NET-ZERO ENERGY COMMERCIAL INDUSTRIAL BUILDING DEVELOPMENT

PART 2: DESIGN GUIDE

ENERGY TRUST OF OREGON NET ZERO FELLOWSHIP, OCTOBER 2022

NOTE: PART 1: RESEARCH REPORT UNDER SEPARATE COVER

mwa architects

Energy Trust of Oregon

CONVERGENCE ARCHITECTURE

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Definitions and Acronyms

AV	audio visual
BMP	best management practices
CATV	cable television
CCT	light correlated color temperature
CCTV	closed circuit television
CLT	cross-laminated timber
COBID	Certification Office for Business Inclusion and Diversity
CPTED	crime prevention through environmental design
DAS	distributed antenna system
DCV	demand control ventilation
DDC	direct digital control
DOAS	direct outdoor air system
ESJ	Equity and Social Justice
ETO	Energy Trust of Oregon
EUI	Energy Use Intensity
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
FAR	floor area ratio
FDC	fire department connection
GIS	geographic information systems
GSI	green stormwater infrastructure
HRV	heat recovery ventilator
HVAC	centralized heating, ventilating, and air conditioning
I&C	instrumentation and control
ILFI	International Living Futures Institute
LBC	Living Building Challenge
LEED	Leadership in Energy and Environmental Design
LED	light emitting diode
LID	low impact development
MWESB	minority-owned, women-owned, or emerging small business
ODOE	Oregon Department of Energy
OEESC	Oregon Efficiency Specialty Code
PV	photovoltaic
PIV	post indicator valve
ROW	right-of-way
TM	technical memorandum
USGBC	United States Green Building Council
VAV	variable air volume
VRF	variable refrigerant flow
OSSC	Oregon Structural Specialty Code

Project Funder

ENERGY TRUST OF OREGON

421 SW Oak St, Suite 300

Portland OR, 97204

(503) 493-8888

Project Team

MWA ARCHITECTS, INC.

70 NW Couch Street #401

Portland, Oregon 97209

(503) 973-5151

Jean Root, Principal

Caitlin Smith, Designer

Melissa Guarin, Architect

Jessie Meeks, Intern

CONVERGENCE ARCHITECTURE

7302 N Richmond Ave

Portland OR 97203

(503) 308-1028

Barb Anderson, Principal

Crystal Glanz-Kreutz, Project Manager

1. Introduction

This Design Guide was developed by MWA Architects, Inc. (MWA) in collaboration with Convergence Architecture (CA).

This is not an exhaustive net zero guide. It is meant to complement other available net zero design resources by focusing on the specific needs of commercial-industrial development and the key building components and systems they need. All design material presented was developed by MWA and represents three decades of commitment to sustainable commercial-industrial development and our Oregon communities.

This guide is a reference document and is the second part of a research project on net zero energy commercial-industrial development in Oregon:

Part 1 Research Report: The Research Report identifies potential barriers in local development codes, standards, and policies for net zero commercial-industrial development. Information gathered from this research collects past and predicted environmental and community factors influencing net zero commercial-industrial development in Oregon.

Part 2 Design Guide: The Design Guide provides examples of design and detailing for four typical commercial-industrial building types.

COMMERCIAL-INDUSTRIAL DEVELOPMENT

Definition: Publicly or privately owned individual buildings or collection of buildings. May be a development on a campus. Typically, they are employment centers located in industrially-zoned neighborhoods and provide living wage jobs to our communities.

1.1 HOW TO USE THIS GUIDE

This guide is a resource for designers and policy makers interested in making their communities more conducive to net zero commercial-industrial developments. This guide has been thoughtfully planned to get practical net zero commercial-industrial design parameters to a wide audience. The target audiences are:

- Architectural design firms; especially small minority and women-owned firms
- Public agencies with commercial-industrial assets
- Public agencies who have influence on local development regulations

This guide is intended to be used as a completement to Part 1, the Research Report. The Research Report suggested a framework for early data collection that could inform net-zero development, specifically the design of the buildings for commercial-industrial development. The following steps will ease the start for this development type:

1. Use the Research Report framework to collect essential project information on climate, regulations, culture and politics.
2. Identify the building typologies needed and refence the Design Guide for technical guidance.

COMMERCIAL INDUSTRIAL TYPOLOGIES

Building typologies addressed in this research include:

- Mixed-use office
- Warehouse
- Pre-engineered metal building
- Unoccupied service building

Approach

NET ZERO ENERGY DESIGN OPPORTUNITIES FOR OREGON

SOLAR-BASED OPPORTUNITIES

- Solar arrays
- Passive heating and cooling
- Daylighting
- Solar shading at windows and doors
- Whole building shading

WATER-BASED OPPORTUNITIES

- Solar water pre-heating
- Rainwater collection for irrigation and toilets
- Grey water recycling for irrigation and toilets
- Vegetated roof

GEOLOGY-BASED OPPORTUNITIES

- Ground source heat pump technology
- Thermal mass
- Earth tubes for cooling
- Geothermal energy generation
- Earth tubes for cooling
- Geothermal energy collection

In Part 1, the Research Report, the top three fastest growing regions in Oregon – Willamette Valley, Rogue Valley, and High Desert – are discussed. The data clearly demonstrates that designing for energy and climate is not optional, but essential to keep our planet and our people healthy. The Research Report also covers each region's unique climate and cultural context and documented progress in sustainable development ordinances.

This Design Guide turns that research into action by providing technical solutions to some of the stated barriers. These solutions are most effective in the earliest stages of design, ensuring that opportunities have the greatest impact on overall energy use. This design guide includes the following:

3. Considerations during each phase of the project (schematic design, design development, and construction documents) with an emphasis on the beginning, planning stages of design.
4. Guidance on specific building systems, including passive design strategies, envelope components, glazing and shading, and Mechanical, Electrical, and Plumbing (MEP) systems.
5. Examples relate to net zero and net positive building design for four major industrial development types: mixed-use office and industrial, warehouse, pre-engineered metal building, and unoccupied service building. Each example showcases the following:
    a. A brief description of the building design. Examples include a building designed for Living Future Institute Petal Certification and a LEED Gold Facility
    b. Example envelope assemblies (including floor, wall, and roof) with descriptions and performance properties
    c. Wall sections and details of important conditions that make the largest impact on energy savings
    d. Materials selection and performance properties

These examples reflect MWA's experience on real projects. They have been carefully collected and combined into this design guide as a reference for designers during each phase of design. We anticipate that building design for net zero will need to evolve to reflect changes in environmental conditions discussed in the Research Report. Energy is growing more precious and our built environment will need to actively participate in energy generation. This guide supports that future.

