code.

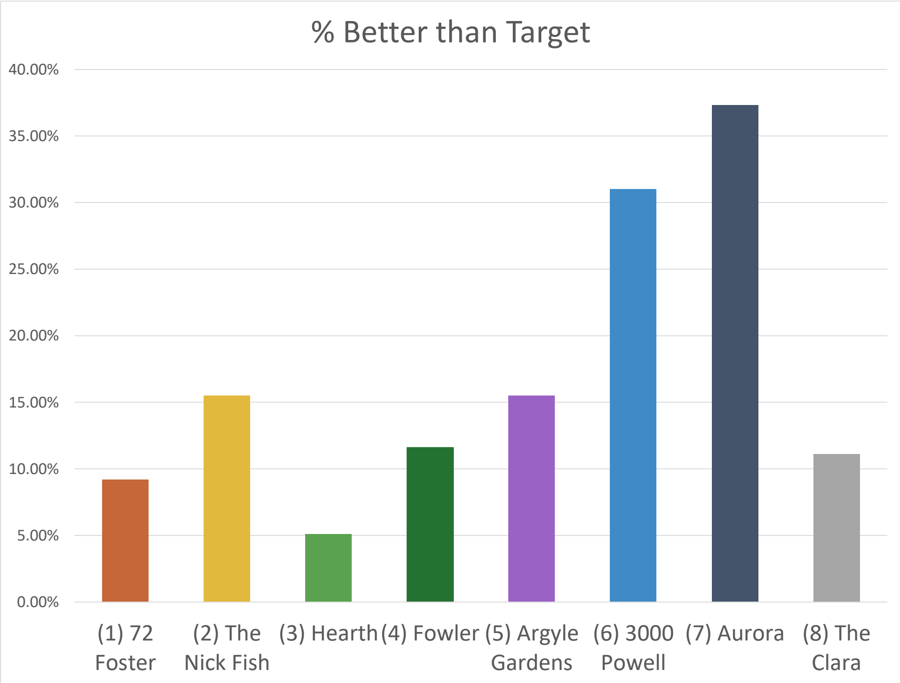
AVERAGE U-VALUE

The average U-Value of the building enclosure shows how insulated the typical assembly is. Lower U-values indicate that a building is more insulated, which is typically associated with higher performance in heating dominated climates. Argyle Gardens has the lowest actual U-Value, which may be due to having fewer/smaller windows than the comparable projects. 3000 Powell and The Aurora have the 2nd and 3rd lowest U-values, which is expected due to the more stringent energy code versions under which they were permitted.

% BETTER THAN TARGET

The percentage better than target shows what percentage better the building's enclosure is when compared to a code minimum enclosure. The Aurora and 3000 Powell were constructed under a newer energy code, and have higher performance enclosures. Because they are not constructed, this % better than target cannot be tracked against the actual energy use. Nevertheless, the energy model does predict that they will have lower EUIs than the other six projects.





5.0 OPERATIONAL CARBON METHODOLOGY

EUI-ENERGY USE INTENSITY

SITE EUI - BASELINE

EUI (Energy Use Intensity) is a measure of how much energy a building uses per sf/yr. The baseline EUIs for the projects were calculated using Architecture 2030's free digital resource, Zero Tool, based on the location and total area of each use (i.e. multifamily, parking, retail) within the building. These baseline EUIs do not account for any site renewable energy such as solar panels. The original Architecture 2030 Challenge called for an 80% reduction from the baseline EUIs by 2020 and a 90% reduction by 2025 - which is effectively impossible to achieve with typical project budgets.

SITE EUI - ACTUAL

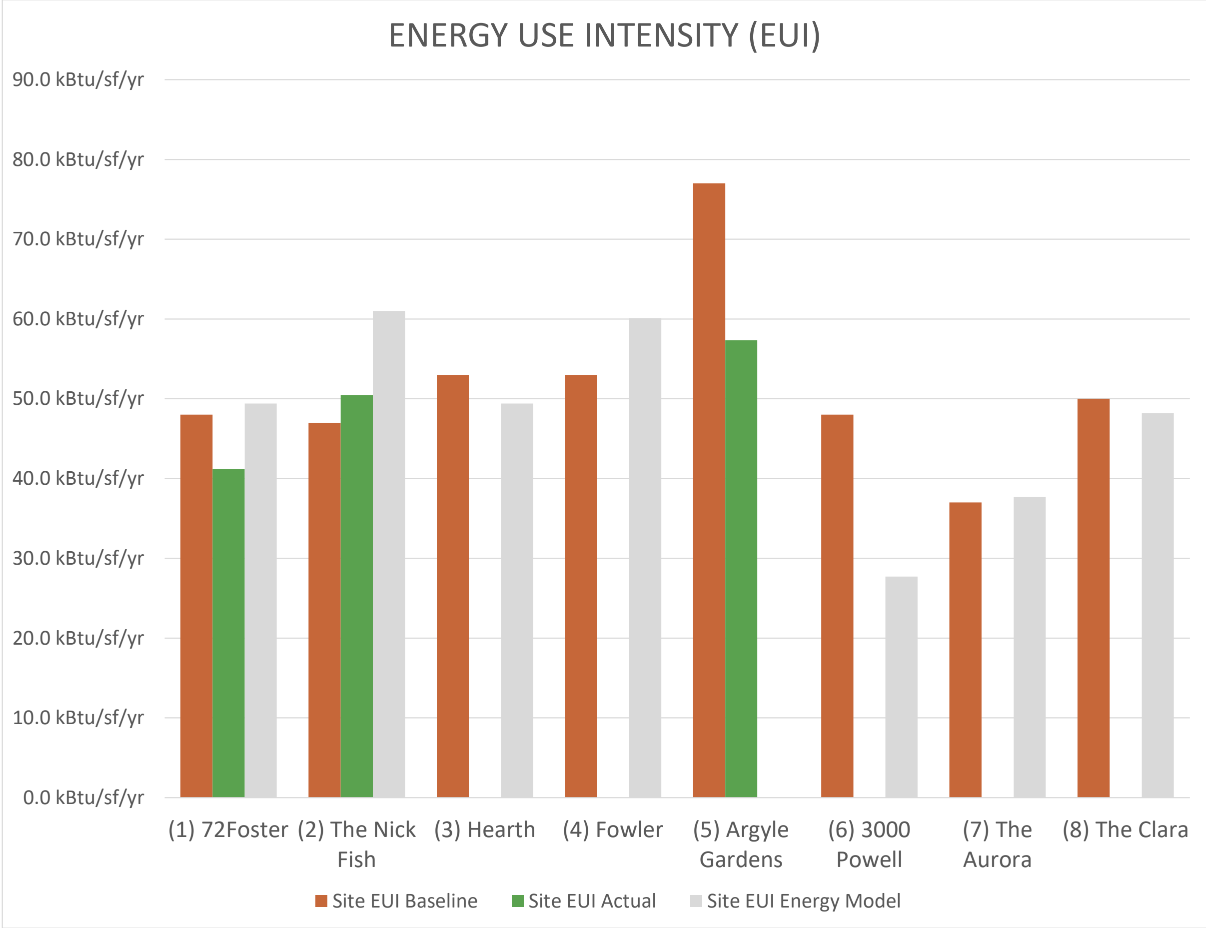
The actual EUI is based on electrical and gas energy usage data received from building owners, with a total sf that includes conditioned and unconditioned space.

SITE EUI - ENERGY MODEL

The EUI - Energy Model was calculated from the outputs of the Revit Insight energy models created for this project.

CONCLUSIONS

Based on the uses and square footages, the typical predicted Architecture 2030 Zerotool's baseline energy use intensities (EUIs) for these projects varied from a low of 37.0 kBtu/sf/yr to a high of 77.0 kBtu/sf/yr for a project with high occupant densities. For the buildings with actual energy usage data, the Site EUI - Actual varied between 43.8 kBtu/sf/yr to 57.3 kBtu/sf/yr. For several of the projects, a prior year of energy usage was unable to be obtained, so energy models were created to predict the energy usage. For the energy modeled projects, the Site EUI



- Energy Model varied between 27.7 kBtu/sf/yr (3000 Powell) to 61.0 kBtu/sf/yr (the Nick Fish).

Argyle Gardens has a high EUI, but also has a high occupant density and number of units per sf. It was able to achieve a reduction from the target EUI likely due to the solar panels that were installed on the buildings.

Of the other projects with actual energy use, 72Foster has a lower EUI than the baseline. 72Foster also has solar panels which help reduce the EUI.

The Nick Fish, unfortunately has a higher actual energy use than the baseline. The baseline EUIs do not take into account building form and orientation, which can have a significant impact on EUI.

Aurora and 3000 Powell will hopefully achieve a EUI of 40 kBtu/sf/yr and 27 kBtu/sf/yr respectively, which would make them the best performing projects to date.

BTU/SF/DEGREE DAY

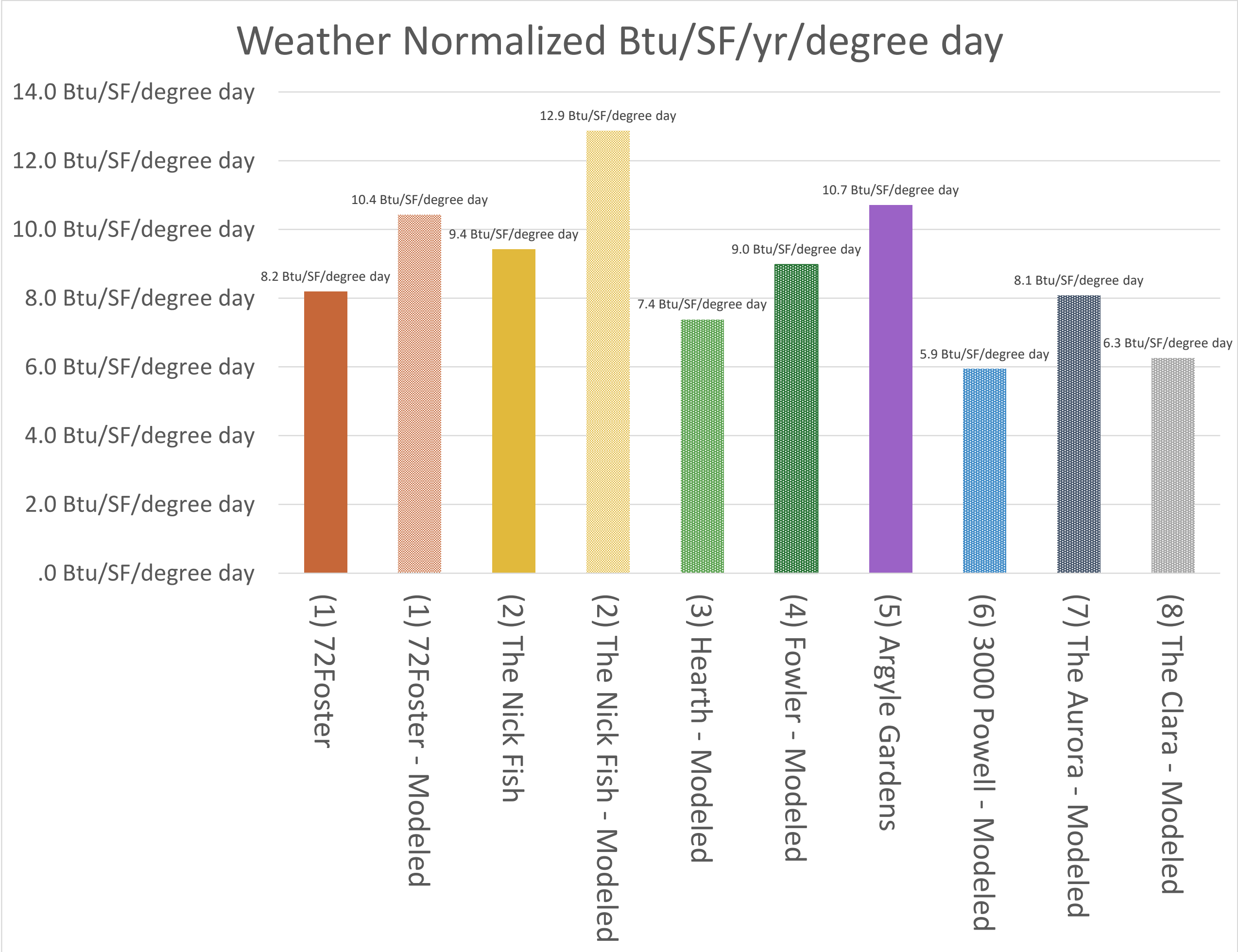
This chart shows the total energy use per square foot of a building divided by the total Heating (HDD) and Cooling Degree Days (CDD). This ratio is meant to reveal differences in building energy use per unit of area due to climate. It has limitations due to the fact that it doesn't account for basic energy use that is not impacted by temperature such as lighting and hot water use. It also assumes that heating and cooling setpoints inside the building are identical, which is unknown.

For the energy model projects, the HDD and CDD were a location-dependent value predetermined in Revit Insight. HDD and CDD for actual energy usage data comes from degreedays.net.

Of the projects with actual energy usage data, Argyle Gardens still has the highest energy use per square foot, likely due to the high density and small size.

The EUI of Hearth is similar to the Nick Fish and 72 Foster, but when the hotter/colder weather of Boise is taken into account, the energy model predicts a lower weather normalized Btu/sf/degree day.

The weather normalized Btu/sf/day ranges from 5.9 Btu/sf/yr/degree day (3000 Powell - Modeled) to 12.9 Btu/sf/yr/degree day (The Nick Fish - Modeled), with a median of 8.9 Btu/sf/yr/degree day.



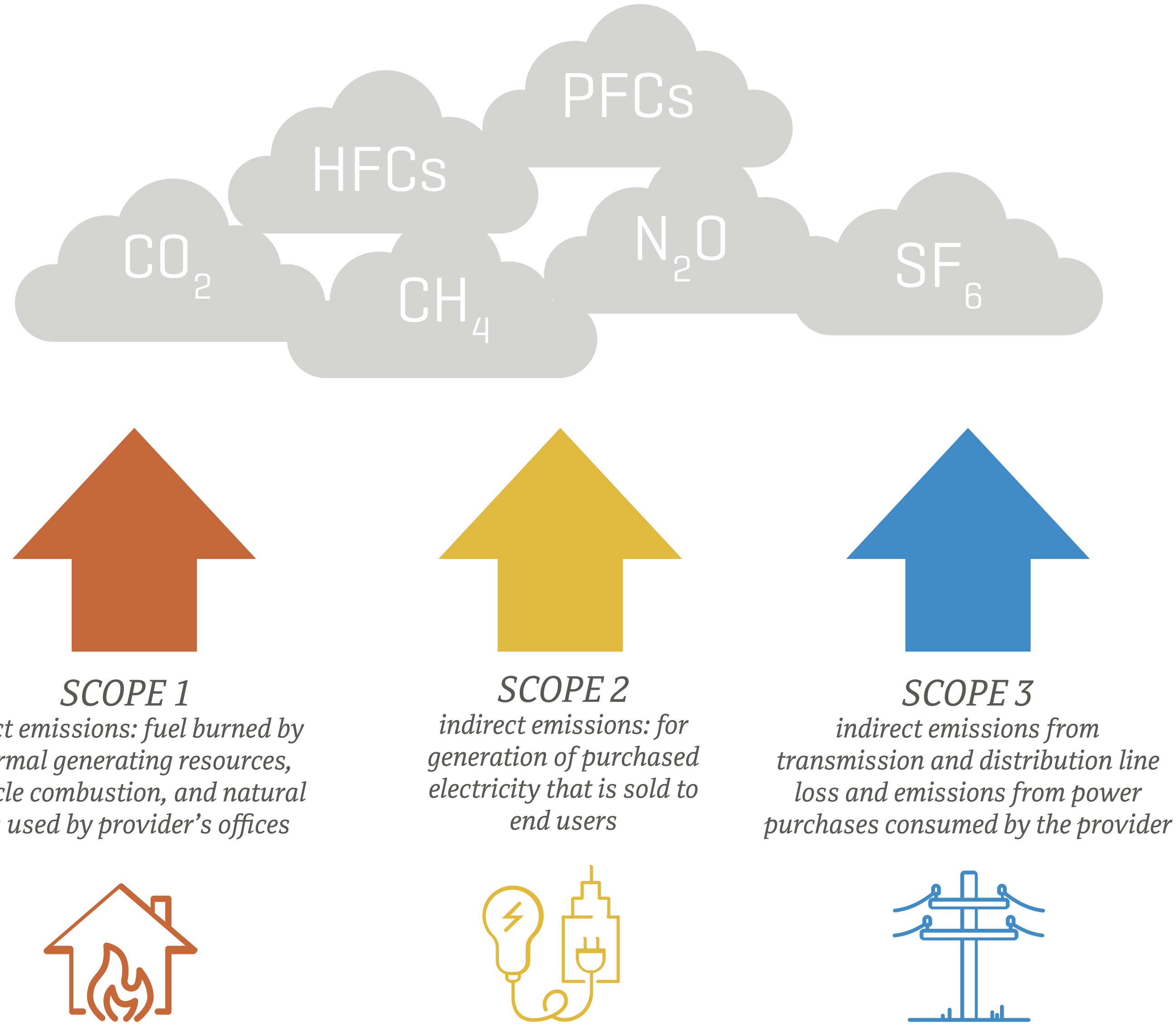
5.0 OPERATIONAL CARBON METHODOLOGY

SOURCE OPERATIONAL CARBON INTENSITY

An EUI does not show the difference in carbon emissions from natural gas and electricity, so the energy use has to be multiplied by an emissions factor for electricity and natural gas. The operational emissions for this study include Scopes 1,2, and 3, as shown in the diagram.

Electrical grid emissions data was gathered from US EPA eGrid Power Profiler and accounts for CO_2 as well as the Global Warming Potential of CH_4 and N_2O. The entirety of Oregon and Idaho are part of the Northwest Power Pool (NWPP), a subregion within the nationwide power grid. While individual utilities have power generation resources (coal, hydro, wind, solar, gas) with unique carbon intensities per unit of energy delivered, utilities within the NWPP commonly buy and sell energy to each other to more efficiently match supply and demand and create a more resilient grid.

Since Natural Gas is used on site (Scope 1 emission), carbon intensity can be determined by a simple equation of the quantity burned. A source factor of 1.05 was also applied to account for transmission loss through leakage.



EMISSIONS SCOPE AS DEFINED IN EPA POWER PROFILER

5.0 OPERATIONAL CARBON METHODOLOGY

SOURCE OPERATIONAL CARBON INTENSITY

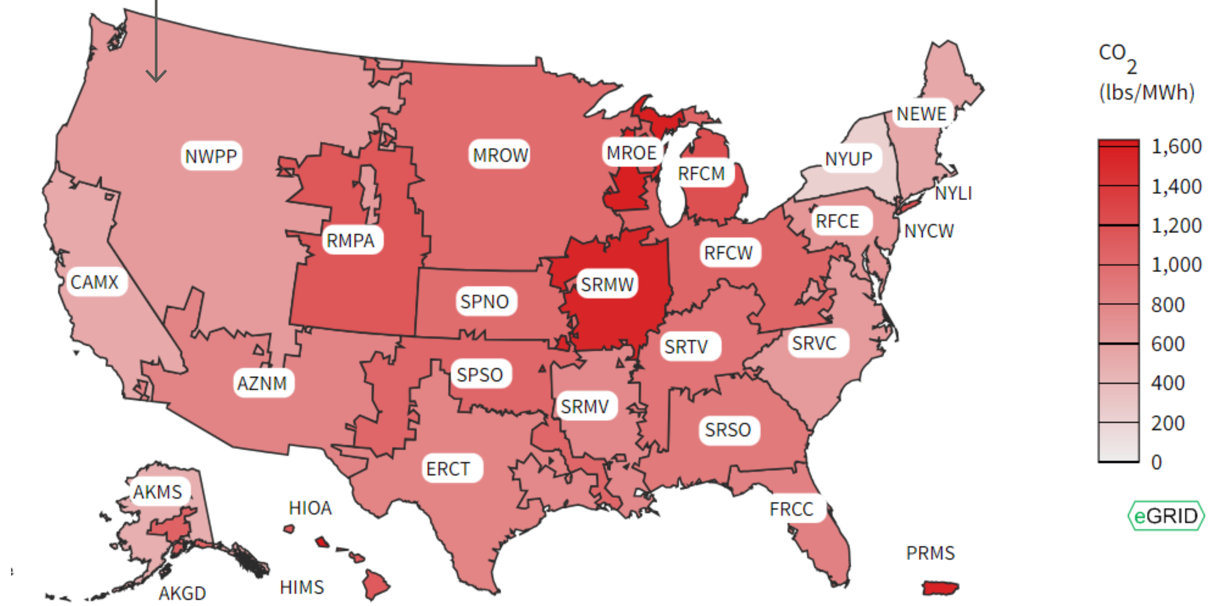
Due to energy sharing between utilities, the carbon intensity of the grid is based on the NWPP regional average. The various utilities of Oregon have carbon intensities that vary from this number. For example:

IDAHO POWER (ONTARIO, OR & BOISE)
886 lbs / MWh[2]

PGE (PORTLAND GENERAL ELECTRIC) (PORTLAND)
705.5 lbs / MWh[3]

CITY OF ASHLAND ELECTRIC DEPARTMENT (MEDFORD)
65 lbs / MWh[4]

NWPP
638.5 lbs CO_2eq / MWh



EMISSIONS RATE MAP[1]

1 https://www.epa.gov/egrid/power-profiler#/

2 2021 & 2022 average, https://www.idahopower.com/energy-environment/energy/energy-sources/our-path-away-from-coal/

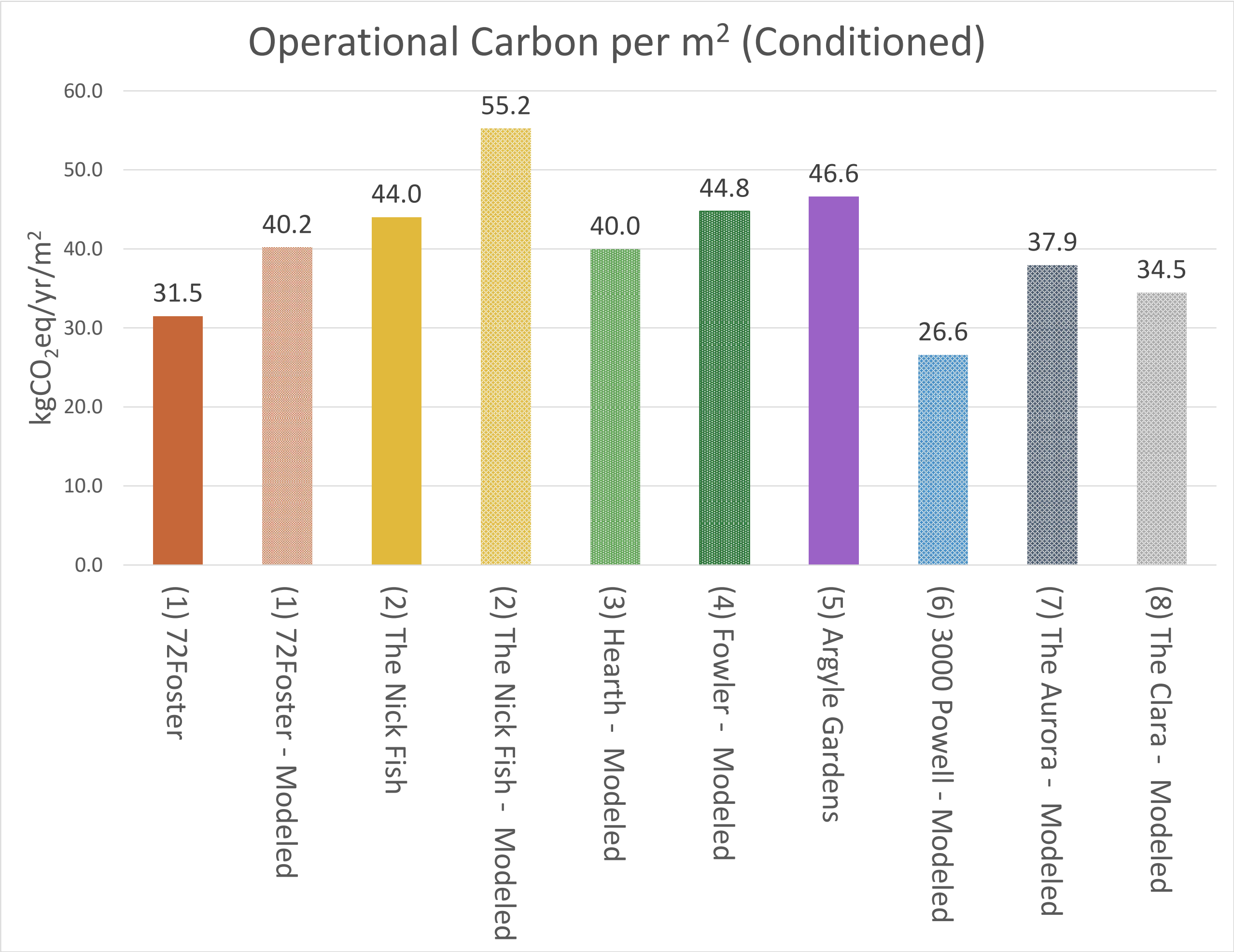
3 Includes purchased and generated energy. Portland General Electric. “2021 ESG Report: Advancing Our Clean Energy Future,” 2021. https://assets.ctfassets.net/416ywc1laqmd/5aLMRJup0FHiMTf0EpgzYO/9e384dc5c6422147ddadbd821913163a/PGE_ESG21_Web.pdf.

4 Energy purchased from BPA, includes direct and indirect emissions. Source: DEQ. “Oregon Clean Fuels Program: Updated Electricity Carbon Intensity Values for 2021,” 2021. https://www.oregon.gov/deq/ghgp/Documents/cfpUpdated2021CIs.pdf

5.0 OPERATIONAL CARBON METHODOLOGY

OPERATIONAL COMPARISONS PER SQUARE METER

The operational carbon per square meter of conditioned space ranges from 26.6 kg CO_2eq/m² to 55.2 kg CO_2eq/m².[1] This operational carbon is based on actual energy use data for 72 Foster, the Nick Fish, and Argyle Gardens. This operational carbon is based on the energy model information (noted as "Modeled") for the Aurora, the Clara, 3000 Powell, Hearth, and Fowler. The average as well as the median of the operational carbon is 40.1 kg CO_2eq/yr/m². For the three projects with actual energy usage data, the operational carbon varied from 31.5 kg CO_2eq/yr/m² to 46.6 kg CO_2eq. yr/m²



- The Nick Fish, the Aurora, 72 Foster, and Argyle Gardens all have solar panel installations that will or do reduce the operational carbon by offsetting a portion of the annual electricity consumption with on-site generation.
- Argyle Gardens likely has the highest actual operational carbon due to the occupant load density.
- The Nick Fish has a higher modeled operational carbon per square meter than actual, likely due to underutilization of offices and retail space during the pandemic recovery.
- 3000 Powell is predicted to have a low operational carbon per square meter, and is one of the projects under the newest energy code.

1 Kg CO_2eq/m2 is the most commonly used metric for comparing a building's operational carbon. This metric can also be calculated per square foot, but only kg CO_2eq/m2 is presented here for simplicity.

5.0 OPERATIONAL CARBON METHODOLOGY

OPERATIONAL COMPARISONS OF HOUSING EFFICIENCY

While operational carbon per square meter/yr is a common metric, other useful comparisons are operational carbon per unit, per bedroom, and per housing occupant.

This chart does not reflect the additional advantages of the mixed uses in 72 Foster, the Nick Fish, Hearth, and the Fowler. Neither the actual energy use data nor the building energy models separated out energy usage by space type, so it was not possible to extricate other uses from the energy use.

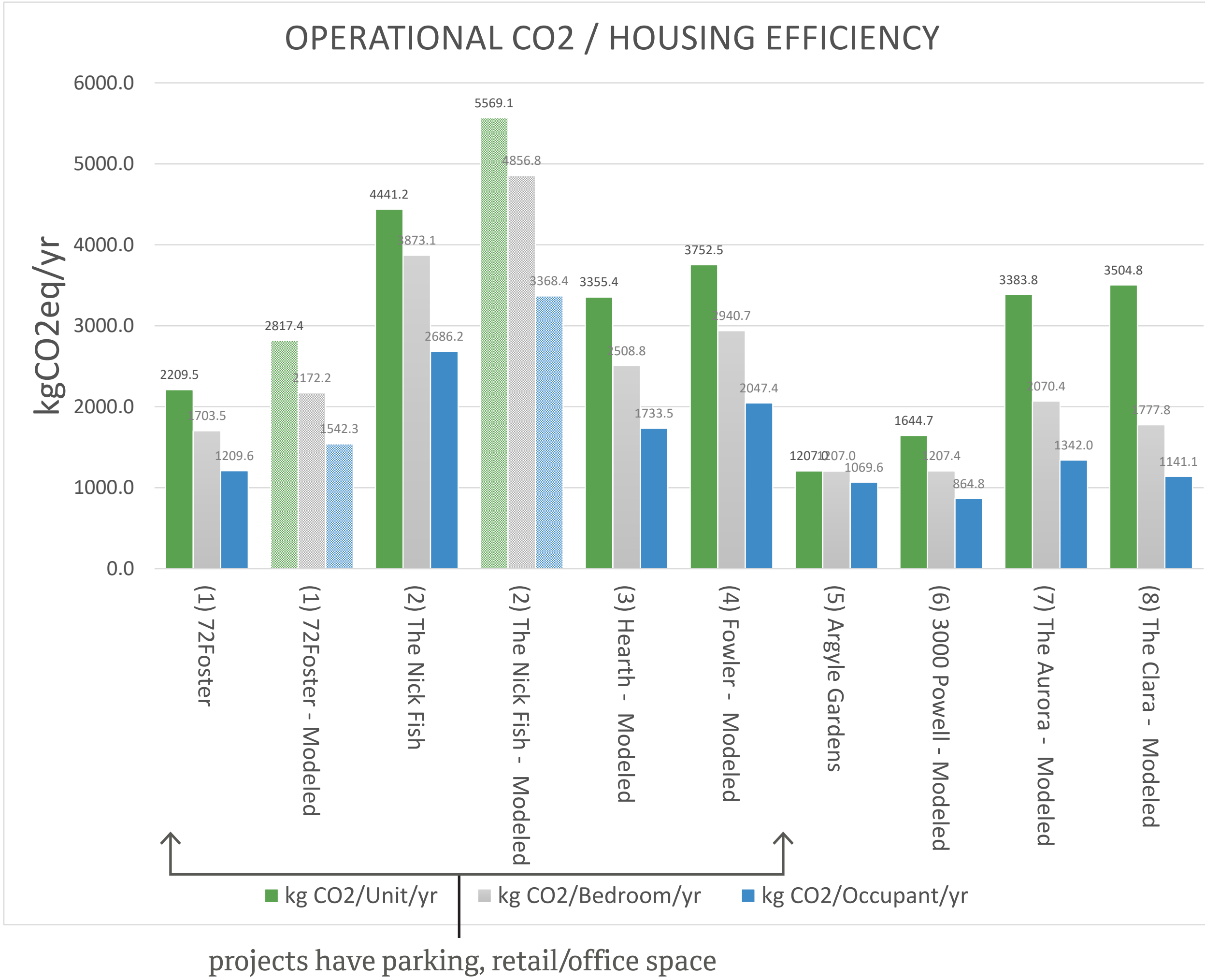
The operational carbon per housing unit varies between a low of 1207 kg CO_2eq/unit/yr for a single residence occupancy (SRO), light wood frame project, to a high of 4441 kg CO_2eq/unit/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per housing unit is 2937 kg CO_2eq/unit/yr.

The average[1] of the operational carbon per bedroom is 2161 kg CO_2eq/bedroom/yr.

<u>When the range of project types are considered, the operational carbon per housing occupant ranges from 865 kg CO_2eq/housing occupant/yr (3000 Powell - Modeled) to 3369 kg CO_2eq/housing occupant/yr (The Nick Fish - Modeled).</u>

<u>When projects with limited or no mixed uses are considered, the operational carbon per housing occupant ranges from 865 kg CO_2eq/housing occupant/yr (3000 Powell - Modeled) to 1342 kg CO_2eq/housing occupant/yr (The Aurora - Modeled).</u>

The average[1] of the operational carbon per occupant is 1512 kg CO_2eq/occupant/yr.

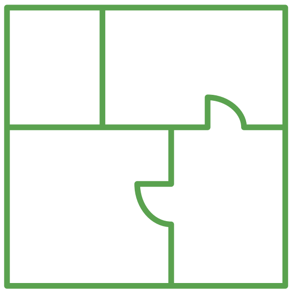


Although Argyle Gardens had the highest EUI and operational carbon per square meter, it had the lowest operational carbon per unit and per bedroom. The affordable housing project 3000 Powell had the lowest operational carbon per occupant, likely due to its multiple bedroom units. This illustrates the importance of looking beyond the per square meter metric when reducing operational carbon emissions of the built environment.

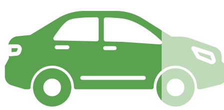
1 20% trimmed mean, excludes The Nick Fish - Modeled and 72Foster - Modeled

5.0 OPERATIONAL CARBON METHODOLOGY

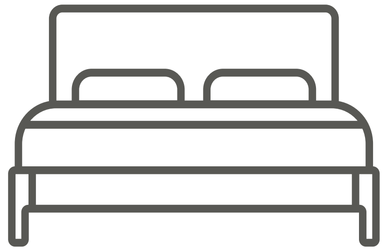
OPERATIONAL COMPARISONS OF HOUSING EFFICIENCY



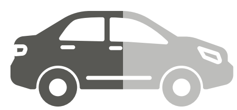
Mean:
2937 kg CO_2eq/unit/yr



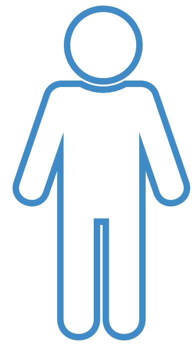
= .65 gasoline-powered car driven for one year (7,529 miles driven)*



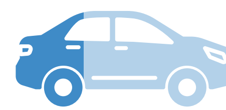
Mean:
2161 kg CO_2eq/bedroom/yr



= .48 gasoline-powered car driven for one year (5,540 miles driven)*



Mean:
1512 kg CO_2eq/occ/yr



= .34 gasoline-powered car driven for one year (3,876 miles driven)*

*Converted using EPA's Greenhouse Gas Equivalencies Calculator https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
**Mean values are 20% trimmed means

6.0 EMBODIED CARBON

PROCESS

The term embodied carbon refers to the greenhouse gas emissions associated with a product, building, or service. It measures a significant component of the carbon footprint of a building.

For the embodied carbon assessments in this study, materials and assemblies in each project's building information model[1] were assigned emissions factors using Tally[2], a software plugin for Revit. The emissions factors determine how much carbon is emitted for a finite material quantity, due to the material's production, transport and disposal. The first phase of the embodied carbon assessment encompassed the building's structure, interior walls, and enclosure for all studied projects. This is designated the 'base' embodied carbon assessment.

The second phase of the embodied carbon assessment was the 'full' embodied carbon assessment. Building on the analysis model of the first phase, this phase added stairs, railings, doors, and ceilings to the embodied carbon assessment.

In both phases, Tally was used to define material assemblies and to link those assemblies or materials to published EPDs (Environmental Product Declaration). Tally's database includes product-specific EPDs as well as regional industry average EPDs.[3] For the scope of this study, none of Tally's product-specific material EPDs matched building materials on these selected projects.

The general formula to calculate the embodied carbon of an individual building material is as follows:

Material Quantity x Material Carbon Intensity = Embodied Carbon

example: 1 sf x 10 kgCO2eq/sf = 10 kgCO2eq

After a user defines all materials on a project, Tally exports a whole building life cycle assessment in an excel and pdf form. For this study, the excel results for each project were linked into a master excel file to compare the embodied carbon across projects. Although Tally reports several environmental impact categories, this study only focuses on the embodied carbon, which is reported as the global warming potential (GWP) in kg CO_2eq.

As with the operational carbon results, these embodied carbon results were normalized for comparison with each other. Calculated metrics include CO_2eq emissions in kg per square meter, CO_2eq emissions in kg per dwelling unit, and CO_2eq emissions in kg per occupant. Although kg/m^2 is a metric unit, it is much more commonly used in embodied carbon calculations in the United States than the imperial equivalent of lbs/ft^2. The building area used throughout is the total unconditioned and conditioned building area as defined by the 2021 International Building Code definition, unless noted otherwise.

SCOPE

For this study, a base scope of embodied carbon was assessed for all eight projects. This base scope included the buildings' structure, enclosure, and interior walls. An enlarged 'full' scope, which added additional categories of stairs, railings, doors, and ceilings was assessed for four projects. These added categories contributed 4 to 6% (average 5%) to the overall embodied carbon of those four projects. This 5% percentage factor was then applied to the projects for which a full scope was not produced.

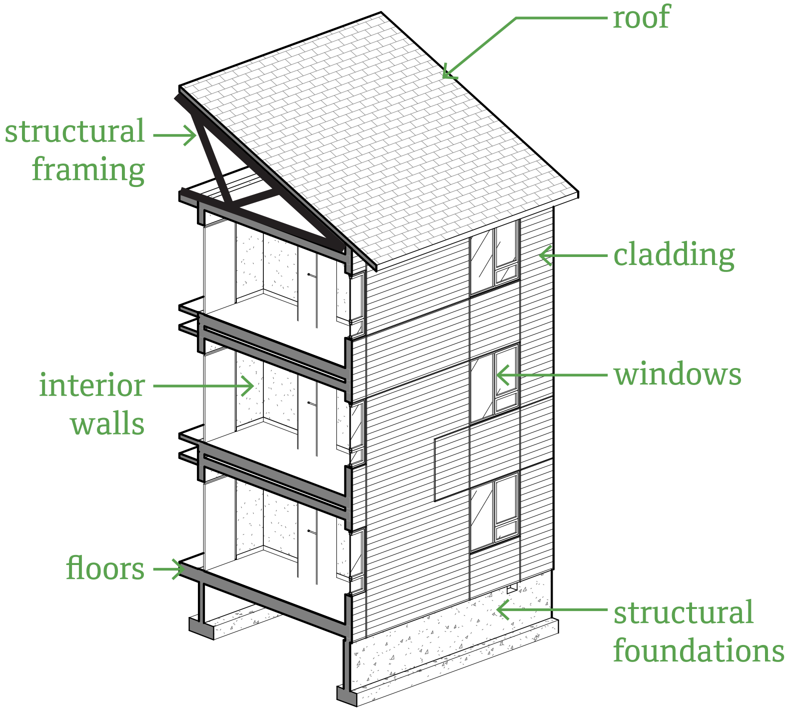
Tally does not currently contain data for all types of materials that make up a complete building. These categories were excluded from both the base and full scope: mechanical, electrical, plumbing, fire sprinklers/alarms, casework, sitework, elevators, furnishings, fixtures & accessories.

1 The building information modeling platform was Revit, version 2022.
2 Tally is a joint development project from Building Transparency, KT Innovations, thinkstep, and Autodesk.
3 https://choosetally.com/faq/

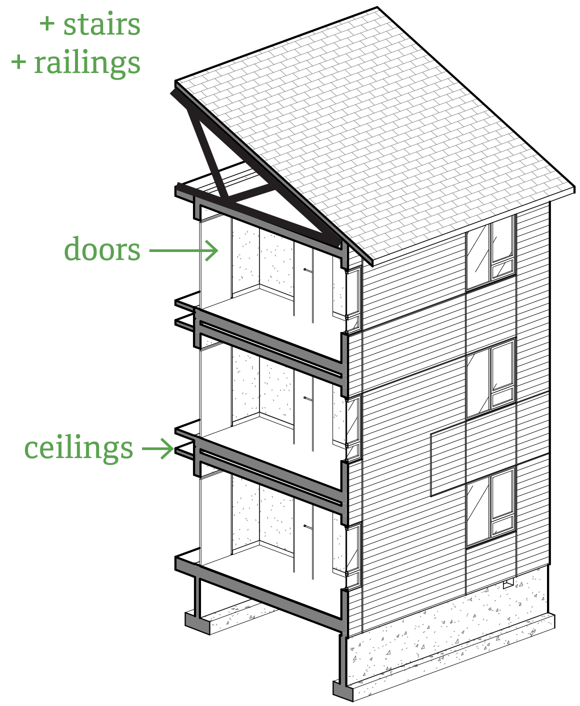
EMBODIED CARBON METHODOLOGY

SCOPE

'BASE' SCOPE INCLUDES



'FULL' SCOPE INCLUDES BASE SCOPE + ADDITIONAL CATEGORIES



EXCLUDED SCOPE

- MEP
- fire sprinklers and alarms
- casework
- sitework
- elevators
- furnishings
- fixtures/ accessories

EMBODIED CARBON METHODOLOGY

BACKGROUND

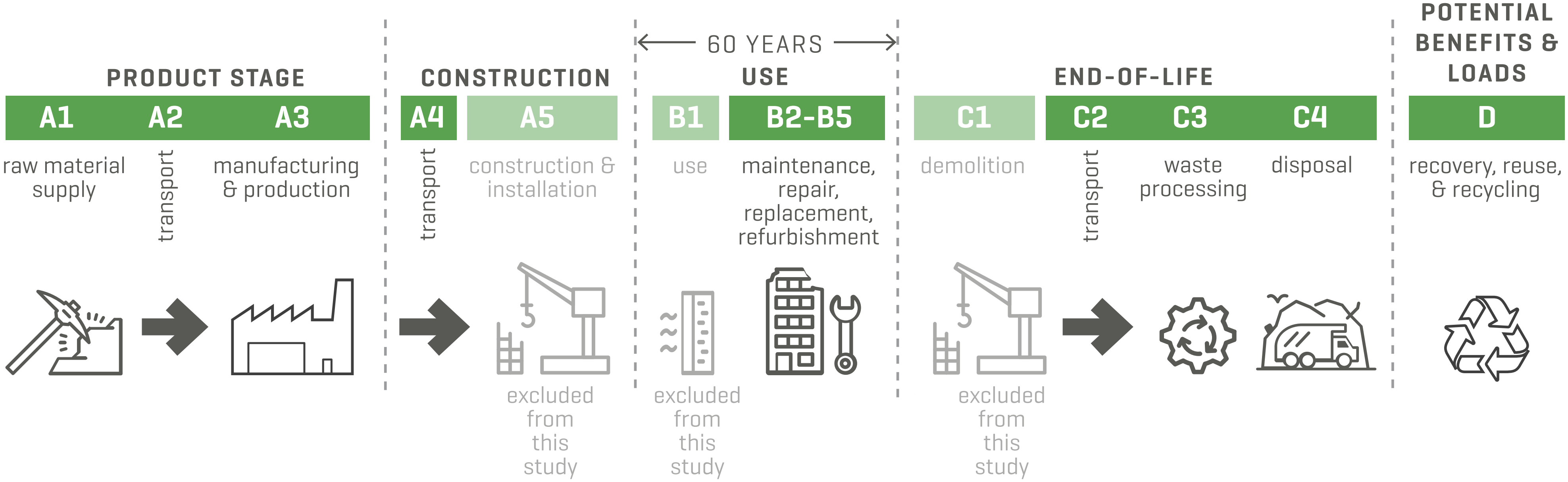
The embodied carbon assessments for this study were calculated using a cradle-to-grave system boundary, so the embodied carbon values include the impacts across the building's life cycle from Stage A: material manufacturing & transport, Stage B: maintenance/replacement, Stage C: end-of-life, and Module D: benefits beyond the system boundary. Due to the limitations of available data, three life cycle modules as defined in EN: 15978 were excluded from the scope of this study. These excluded modules are A5: Construction & Installation, B1: Use, and C1: Demolition.

For this study, a 60 year building life span was selected, which influences the total impacts associated with maintenance, repair, replacement and refurbishment. This life span is consistent with current WBLCA guidance.

Module D is the life cycle module that calculates the environmental impacts beyond the system boundary. Module D benefits are future benefits that are uncertain and that occur at the end-of-life of a building. These impacts are generally benefits or offsets from recyclable or reusable materials. The inclusion or exclusion of module D is a debated topic within LCA practitioners.

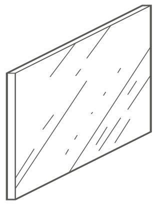
Recycling rates and mandates vary, and the values may not reflect what is feasible or standard practice for a particular area. These values also do not reflect the decreased material quality that may occur after recycling materials several times. Module D benefits are counted in Tally (and in this study) as noted on the following page.

LIFE CYCLE STAGES & MODULES

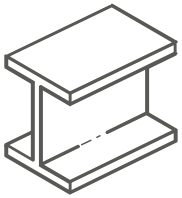


EMBODIED CARBON METHODOLOGY

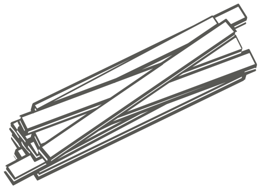
BACKGROUND: LIFE CYCLE MODULE D



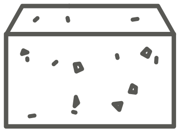
Aluminum: Module D: Accounts for the avoided burden for the 95% recycled aluminum.



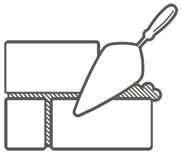
Steel: Module D: Accounts for the avoided burden for the difference between recycling at the end-of-life and the recycled content in the initial steel product. If less steel is recycled at the end of life, than the initial recycled content, Module D will contribute additional emissions to the embodied carbon of the steel.



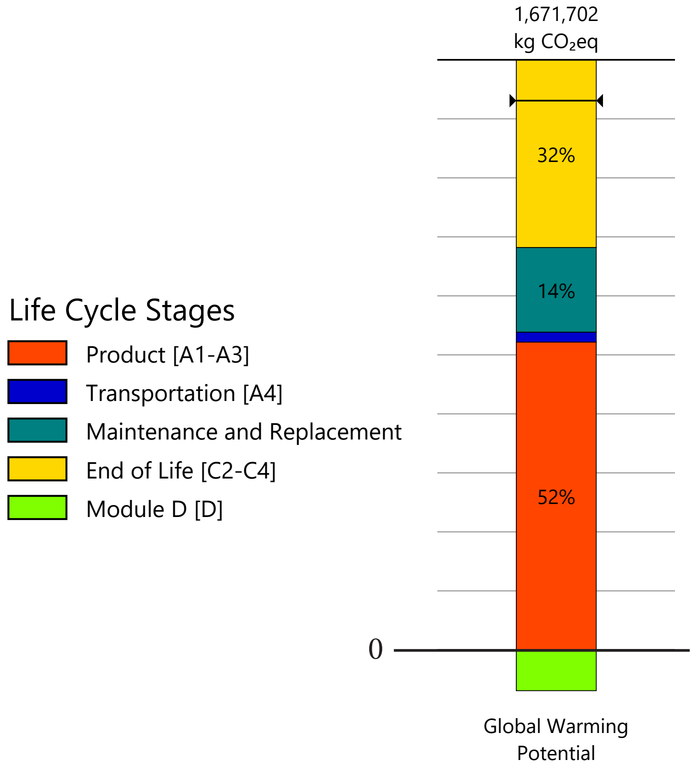
Wood: Module D: 14.5% of wood is recycled and credited as a avoided burden. Wood that is incinerated receives credit for the energy that is recovered from it.[1]



Concrete: Module D: 55% of concrete is recycled into new coarse aggregate and credited as avoided burden. Grinding energy is included in the calculation.



Brick Mortar: 55% of mortar is recycled into new coarse aggregate and credited as avoided burden. Grinding energy is included in the calculation.



Example of Module D benefits shown as emissions reduction.

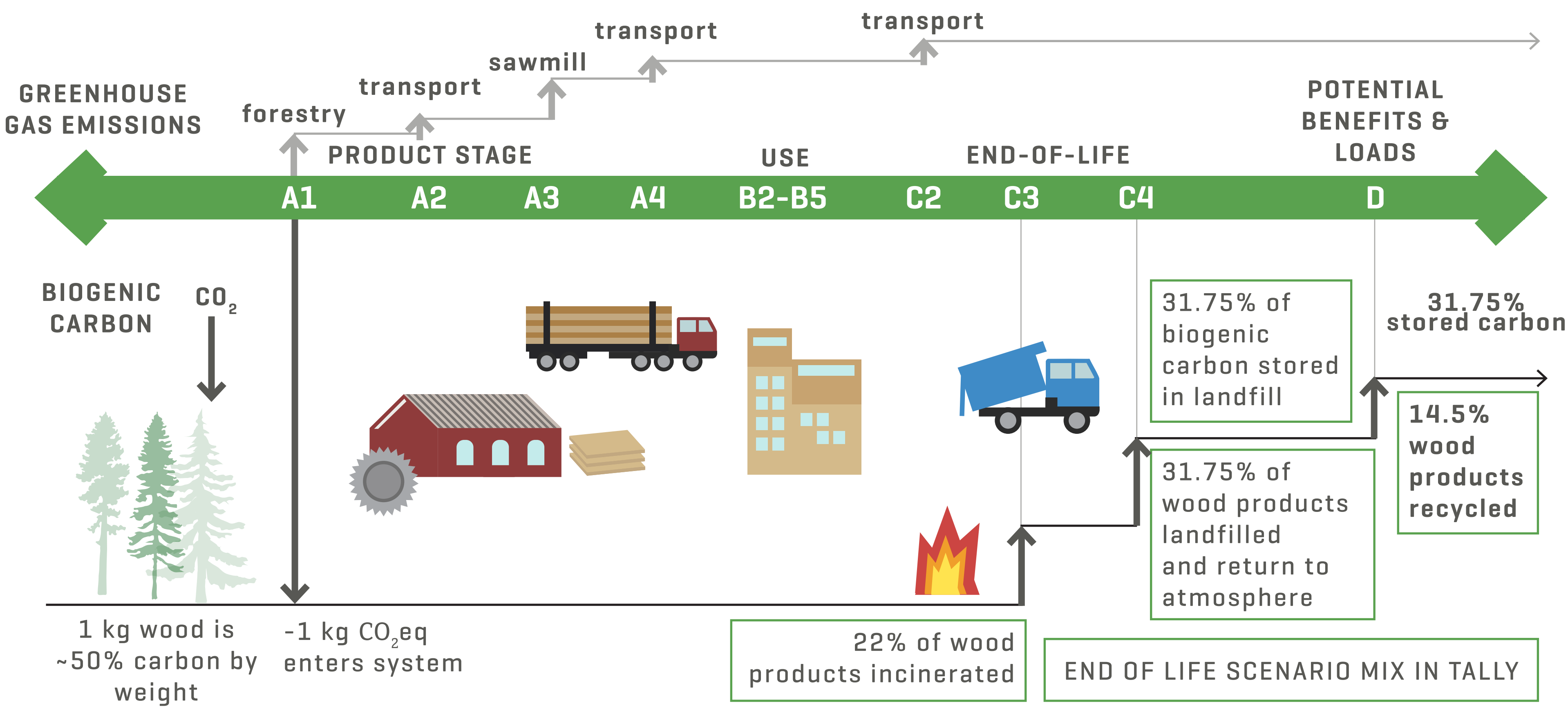
EMBODIED CARBON METHODOLOGY

BACKGROUND: BIOGENIC CARBON FLOWS

One important factor in the embodied carbon of buildings with wood materials is biogenic carbon, which is the carbon stored in wood or other natural materials. This carbon storage is a primary reason why wood and natural materials can have such a low (even negative embodied carbon).

In Tally, you can choose to include or exclude the biogenic carbon stored in wood. Because wood is about 50% carbon by weight, it has great potential to sequester carbon in our buildings. When you include the carbon stored in the wood, the carbon storage enters the life cycle at the product stage. It then leaves the system boundary when the building is demolished. There are several options for biogenic materials at the end of life. They may be incinerated, landfilled, or recycled. Tally uses a specific scenario mix that designates a certain portion to be incinerated, recycled, and landfilled. Of the portion that is landfilled, 50% returns to the atmosphere and 50% is considered permanently stored. The 31.75% carbon that is permanently stored is credited against the normal greenhouse gas emissions for wood, lowering the overall embodied carbon.

Because Tally looks at the whole building life cycle, it is appropriate to include biogenic carbon. Excluding biogenic carbon is a conservative choice and should be used for LCAs that do not include end-of-life impacts. Both are shown in this study, but the primary charts include biogenic carbon.



EMBODIED CARBON METHODOLOGY

NOTES & LIMITATIONS

EMBODIED CARBON TOOLS

Several tools were considered for use in the 'quick' embodied carbon assessment of the projects. These tools were Kaliedoscope, EC3, TallyCAT (connects to EC3), and the SE2050 ECOM Embodied Carbon Estimator. With the available building information models, Tally was the fastest and most effective tool to get an embodied carbon estimate for interior walls, structure, and enclosure. Other tools had a limited scope of available materials, or required significant vetting/processing of Revit outputs.