2. Design Guidelines

2.1 IMPLEMENTATION IN DESIGN

2.1.1 PRE-DESIGN

Planning for net zero is the first step before any design can start. Before the schematic phase, it is imperative to:

Define project goals and EUI performance targets related to sustainability, operation, and maintenance.

Define an integrated project team including architect, interior designer, landscape designer, civil engineer, MEP engineer, lighting designer, sustainability consultant, etc. All team members should be included early in the design process to provide influence into the initial design and insight into project goals.

2.1.2 SCHEMATIC DESIGN

During the early design phase, sustainability goals should be established. Goals should be revisited throughout the design process to check design progress against sustainable criteria that has been set. During the schematic design phase, initial decisions are being made related to building site, orientation, form, and fenestration. These decisions have the largest overall impact on the efficiency of a building and should be closely analyzed. Early comparative energy modeling can help to narrow down different design options. Iterative building systems can help to inform fundamental design decisions. Placement and programming of interior spaces should take into consideration daylighting, heating and cooling needs, passive design strategies, and reducing overall building footprint. Some strategies to consider during this phase are:

1. Solar-based opportunities
    a. Building orientation and site viability for solar array (photovoltaics)
    b. Passive heating and cooling strategies (operable windows, utilizing thermal mass, shade from vegetation)
    c. Daylighting (clerestories, skylights, fenestration location, and overall window-wall ratio)
    d. Solar shading (trees and vegetation, exterior shading devices)
    e. Whole building shading (surrounding buildings and other geographic site elements)
2. Water-based opportunities
    a. Rainwater collection viability
    b. Greywater recycling viability
    c. Vegetated roof (intensive or extensive), raingarden, or stormwater planter system location and viability based on climate zone
3. Geology & site-based opportunities
    a. Ground source heat pump viability
    b. Thermal mass building envelope
    c. Topography and building design (utilizing slopes, basement, plinth)

d. Building massing configuration (one story vs. two stories and the impact on energy)
e. Wind-power opportunities

It is imperative during this stage in the design process to get all members of the design team involved in conversations. Gathering input from all team members will result in a holistic and efficient design in which no system is underrepresented.

2.1.3 DESIGN DEVELOPMENT

In the Design Development phase, building massing and orientation should be finalized. In Oregon, a rectangular building massing with a long direction oriented on the east-west axis is usually the most efficient shape for envelope performance. This allows for the greatest amount of daylighting (and therefore reduced electrical loads) and minimizes solar heat gain through the east and west windows. However, site opportunities, zoning, building codes, and building programs must be studied to determine if this building massing and orientation are feasible. Additional details on passive strategies may need to be refined during design development, and more detailed conversations about building systems, especially mechanical and electrical systems, will need to be decided. Some considerations during this phase are:

1. Solar-based opportunities
    a. Sizing the solar array to meet net zero
    b. Passive heating and cooling (operable windows, night flush) and integration into building automation systems
    c. Daylighting (finalizing placement and size of fenestrations, optimizing window-wall ratio)
    d. Glazing performance selection (U-value, SHGC, low-e)
    e. Solar shading
        i. Vertical or slanted fins on east and west
        ii. Vertical fins on the north
        iii. Horizontal shades on south
    f. Solar shades (exterior or interior) and integration with building automation system
    g. Electric lighting and daylighting integration
2. Water-based opportunities
    a. Solar-water preheat for use in showers and plumbing fixtures (size and placement of system)
    b. Rainwater collection for irrigation and toilet flushing (sizing the system)
    c. Greywater recycling for irrigation and toilet flushing
    d. Vegetated roof (intensive or extensive), raingarden, or stormwater planter system design
3. Geology and site-based opportunities
    a. Ground source heat pump technology

2.1.4 CONSTRUCTION DOCUMENTATION

At the conclusion of the Design Development Phase, all design decisions related to building systems and automation should be accounted for. If all team members have been involved in the design process thus far, there should be no revelations during the Construction Documentation phase. At this point, all decisions on which systems are being utilized should be finalized, sizing and placement of building elements should be determined, and only small revisions are being made. Most adjustments should be minor. Occupancy and use needs are crucial to right-size the systems and reduce mechanical and electrical system loads. The goal by the end of this phase is whole-building integration in which all systems work seamlessly to provide an energy-efficient building. Writing clear specifications that address net zero design products and processes should be coordinated with each discipline.

2.1.5 CONSTRUCTION ADMINISTRATION

Relate construction administration activities back to the project energy goals; make the contractor aware of those goals. Add considerations related to meeting net zero goals such as air infiltration testing needed during construction. During construction, some considerations to energy conscious design include:

1. Managing construction waste – a waste management plan should be provided within the specifications
2. Managing water use and energy use on site
3. Minimizing site disturbance

2.1.6 POST-OCCUPANCY

Building commissioning checks the building performance against design intent and ensures that the building is operating as designed. It is important to connect commissioning to project goals and to acknowledge regional jurisdictional sustainability goals when planning commissioning activities. Bring any energy modeling projections into a review of building performance. Look for ways to connect commissioning to ongoing Strategic Energy Management. Build a continuum from owner's goals to post-occupancy and beyond. Building commissioning can include but is not limited to the envelope, HVAC system, electrical and automation system, lighting, life safety, specialty systems, plumbing, and interior finishes. This includes documentation of systems operation and maintenance, performance testing, and training for building owners and maintenance crew members. Building commissioning can improve energy performance and system operation and ensure proper maintenance and inspection.

After the first year of occupancy, an occupant survey should be conducted to evaluate occupant comfort and satisfaction. An energy-efficient building needs to be functional and easy to use for the people who live or work in the space.

Additionally, metered data should be monitored to ensure that the building is operating at net zero as intended post-occupancy. There are challenges to professional monitoring in rural areas. Access to certified building and equipment commissioning agents can be cost prohibitive as travel and availability of agents may be seen as an added and unnecessary expense. One approach to this challenge is to leverage warranties and equipment providers within the warranty period for verification of performance. Another is to embed Strategic Energy Management practices within the organizational culture.