Autodesk Revit is planning to offer their own embodied carbon tool, which will hopefully offer another option when it is released.

TALLY LIMITATIONS

1. Tally does not allow users to add product-specific EPDs that are not already in their database.

2. Tally does not include any way to estimate mechanical, electrical, plumbing, or general sitework embodied carbon impacts.

3. Tally uses national average transportation distance factors for life cycle stage A4, which may differ from region to region.

EMBODIED CARBON LIMITATIONS

For key cladding materials, travel distances were adjusted where available. The study planned to use more specific travel distances, but not many were able to be determined from submittal information/manufacturer information typically available for a project.

EMBODIED CARBON RESULTS

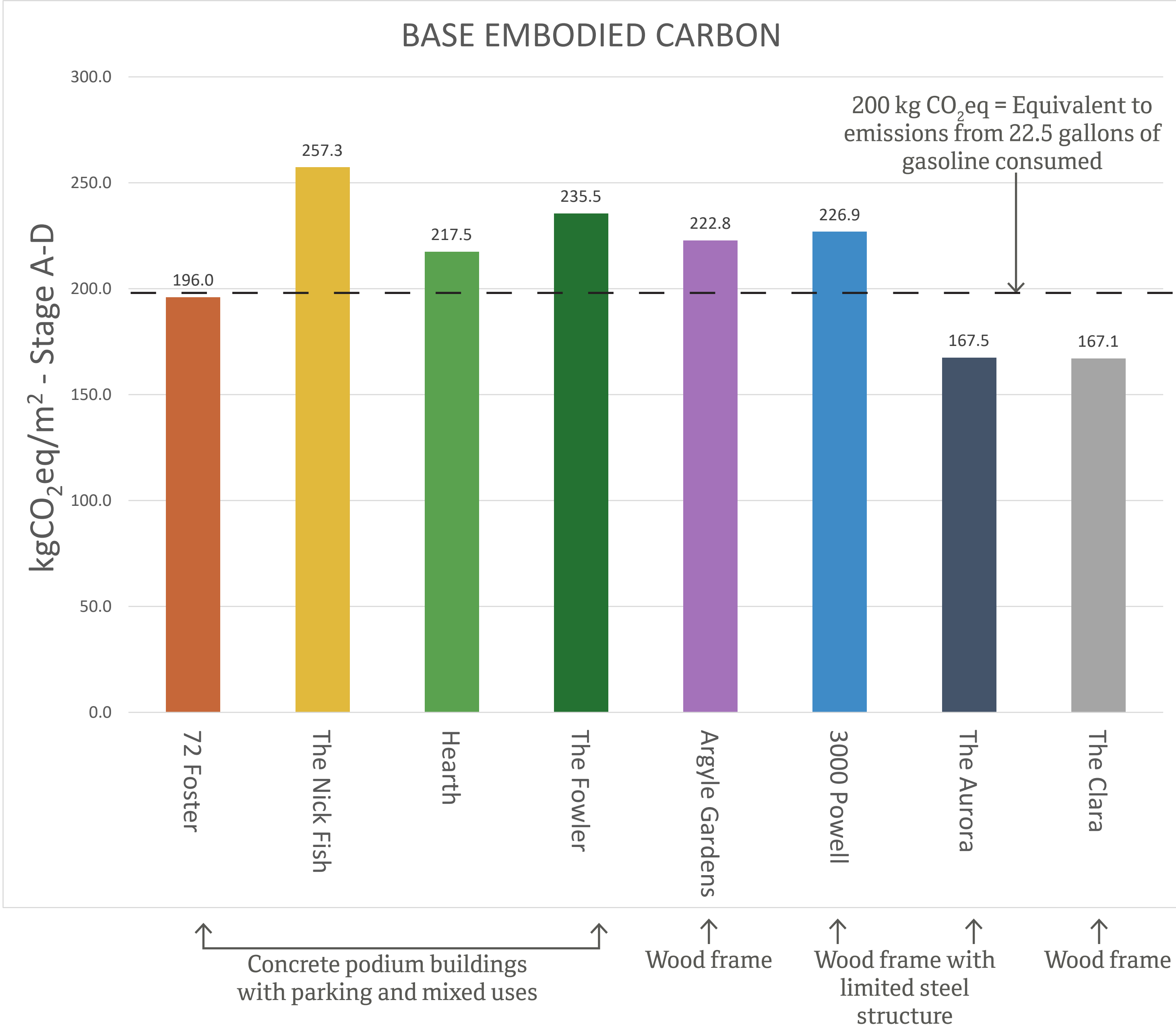
BASE

This chart shows the base embodied carbon, including biogenic carbon, normalized by kg CO_2eq per square meter of the building area.[1]

The embodied carbon ranges from a low of 167.1 kg CO_2eq/m^2, to an average of 219.4 kg CO_2eq/m^2, to a high of 257.3 kg CO_2eq/m^2. There is approximately a 35% difference between the low and high values.

Although wood frame buildings were expected to have a significantly lower embodied carbon than wood frame on concrete podiums, these results indicate that the structural system does not outweigh other considerations such as surface area ratios and housing efficiency.

Because many of the concrete podium buildings have a significant area of unconditioned parking included in this square footage, this normalization is important to look at with the context of the other embodied carbon charts that compare embodied carbon with housing efficiency. Additionally, the parking areas typically do not have a complete thermal enclosure or windows.



1 Gross building area as defined in the 2021 IBC including conditioned and unconditioned area.

EMBODIED CARBON

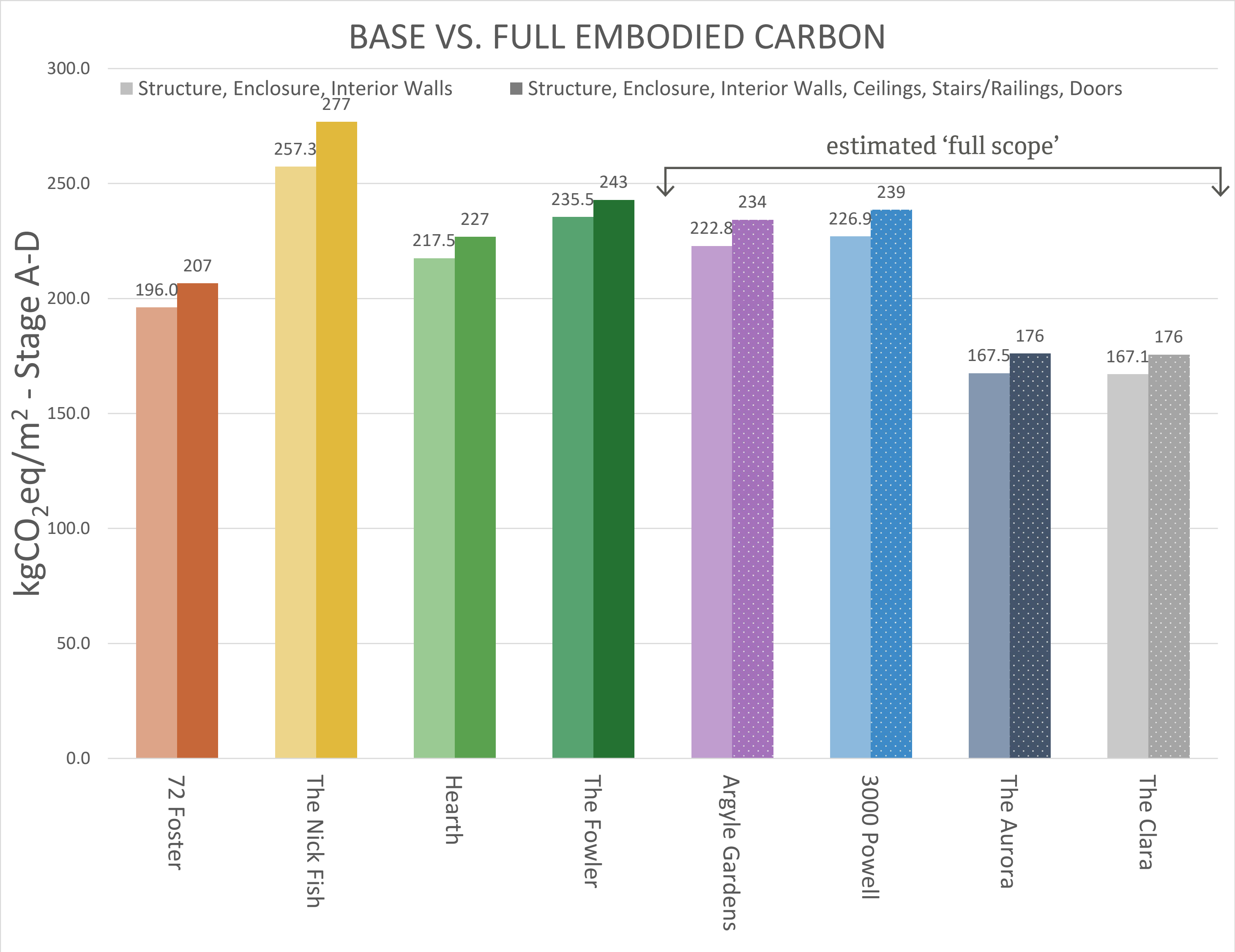
BASE VS. FULL

This chart compares the embodied carbon (GWP) of the base and full scope normalized by kg CO_2 eq per square meter of the building area.

The base scope included the buildings' structure, enclosure, and interior walls; the full scope added categories of stairs, railings, doors, and ceilings. These added categories contributed 4 to 6% (average 5%) to the overall embodied carbon of the four in-depth projects: 72 Foster, Nick Fish, Hearth and Fowler.

This 5% percentage factor was then applied to the projects for which a full scope was not produced.

Although 5% does not seem like much, it is a significant amount when the total building area is considered.



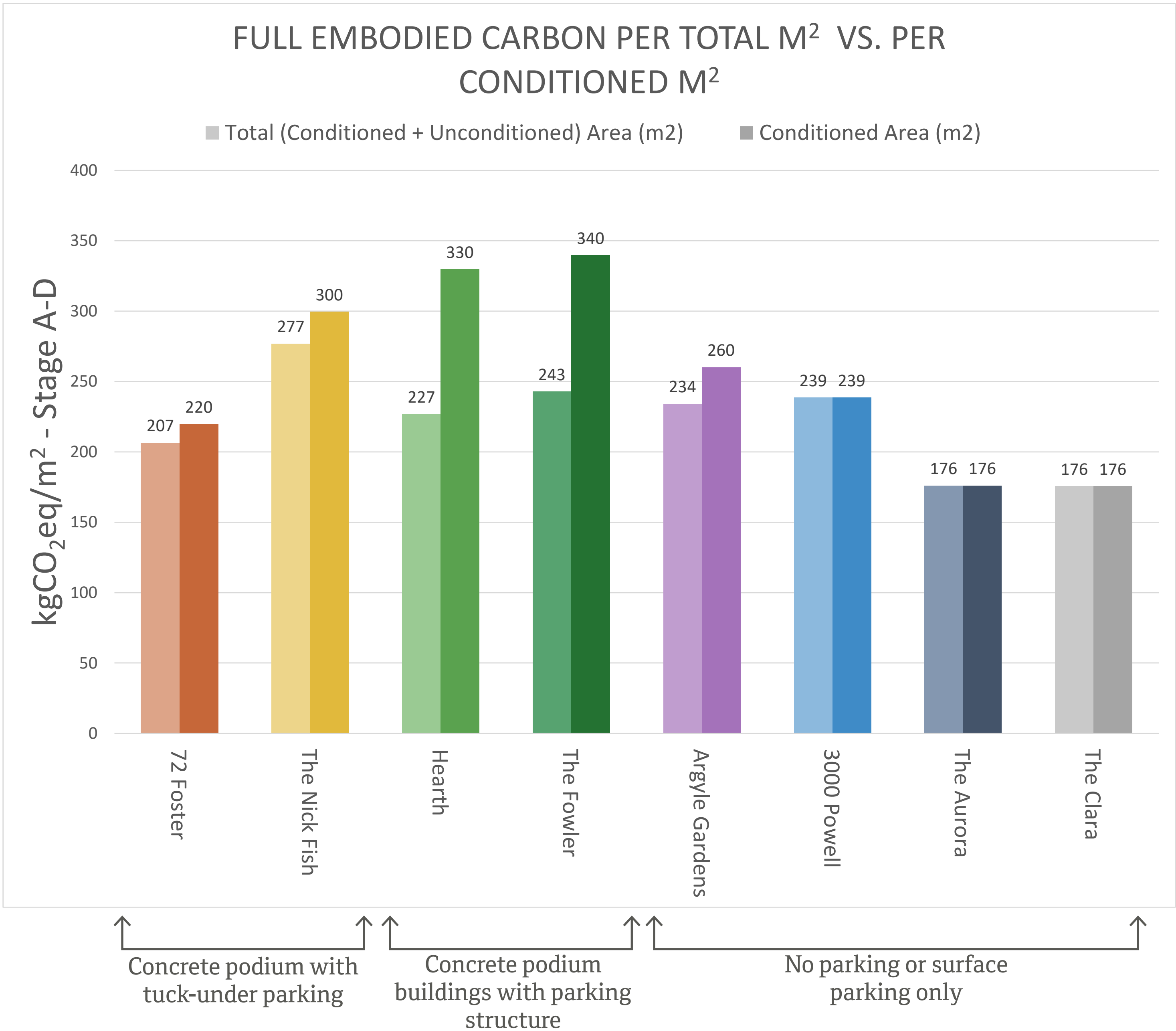
EMBODIED CARBON

TOTAL VS. CONDITIONED AREA

This chart compares the embodied carbon of the base and full scope normalized by kg CO_2 eq per square meter of the total (conditioned + unconditioned) building area.

Although concrete podium help provide parking in a way that conserves density, they come with a significant embodied carbon cost.

In multifamily buildings, decreasing the amount of conditioned space through outdoor walkways and stairs is one strategy that can reduce embodied carbon by reducing the area that needs to be heated and cooled. This can also potentially reduce embodied carbon if less materials need to be used.



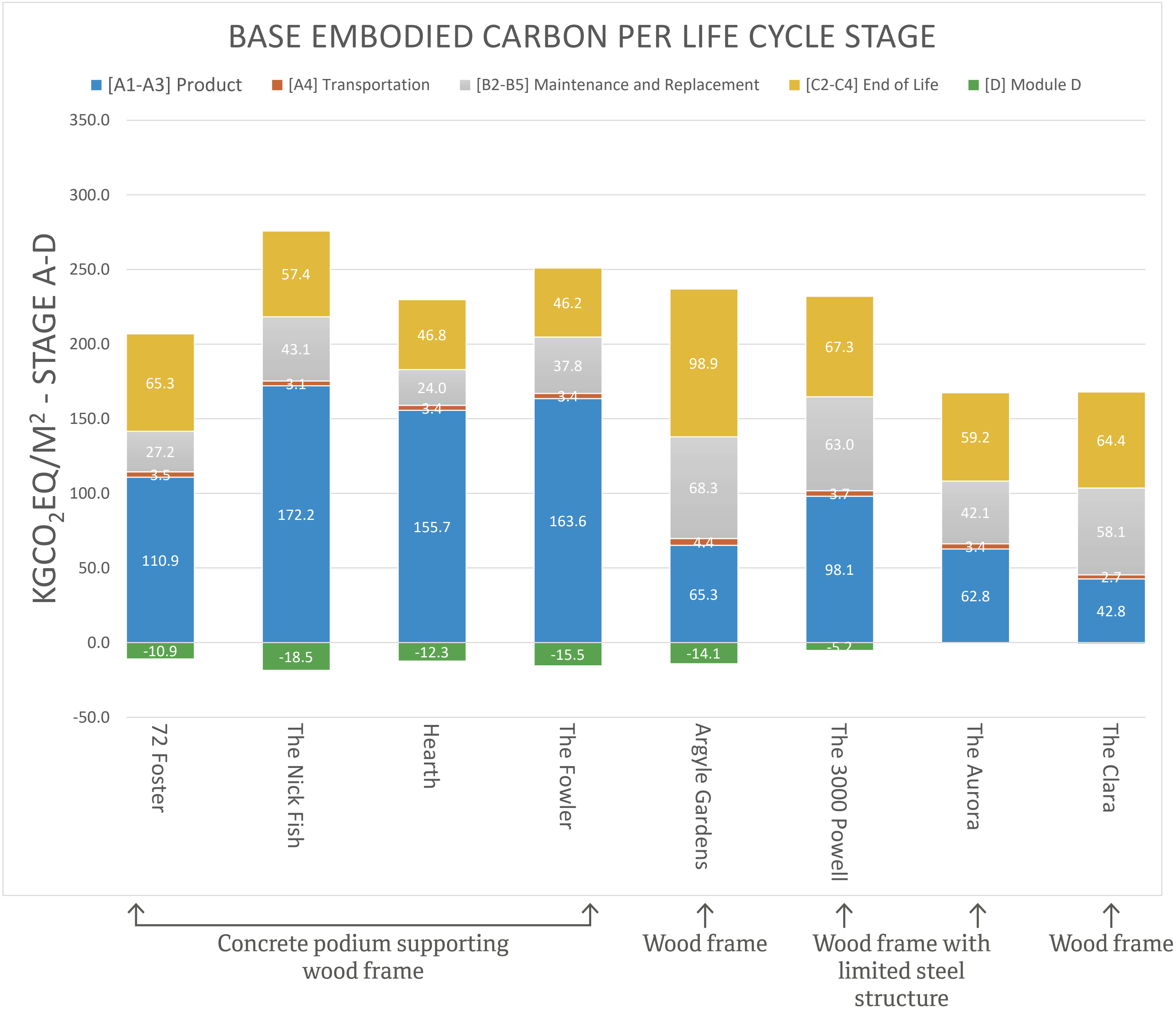
EMBODIED CARBON

PER LIFE CYCLE STAGE

This chart compares the base embodied carbon per life cycle stage, normalized by kg CO_2 eq per square meter of the total building area and including biogenic carbon.

For the concrete podium buildings, the product stage makes up the largest component of the embodied carbon. However, for the primarily wood frame buildings, the use and end-of-life stages combined make up the greatest component of the embodied carbon.

Shifting the embodied carbon burden towards the use and end-of-life stage helps push down present emissions and provides more time to solve for embodied carbon reductions.

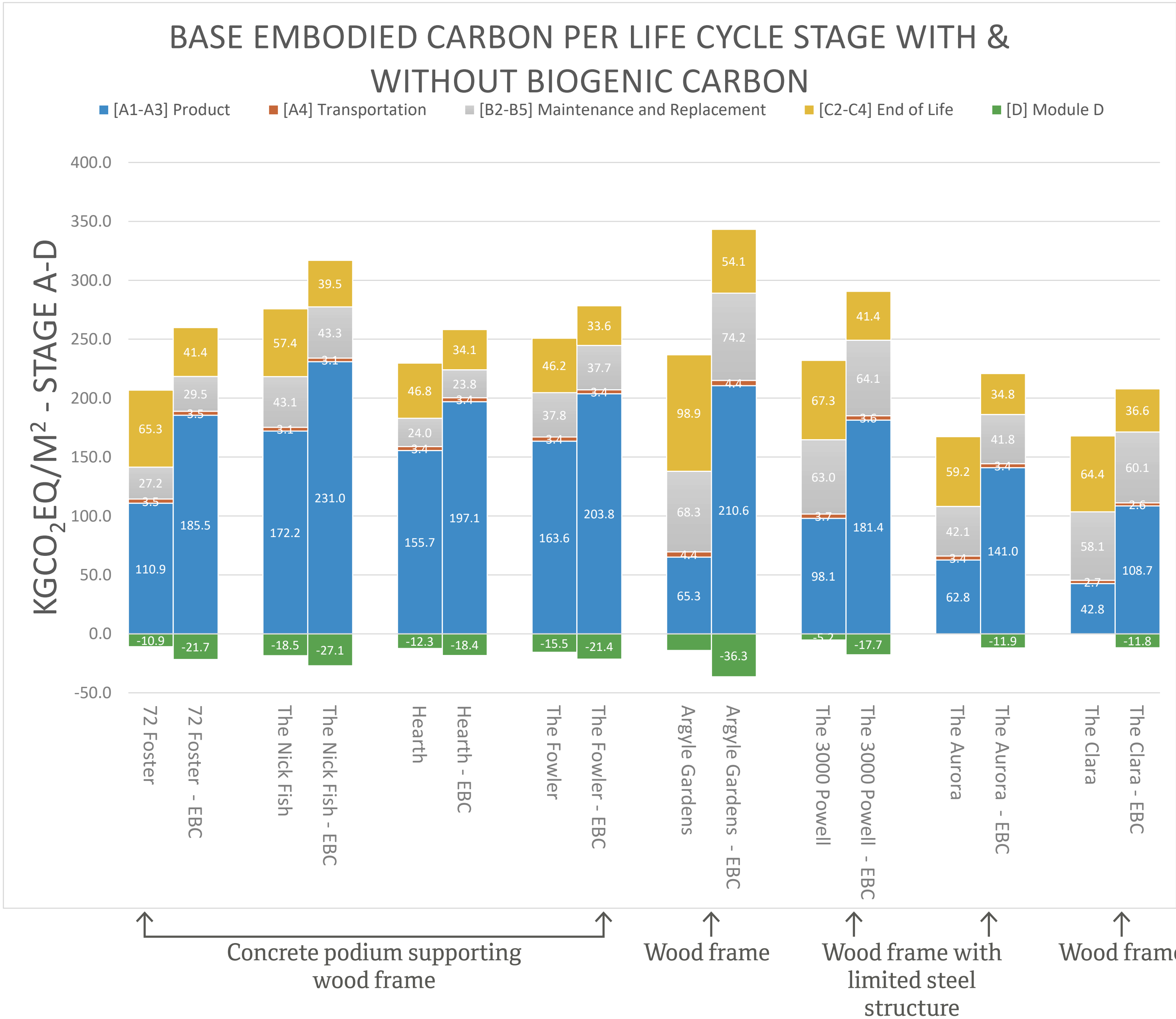


EMBODIED CARBON

PER LIFE CYCLE STAGE - INCLUDING AND EXCLUDING BIOGENIC CARBON

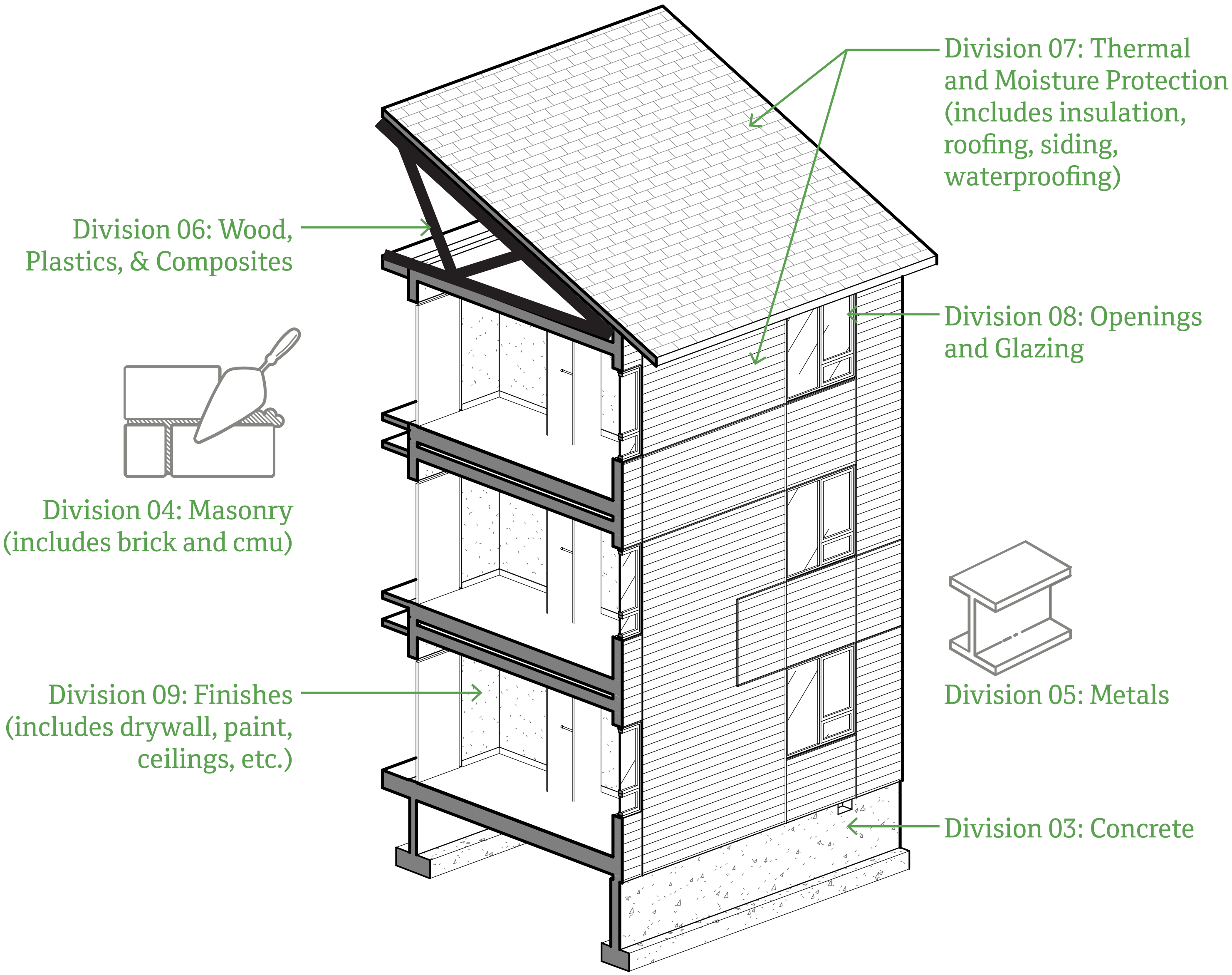
This chart compares the base embodied carbon per life cycle stage, normalized by kg CO_2 eq per square meter of the total building area, including and excluding biogenic carbon (EBC).

Across the board, all projects display a higher total embodied carbon when biogenic carbon is excluded. This variation is most apparent in the Argyle Gardens project, which is a Type V wood construction with small units (primarily single room occupancy) with two and three story buildings. Excluding biogenic carbon actually displays a lower end-of-life embodied carbon, because some biogenic carbon leaves the system at end-of-life, when including biogenic carbon.



EMBODIED CARBON

PER DIVISION



The next page's graph breaks down the embodied carbon per material division, a standard way that materials are categorized during construction. These are all the categories that are currently able to be assessed with Tally. Those that are not able to be assessed are not shown.

EMBODIED CARBON

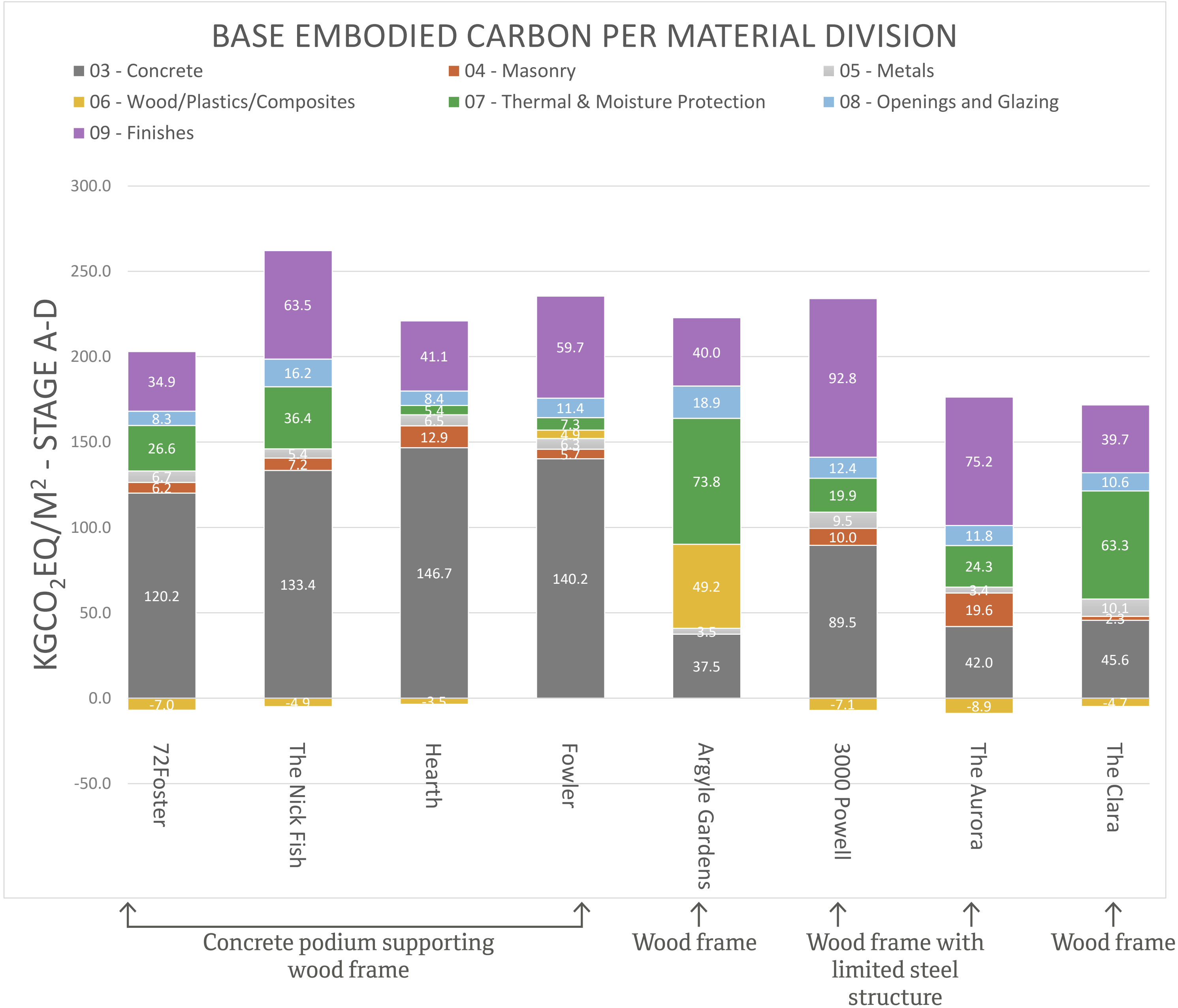
PER DIVISION

This chart compares the base embodied carbon per material division, normalized by kg CO_2 eq per square meter of the total building area.

Concrete makes up over half of the base embodied carbon for the concrete podium buildings.

For the smaller two/three story projects (Argyle Gardens and The Clara), the smaller concrete foundations contribute a smaller percentage to the overall embodied carbon. These projects have a greater surface area ratio, which is likely reflected in the higher embodied carbon of the thermal and moisture protection.

There is a large variation in finishes, which could relate to the amount of gypsum wallboard needed to achieve fire ratings in different construction types.



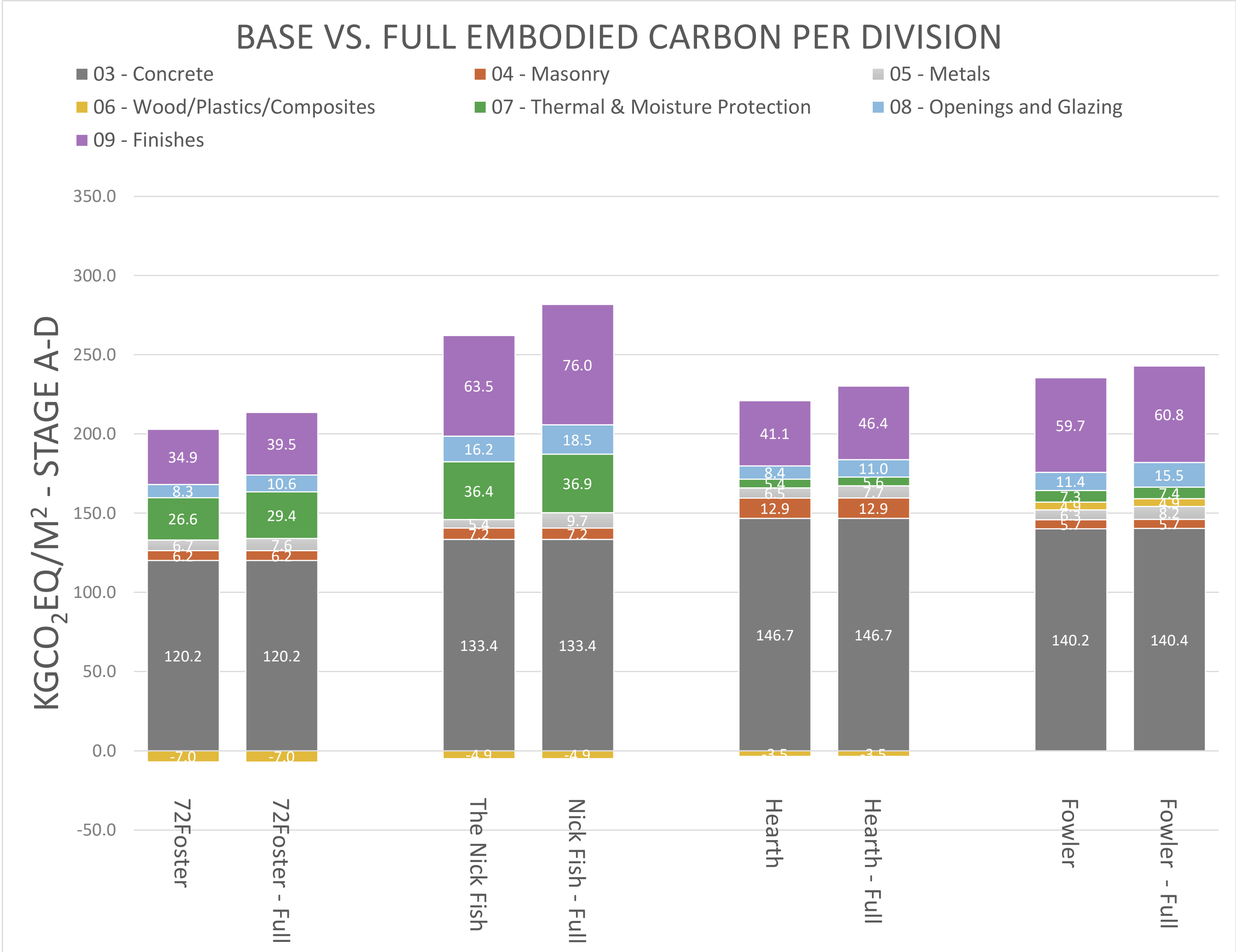
EMBODIED CARBON

PER DIVISION - 'BASE' VS. 'FULL' EMBODIED CARBON

This chart compares the base vs. full embodied carbon per material division, normalized by kg CO_2 eq per square meter of the total building area, including biogenic carbon.

The base scope included the buildings' structure, enclosure, and interior walls; the full scope added categories of stairs, railings, doors, and ceilings. These added categories contributed 4 to 6% (average 5%) to the overall embodied carbon of the four in-depth projects: 72 Foster, Nick Fish, Hearth and Fowler.

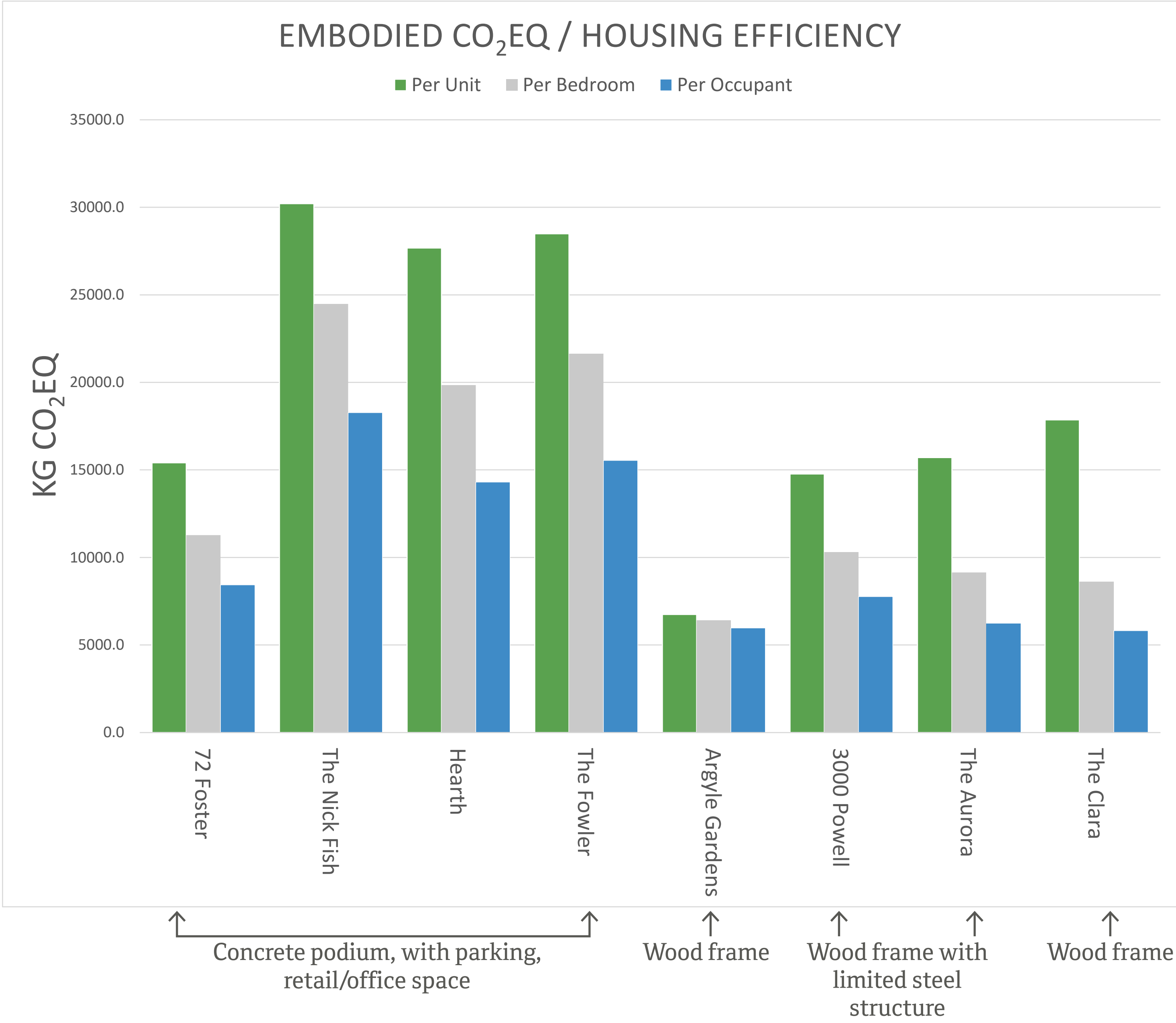
The impact of the additional scope is reflected in the categories of finishes, openings, thermal/moisture protection, and metals.



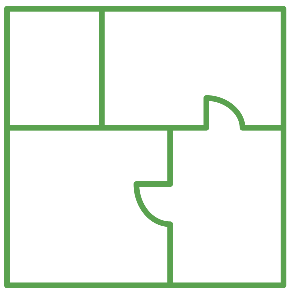
Embodied carbon is not typically communicated in terms of embodied carbon per unit, bedroom, or occupant. However, this metric is an interesting way to show the efficiency of a building's embodied carbon.

Four of the projects contain office, retail, or parking uses, which is reflected in the lower housing efficiency for the embodied carbon.

The average[1] embodied carbon per unit, per bedroom, and per occupant respectively is 19,604 kg CO_2eq/unit, 13,965 kg CO_2eq/bedroom and 10,290 kg CO_2eq/occupant. Per year of a sixty year life span, the median embodied carbon is 326 kg CO_2eq/unit/yr, 233 kg CO_2eq/bedroom/yr, and 172 kg CO_2eq/occupant/yr.

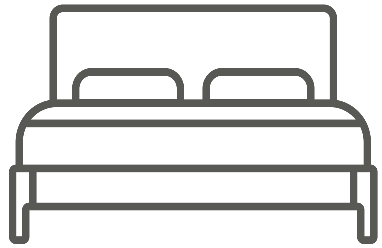


1 20% trimmed mean

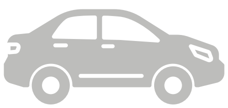


Mean:
326 kg CO_2eq/unit/yr

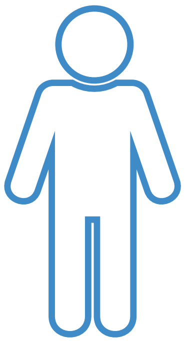
= .073 gasoline-powered car driven for one year (836 miles driven)*



Mean:
233 kg CO_2eq/bedroom/yr



= .052 gasoline-powered car driven for one year (597 miles driven)*



Mean:
172 kg CO_2eq/occ/yr

= .038 gasoline-powered car driven for one year (441 miles driven)*

*Converted using EPA's Greenhouse Gas Equivalencies Calculator https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
**Mean values are 20% trimmed means

7.0 OPERATIONAL VS. EMBODIED CARBON

EMBODIED VS. OPERATIONAL

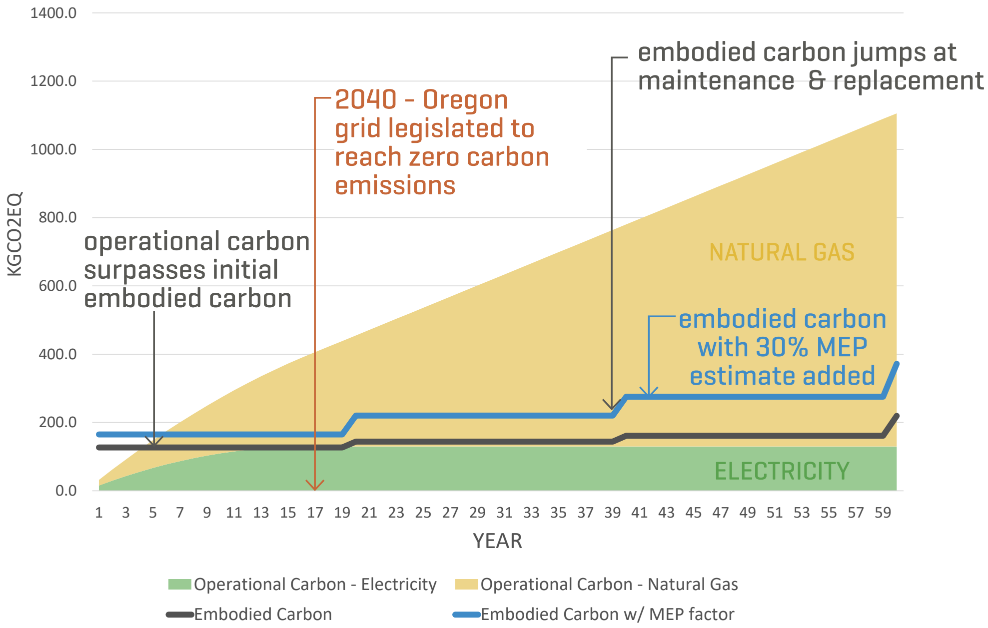
The following pages compare the operational and embodied carbon across a sixty year lifespan for the studied projects. Although the projects have different years of construction, for the purposes of this comparison, year one is equivalent to 2023. Year 17 is equivalent to 2040, which is the year that the Oregon is scheduled to achieve zero carbon emissions. The operational carbon emissions from natural gas continue to increase throughout the building's life cycle and becomes an increasingly large component of the carbon footprint, while emissions due to electricity trend towards zero on an annual basis.

The embodied carbon is shown two ways - one as calculated for this study, and one as estimated to include an additional approximation for MEP systems. There is little existing research on MEP systems in housing or other building types. One study by Chartered Institution of Building Services Engineers (CIBSE) and Elementa Consulting found that the embodied carbon of a dwelling's heating and hot-water systems accounts for up to 25% of the total embodied carbon, and that refrigerant leakage has a notable impact.[1] A Carbon Leadership forum study estimated that, for commercial offices in the Pacific Northwest, the embodied carbon from the initial MEP systems ranged from a low estimate of 40 kg CO_2eq/m^2, to a medium estimate of 50 kg CO_2eq/m^2, to a high estimate of 75 kg CO_2eq/m^2. [2] The MEP impacts made up about 11% of their initial embodied carbon, and they estimate that these impacts reoccur every fifteen years.[2] The research team expects multifamily MEP impacts to exceed an office building due to the density of bathrooms and kitchens, as well as the more continuous occupation of a residential building.

Based on this limited background info, the MEP embodied carbon was estimated to be 30% of the embodied carbon impacts for this study's initial embodied carbon. Depending on the initial embodied carbon of the project, this ranged from 14.3 kg CO_2eq/m^2 to 57.5 kg CO_2eq/m^2 across the projects.

The MEP estimate was then applied again at year 20, year 40, and year 60, to account for MEP replacements and end-of-life. Hopefully, this estimate MEP factor will, at least, account for some of elements that are not included in the LCA.

Example of an Embodied vs. Operational Chart:

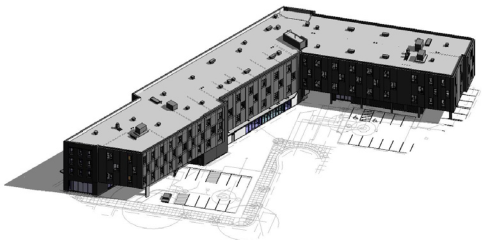


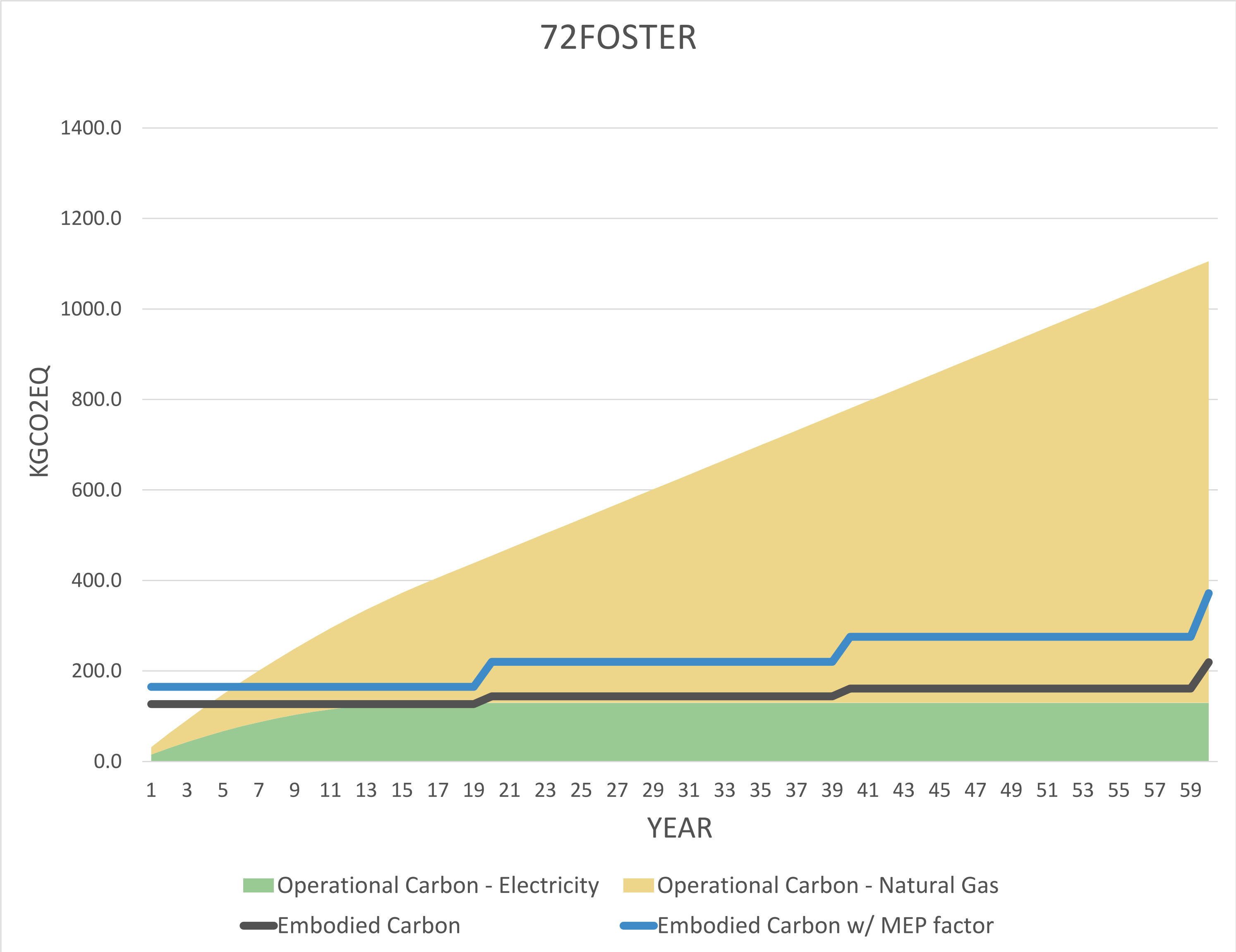
1 Hamot, L., Bagenal George, C., Machnouk, Y., &; Dugdale, H. 2021. *Embodied Carbon in Building Services - Residential Heating - CIBSE TM65.1*. The Chartered Institution of Building Services Engineers (CIBSE).

2 Rodriguez, B.X., Lee H.W., Simonen, K., Huang, M., & Ditto, J. 2019. *Estimates of Embodied Carbon for Mechanical, Electrical, Plumbing and Tenant Improvements, Summary Document.* The Carbon Leadership Forum.

EMBODIED VS. OPERATIONAL

72FOSTER

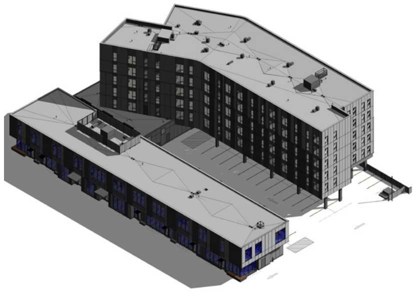




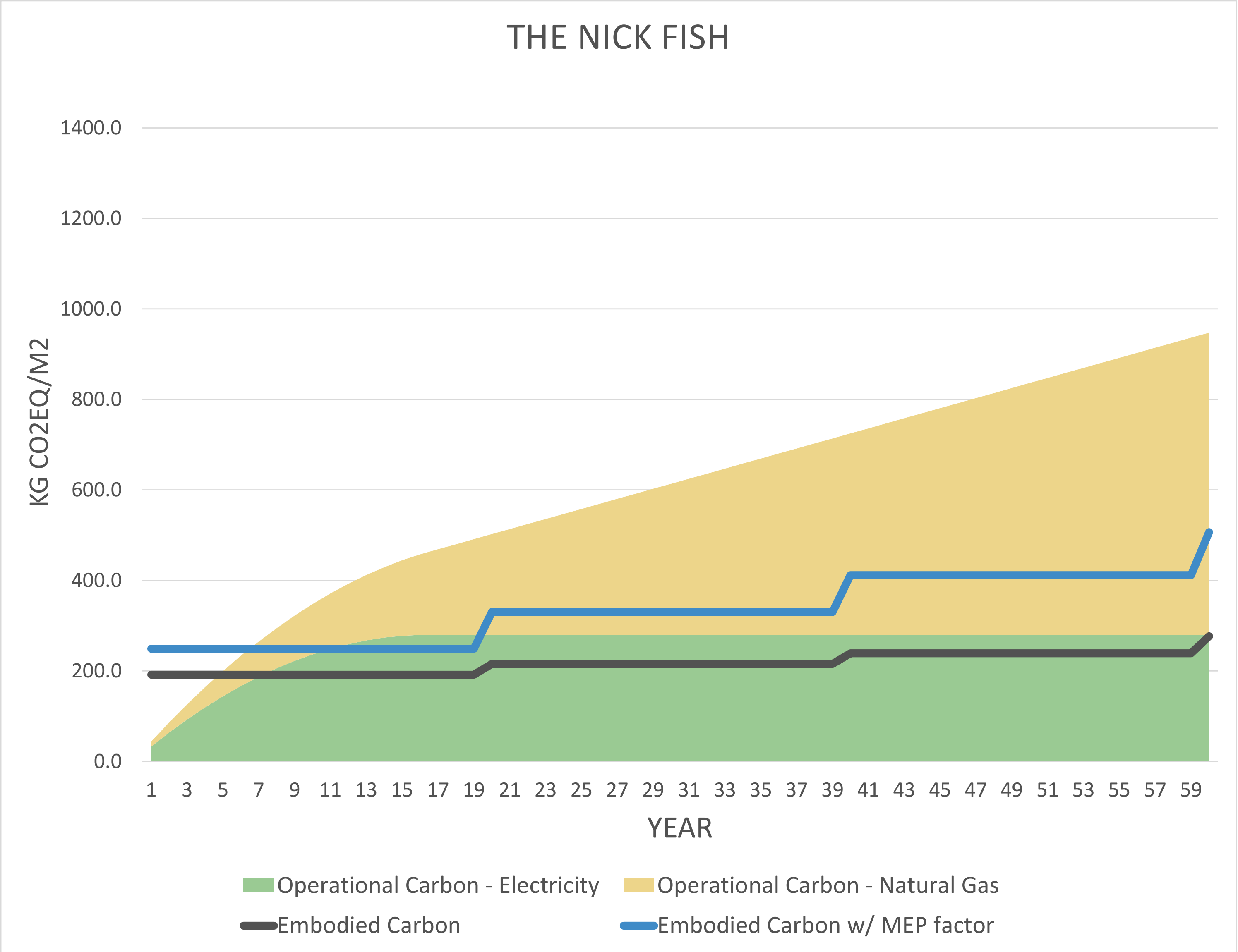
- For 72Foster, the operational carbon overtakes the initial embodied carbon calculated in this study at year 4.2, or year 5.6 if the MEP factor of 30% is included.
- This project has a large solar panel installation, which is evident in the relatively low portion of operational carbon from electricity.
- Replacing the gas systems around year 20 could lead to an lower whole life carbon.