2.2 BUILDING COMPONENT CONSIDERATIONS

2.2.1 ENVELOPE

The building envelope is the most important design component for a net zero or net positive building. It is comprised of three main elements: thermal resistance, moisture management, and air infiltration.

THERMAL RESISTANCE

All building materials have thermal resistance (R-value). Insulation is the major component in resisting thermal transfer between the exterior and interior of the building. In most cases, insulation R-values should be specified to exceed energy code required minimums, however additional material thickness has a logarithmic impact, in which at some point, adding more insulation is not cost-effective or feasible for construction. Finding the correct balance between insulation thickness and necessary R-value is vital in designing net zero buildings efficiently. Insulation has the highest impact when placed continuously outboard of the wall structure. This reduces thermal bridging that occurs when other building materials disrupt the insulation in the wall. The more instances of thermal bridges that occur, the more areas that thermal transfer occurs, therefore requiring more energy from the building HVAC system to heat and cool a space. Common insulating materials and their application are listed below.

INSULATING MATERIALS

MATERIAL	PROPERTIES/DETAILS
Rigid Insulation	Rigid insulation can be made of polystyrene, polyisocyanurate, or polyurethane Depending on the material, it can provide between R-3.65 to R-8 per inch of thickness (up to 2 times greater than other insulating materials of the same thickness). Rigid insulation is effective in reducing thermal bridging as it provides a continuous barrier when installed outboard of the wall structure.
Loose fill/blow-in	Made up of small particles of fiber or foam, loose fill and blow in insulation is generally made using recycled waste materials of cellulose, fiberglass, or mineral wool.
Batt Insulation	Batt insulation can be made of fiberglass, mineral wool, plastic or natural fibers. It is fitted between studs, joists, and beams. R-19 is most common in 6" stud walls.
Spray-foam	Spray foam is generally used to fill small cavities, openings, and other penetrations to reduce air infiltration. Closed cell spray foam has an R-value of R-7 per inch.
Insulating Concrete Forms (ICFs)	These are used as forms for pouring concrete walls and remain part of the assembly even after the wall is in place. Typical wall R-value is R-20.

MOISTURE MANAGEMENT

Moisture management has an indirect impact on the design of net zero buildings. Proper moisture management greatly increases the longevity of building materials and systems, decreasing maintenance and replacement cost. The decay of building materials can reduce the efficiency of insulation, making the heating/cooling system work harder than necessary. In addition, moisture intrusion has an impact on the humidity of the interior environment, which could cause the ventilation system to overwork to keep indoor humidity levels in the desired range. Moisture sources can include indoor sources such as poor or inadequate ventilation, particularly in high moisture areas such as industrial processes, or areas for cooking or washing.

There are four major ways that moisture can enter a building, these are affected by snow loads and ice dams which demand larger areas in these systems for retention, detention and runoff:

1. Capillary Action – Water moving through a porous material as the result of adhesion, cohesion, and/or surface tension. To mitigate this type of moisture intrusion, capillary breaks of non-porous material are required. This can include air gaps, sheet metal, or impermeable membranes.
2. Air Movement – Water through air movement typically occurs where penetrations exist in the envelope. Where water intrusion occurs at the same time a large temperature differential exists between the interior and exterior of the building, condensation can occur. Condensation can be blocked by using a continuous air barrier. In addition, caulk, sealant, or spray foam insulation around penetrations can reduce the risk of unwanted air infiltration.
3. Vapor Diffusion – This occurs because of a difference in vapor pressure. There is a delicate balance to reduce the amount of vapor diffusion moving into building assemblies, however, if water vapor does intrude, vapor diffusion also allows for drying out of the assemblies.
4. Bulk Water – Rain, runoff, and wind driven water. This type of moisture intrusion is best managed with effective flashing, drainage planes, and exterior cladding materials such as rainscreens.

A combination of strategies is advised, in order to mitigate moisture intrusion for the four instances described above. Some moisture control strategies are listed below.

MOISTURE CONTROL

MATERIAL	PROPERTIES/DETAILS
Capillary breaks	A non-porous material, usually glass, plastic or metal, that stops water from getting between layers of material.
Vapor barrier	Always install a vapor barrier on the warm side of the insulation in order to prevent condensation. A vapor barrier reduces the movement of water vapor that can get through a wall assembly.
Flashing	Flashing directs the flow of water away from the building and should be used around all openings and penetrations. It is usually made of sheet metal.
Caulking, sealing, and spray foam	Used for sealing and blocking penetrations, cracks, and unwanted gaps that could cause air infiltration.
Exterior cladding	The rainscreen system allows for a capillary break to occur between the cladding and the drain-age layer behind. This allows for drainage and evaporation to occur before water reaches the envelope structure.

AIR INFILTRATION

Air infiltrations are small cracks and penetrations in the building envelope and have one of the largest impacts on heat gain and loss in the building. If penetrations are not properly sealed, air infiltration will occur and impact HVAC system loads. In addition, a continuous weather barrier can decrease the amount of air that can get through porous materials that make up the envelope. An air infiltration strategy to consider:

AIR INFILTRATION MANAGEMENT	
MATERIAL	**PROPERTIES/DETAILS**
Continuous Air Barrier	Controls the infiltration of air into the building. These need to be continuous to be effective.
Air Infiltration Testing	Testing during construction to find and seal air gaps at the appropriate stage of construction, while the envelope and framing are accessible.

2.2.2 GLAZING

Glazing can be a major source of air and moisture infiltration, heat gain/loss and glare. Some aspects to consider when designing glazing and window systems are:

- Orientation, placement, and size
- Sizing and placement of windows for quality daylighting
- Location and size of view windows with framed views
- Clerestories vs. skylights. Clerestories are better suited for glare control and are easier for maintenance, but may not be effective on large-footprint facilities
- Determining the correct window-wall ratio that provides adequate daylighting and views without putting an unnecessary strain on the building's heating and cooling system

OPENING TYPES	
COMPONENTS	**PROPERTIES/DETAILS**
Daylighting	Windows for daylighting are used above 7 ft. on the wall – above the eyeline of occupants. These windows are important for the light to reach deep into the space.
View	View windows allow for daylight as well as views to the exterior. These types of windows are the biggest cause of glare, and large windows will create a larger heating and cooling load for the building. Mindful placement of view windows can reduce building energy consumption significantly.
Top lighting (skylights)	Skylights can allow light to get into a building with very large footprints, such as warehouses. However, they require a large amount of maintenance to prevent water infiltration and eliminate glare conditions in the summer. These should be used strategically in facilities that do not have regular occupants working on screens.
Clerestories	Clerestories are located high on the wall and are used for daylighting. They can be in the center of a building to function like skylights but with less maintenance required for horizontal glazing.