EMBODIED VS. OPERATIONAL

THE NICK FISH

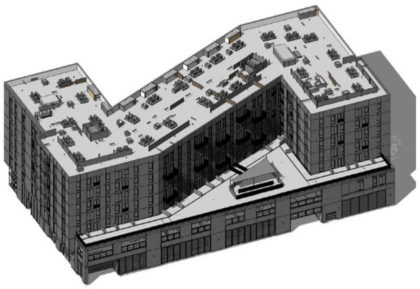


- For the Nick Fish, the operational carbon overtakes the calculated initial embodied carbon at year 5.8, or year 6.5 if a 30% MEP factor is included.
- At the end-of-life, the embodied carbon makes up 35% of the whole life carbon if the MEP factor is included.
- The Nick Fish has a smaller solar panel installation compared to 72 Foster, so it makes less of an impact on reducing the electricity use.

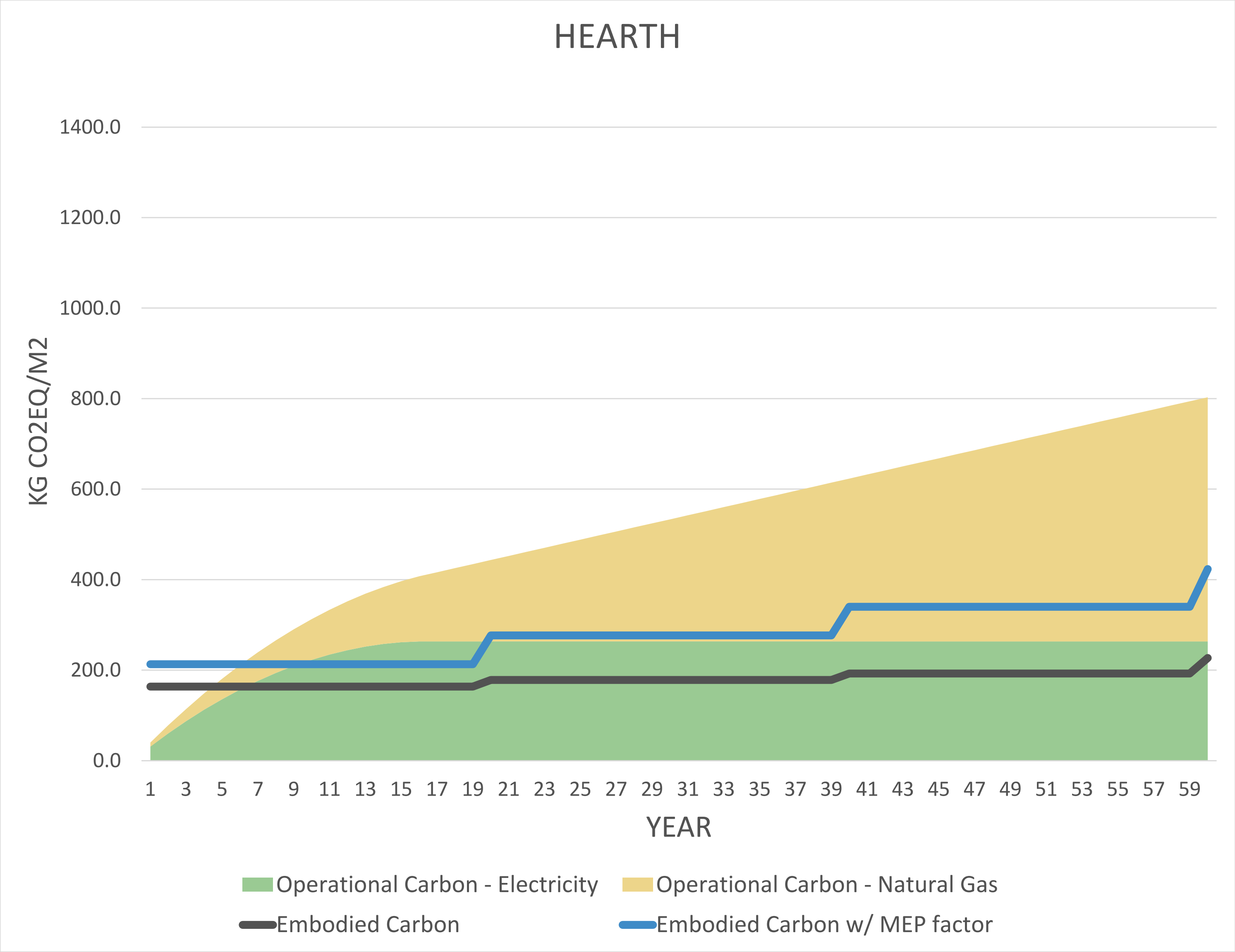


EMBODIED VS. OPERATIONAL

HEARTH



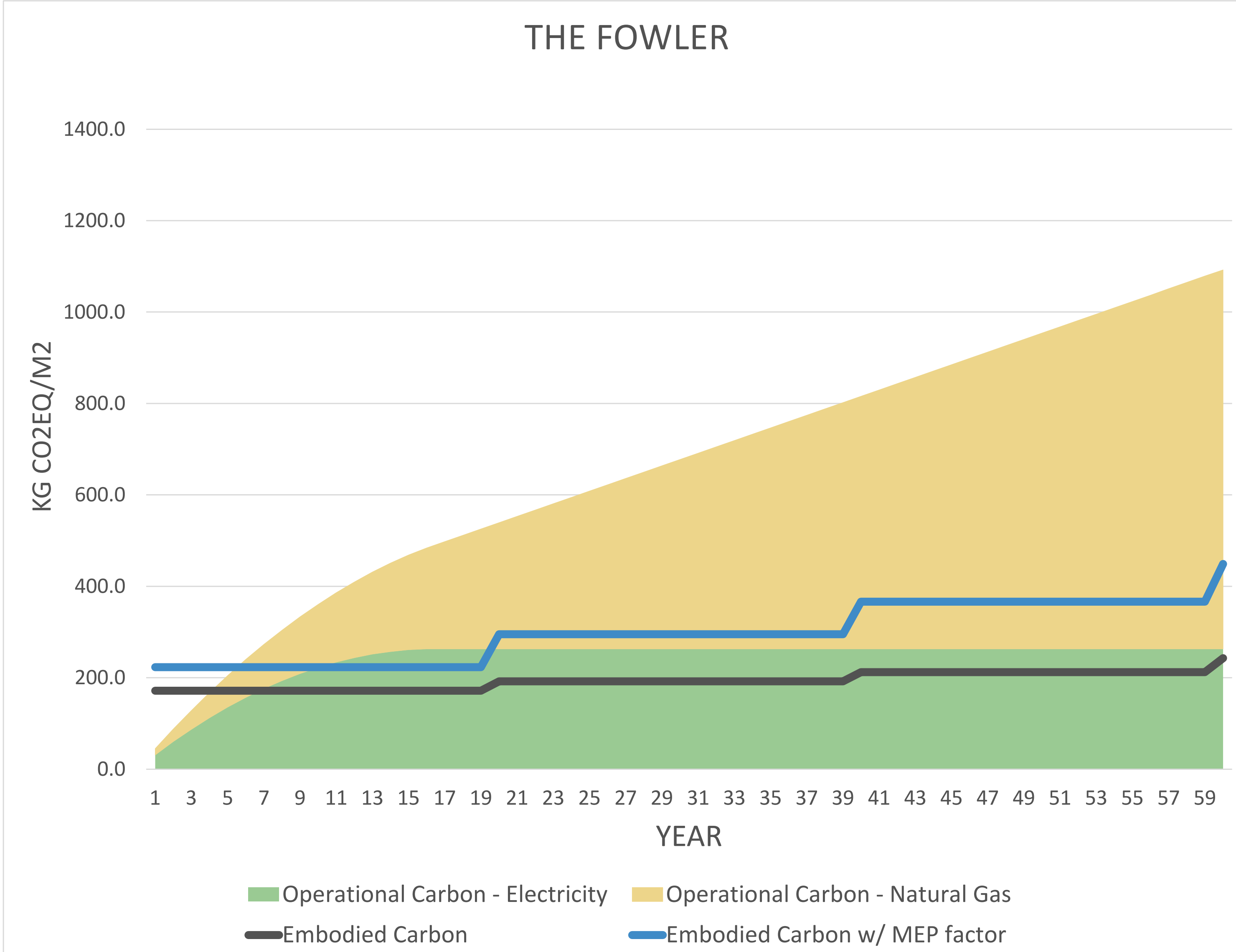
- For Hearth, the operational carbon (predicted by energy model) overtakes the calculated initial embodied carbon at year 4.5, or year 6.1 if the 30% MEP factor is included.
- As with the Nick Fish, at the end-of-life, the embodied carbon makes up 35% of the whole life carbon if the MEP factor is included.
- The cumulative operational carbon for reaches 800 kg CO_2/ m^2 at year sixty.



EMBODIED VS. OPERATIONAL

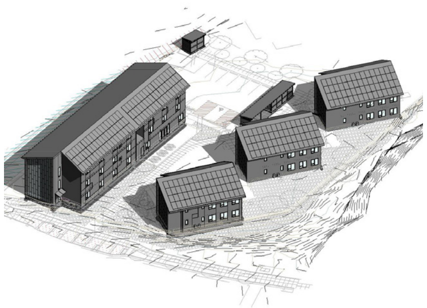
THE FOWLER

- For the Fowler, the operational carbon (predicted by energy model) overtakes the calculated initial embodied carbon at year 4.1, or year 5.5 if the 30% MEP factor is included.
- At the end-of-life, the embodied carbon makes up 30% of the whole life carbon if the MEP factor is included.
- Replacing the gas MEP systems around year 20 could lead to an overall lower whole life carbon.

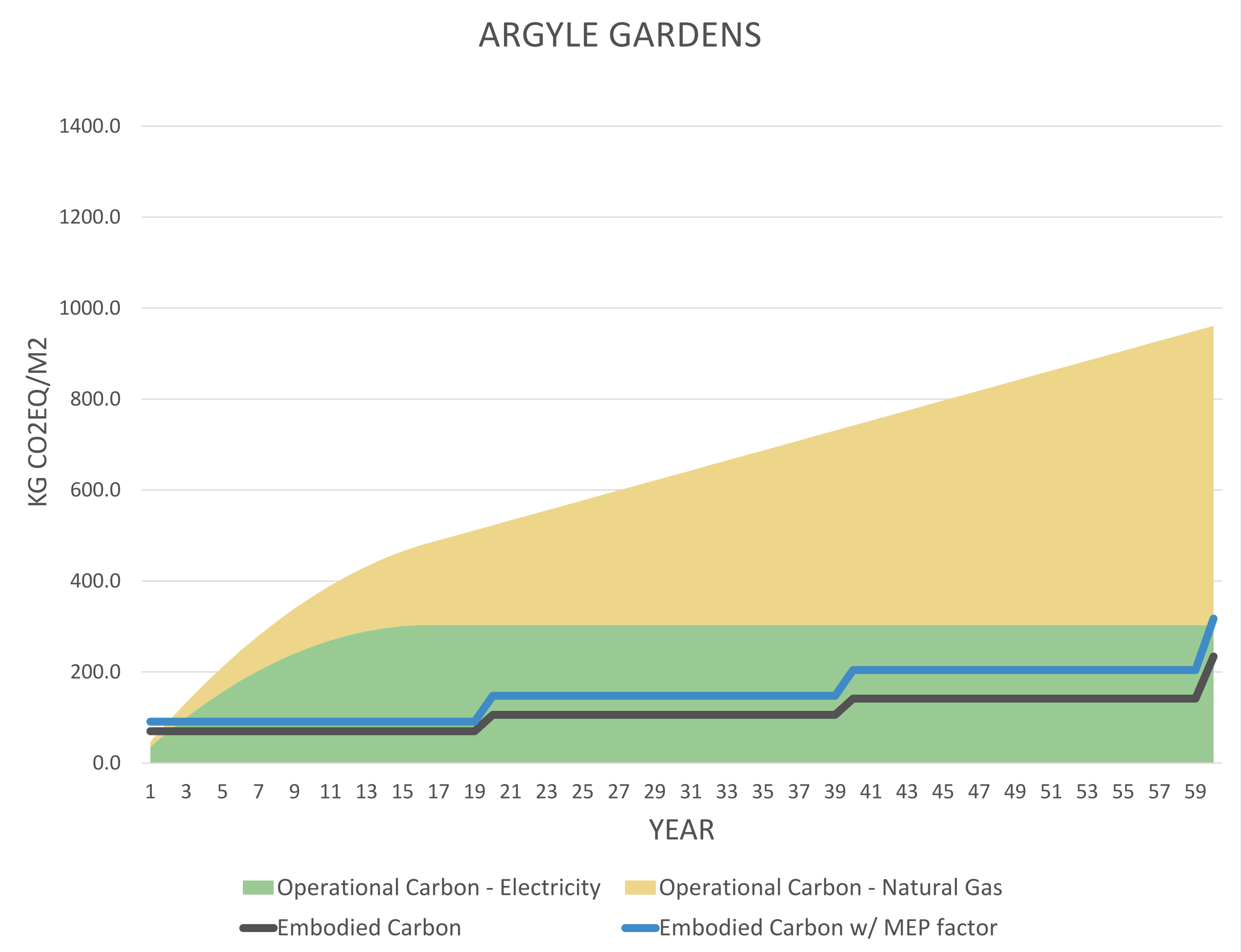


EMBODIED VS. OPERATIONAL

ARGYLE GARDENS

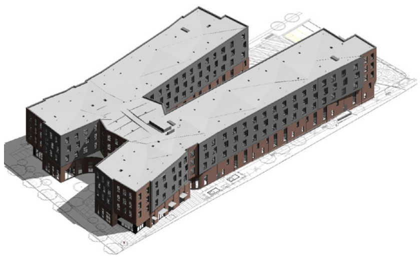


- For Argyle Gardens, the operational carbon (from actual building energy use data) overtakes the calculated initial embodied carbon at year 1.6, or during year 2.1 if a 30% MEP factor is included.
- At the end-of-life, the embodied carbon makes up 25% of the whole life carbon if the MEP factor is included.
- Argyle Gardens does have a solar panel installation which helps reduce the current electricity use.
- The cumulative operational carbon for reaches close to 1000 kg CO_2/m^2 at year sixty.

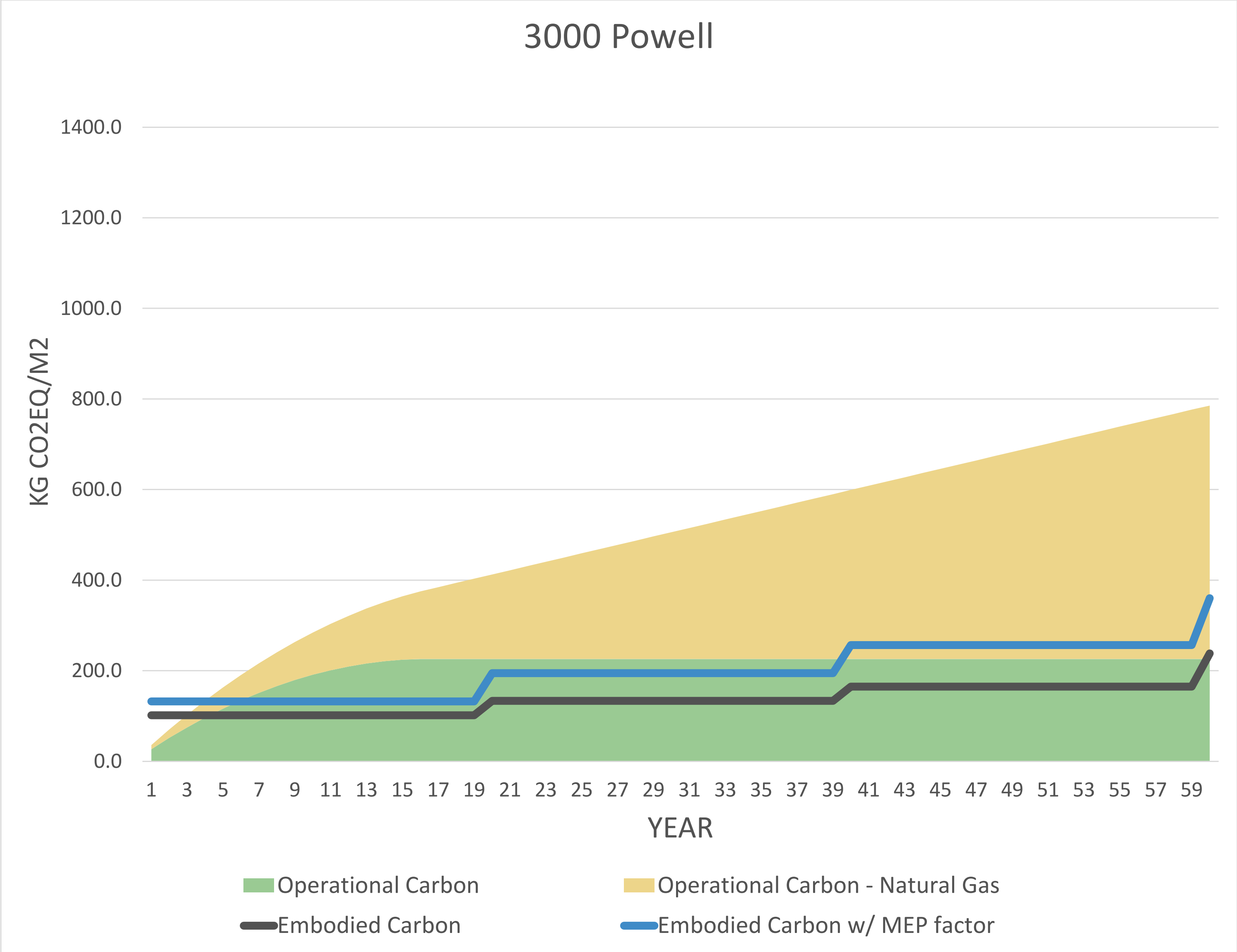


EMBODIED VS. OPERATIONAL

3000 POWELL

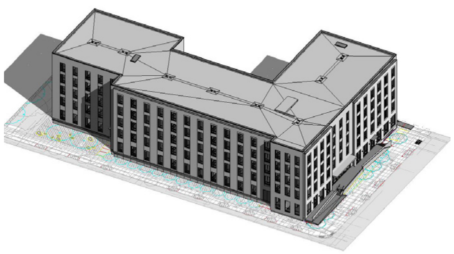


- The cumulative operational carbon for 3000 Powell reaches close to 800 kg CO_2/m^2 at year sixty.
- Operational carbon overtakes the embodied carbon at year 3.1 (or 4.2 when an additional MEP estimate is included).
- At the end of the sixty year life, embodied carbon (with MEP estimate) makes up 32% of the carbon impacts.

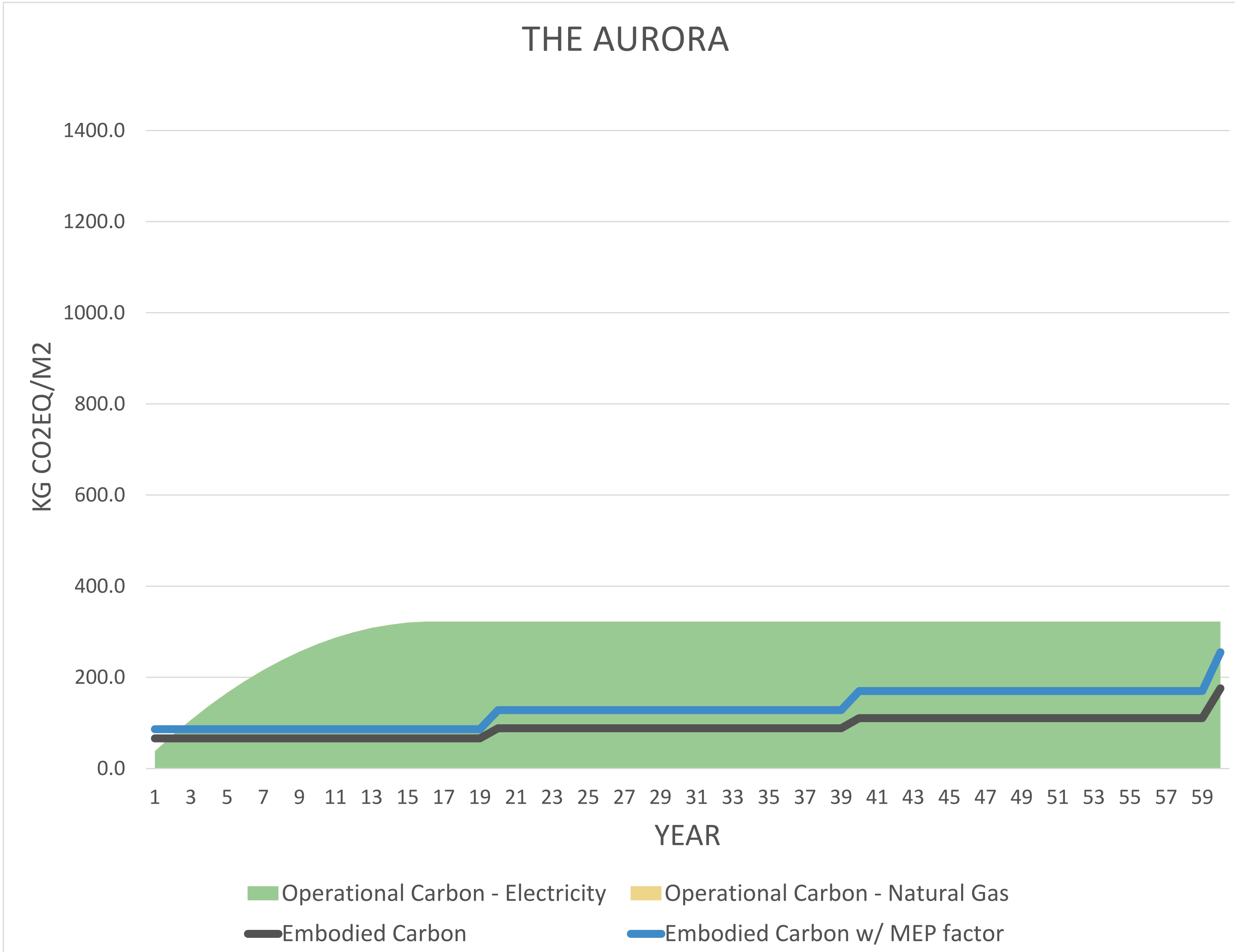


EMBODIED VS. OPERATIONAL

THE AURORA

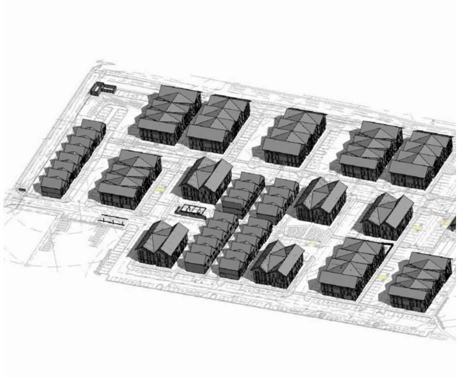


- For Aurora, the operational carbon (from actual building energy use data) overtakes the calculated initial embodied carbon at year 1.2, or year 2.5 if an MEP factor is included.
- This is the only all-electric project in this study, and the carbon savings are significant by 2040. The total cumulative operational carbon is approximately 322.5 kg CO_2eq/m^2 at year sixty.
- At the end-of-life, the embodied carbon (with MEP Estimate is predicted to make up 45% of the total whole life carbon impacts.

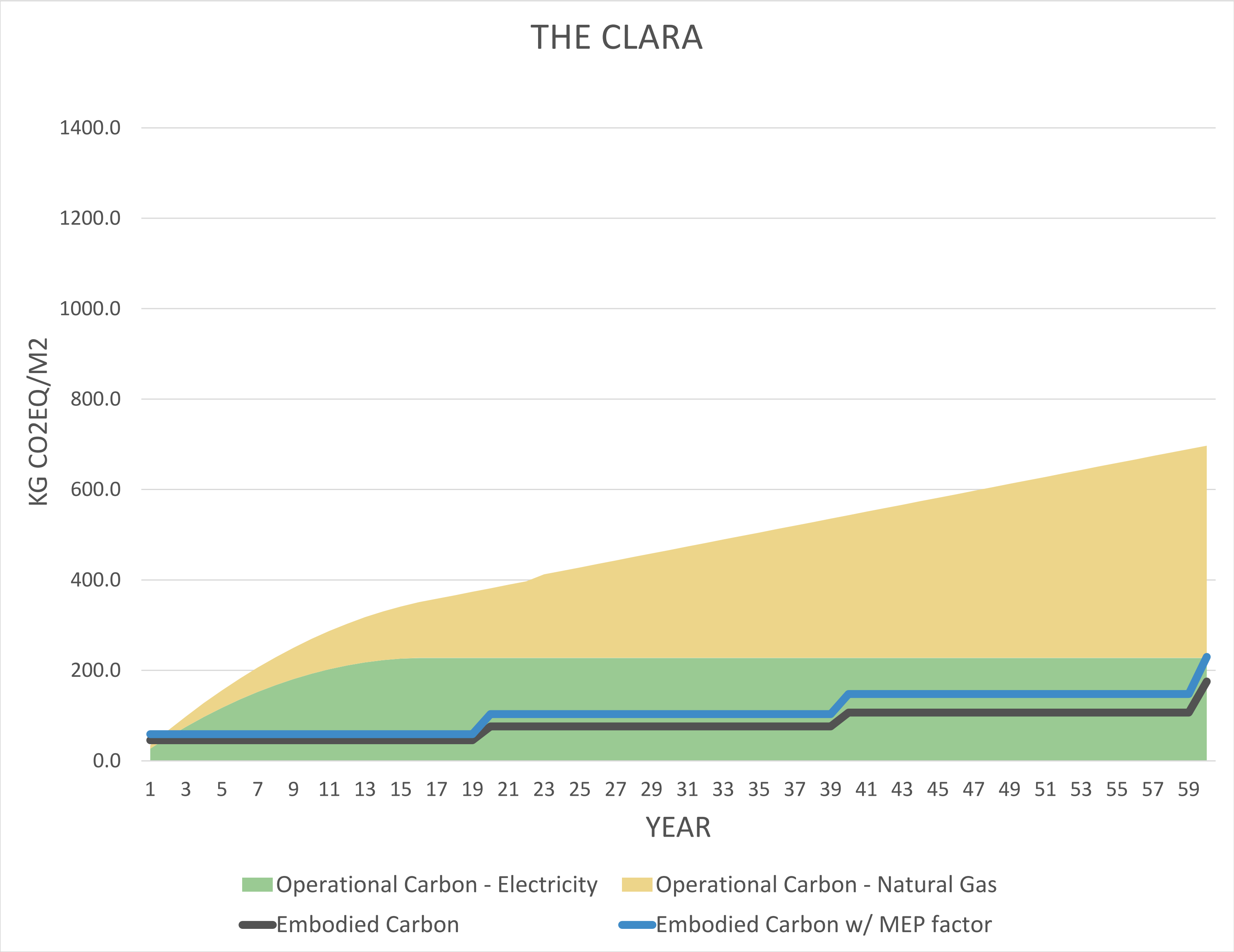


EMBODIED VS. OPERATIONAL

THE CLARA



- For the Clara, the operational carbon (from actual building energy use data) overtakes the calculated initial embodied carbon around year 1.4, or year 1.8 if the MEP factor is included.
- As with Argyle Gardens, compared to the concrete podium buildings, the operational carbon overtakes the embodied carbon sooner in these wood frame buildings
- At the end of the sixty year life, embodied carbon (with MEP estimate) makes up 25% of the carbon impacts.



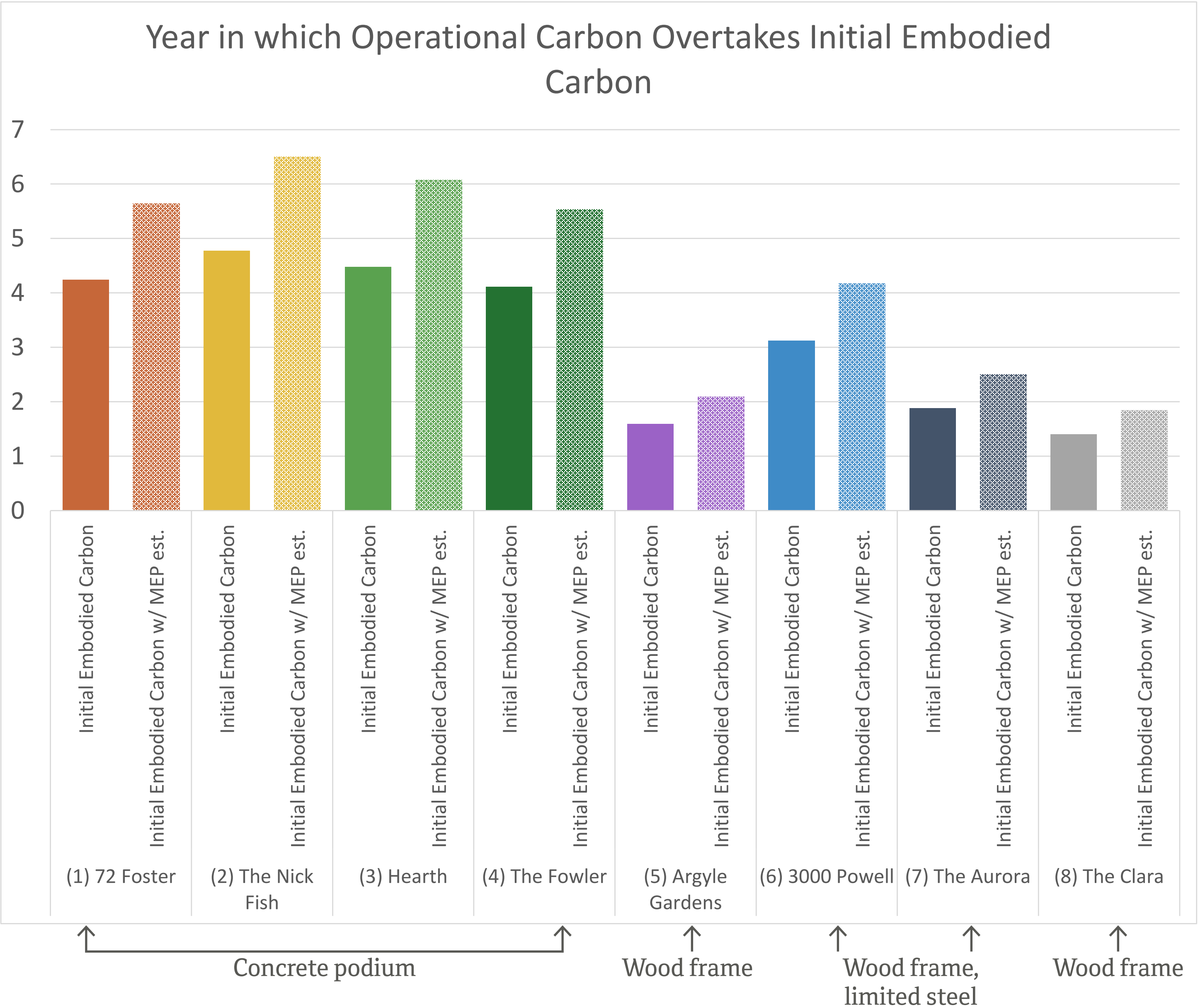
EMBODIED VS. OPERATIONAL: CROSSOVER YEAR

In the concrete podium projects, the operational carbon surpasses the initial embodied carbon in the 4th year (excluding an estimate of MEP embodied carbon) or in the 6th or 7th year if an MEP embodied carbon estimate is included.

In the projects with all wood frame construction, the operational carbon overtakes the initial embodied carbon in the 1st year (excluding an estimate of MEP embodied carbon) or in the 2nd or 3rd year if an MEP embodied carbon estimate is included.

Between the two wood frame + limited steel buildings, 3000 Powell has both a lower estimated operational carbon and higher embodied carbon (likely attributable to a higher concrete quantity) when compared to the similar project The Aurora. As expected, the operational carbon overtakes the embodied carbon later in 3000 Powell than the Aurora.

It's important to recognize that due to the limitations (necessary omissions) of embodied carbon estimate, the actual crossover year is almost certainly higher.

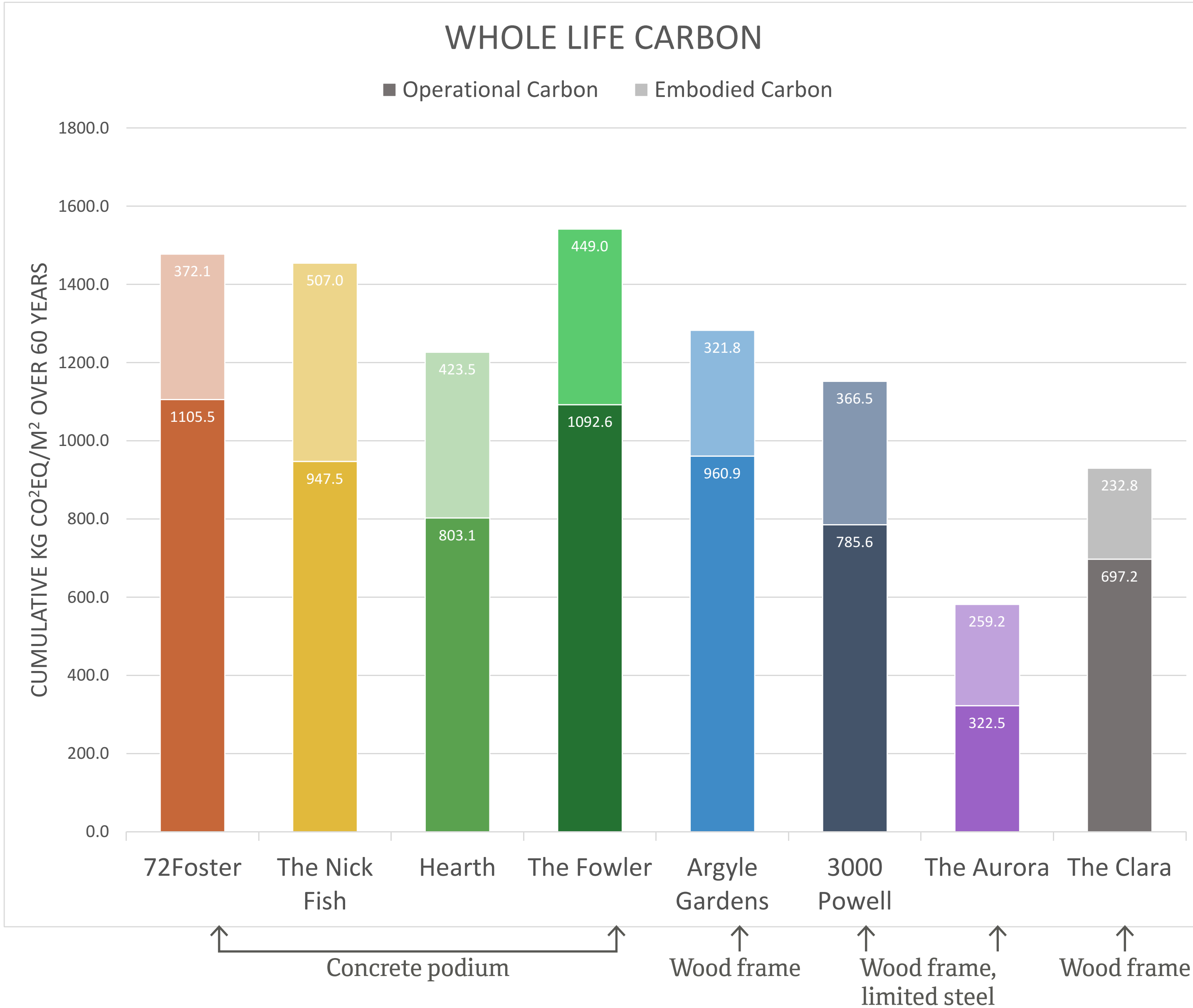


The total whole life carbon ranges from 582 kg CO_2eq/m² to 1542 CO_2eq/m². Over the 60-year lifespan of each building, operational carbon tends to dominate the overall whole life carbon of these projects.

The benefits of lower carbon intensity construction techniques (wood framed only) can easily be overcome with natural gas systems and/or less-than-optimium HVAC systems.

Note that the Argyle Gardens, the small-scale all-wood modular project in Climate Zone 4 exceeds the whole life carbon of some of the large housing projects that incorporate steel and concrete in their construction.

The Aurora accumulation over time is lower than the others due to the benefits of an all-electric building where the grid becomes more renewable over time.

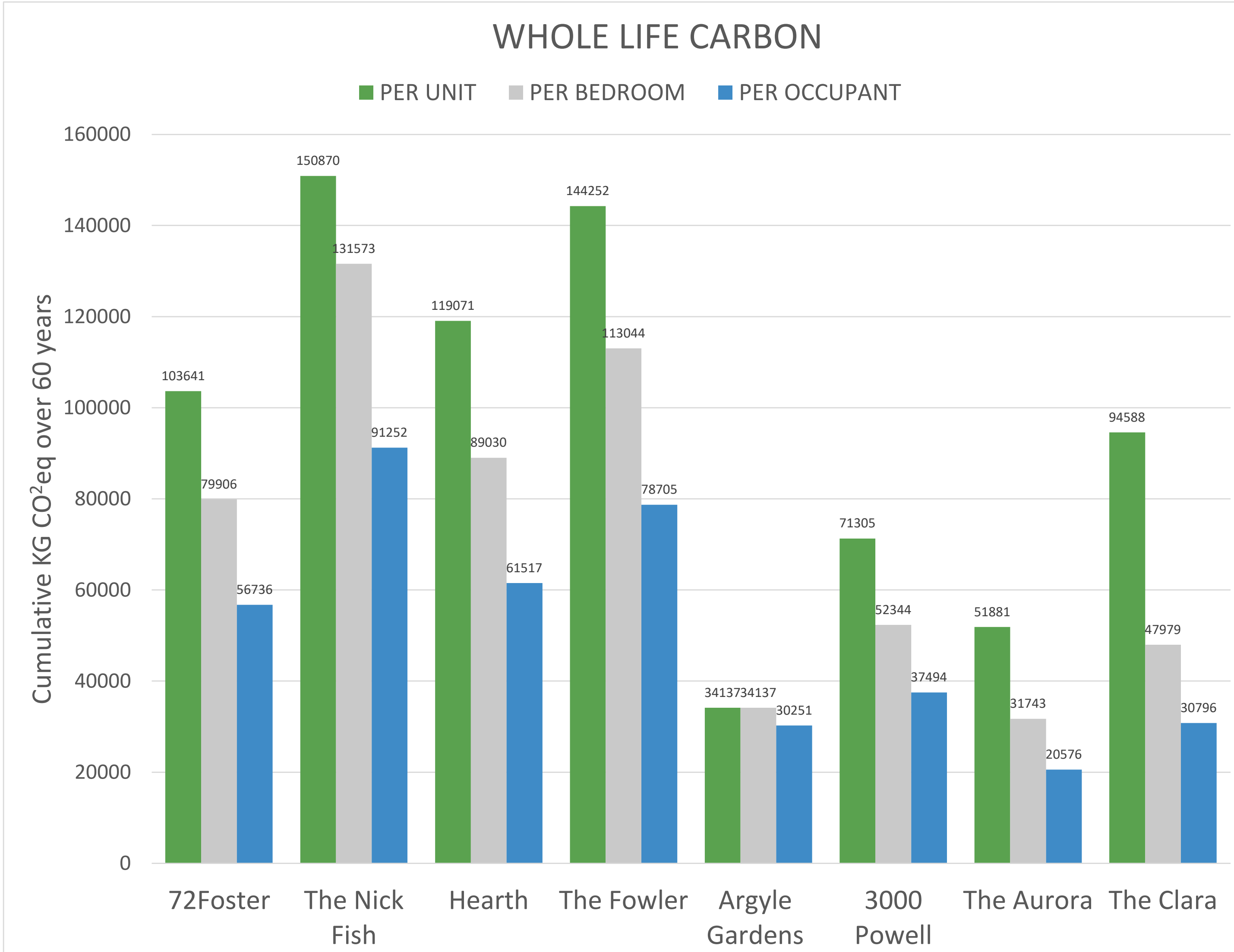


When looking at ways in which to maximize housing availability while reducing carbon impacts, this chart is instructive. Understanding carbon intensity by unit, bedroom and occupant helps to inform the most effective ways to house people while minimizing climate impacts.

Density, unit size, construction type, building systems and other factors that influence the whole life carbon as they relate to housing are reflected here.

The all-wood and limited-wood construction types generally perform well in all categories, though the Clara shows relatively high CO_2eq per unit because each unit tends to be larger than the other projects.

Argyle Gardens and the Aurora are the best performers, but for different reasons. Argyle Gardens performs well because of very high housing density (many units and occupants in a small footprint) and the Aurora performs well because of its all-electric building systems.



8.0 CONCLUSIONS

8.0 CONCLUSIONS

FINDINGS - OPERATIONAL CARBON

For the studied projects, the operational carbon per square meter of space ranges from 26.6 kg CO_2eq/yr/m² to 55.2 kg CO_2eq/yr/m² across a range of modeled and actual data. The average as well as the median of the operational carbon is 40.1 kg CO_2eq/yr/m². For the three projects with actual energy usage data, the operational carbon varied from 31.5 kg CO_2eq/yr/m² to 46.6 kg CO_2eq.yr/m² - these three projects all had solar panels that offset their carbon emissions.

The operational carbon in terms of housing efficiency is an interesting perspective to analyze. The operational carbon per housing unit varies between a low of 1207 kg CO_2eq/unit/yr for a single residence occupancy (SRO), light wood frame project, to a high of 4441 kg CO_2eq/unit/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per housing unit is 2937 kg CO_2eq/unit/yr.

The operational carbon per residential bedroom varies between a low of 1207 kg CO_2eq/bedroom/yr for a light wood frame project to a high of 4857 kg CO_2eq/occupant/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per occupant is 2161 kg CO_2eq/occupant/yr.

The operational carbon per residential occupant varies between a low of 865 kg CO_2eq/occupant/yr for the light wood frame project to a high of 2686 kg CO_2eq/occupant/yr for a mixed-use concrete podium project with office and parking. The average[1] of the operational carbon per occupant is 1512 kg CO_2eq/occupant/yr.

For the all-wood buildings, Argyle Gardens was the most efficient in terms of CO_2eq intensity per unit and bedroom. 3000 Powell was the most efficient in terms of CO_2eq intensity per occupant. The Clara scored poorly on intensity per unit but similar on intensity per occupant. This appears to be due to the larger unit sizes at the Clara (many two and three bedroom units) where each unit consumes a larger amount of energy but more people are assumed to live in each unit. For the concrete podium buildings, it is difficult to compare operational carbon due to the mixed uses and parking in the podium.

The operational carbon for all projects is expected to continue to decrease year-over-year due to decreasing grid emissions overall. However, climate variability may increase the amount of energy needed due to hotter summers and cooler winters.

FINDINGS - EMBODIED CARBON

For the studied projects, the initial embodied carbon (base scope of structure, enclosure, and interior walls) varied between 42.8 to 172.2 kg CO_2eq/m². The life cycle embodied carbon (base scope) varied between 167.1 kg CO_2eq/m² and 257.3 kg CO_2eq/m², with an average of 219.4 kg CO_2eq/m². For the full scope (base scope + stairs/railings, ceilings, and doors), the embodied carbon increased by approximately 5% over the base scope. Refer to section 6.0 Embodied Carbon for more information.

The average[1] embodied carbon per unit, per bedroom, and per occupant respectively is 19,604 kg CO_2eq/unit, 13,965 kg CO_2eq/bedroom and 10,290 kg CO_2eq/occupant. Per year of a sixty year life span, the median embodied carbon is 326 kg CO_2eq/unit/yr, 233 kg CO_2eq/bedroom/yr, and 172 kg CO_2eq/occupant/yr. For a sixty year lifespan, we found that the most efficient multifamily buildings had an embodied carbon per occupant that ranged from 5815 kg CO_2eq (100kg CO_2eq/occupant/yr) to 7762 kg CO_2eq (129 kg CO_2eq/occupant/yr), although the actual values are likely higher. This is due to the large number of building construction categories that currently do not have available embodied carbon data (i.e. MEP systems).

Concrete podium buildings had a higher initial (day one) embodied carbon, and concrete materials were an overwhelming portion of the initial impacts in these buildings.

1 20% trimmed mean

8.0 CONCLUSIONS

CONTINUED

Although the all wood buildings did not consistently show a lower whole life embodied carbon (per square meter of total space) than concrete podium buildings, they showed a lower embodied carbon per square meter of conditioned space (with the exception of 72Foster).

FINDINGS - OPERATIONAL VS. EMBODIED CARBON

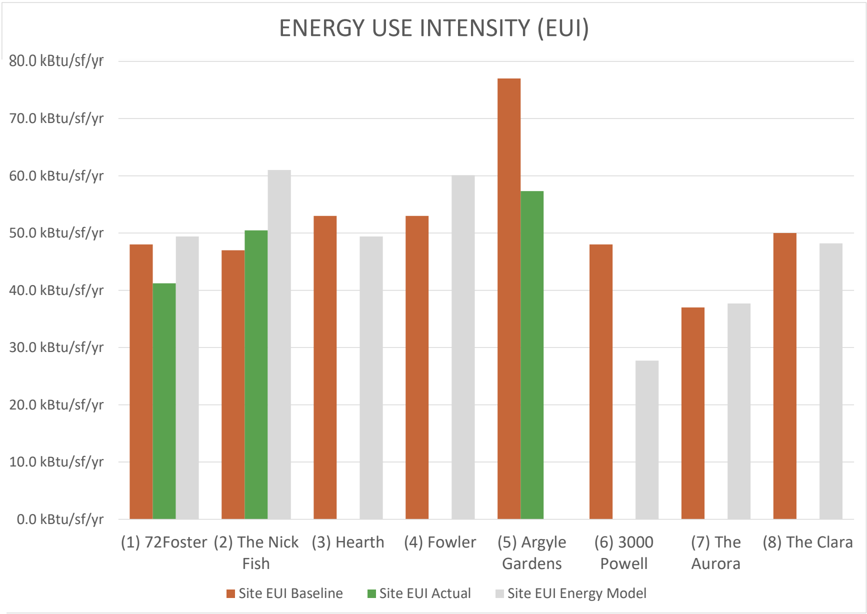
Among the projects, the operational carbon emissions surpasses the embodied carbon emissions. The surpassing year for wood (light frame) buildings occurs in the first year (or second year if an MEP estimate is included). The surpassing year for wood light frame over concrete podium buildings occurs in the fourth year (or the fifth/sixth year if the MEP estimate is included).

Although targeting embodied carbon reductions is important in all buildings, it is perhaps more important in the buildings that have a higher balance of embodied carbon compared to operational carbon (typically concrete podium). Additionally, it's important to remember that embodied carbon assessments, like these, are an incomplete picture of a building's embodied carbon - the actual embodied carbon is undoubtedly higher than these estimates, because life cycle data for various building systems is not readily available.

Neither operational nor embodied carbon showed any trends that seemed to be linked to geographic location; instead they appear to be linked to structural material, form, and building program. A more granular analysis that took the local utilities and their differing source energy generation intensities may have revealed stronger differences, but our choice to use NWPP values was intended to be in accordance with the EPA calculation methodologies.

MEETING TARGETS

The project's operational carbon findings illustrate the difficulty of meeting Architecture 2030 / the AIA 2030 Commitment targets with code compliant practices. Out of the three projects with actual usage data, two projects achieved a lower EUI than the baseline, and one project exceed both the site EUI baseline.



To reduce operational energy and carbon emissions, EUI and operational carbon targets should be agreed on early in a project and be integrated into an owner's project requirements. These targets should be based on a baseline number that accounts for the efficiency of dwelling unit density, as illustrated by the higher baseline for Argyle Gardens.

Embodied carbon targets are more difficult to establish due to the lack of data. For example, Architecture 2030 Challenge for Embodied Carbon entreats the architecture and building community to reduce embodied carbon 40% the industry average today - but only offers general data on the embodied carbon of the entire design and construction industry.

Currently, embodied carbon reduction programs (i.e. WBLCA LEED credit, Vancouver's anticipated embodied carbon guidelines) require projects to conduct a WBLCA for a baseline and reduction case, but there is no guidance on what a 'good' embodied carbon metric is for different building types. These requirements put a cost burden on a group (usually an architect, consultant or engineer) to perform a WBLCA for both the baseline and proposed building.

IMPACTS OF GRID DECARBONIZATION

Holst has shifted to all-electric buildings where at all possible. Over time, the operational carbon of all-electric buildings will continue to decline as more fossil fuel generation capacity is replaced with renewable energy sources. Oregon's electricity grid is planned to decarbonize in 2040, but there remains the possibly that other electric utility providers in the NWPP region will still produce carbon emissions.

For example, Holst tracks and offsets our emissions with purchased carbon credits; from 2021 to 2022 our overall use went up 32% (due to people returning to the office from pandemic quarantine). Incredibly, the carbon intensity of that use went up just 3%. This is due to our utility (PGE) reducing the CO_2e of their production from 0.41 tonnes per megawatt hour to 0.32 tonnes per Megawatt hour.[1]

IMPACTS OF RENEWABLES - ON SITE

Despite the solar panels in multiple projects, the energy use intensity and operational carbon remained significant for these buildings. There may be room to improve battery storage capabilities of these systems in order to reduce operational carbon sooner than grid decarbonization.

IMPACTS OF RENEWABLES - OFF SITE

Although it is impossible to determine the actual electricity mix due to energy sharing between providers, it is likely that the operational carbon intensity of provided electricity more closely aligns to that of the local utility provider than the whole NWPP average. With this in mind, the Portland and Boise (proxy for Eastern Oregon locations) buildings would actually have a higher operational carbon than estimated using the NWPP carbon intensity.

For Oregon buildings served by low carbon intensity providers, such as in Medford (primarily BPA hydropower purchased by local utility provider), targeting embodied carbon reductions and fully electric systems should be a priority.

CAPITAL AND OPERATIONAL COST IMPLICATIONS FOR MULTIFAMILY PROJECTS

Whether affordable or market rate, all multifamily housing is subject to challenging economics. The way those economics play out are somewhat different.

Market rate projects are driven by a return on investment where unit types, size and amenities can dramatically impact lease rates and the bottom line of the project. The initial cost is often prioritized above all else, including embodied carbon and life cycle cost. For example, a brick facade might be more expensive than a fiber cement facade, but ultimately will be a much lower embodied carbon and cost over the life cycle. A less efficient HVAC system may cost less upfront, but may cost more to operate each year than a more efficient systems. Since tenants often pay their own utility bills, developers can enhance their bottom line at the expense of the tenants (and the environment). Especially when developers plan to sell a project after construction, cost is prioritized over the environmental impact.

In affordable housing, it can also be difficult to prioritize lower embodied or operational carbon over the initial cost, especially when the total cost of the building is predetermined and challenging to keep low. Usually, clients begin a project with a set budget in mind, and it is up to the design and construction team to optimize that budget for energy efficiency, design, and function. Luckily, government funding for affordable projects can include sustainability requirements that reduce the carbon impact of a project. For example, the Aurora and 3000 Powell were funded by the Portland Housing Bond program (PHB), which has a Green Building Policy that requires above-code sustainability measures, many of which reduce operational emissions (although none currently address embodied carbon).

Ultimately, across market rate and affordable housing, the operational and embodied carbon savings that will be most easily achieved are those that have an initial cost savings or minimal cost add. For example, reducing structured concrete parking will reduce cost, embodied carbon, and operational carbon.