SHADING COMPONENTS

Shading strategies are used on all facades to block solar heat gain and unwanted glare while filtering in daylight. Some strategies and their uses are listed below.

SHADING STRATEGIES	
COMPONENT	**PROPERTIES/DETAILS**
Light shelves	An overhang that is placed above eye level, with a window above and below to reflect daylight into the interior of the space while reducing glare from direct sun. These are best used on the south elevation to block summer sun. They can be located on the exterior or interior of the building envelope.
Horizontal sunshades	Can be used on the east, west, and south facades to block summer sun, reducing heat gain.
Vertical sunshades	Best used on the east, west, and north to block harsh low sunlight during sunrise/sunset and in the winter.

GLAZING PERFORMANCE

Glazing performance is the measure of the total amount of heat and light passing through the glazing compared with what would pass through a single pane of clear glass.

SHADING STRATEGIES	
COMPONENT	**PROPERTIES/DETAILS**
U-value	The u-value measures the thermal resistance properties of the glazing. A lower u-value is desired to reduce the transfer of temperature through the window. Generally, the u-value should be less than 0.35 for windows.
Visible Transmittance (VT)	VT is the amount of visible light that penetrates through a window. It is expressed as a number between zero and one. A value of 0 indicates low visibility through the glazing, while a value of one indicates clear glass and full visibility. A VT value between 0.30 and 0.70 is typical for double or triple pane windows. Lower VT values usually have lower U-factors, however higher VT values result in better connection to nature. This must be balanced with project needs and goals.
Solar Heat Gain Coefficient (SHGC)	SHGC is measured on a scale of zero to one. A value of zero indicates that no solar heat gain enters the building, while one indicates that all solar heat gain enters the building. A lower SHGC is desired, especially on east and west facades. North-facing windows typically may have higher SHGC values. A value of less than 0.35 is preferred.
Low-e glazing	Low-e glazing is glazing with one or more extremely thin layers of metallic particles applied to the glass, allowing it to filter long wavelengths, or heat, out, while short wavelengths (the visible light spectrum) are allowed to pass through. Emissivity is a measure of how much thermal energy (such as sunlight or indoor heat) is absorbed by or reflected away from a material. Lower emissivity reflects the heat rather than absorbing it, increasing the glass' insulating value. Low-e glass can be created to meet specific climate and project needs.

2.3 BUILDING TYPOLOGY

Four commercial-industrial building typologies are addressed in this guide:

- Mixed-use office and industrial
- Warehouse
- Pre-engineered metal building
- Unoccupied service building

In contrast to including all possible typologies across Oregon industries, this guide focuses on the typologies required by the industries identified during research and outreach. This includes fruit packing, marijuana grows, wine making, wastewater treatment, water treatment, semi-conductor design and manufacture, timber processing, and public works facilities, in addition to others named in the Research Report, Part 1.

Linking these typologies to their climatic opportunities are the details and guidance provided in this document. The adjacent tables provide a multi-disciplinary list of net zero design opportunities. These should be considered in parallel with the architectural design guidance provided in sections 3.3.1 through 3.3.4.

2.3.1 MIXED-USE OFFICE/INDUSTRIAL

Mixed-use office and industrial developments are a necessary building typology for businesses that provide services to the community. Because this type of development is occurring in populated and urban areas, it is increasingly important to design not only for industrial function, but for the health and well-being of the people who work at the facility and live nearby. In addition, as growth occurs, it is important to accommodate not only current but future planned operations and needs.

Mixed-used office and industrial usually have three major space components. Office space for administrative and dispatch activities is typically needed alongside locker rooms, break rooms, and other support spaces. Industrial maintenance and warehouse spaces often include carpentry or metal shops that have exhaust or storage concerns.

Some or all of the mixed-use buildings, depending on programmatic requirements, may need to be operational 24 hours a day, seven days a week.

In the following example, warehousing and maintenance functions exist on the first floor, utilizing wall assembly A, shown in Figure 1 below. A parking garage is located on the second floor, requiring a percentage of the wall to be open to the air. Structurally, the first two levels are supported by concrete beams, columns, and shear walls to comply with Type I-A construction requirements. The third and fourth floors contain office and support spaces that utilize wall assembly B for the exterior envelope and comply with Type V-B construction. The upper floors are supported by CLT floors, beams and columns.

This mixed-use building also features a photovoltaic array on the roof that is designed to account for 110% of the building energy needs, battery power supply storage located on the first floor to keep parts of the building operational in emergencies, a cistern to collect rainwater for specific greywater activities, such as toilet flushing, and a bioretention planter for both biophilia and stormwater management.

The exterior envelope is designed to exceed energy minimum requirements by providing R-50+ for walls, R-48 for the roof, and triple-pane glazing throughout. The heating and cooling requirements for the building are covered by a ground-source system for equivalent loads. Air-water heat pumps are provided for the remainder of the heating and cooling loads. Ventilation is provided through operable windows that have motorized dampers with system automation for operation when outdoor temperature and humidity is in an acceptable range, otherwise, a dedicated outdoor air system (DOAS) is provided.

2.3.1.1 ENVELOPE DESIGN

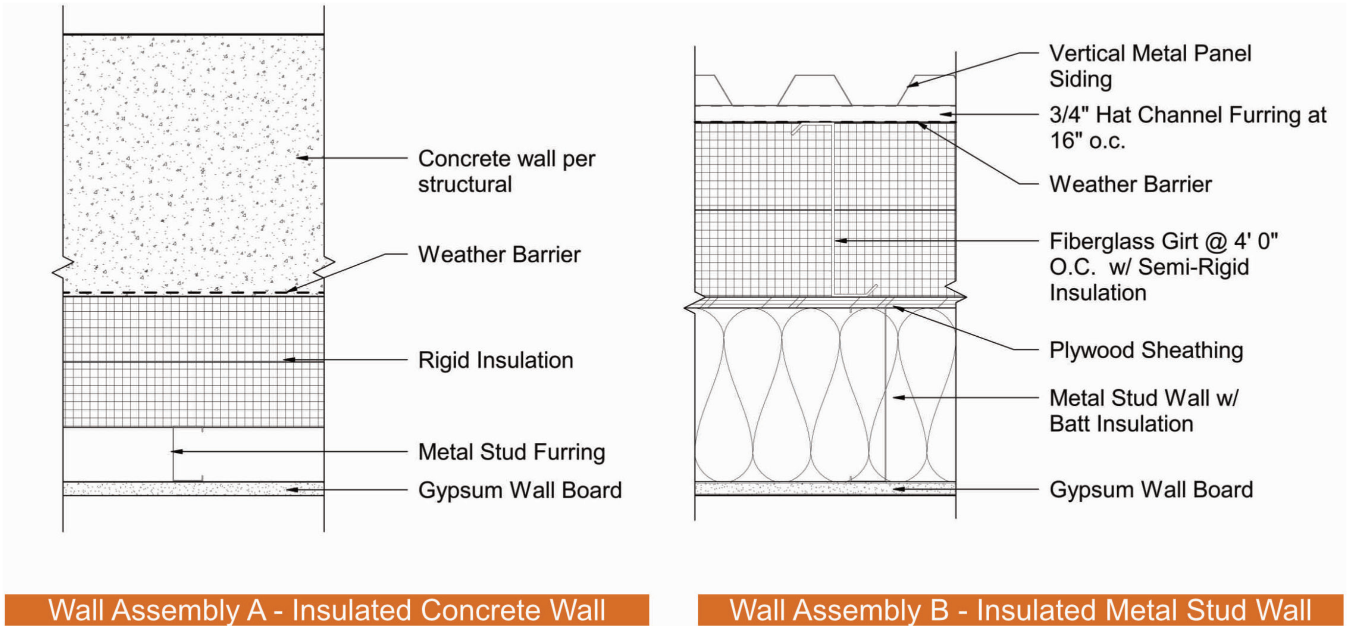


FIGURE 1 - TYPICAL WALL ASSEMBLIES

1. Wall Assembly A – Insulated Concrete Wall

This insulated concrete wall is used where Type I or II fire-resistive construction is required. This is typical for industrial functions such as manufacturing, warehousing, and maintenance areas. A layer of continuous rigid insulation is provided behind the exterior concrete wall for thermal resistance

MAJOR COMPONENT	PROPERTIES/DETAILS
Concrete wall	R-0.2/inch
Weather barrier	Water & air management
Rigid insulation	R-20+
Metal stud	Confirm thermal break

2. Wall Assembly B – Insulated Metal Stud Wall

This wall type is used where Type V construction is acceptable, such as office and support spaces. The vertical metal panel siding acts as a rainscreen, with an air gap and drainage plane behind to block moisture infiltration before it reaches the insulation. Continuous insulation is provided outboard of the wall structure. This eliminates the number of thermal breaks in the wall. Z-girts are used to attach the furring channel to the structure of the building. Fiberglass Z-girts are specially designed to reduce the conduction of temperature from exterior to interior. Batt insulation is provided in the stud wall

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal panel siding	Capillary break
Furring	Confirm thermal break
Rigid insulation	R-20+
Z-Girt (Fiberglass)	Confirm thermal break
Weather barrier	Water & air management
Metal stud	Confirm thermal break
Batt insulation	R-19+

2.3.1.2 FLOOR DESIGN

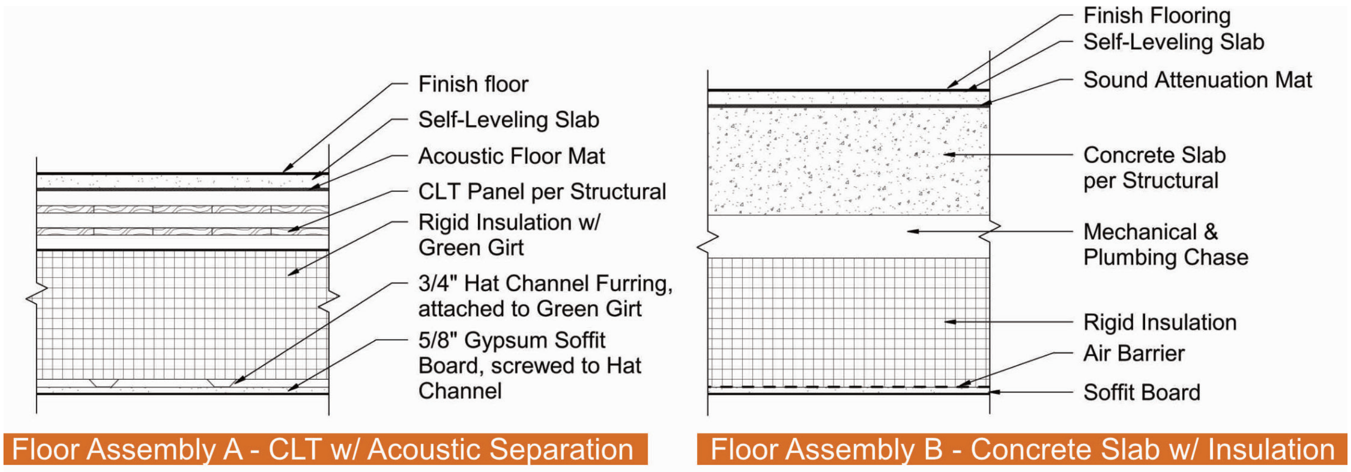


FIGURE 2 - TYPICAL FLOOR ASSEMBLIES

1. Floor Assembly A – CLT with Acoustic Separation

CLT is becoming increasingly popular in construction, especially in Oregon because of the abundance of trees. It has high insulation quality performance compared to concrete. Adding a layer of rigid insulation below helps to improve the thermal performance, airtightness, and acoustic properties of the entire assembly.