1 Includes purchased and generated energy. Portland General Electric. "2021 ESG Report: Advancing Our Clean Energy Future," 2021. https://assets.ctfassets.net/416ywc1laqmd/5aLMRJup0FHiMTf0EpgzYO/9e384dc5c6422147ddadbd821913163a/PGE_ESG21_Web.pdf.

8.0 CONCLUSIONS
CONTINUED

BEST PRACTICES AND LESSONS LEARNED

OPERATIONAL CARBON

For architects and engineers, gathering actual energy usage data from built projects should be a standard process. Collecting and analyzing this data is an important step to improve future projects. Streamlined energy sharing between utilities, owners/managers, and other stakeholders could occur through a software such as the Energy Star Portfolio Manager.

Throughout the research, it became evident that building owners typically did not know how their buildings were performing, and that it was often difficult or impossible to collect the energy data. Tying post-occupancy evaluation of energy use to commissioning and ensuring the necessary metering infrastructure is in place could alleviate this.

For this research project, the inability of Revit's Insight Energy Modeling tool to model precise HVAC systems limited its capability to provide precise EUI estimates. Insight is designed to be used early and often on projects before the building's shape, fenestration percentage, thermal envelope values, and HVAC's systems are finalized, in order to optimize the building's design. Moving forward, presetting thermal values into a Revit material library and presetting energy settings for a typical housing project will help speed up the energy modeling process.

Revit's Insight energy modeling tool is complex, but should be used early in a project to help determine which building choices will have the greatest impact on operational carbon. Precise modeling of Revit materials and thermal properties could speed up the energy modeling process and make the model more accurate.

EMBODIED CARBON

Tally, a Revit add-in, is an effective way to measure the embodied carbon of structure and enclosure. Pre-defining a Revit template with Tally definitions could be used in future projects to help quickly estimate embodied carbon.

For comparing different enclosure assemblies, Kaleidoscope is a fast web-based tool that could be used at the early stages of project.

RECOMMENDATIONS FOR FUTURE PROJECTS

Adaptive Reuse
The most sustainable building is the one that already exists. Where possible, reusing existing building structure will drastically reduce the embodied carbon of a project.

All-Electric Buildings
With Oregon's ambitious (mandated) grid decarbonization, it is this research team's recommendation that all-electric buildings should be a priority for future projects. Many of the studied projects only have gas water heating, yet the carbon emissions from natural gas still make up a sizable percentage that increases over time. As the electric grid gets cleaner over time (tracking to net-zero by 2040) the resulting annual emissions from all-electric buildings will decrease with it. Buildings using natural gas have no way to reduce emissions due to on-site burning of fossil fuels causing an unavoidable release of byproducts that cause climate change.

On-Site Renewables with Battery Storage
Onsite renewables with battery storage can help increase the efficiency of a renewable energy system and reduce demand on the grid during peak periods.

Concrete Reduction and Optimization
Concrete has an oversized impact on embodied carbon, and makes up over half of the embodied carbon footprint of the concrete podium buildings. Concrete is present on almost every project, and represents a significant portion of carbon emissions, even for wood buildings. Concrete enables higher density and ground floor services and is necessary for building foundations - it is one of the best materials to target for embodied carbon reduction. Strategic reduction of the quantity of concrete used, combined with specification of lower-carbon concrete through sourcing and mix design are methods by which this can be achieved.

On a statewide level, setting limits on the embodied carbon of concrete mixes could be an effective way to increase concrete optimization.

8.0 CONCLUSIONS

CONTINUED

Fire Rating and Gypsum Board
Where possible, using different construction types and acoustic assemblies could help reduce the embodied carbon due to extra gypsum board and fireproofing.

Enclosure
Local brick materials provide a lower embodied carbon due to their long lifespan and their natural finish that does not require repainting. Continued improvements to the energy code are driving more and more efficient building enclosures in terms of insulation levels, required air-tightness, and mechanical systems. Project teams should consider where improvements can be made that go beyond energy code minimums to improve performance further. These need to be balanced with potential additional embodied carbon impacts.

Building Systems
In addition to electrifying buildings as mentioned above, selecting efficient options for building systems can significantly reduce operational carbon impacts. In multifamily housing, hot water use is a significant contributor to overall energy demand, and electric heat pump water heater systems use a fraction of the energy traditional electric resistance water heaters consume.

These recommendations can be applied to any building type, regardless of use, to reduce the carbon intensity of construction and operation.

OPPORTUNITIES FOR FURTHER RESEARCH

Many of the projects in the study contain mixed uses (retail, restaurants, offices, amenity spaces), making it difficult to analyze the operational and embodied carbon efficiency of the different uses of the building. The actual energy use data did not adequately separate uses due to multiple areas sharing equipment, so discrete modeling of mixed uses was not carried out. A future study to look closely at housing-only projects or more time/resources to weed out the mixed uses so the specific housing-only impacts can be discerned would be very useful.

This project made evident that the true embodied carbon impact cannot yet be easily calculated. Research into the embodied carbon of various building systems used in housing is crucial in order to target future research in this area. A larger sample size of completed projects across many climate zones with reliable real-world data would be crucial to the accuracy and applicability of this research.

IMPLICATIONS FOR ENERGY TRUST PROGRAM SUPPORT

This study would not have been possible without the support of the Energy Trust's Net Zero Fellowship. While we always desire to perform comparative analysis of embodied and operational energy impacts during the design, the demands of schedule and fee often make this challenging or impossible, particularly in housing projects where the margins are already slim. The Net Zero Fellowship has enabled this team to develop a basic infrastructure of tools that makes future analysis more feasible, and it is our hope that we can continue to grow this capability in the future.

To reduce the operational carbon of our existing and new buildings, a key step is tracking the operational carbon. A statewide, publicly available database of energy usage would be a useful tool for building owners, government agencies, and utility providers. Portland currently requires commercial buildings 20,000 sf and larger to track and report building energy performance. This enlightens building owners about how a building's performance compares to others and can help them target energy performance measures. Additionally, it allows for the city and the public to see how energy performance and carbon emissions change over time. There is an opportunity to expand this program across the state, to smaller buildings, and multifamily buildings. As a part of this program, separate metering and reporting in mixed use buildings will aid in effective comparisons of mixed use buildings, which can vary widely in energy usage. Energy Trust's support could be used to help building owners set up their building data in the Energy Star Portfolio Manager.

CLOSING THOUGHTS

Reducing the whole life carbon footprint of the built environment requires continued action to reduce both embodied and operational carbon. With the pressing need for housing in Oregon and beyond, there is a great opportunity to build a cleaner foundation for future generations.

9.0 APPENDIX

SOURCES

HEATING / COOLING DEGREE DAYS:
https://www.degreedays.net/

SCOPE 2, & 3 CO_2eq data:
https://www.epa.gov/egrid/power-profiler#/

CARBON INTENSITY OF NATURAL GAS USE:
https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references#:~:text=Carbon%20dioxide%20emissions%20per%20therm,one%20therm%20(EIA%202021).

MEP EMBODIED CARBON FACTOR
Rodriguez, B.X., Lee H.W., Simonen, K., Huang, M., & Ditto, J. (2019) *Estimates of Embodied Carbon for Mechanical, Electrical, Plumbing and Tenant Improvements, Summary Document.* The Carbon Leadership Forum.*t*.

72FOSTER INSIGHT (ENERGY MODEL) SETTINGS

6/29/23, 4:39 PM Green Building Studio Energy and Carbon Results

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My Projects > **72 Foster_R22_bottSPVAE**

Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: 72 Foster_R22_bottSPVAE

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: 72 Foster_R22_bottSPVAE_default
Location: Hollywood, OR
Building Type: MultiFamily
Floor Area: 61,773 ft²
Electric Cost: $0.08 / kWh
Fuel Cost: $0.99 / Therm
Utility Data Used: Project Default Utility Rates

1 Base Run | 2 Design Alternative | Carbon Footprint

Energy, Carbon and Cost Summary

Annual Energy Cost	$72,801
Lifecycle Cost	$991,547
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	79.2 tons
Large SUV Equivalent	7.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	63 kBtu / ft² / year
Electric	732,705 kWh
Fuel	13,652 Therms
Annual Peak Demand	204.4 kW
Lifecycle Energy	
Electric	21,981,138 kW
Fuel	409,546 Therms

Assumptions

Create a Design Alternative to improve your building performance.

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **72 Foster_R22_bottSPVAE** — Updating your building assumptions

Building Summary - Quick Stats

Number of People:	366 people ⬇
Average Lighting Power Density:	0.87 W / ft²
Average Equipment Power Density:	0.99 W / ft²
Specific Fan Flow:	0.7 cfm / ft²
Specific Fan Power:	-4,438.831 W / cfm ⬇
Specific Cooling:	-4 ft² / ton ⬇

Base Run Construction

Roofs	R20 over Roof Deck U-Value: 0.05	17,108 ft²
	R20 over Roof Deck - Cool Roof U-Value: 0.04	152 ft²
Ceilings	Interior Drop Ceiling Tile U-Value: 0.46	219 ft²
Exterior Walls	R30 Wood Frame Wall U-Value: 0.04	27,706 ft²

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Specific Heating:	0 ft² / kBtu ⬇
Total Fan Flow:	45,050 cfm
Total Cooling Capacity:	-16,554 tons
Total Heating Capacity:	201,078 kBtuh

⬆ higher than typical value
⬇ lower than typical value

Interior Walls	R30 Wood Frame Wall U-Value: 0.04	401 ft²
	Uninsulated Interior Wall U-Value: 0.41	51,658 ft²
Interior Floors	R0 Wood Frame Carpeted Floor U-Value: 0.20	48,938 ft²
Raised Floors	R30 Wood Frame Wall U-Value: 0.04	9 ft²
	Slab edge R-5 insulation U-Value: 0.03	8,753 ft²
	R10.4 Mass Floor U-Value: 0.07	5,048 ft²
Slabs On Grade	R30 Wood Frame Wall U-Value: 0.04	3 ft²
	Slab edge R-5 insulation U-Value: 0.03	3,283 ft²
Underground Ceilings	R20 over Roof Deck U-Value: 0.05	27 ft²
Underground Walls	R30 Wood Frame Wall U-Value: 0.04	4,430 ft²
	R7.5 8 in CMU under ground wall U-Value: 0.03	209 ft²
Underground Slabs	Slab edge R-5 insulation U-Value: 0.03	111 ft²
Nonsliding Doors	R5 Door (125 doors) U-Value: 0.19	3,199 ft²
Air Openings	North Facing Windows: Air partition (3 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	16 ft²
	Non-North Facing Windows: Air partition (91 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	529 ft²
Fixed Windows	North Facing Windows: Large single-glazed windows (10 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	201 ft²
	Non-North Facing Windows: Large single-glazed windows (13 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	193 ft²
Operable Windows	North Facing Windows: Double glazing - 1/8 in thick - low-E/clear (e = 0.1) glass (48 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	1,286 ft²
	Non-North Facing Windows: Double glazing - 1/8 in thick - low-E/clear (e = 0.1) glass (109 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	2,938 ft²

> 3D VRML View

Base Run Hydronic Equipment — **Note:** this information should not be used for sizing purposes.

Domestic Hot Water	Average Demand	329,052 Btu/hr

Base Run Air Equipment — **Note:** this information should not be used for sizing purposes.

Packaged Single Zone	Supply Fan Flow	729 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	21 kBtu/hr
	Heating Capacity	17 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,775 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	110 kBtu/hr
	Heating Capacity	88 kBtu/hr
Packaged Single Zone	Supply Fan Flow	20 cfm

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Green Building Studio Energy and Carbon Results

	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-99,998 kBtu/hr
	Heating Capacity	99,999 kBtu/hr
Packaged Single Zone	Supply Fan Flow	41 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	-99,998 kBtu/hr
	Heating Capacity	100,000 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,518 cfm
	Annual Supply Fan Run Time	4,914 Hours
	Cooling Capacity	126 kBtu/hr
	Heating Capacity	101 kBtu/hr
Packaged Single Zone	Supply Fan Flow	4,635 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	134 kBtu/hr
	Heating Capacity	107 kBtu/hr
Packaged Single Zone	Supply Fan Flow	81 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	6,308 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	184 kBtu/hr
	Heating Capacity	147 kBtu/hr
Packaged Single Zone	Supply Fan Flow	788 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	34 kBtu/hr
	Heating Capacity	27 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,378 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	69 kBtu/hr
	Heating Capacity	55 kBtu/hr
Packaged Single Zone	Supply Fan Flow	308 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	7 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,822 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	82 kBtu/hr
	Heating Capacity	66 kBtu/hr
Packaged Single Zone	Supply Fan Flow	785 cfm
	Annual Supply Fan Run Time	4,914 Hours
	Cooling Capacity	28 kBtu/hr
	Heating Capacity	23 kBtu/hr
Packaged Single Zone	Supply Fan Flow	111 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Single Zone	Supply Fan Flow	177 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr

https://gbs.autodesk.com/GBS/Scheme/EnergyAndCarbonResults?RunID=nOEDc2Y%2fB7I%3d&AltRunID=cJfGmxrUVvo%3d 3/6

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Green Building Studio Energy and Carbon Results

	Heating Capacity	4 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,165 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	34 kBtu/hr
	Heating Capacity	27 kBtu/hr
Packaged Single Zone	Supply Fan Flow	129 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Single Zone	Supply Fan Flow	672 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	18 kBtu/hr
	Heating Capacity	14 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,012 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	59 kBtu/hr
	Heating Capacity	47 kBtu/hr
Packaged Single Zone	Supply Fan Flow	833 cfm
	Annual Supply Fan Run Time	4,914 Hours
	Cooling Capacity	30 kBtu/hr
	Heating Capacity	24 kBtu/hr
Packaged Single Zone	Supply Fan Flow	319 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	7 kBtu/hr
Packaged Single Zone	Supply Fan Flow	84 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	264 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	8 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Single Zone	Supply Fan Flow	93 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,882 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	54 kBtu/hr
	Heating Capacity	44 kBtu/hr
Packaged Single Zone	Supply Fan Flow	641 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	15 kBtu/hr
Packaged Single Zone	Supply Fan Flow	95 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr

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Packaged Single Zone	Supply Fan Flow	1,979 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	58 kBtu/hr
	Heating Capacity	46 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,407 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	99 kBtu/hr
	Heating Capacity	79 kBtu/hr
Packaged Single Zone	Supply Fan Flow	491 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	13 kBtu/hr
	Heating Capacity	11 kBtu/hr
Packaged Single Zone	Supply Fan Flow	204 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	5 kBtu/hr
Packaged Single Zone	Supply Fan Flow	210 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	5 kBtu/hr
Packaged Single Zone	Supply Fan Flow	85 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	988 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	29 kBtu/hr
	Heating Capacity	23 kBtu/hr
Packaged Single Zone	Supply Fan Flow	915 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	25 kBtu/hr
	Heating Capacity	20 kBtu/hr
Packaged Single Zone	Supply Fan Flow	874 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	25 kBtu/hr
	Heating Capacity	20 kBtu/hr
Packaged Single Zone	Supply Fan Flow	345 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	10 kBtu/hr
	Heating Capacity	8 kBtu/hr
Packaged Single Zone	Supply Fan Flow	665 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	16 kBtu/hr
Packaged Single Zone	Supply Fan Flow	70 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	150 cfm
	Annual Supply Fan Run Time	8,760 Hours

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Cooling Capacity	4 kBtu/hr
Heating Capacity	4 kBtu/hr

THE NICK FISH INSIGHT (ENERGY MODEL) SETTINGS

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Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: Nick Fish_R22 Energy Model

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: Nick Fish_R22 Energy Model_default

Building Type: MultiFamily

Floor Area: 61,329 ft²

Electric Cost: $0.08 / kWh

Fuel Cost: $0.99 / Therm

Utility Data Used: Project Default Utility Rates

Location: Hazelwood, OR

1 Base Run | 2 Design Alternative | Carbon Footprint

Energy, Carbon and Cost Summary

Annual Energy Cost	$101,918
Lifecycle Cost	$1,388,121
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	173.9 tons
Large SUV Equivalent	15.8 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	99 kBtu / ft² / year
Electric	893,529 kWh
Fuel	29,981 Therms
Annual Peak Demand	237.4 kW
Lifecycle Energy	
Electric	26,805,873 kW
Fuel	899,423 Therms

Assumptions

Create a Design Alternative to improve your building performance.

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **Nick Fish_R22 Energy Model** — Updating your building assumptions

Building Summary - Quick Stats

Number of People:	371 people (lower than typical value)
Average Lighting Power Density:	0.90 W / ft²
Average Equipment Power Density:	1.06 W / ft²
Specific Fan Flow:	1.1 cfm / ft²
Specific Fan Power:	0.900 W / cfm
Specific Cooling:	310 ft² / ton
Specific Heating:	21 ft² / kBtu
Total Fan Flow:	69,622 cfm
Total Cooling Capacity:	205 tons
Total Heating Capacity:	3,012 kBtuh

higher than typical value
lower than typical value

Base Run Construction

Roofs	R20 over Roof Deck - Cool Roof, U-Value: 0.05	19,674 ft²
	4 in reinforced-concrete ceiling, U-Value: N/A	677 ft²
Ceilings	4 in reinforced-concrete ceiling, U-Value: N/A	2,014 ft²
Exterior Walls	R13 Wood Frame Wall, U-Value: 0.09	31,423 ft²
Interior Walls	R0 Metal Frame Wall, U-Value: 0.57	57,412 ft²
	R13 Wood Frame Wall, U-Value: 0.09	1,903 ft²
Interior Floors	4 in reinforced-concrete ceiling, U-Value: N/A	3,098 ft²
	R0 Wood Frame Carpeted Floor, U-Value: 0.20	43,574 ft²
Raised Floors	R13 Wood Frame Wall, U-Value: 0.09	28 ft²
	R20 over Roof Deck - Cool Roof, U-Value: 0.05	4,995 ft²
	4 in reinforced-concrete ceiling, U-Value: N/A	361 ft²
	Slab edge uninsulated, U-Value: 0.03	327 ft²
Slabs On Grade	R13 Wood Frame Wall, U-Value: 0.09	7 ft²
	Slab edge uninsulated, U-Value: 0.03	2,776 ft²
Underground Walls	R7.5 8 in CMU under ground wall, U-Value: 0.03	4 ft²
Underground Slabs	Slab edge uninsulated, U-Value: 0.03	5,857 ft²
	Concrete slab R10 perim, U-Value: 0.01	5,229 ft²
Nonsliding Doors	R5 Door (223 doors), U-Value: 0.19	4,441 ft²
Fixed Windows	North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (96 windows), U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	2,684 ft²
	Non-North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (231 windows), U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	5,132 ft²
Operable Windows	North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (83 windows), U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	1,843 ft²
	Non-North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (163 windows), U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	3,425 ft²

> 3D VRML View

Base Run Hydronic Equipment — **Note:** this information should not be used for sizing purposes.

Hot Water	Boiler Capacity	3,009,620 Btu/hr
	Pump Flow	151 gpm
Secondary Chilled Water	Pump Flow	493 gpm
Primary Chilled Water	Electric Chiller Capacity	2,521,933 Btu/hr
	Pump Flow	493 gpm
Condenser Water	Pump Flow	573 gpm
	Cooling Tower Capacity (Approach:2.8)	2,897,416 Btu/hr
Domestic Hot Water	Average Demand	291,688 Btu/hr

Base Run Air Equipment — **Note:** this information should not be used for sizing purposes.

Variable Air Volume	Supply Fan Flow	10 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Variable Air Volume	Supply Fan Flow	20 cfm

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https://gbs.autodesk.com/gbs/Scheme/EnergyAndCarbonResults?RunId=ICGiipWk9QY%3d&AltRunID=cJfGmxrUVvo%3d 2/7

	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1 kBtu/hr
	Heating Capacity	1 kBtu/hr
Variable Air Volume	Supply Fan Flow	43 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Variable Air Volume	Supply Fan Flow	10 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Variable Air Volume	Supply Fan Flow	97 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	4 kBtu/hr
Variable Air Volume	Supply Fan Flow	382 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	14 kBtu/hr
	Heating Capacity	16 kBtu/hr
Variable Air Volume	Supply Fan Flow	145 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	6 kBtu/hr
Variable Air Volume	Supply Fan Flow	509 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	22 kBtu/hr
Variable Air Volume	Supply Fan Flow	938 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	34 kBtu/hr
	Heating Capacity	41 kBtu/hr
Variable Air Volume	Supply Fan Flow	320 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	12 kBtu/hr
	Heating Capacity	14 kBtu/hr
Variable Air Volume	Supply Fan Flow	180 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	7 kBtu/hr
	Heating Capacity	8 kBtu/hr
Variable Air Volume	Supply Fan Flow	7,392 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	258 kBtu/hr
	Heating Capacity	319 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,199 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	42 kBtu/hr
	Heating Capacity	52 kBtu/hr
Variable Air Volume	Supply Fan Flow	471 cfm
	Annual Supply Fan Run Time	6,920 Hours
	Cooling Capacity	16 kBtu/hr

	Heating Capacity	20 kBtu/hr
Variable Air Volume	Supply Fan Flow	2,740 cfm
	Annual Supply Fan Run Time	6,854 Hours
	Cooling Capacity	100 kBtu/hr
	Heating Capacity	118 kBtu/hr
Variable Air Volume	Supply Fan Flow	3,805 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	132 kBtu/hr
	Heating Capacity	164 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,664 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	58 kBtu/hr
	Heating Capacity	72 kBtu/hr
Variable Air Volume	Supply Fan Flow	639 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	23 kBtu/hr
	Heating Capacity	28 kBtu/hr
Variable Air Volume	Supply Fan Flow	618 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	22 kBtu/hr
	Heating Capacity	27 kBtu/hr
Variable Air Volume	Supply Fan Flow	4,723 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	167 kBtu/hr
	Heating Capacity	204 kBtu/hr
Variable Air Volume	Supply Fan Flow	6,615 cfm
	Annual Supply Fan Run Time	6,842 Hours
	Cooling Capacity	242 kBtu/hr
	Heating Capacity	286 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,354 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	47 kBtu/hr
	Heating Capacity	59 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,562 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	54 kBtu/hr
	Heating Capacity	67 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,102 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	39 kBtu/hr
	Heating Capacity	48 kBtu/hr
Variable Air Volume	Supply Fan Flow	2,948 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	104 kBtu/hr
	Heating Capacity	127 kBtu/hr
Variable Air Volume	Supply Fan Flow	668 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	23 kBtu/hr
	Heating Capacity	29 kBtu/hr

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Green Building Studio Energy and Carbon Results

Variable Air Volume	Supply Fan Flow	3,378 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	119 kBtu/hr
	Heating Capacity	146 kBtu/hr
Variable Air Volume	Supply Fan Flow	120 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	5 kBtu/hr
Variable Air Volume	Supply Fan Flow	6,876 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	241 kBtu/hr
	Heating Capacity	297 kBtu/hr
Variable Air Volume	Supply Fan Flow	90 cfm
	Annual Supply Fan Run Time	5,460 Hours
	Cooling Capacity	4 kBtu/hr
	Heating Capacity	4 kBtu/hr
Variable Air Volume	Supply Fan Flow	715 cfm
	Annual Supply Fan Run Time	5,773 Hours
	Cooling Capacity	28 kBtu/hr
	Heating Capacity	31 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,449 cfm
	Annual Supply Fan Run Time	7,514 Hours
	Cooling Capacity	51 kBtu/hr
	Heating Capacity	63 kBtu/hr
Variable Air Volume	Supply Fan Flow	4,908 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	171 kBtu/hr
	Heating Capacity	212 kBtu/hr
Variable Air Volume	Supply Fan Flow	155 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	7 kBtu/hr
Variable Air Volume	Supply Fan Flow	292 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	10 kBtu/hr
	Heating Capacity	13 kBtu/hr
Variable Air Volume	Supply Fan Flow	48 cfm
	Annual Supply Fan Run Time	5,219 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Variable Air Volume	Supply Fan Flow	5,102 cfm
	Annual Supply Fan Run Time	7,730 Hours
	Cooling Capacity	179 kBtu/hr
	Heating Capacity	220 kBtu/hr
Variable Air Volume	Supply Fan Flow	840 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	29 kBtu/hr
	Heating Capacity	36 kBtu/hr
Variable Air Volume	Supply Fan Flow	97 cfm
	Annual Supply Fan Run Time	4,951 Hours

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Green Building Studio Energy and Carbon Results

	Cooling Capacity	4 kBtu/hr
	Heating Capacity	5 kBtu/hr
Variable Air Volume	Supply Fan Flow	108 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4 kBtu/hr
	Heating Capacity	5 kBtu/hr
Variable Air Volume	Supply Fan Flow	11 cfm
	Annual Supply Fan Run Time	5,811 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Variable Air Volume	Supply Fan Flow	202 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	7 kBtu/hr
	Heating Capacity	9 kBtu/hr
Variable Air Volume	Supply Fan Flow	524 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	23 kBtu/hr
Variable Air Volume	Supply Fan Flow	240 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	14 kBtu/hr
Variable Air Volume	Supply Fan Flow	521 cfm
	Annual Supply Fan Run Time	6,373 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	22 kBtu/hr
Variable Air Volume	Supply Fan Flow	423 cfm
	Annual Supply Fan Run Time	6,103 Hours
	Cooling Capacity	15 kBtu/hr
	Heating Capacity	18 kBtu/hr
Variable Air Volume	Supply Fan Flow	50 cfm
	Annual Supply Fan Run Time	5,368 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,201 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	42 kBtu/hr
	Heating Capacity	52 kBtu/hr
Variable Air Volume	Supply Fan Flow	45 cfm
	Annual Supply Fan Run Time	4,932 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Variable Air Volume	Supply Fan Flow	1,990 cfm
	Annual Supply Fan Run Time	5,539 Hours
	Cooling Capacity	73 kBtu/hr
	Heating Capacity	86 kBtu/hr
Variable Air Volume	Supply Fan Flow	11 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr

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My Projects > **Hearth-Cartee_R22_bottSPVAE**

Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: Hearth-Cartee_R22_bottSPVAE

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: Hearth-Cartee_R22_bottSPVAE_default
Location: Downtown Boise, ID

Building Type: MultiFamily
Floor Area: 124,485 ft²

Electric Cost: $0.06 / kWh
Fuel Cost: $0.80 / Therm

Utility Data Used: Project Default Utility Rates

1 Base Run

2 Design Alternative

Carbon Footprint

Energy, Carbon and Cost Summary

Annual Energy Cost	$101,992
Lifecycle Cost	$1,389,132
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	128.2 tons
Large SUV Equivalent	11.7 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	58 kBtu / ft² / year
Electric	1,463,673 kWh
Fuel	22,106 Therms
Annual Peak Demand	371.0 kW
Lifecycle Energy	
Electric	43,910,190 kWh
Fuel	663,170 Therms

Assumptions

Create a Design Alternative to improve your building performance.

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **Hearth-Cartee_R22_bottSPVAE** Updating your building assumptions

Building Summary - Quick Stats

Number of People:	561 people (lower than typical value)
Average Lighting Power Density:	0.76 W / ft²
Average Equipment Power Density:	1.00 W / ft²
Specific Fan Flow:	1.0 cfm / ft²
Specific Fan Power:	0.522 W / cfm
Specific Cooling:	479 ft² / ton
Specific Heating:	58 ft² / kBtu
Total Fan Flow:	117,713 cfm
Total Cooling Capacity:	257 tons
Total Heating Capacity:	2,133 kBtuh

higher than typical value
lower than typical value

Base Run Construction

Roofs	Standard wall construction - C U-Value: 1.10	124 ft²
	R0 Metal Frame Wall U-Value: 0.57	3 ft²
	R20 over Roof Deck - Cool Roof U-Value: 0.05	8,513 ft²
	R20 over Roof Deck U-Value: 0.05	22,361 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	257 ft²
Ceilings	4 in reinforced-concrete ceiling U-Value: N/A	517 ft²
	Interior Drop Ceiling Tile U-Value: 0.46	214 ft²
Exterior Walls	Standard wall construction - C U-Value: 1.10	64,152 ft²
Interior Walls	Standard wall construction - C U-Value: 1.10	968 ft²
	R0 Metal Frame Wall U-Value: 0.57	83,209 ft²
	R7.5 8 in CMU under ground wall U-Value: 0.03	63 ft²
Interior Floors	4 in reinforced-concrete ceiling U-Value: N/A	5,223 ft²
	R0 Wood Frame Carpeted Floor U-Value: 0.20	97,193 ft²
Raised Floors	R20 over Roof Deck - Cool Roof U-Value: 0.05	25,088 ft²
	R20 over Roof Deck U-Value: 0.05	16 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	61 ft²
Underground Walls	R7.5 8 in CMU under ground wall U-Value: 0.03	1,463 ft²
Underground Slabs	R20 over Roof Deck - Cool Roof U-Value: 0.05	520 ft²
	Slab edge uninsulated U-Value: 0.03	6,620 ft²
Nonsliding Doors	R5 Door (294 doors) U-Value: 0.19	6,672 ft²
Air Openings	North Facing Windows: Air partition (5 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	69 ft²
	Non-North Facing Windows: Air partition (111 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	699 ft²
Fixed Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (43 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	1,225 ft²
	North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (6 windows) U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	191 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (136 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	3,448 ft²
	Non-North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (30 windows) U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	759 ft²
Operable Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (60 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	2,031 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (375 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	12,122 ft²

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> 3D VRML View

Base Run Hydronic Equipment **Note:** this information should not be used for sizing purposes.

Domestic Hot Water	Average Demand	628,356 Btu/hr

Base Run Air Equipment **Note:** this information should not be used for sizing purposes.

Packaged Single Zone	Supply Fan Flow	12,327 cfm

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	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	319 kBtu/hr
	Heating Capacity	220 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,589 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	71 kBtu/hr
	Heating Capacity	49 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,889 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	77 kBtu/hr
	Heating Capacity	53 kBtu/hr
Packaged Single Zone	Supply Fan Flow	19,966 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	519 kBtu/hr
	Heating Capacity	358 kBtu/hr
Packaged Single Zone	Supply Fan Flow	7,384 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	195 kBtu/hr
	Heating Capacity	134 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,816 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	49 kBtu/hr
	Heating Capacity	34 kBtu/hr
Packaged Single Zone	Supply Fan Flow	4,124 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	106 kBtu/hr
	Heating Capacity	73 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,524 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	92 kBtu/hr
	Heating Capacity	63 kBtu/hr
Packaged Single Zone	Supply Fan Flow	10,105 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	259 kBtu/hr
	Heating Capacity	179 kBtu/hr
Packaged Single Zone	Supply Fan Flow	4,147 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	109 kBtu/hr
	Heating Capacity	75 kBtu/hr
Packaged Single Zone	Supply Fan Flow	4,626 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	121 kBtu/hr
	Heating Capacity	83 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,064 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	29 kBtu/hr
	Heating Capacity	20 kBtu/hr
Packaged Single Zone	Supply Fan Flow	325 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	8 kBtu/hr

	Heating Capacity	6 kBtu/hr
Packaged Single Zone	Supply Fan Flow	891 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	23 kBtu/hr
	Heating Capacity	16 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,892 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	77 kBtu/hr
	Heating Capacity	53 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,735 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	97 kBtu/hr
	Heating Capacity	67 kBtu/hr
Packaged Single Zone	Supply Fan Flow	6,124 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	162 kBtu/hr
	Heating Capacity	112 kBtu/hr
Packaged Single Zone	Supply Fan Flow	6,323 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	166 kBtu/hr
	Heating Capacity	115 kBtu/hr
Packaged Single Zone	Supply Fan Flow	7,153 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	185 kBtu/hr
	Heating Capacity	128 kBtu/hr
Packaged Single Zone	Supply Fan Flow	554 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	15 kBtu/hr
	Heating Capacity	10 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,173 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	29 kBtu/hr
	Heating Capacity	20 kBtu/hr
Packaged Single Zone	Supply Fan Flow	5,902 cfm
	Annual Supply Fan Run Time	4,914 Hours
	Cooling Capacity	171 kBtu/hr
	Heating Capacity	118 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,593 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	42 kBtu/hr
	Heating Capacity	29 kBtu/hr
Packaged Single Zone	Supply Fan Flow	190 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Single Zone	Supply Fan Flow	551 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	15 kBtu/hr
	Heating Capacity	10 kBtu/hr

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Packaged Single Zone	Supply Fan Flow	1,673 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	44 kBtu/hr
	Heating Capacity	30 kBtu/hr
Packaged Single Zone	Supply Fan Flow	336 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,146 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	29 kBtu/hr
	Heating Capacity	20 kBtu/hr
Packaged Single Zone	Supply Fan Flow	635 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	17 kBtu/hr
	Heating Capacity	12 kBtu/hr
Packaged Single Zone	Supply Fan Flow	276 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	7 kBtu/hr
	Heating Capacity	5 kBtu/hr
Packaged Single Zone	Supply Fan Flow	671 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	17 kBtu/hr
	Heating Capacity	12 kBtu/hr
Packaged Single Zone	Supply Fan Flow	859 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	22 kBtu/hr
	Heating Capacity	15 kBtu/hr
Packaged Single Zone	Supply Fan Flow	70 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	1 kBtu/hr
Packaged Single Zone	Supply Fan Flow	81 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr

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THE FOWLER INSIGHT (ENERGY MODEL) SETTINGS

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Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: Roost_R22_bottSPVAE

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: Roost_R22_bottSPVAE_default
Location: Boise Airport, ID

Building Type: MultiFamily
Floor Area: 115,037 ft²

Electric Cost: $0.06 / kWh
Fuel Cost: $0.80 / Therm

Utility Data Used: Project Default Utility Rates

1 Base Run — 2 Design Alternative — Carbon Footprint

Energy, Carbon and Cost Summary

Annual Energy Cost	$111,232
Lifecycle Cost	$1,514,975
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	196.9 tons
Large SUV Equivalent	17.9 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	73 kBtu / ft² / year
Electric	1,459,533 kWh
Fuel	33,953 Therms
Annual Peak Demand	379.3 kW
Lifecycle Energy	
Electric	43,785,990 kW
Fuel	1,018,595 Therms

Assumptions

Create a Design Alternative to improve your building performance.

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **Roost_R22_bottSPVAE** — Updating your building assumptions

Building Summary - Quick Stats

Number of People:	660 people ↓
Average Lighting Power Density:	0.74 W / ft²
Average Equipment Power Density:	0.99 W / ft²
Specific Fan Flow:	1.0 cfm / ft²
Specific Fan Power:	0.236 W / cfm ↓
Specific Cooling:	516 ft² / ton

Base Run Construction

Roofs	R20 over Roof Deck - Cool Roof U-Value: 0.05	3,401 ft²
	R20 over Roof Deck U-Value: 0.05	20,299 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	232 ft²
Ceilings	Interior Drop Ceiling Tile U-Value: 0.46	8 ft²

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Specific Heating:	62 ft² / kBtu
Total Fan Flow:	116,563 cfm
Total Cooling Capacity:	231 tons
Total Heating Capacity:	1,921 kBtuh

↑ higher than typical value
↓ lower than typical value

Exterior Walls	Brick, sheathing, R-11 batt insulation, gypsum U-Value: 0.57	74,339 ft²
Interior Walls	R0 Metal Frame Wall U-Value: 0.57	89,391 ft²
	Brick, sheathing, R-11 batt insulation, gypsum U-Value: 0.57	409 ft²
Interior Floors	4 in reinforced-concrete ceiling U-Value: N/A	139 ft²
	R0 Wood Frame Carpeted Floor U-Value: 0.20	94,470 ft²
Raised Floors	Slab edge uninsulated U-Value: 0.03	298 ft²
	Brick, sheathing, R-11 batt insulation, gypsum U-Value: 0.57	62 ft²
	R20 over Roof Deck - Cool Roof U-Value: 0.05	16,599 ft²
	R20 over Roof Deck U-Value: 0.05	195 ft²
Slabs On Grade	Slab edge uninsulated U-Value: 0.03	4,467 ft²
Underground Walls	R7.5 8 in CMU under ground wall U-Value: 0.03	706 ft²
Underground Slabs	Slab edge uninsulated U-Value: 0.03	2,756 ft²
	R7.5 8 in CMU under ground wall U-Value: 0.03	60 ft²
	Concrete slab R10 perim U-Value: 0.01	760 ft²
Nonsliding Doors	R5 Door (271 doors) U-Value: 0.19	5,720 ft²
Air Openings	North Facing Windows: Air partition (2 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	4 ft²
	Non-North Facing Windows: Air partition (8 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	79 ft²
Fixed Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (17 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	450 ft²
	North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (11 windows) U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	271 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (27 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	510 ft²
	Non-North Facing Windows: Pilkington RW33 double glazing (1/4 in + 1/4 in) (7 windows) U-Value: 2.86 W / (m²-K), SHGC: 0.76 , Vlt: 0.81	131 ft²
Operable Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (118 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	2,733 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (639 windows) U-Value: 1.67 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	13,461 ft²

> 3D VRML View

Base Run Hydronic Equipment — **Note:** this information should not be used for sizing purposes.

Domestic Hot Water	Average Demand	860,466 Btu/hr

Base Run Air Equipment — **Note:** this information should not be used for sizing purposes.

Packaged Terminal Air Conditioner	Supply Fan Flow	11 cfm
	Annual Supply Fan Run Time	8,760 Hours

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	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	161 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	34 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1 kBtu/hr
	Heating Capacity	1 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	11 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	1,343 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	32 kBtu/hr
	Heating Capacity	22 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	176 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	5,101 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	120 kBtu/hr
	Heating Capacity	83 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	2,384 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	55 kBtu/hr
	Heating Capacity	38 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	6,377 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	151 kBtu/hr
	Heating Capacity	104 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	3,066 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	73 kBtu/hr
	Heating Capacity	51 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	11 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	2,891 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	68 kBtu/hr
	Heating Capacity	47 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	17,877 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	424 kBtu/hr
	Heating Capacity	294 kBtu/hr

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Packaged Terminal Air Conditioner	Supply Fan Flow	388 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	460 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	11 kBtu/hr
	Heating Capacity	8 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	826 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	13 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	3,502 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	108 kBtu/hr
	Heating Capacity	75 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	4,259 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	98 kBtu/hr
	Heating Capacity	68 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	1,467 cfm
	Annual Supply Fan Run Time	4,914 Hours
	Cooling Capacity	37 kBtu/hr
	Heating Capacity	26 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	3,005 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	69 kBtu/hr
	Heating Capacity	48 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	7,143 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	168 kBtu/hr
	Heating Capacity	116 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	2,121 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	51 kBtu/hr
	Heating Capacity	35 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	1,385 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	32 kBtu/hr
	Heating Capacity	22 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	25,844 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	606 kBtu/hr
	Heating Capacity	420 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	937 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	22 kBtu/hr
	Heating Capacity	15 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	94 cfm
	Annual Supply Fan Run Time	8,760 Hours

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	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	13,721 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	324 kBtu/hr
	Heating Capacity	225 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	1,944 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	46 kBtu/hr
	Heating Capacity	32 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	5,641 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	134 kBtu/hr
	Heating Capacity	93 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	684 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	16 kBtu/hr
	Heating Capacity	11 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	380 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	761 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	18 kBtu/hr
	Heating Capacity	12 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	247 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	4 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	117 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	204 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	286 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	7 kBtu/hr
	Heating Capacity	5 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	198 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	664 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	16 kBtu/hr

https://gbs.autodesk.com/gbs/Scheme/EnergyAndCarbonResults?RunId=685kXSmNVuw%3d&AltRunID=cJfGmxrUVvo%3d 5/6

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	Heating Capacity	11 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	842 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	13 kBtu/hr

https://gbs.autodesk.com/gbs/Scheme/EnergyAndCarbonResults?RunId=685kXSmNVuw%3d&AltRunID=cJfGmxrUVvo%3d 6/6

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Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: Aurora_Stark_R22_bottSPVAE

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: Aurora_Stark_R22_bottSPVAE_default

Location: Centennial, OR

Building Type: MultiFamily

Floor Area: 77,324 ft²

Electric Cost: $0.08 / kWh

Fuel Cost: $0.99 / Therm

Utility Data Used: Project Default Utility Rates

1 Base Run

2 Design Alternative

Carbon Footprint

Energy, Carbon and Cost Summary

Annual Energy Cost	$79,980
Lifecycle Cost	$1,089,323
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	81.6 tons
Large SUV Equivalent	7.4 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	54 kBtu / ft² / year
Electric	816,283 kWh
Fuel	14,067 Therms
Annual Peak Demand	213.5 kW
Lifecycle Energy	
Electric	24,488,475 kW
Fuel	422,000 Therms

Assumptions

Create a Design Alternative to improve your building performance.

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **Aurora_Stark_R22_bottSPVAE** Updating your building assumptions

Building Summary - Quick Stats

Number of People:	307 people ⬇
Average Lighting Power Density:	0.70 W / ft² ⬇
Average Equipment Power Density:	1.00 W / ft²
Specific Fan Flow:	0.8 cfm / ft²
Specific Fan Power:	0.563 W / cfm

Base Run Construction

Roofs	R50 over Roof Deck U-Value: 0.02	14,911 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	133 ft²
Ceilings	Timber flooring, joists, plasterboard ceiling U-Value: N/A	767 ft²
Exterior Walls	R30 Wood Frame Wall U-Value: 0.04	32,383 ft²

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Specific Cooling:	547 ft² / ton
Specific Heating:	66 ft² / kBtu
Total Fan Flow:	59,334 cfm
Total Cooling Capacity:	143 tons
Total Heating Capacity:	1,185 kBtuh

⬆ higher than typical value
⬇ lower than typical value

Interior Walls	R30 Wood Frame Wall U-Value: 0.04	479 ft²
	R0 Metal Frame Wall U-Value: 0.57	54,983 ft²
Interior Floors	Slab edge R-10 insulation U-Value: 0.03	140 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	3,949 ft²
	Timber flooring, joists, plasterboard ceiling U-Value: N/A	60,678 ft²
Raised Floors	Slab edge R-10 insulation U-Value: 0.03	2,413 ft²
Underground Walls	R7.5 8 in CMU under ground wall U-Value: 0.03	268 ft²
Underground Slabs	Slab edge R-10 insulation U-Value: 0.03	13,015 ft²
Nonsliding Doors	R5 Door (143 doors) U-Value: 0.19	3,349 ft²
Air Openings	North Facing Windows: Air partition (2 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	21 ft²
	Non-North Facing Windows: Air partition (63 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	1,501 ft²
Fixed Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (14 windows) U-Value: 2.10 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	307 ft²
	North Facing Windows: Double glazing - 1/4 in thick - clear/low-E (e = 0.2) glass (8 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.45 , Vlt: 0.45	120 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (28 windows) U-Value: 2.10 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	729 ft²
	Non-North Facing Windows: Double glazing - 1/4 in thick - clear/low-E (e = 0.2) glass (33 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.45 , Vlt: 0.45	347 ft²
Operable Windows	North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (60 windows) U-Value: 2.10 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	1,729 ft²
	Non-North Facing Windows: Low-E double glazing (1/4 in + 1/4 in) (234 windows) U-Value: 2.10 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	6,825 ft²

> 3D VRML View

Base Run Hydronic Equipment **Note:** this information should not be used for sizing purposes.

Domestic Hot Water	Average Demand	377,449 Btu/hr

Base Run Air Equipment **Note:** this information should not be used for sizing purposes.

Packaged Single Zone	Supply Fan Flow	136 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	4 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Single Zone	Supply Fan Flow	12,005 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	349 kBtu/hr
	Heating Capacity	241 kBtu/hr
Packaged Single Zone	Supply Fan Flow	457 cfm
	Annual Supply Fan Run Time	8,760 Hours

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	Cooling Capacity	2 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	13,721 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	324 kBtu/hr
	Heating Capacity	225 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	1,944 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	46 kBtu/hr
	Heating Capacity	32 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	5,641 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	134 kBtu/hr
	Heating Capacity	93 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	684 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	16 kBtu/hr
	Heating Capacity	11 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	380 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	9 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	761 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	18 kBtu/hr
	Heating Capacity	12 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	247 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	4 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	117 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	204 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	286 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	7 kBtu/hr
	Heating Capacity	5 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	198 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	5 kBtu/hr
	Heating Capacity	3 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	664 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	16 kBtu/hr

	Heating Capacity	11 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	842 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	19 kBtu/hr
	Heating Capacity	13 kBtu/hr

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	Cooling Capacity	14 kBtu/hr
	Heating Capacity	10 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,560 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	103 kBtu/hr
	Heating Capacity	71 kBtu/hr
Packaged Single Zone	Supply Fan Flow	7,936 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	230 kBtu/hr
	Heating Capacity	159 kBtu/hr
Packaged Single Zone	Supply Fan Flow	460 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	13 kBtu/hr
	Heating Capacity	9 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,015 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	58 kBtu/hr
	Heating Capacity	40 kBtu/hr
Packaged Single Zone	Supply Fan Flow	178 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	4 kBtu/hr
Packaged Single Zone	Supply Fan Flow	450 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	13 kBtu/hr
	Heating Capacity	9 kBtu/hr
Packaged Single Zone	Supply Fan Flow	8,230 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	236 kBtu/hr
	Heating Capacity	163 kBtu/hr
Packaged Single Zone	Supply Fan Flow	4,314 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	124 kBtu/hr
	Heating Capacity	86 kBtu/hr
Packaged Single Zone	Supply Fan Flow	797 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	23 kBtu/hr
	Heating Capacity	16 kBtu/hr
Packaged Single Zone	Supply Fan Flow	383 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	13 kBtu/hr
	Heating Capacity	9 kBtu/hr
Packaged Single Zone	Supply Fan Flow	2,386 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	69 kBtu/hr
	Heating Capacity	47 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,292 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	95 kBtu/hr
	Heating Capacity	66 kBtu/hr

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Packaged Single Zone	Supply Fan Flow	4,078 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	119 kBtu/hr
	Heating Capacity	82 kBtu/hr
Packaged Single Zone	Supply Fan Flow	315 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	8 kBtu/hr
	Heating Capacity	6 kBtu/hr
Packaged Single Zone	Supply Fan Flow	364 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	11 kBtu/hr
	Heating Capacity	7 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,103 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	32 kBtu/hr
	Heating Capacity	22 kBtu/hr
Packaged Single Zone	Supply Fan Flow	54 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	1 kBtu/hr
Packaged Single Zone	Supply Fan Flow	74 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	3,435 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	98 kBtu/hr
	Heating Capacity	68 kBtu/hr
Packaged Single Zone	Supply Fan Flow	10 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	0 kBtu/hr
	Heating Capacity	0 kBtu/hr
Packaged Single Zone	Supply Fan Flow	100 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	1,871 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	53 kBtu/hr
	Heating Capacity	37 kBtu/hr
Packaged Single Zone	Supply Fan Flow	107 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	3 kBtu/hr
	Heating Capacity	2 kBtu/hr
Packaged Single Zone	Supply Fan Flow	433 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	12 kBtu/hr
	Heating Capacity	8 kBtu/hr
Packaged Single Zone	Supply Fan Flow	606 cfm
	Annual Supply Fan Run Time	8,760 Hours

https://gbs.autodesk.com/gbs/Scheme/EnergyAndCarbonResults?RunId=%2fbfwex6mZbY%3d&AltRunID=cJfGmxrUVvo%3d 4/5

	Cooling Capacity	17 kBtu/hr
	Heating Capacity	11 kBtu/hr
Packaged Single Zone	Supply Fan Flow	186 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	6 kBtu/hr
	Heating Capacity	4 kBtu/hr

Run List | Project Defaults | Project Details | Project Members | Utility Information | Weather Station | Notes

Run Name: The Clara_R22_bottSPVAE

Energy and Carbon Results | Water Usage | Photovoltaic Analysis | LEED Daylight | 3D VRML View | Export and Download Data Files | Design Alternatives

Project Template Applied: The Clara_R22_bottSPVAE_default
Location: Eagle, ID

Building Type: MultiFamily
Floor Area: 229,593 ft²

Electric Cost: $0.06 / kWh
Fuel Cost: $0.80 / Therm

Utility Data Used: Project Default Utility Rates

1 Base Run

Energy, Carbon and Cost Summary

Annual Energy Cost	$183,079
Lifecycle Cost	$2,493,532
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	228.6 tons
Large SUV Equivalent	20.8 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	56 kBtu / ft² / year
Electric	2,631,061 kWh
Fuel	39,412 Therms
Annual Peak Demand	710.3 kW
Lifecycle Energy	
Electric	78,931,830 kW
Fuel	1,182,361 Therms

Assumptions

2 Design Alternative

Create a Design Alternative to improve your building performance.

Carbon Footprint

Base Run Carbon Neutral Potential

Annual CO_2 Emissions	
1 Base Run	N/A
Onsite Renewable Potential	N/A
Natural Ventilation Potential	N/A
Onsite Biofuel Use	N/A
Net CO_2 Emissions	**N/A**
Net Large SUV Equivalent:	N/A

Assumptions

Electric Power Plant Sources in Your Region

Fossil	N/A
Nuclear	N/A
Hydroelectric	N/A
Renewable	N/A
Other	N/A

Assumptions

LEED, Photovoltaic, Wind Energy, and Natural Ventilation Potential

Energy End Use Charts

Building Details and Assumptions

Note: Details shown below are for the Base Run **The Clara_R22_bottSPVAE**

Updating your building assumptions

Building Summary - Quick Stats

Number of People:	765 people ⬇
Average Lighting Power Density:	0.70 W / ft² ⬇
Average Equipment Power Density:	1.00 W / ft²
Specific Fan Flow:	0.8 cfm / ft²
Specific Fan Power:	0.234 W / cfm ⬇
Specific Cooling:	620 ft² / ton

Base Run Construction

Roofs	R38 Wood Frame Roof U-Value: 0.02	64,102 ft²
Ceilings	4 in reinforced-concrete ceiling U-Value: N/A	17,967 ft²
Exterior Walls	R21 Wood Frame Wall U-Value: 0.05	170,421 ft²
	R38 Wood Frame Roof U-Value: 0.02	37,448 ft²

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Specific Heating:	75 ft² / kBtu
Total Fan Flow:	198,691 cfm
Total Cooling Capacity:	420 tons
Total Heating Capacity:	3,486 kBtuh

⬆ higher than typical value
⬇ lower than typical value

Interior Walls	4 in reinforced-concrete ceiling U-Value: N/A	67 ft²
	Uninsulated Interior Wall U-Value: 0.41	153,360 ft²
Interior Floors	Timber flooring, joists, plasterboard ceiling U-Value: N/A	148,377 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	98,328 ft²
Raised Floors	Timber flooring, joists, plasterboard ceiling U-Value: N/A	656 ft²
	4 in reinforced-concrete ceiling U-Value: N/A	229 ft²
Slabs On Grade	Slab edge R-10 insulation U-Value: 0.03	95,343 ft²
Nonsliding Doors	R5 Door (801 doors) U-Value: 0.19	18,409 ft²
Air Openings	North Facing Windows: Air partition (28 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	2,121 ft²
	Non-North Facing Windows: Air partition (55 doors) U-Value: 3.76 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	4,586 ft²
Operable Windows	North Facing Windows: Double glazing - 1/8 in thick - low-E/clear (e = 0.1) glass (543 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	8,572 ft²
	Non-North Facing Windows: Double glazing - 1/8 in thick - low-E/clear (e = 0.1) glass (1122 windows) U-Value: 1.99 W / (m²-K), SHGC: 0.65 , Vlt: 0.76	17,899 ft²

> 3D VRML View

Base Run Hydronic Equipment — **Note:** this information should not be used for sizing purposes.

Domestic Hot Water	Average Demand	993,200 Btu/hr

Base Run Air Equipment — **Note:** this information should not be used for sizing purposes.

Packaged Terminal Air Conditioner	Supply Fan Flow	48,332 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1,215 kBtu/hr
	Heating Capacity	841 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	53,782 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	1,362 kBtu/hr
	Heating Capacity	943 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	13,486 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	338 kBtu/hr
	Heating Capacity	234 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	7,633 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	192 kBtu/hr
	Heating Capacity	133 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	28,641 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	739 kBtu/hr
	Heating Capacity	511 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	27,844 cfm
	Annual Supply Fan Run Time	8,760 Hours

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	Cooling Capacity	717 kBtu/hr
	Heating Capacity	496 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	5,255 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	130 kBtu/hr
	Heating Capacity	90 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	2,221 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	55 kBtu/hr
	Heating Capacity	38 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	821 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	20 kBtu/hr
	Heating Capacity	14 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	2,364 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	59 kBtu/hr
	Heating Capacity	41 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	7,080 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	178 kBtu/hr
	Heating Capacity	123 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	518 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	13 kBtu/hr
	Heating Capacity	9 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	79 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	2 kBtu/hr
	Heating Capacity	1 kBtu/hr
Packaged Terminal Air Conditioner	Supply Fan Flow	637 cfm
	Annual Supply Fan Run Time	8,760 Hours
	Cooling Capacity	16 kBtu/hr
	Heating Capacity	11 kBtu/hr

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