MAJOR COMPONENT	PROPERTIES/DETAILS
CLT panel	R1.25/inch
Rigid insulation	R-20+
Furring	Confirm thermal break

2. Floor Assembly B – Concrete Slab with Insulation

Floor Assembly B shows a concrete floor slab with a chase for mechanical and plumbing serving the office floors. Rigid insulation is provided for thermal performance and acoustic separation between the parking level and office floors. An air barrier provides protection from the open-air parking garage.

MAJOR COMPONENT	PROPERTIES/DETAILS
Concrete slab	R-0.2/inch
Air gap	Chase for MEP systems
Rigid insulation	R-20+
Air barrier	Air management

2.3.1.3 ROOF DESIGN

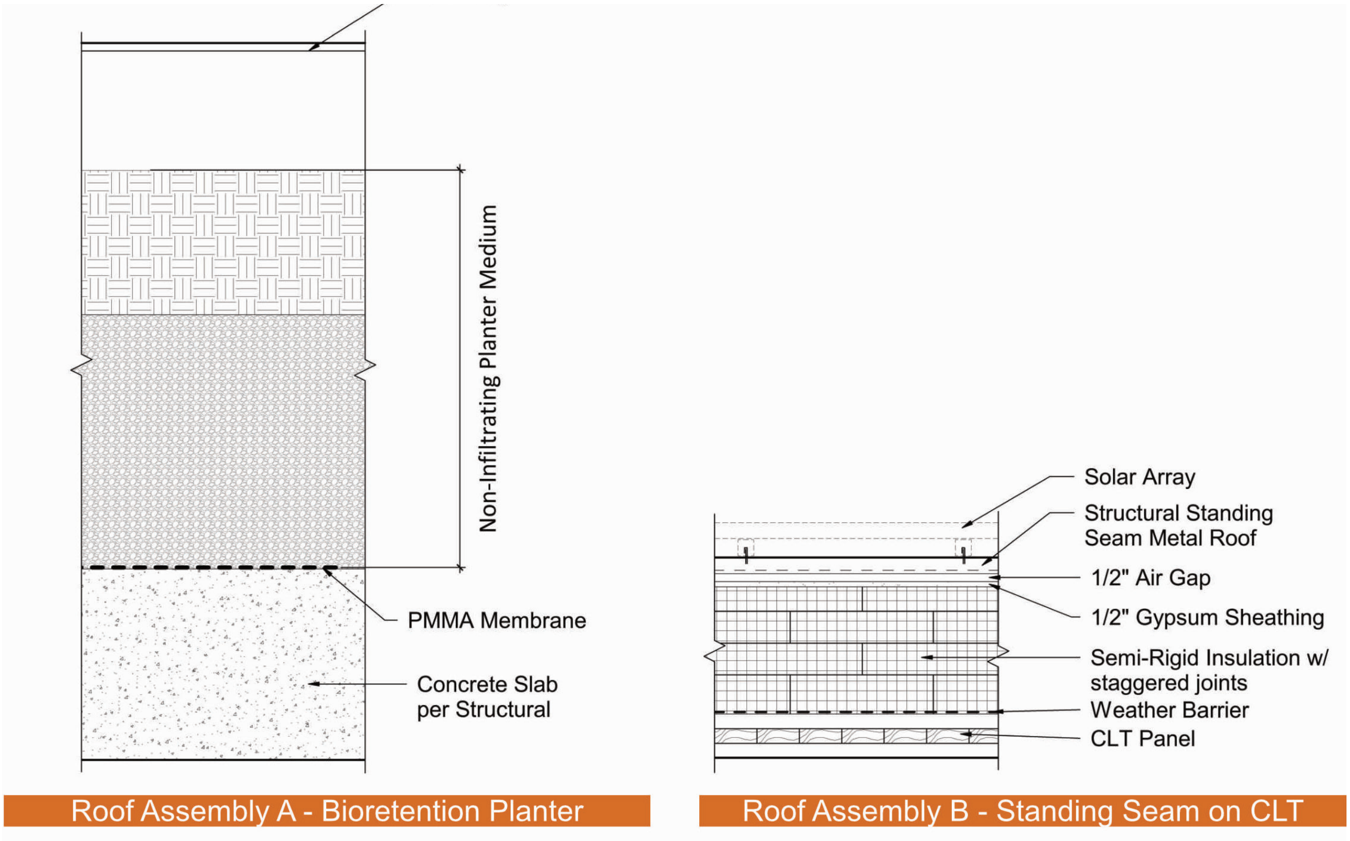


FIGURE 3 - TYPICAL ROOF ASSEMBLIES

1. Roof Assembly A – Bioretention Planter

The intensive vegetated roof is composed of a layer of native plantings within a growing medium of about 6 inches. A root repellant layer is required for intensive vegetative roofs that may include larger plants. A drainage layer of gravel is included. The green roof exists over the parking garage, so no insulation is provided in the following example, however, if a green roof is located over a heated/cooled space, an insulation layer should be provided below the drainage layer. Finally, a waterproof membrane is provided above the structure to prevent any moisture from accumulating.

MAJOR COMPONENT	PROPERTIES/DETAILS
Earth/planting medium	Storm water management
Gravel/drainage	Storm water management
PMMA membrane	Moisture management
Concrete slab	R-0.2/inch
Rigid insulation	Provide if over occupied space

2. Roof Assembly B – Standing Seam on CLT

The roof structure for this building is Cross-Laminated Timber (CLT). A weather barrier is provided above the structure, as well as 8 inches of rigid insulation with staggered joints. The staggered joints help to prevent air and moisture infiltration. Rigid insulation allows this roof to reach R-48. Metal standing seam roof is attached to the structure with Z-girts. A solar array is mounted on the standing seam and allows the building to produce 110% of its own energy.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal roof	Capillary break
Furring	Confirm thermal break
Rigid insulation	R-20+, stagger seams
Weather barrier	Water & air management
CLT Panel	R1.25/inch

2.3.1.4 WALL SECTIONS AND DETAILS

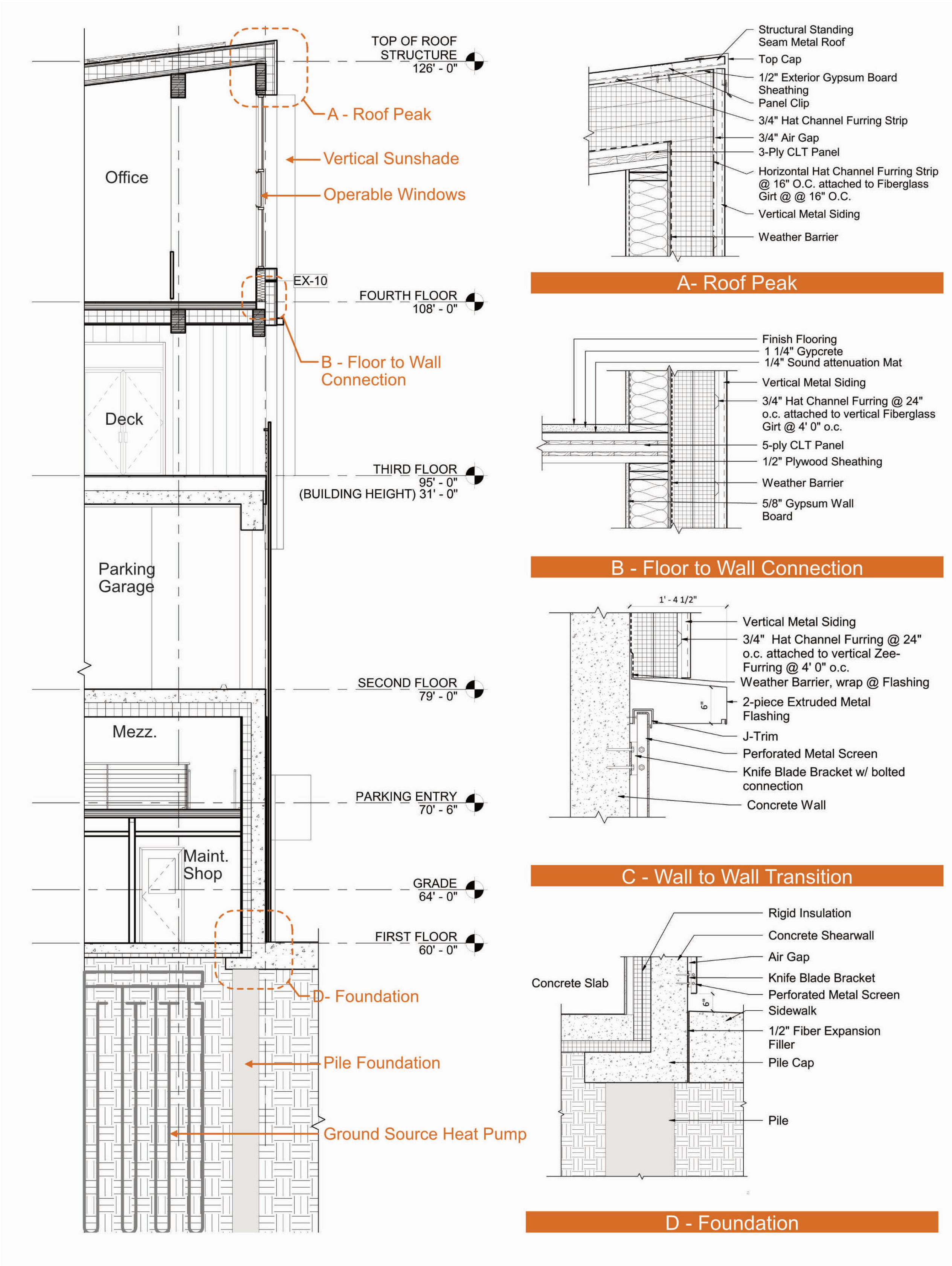


FIGURE 4 - MIXED-USE INDUSTRIAL WALL SECTION & DETAILS (TYPICAL CONDITIONS)

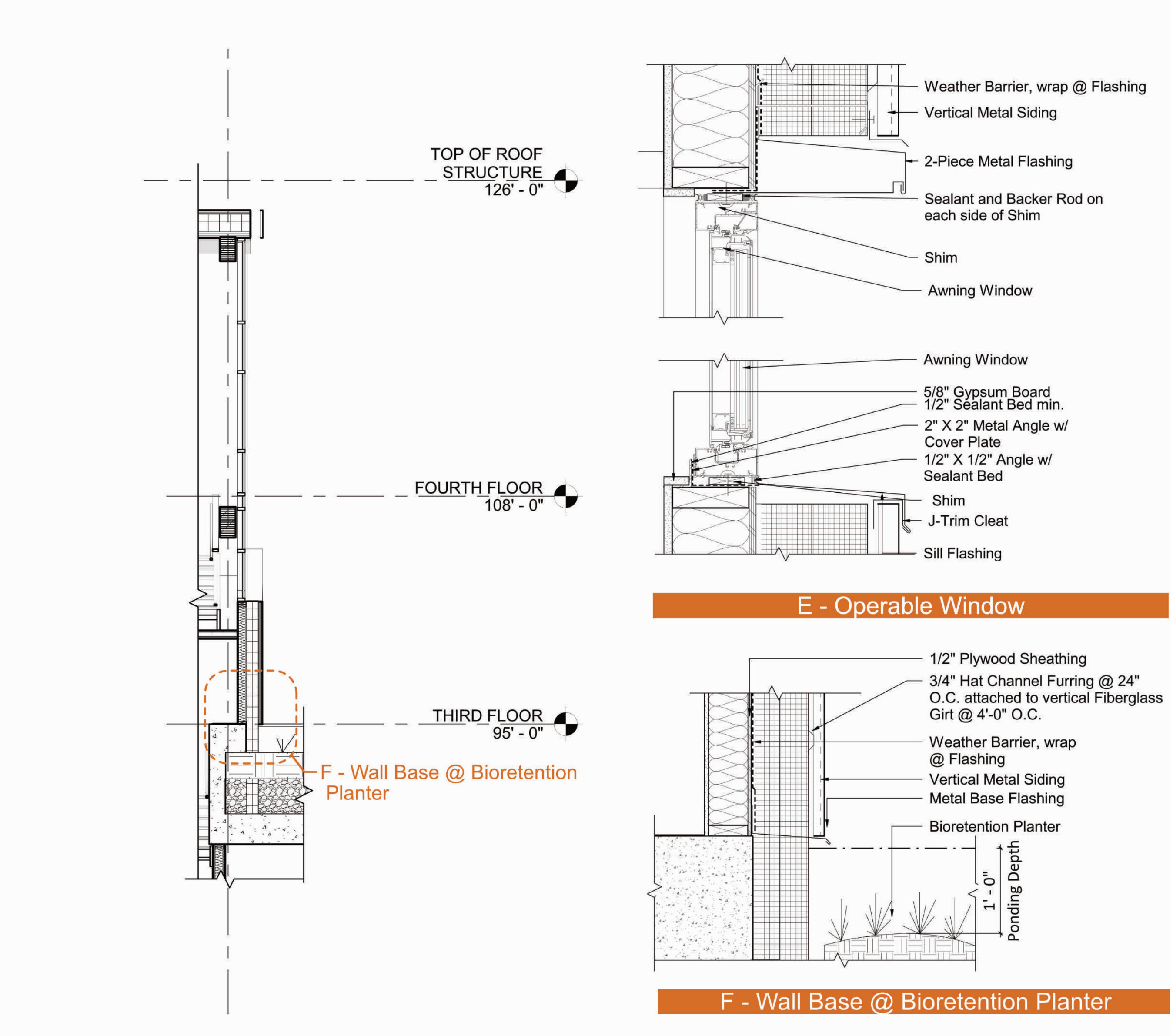


FIGURE 5 - MIXED-USE INDUSTRIAL WALL SECTION AND DETAILS (GREEN ROOF & CURTAIN WALL)

2.3.2 WAREHOUSE

The global pandemic has caused a significant rise of E-commerce and direct-to-consumer warehouse needs for commercial industrial businesses. This growth will continue to transform fulfilment operations for warehouse facilities. Planning considerations for warehouses include accommodations for business service requirements, the products to be stored/handled, and workers within the facility. Designing for the health and well-being of the people who work at the facility should be considered. Additionally, it is important to consider planning for future operations, technologies, and expansion needs. Some or all the buildings, depending on programmatic requirements, may need to be operational 24 hours a day, seven days a week.

Warehouse facilities are classified by their interior thermal and moisture conditioning and include heated, unheated, refrigerated, and controlled humidity. In the following example, a one-story multifunctional warehouse with employee supportive spaces, and a maintenance facility containing heated and unheated spaces, utilizing exterior wall assembly A and B for exterior wall, shown in figures below. Structurally, the warehouse and maintenance facility are supported by long span steel roof trusses, steel beams, steel columns, and structural steel shear wall components to comply with Type III-A construction requirements.

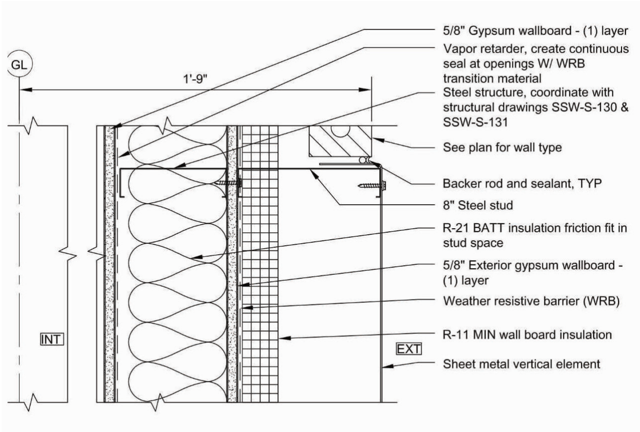
With the Warehouse's large footprint and orientation, the roof area provided an optimal location for solar array photovoltaics. The Warehouse building incorporated a structural frame system for the future photovoltaic panels to be mounted to. This structural frame system was coordinated with the location of the roof truss system and proper roof flashing and sealing were provided at the roofing membrane for moisture control. The infrastructure and space allocations for future installation of additional solar array system inverters, electrical panels, and electric meters were installed.

Though the Warehouse has a large roof footprint ideal for green roof applications, (25 per square foot) the structural requirements for long clear spans within the interior spaces made the lighter dead loads of the solar panel array (5 per square foot) more cost effective at the warehouse. It was decided the green roof system would be located on another facility building located on the same site to provide for additional stormwater management for the overall campus. The Warehouse roof rainwater collection was directed to specific site stormwater treatment facilities on-site. This stormwater treatment became the landscape buffer between the building and the public sidewalk while allowing pedestrians to see the various bioretention planters for both biophilia and stormwater management.

To address visual security in the Warehouse, location and type of windows were considered. A translucent wall system was placed above 9'-0" floor level and selective locations to provide optimal daylighting within the Warehouse. Selective locations of skylights provided daylighting into the large footprint of the warehouse and over circulation spaces versus storage rack locations, as well as being coordinated with the location of the roof solar array system. A strategy of dual-use was applied at the continuous loading dock canopy, creating weather protection for the loading dock area as well as sun shading on the south side of the building.

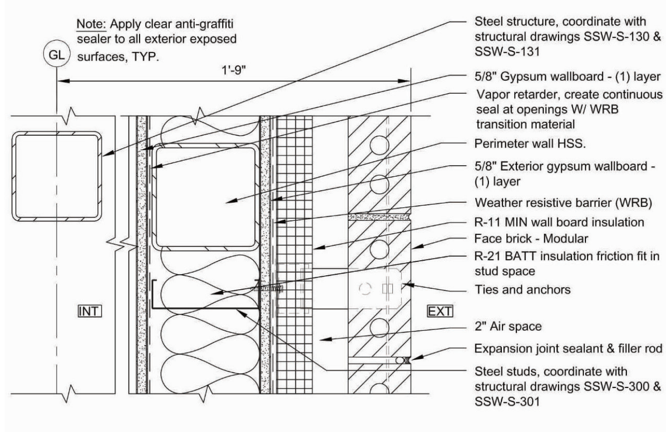
The exterior envelope is designed to exceed energy requirements by providing continuous exterior wall board insulation and interior batt insulation, limited glazing areas, increased roof insulation, and a raised first floor level with geofoam insulation for loading dock height requirements and further thermal insulation. Thermal breaks systems at structural components from interior to exterior wall were addressed at the covered loading dock location.

Depending on the type of Warehouse facility and functions within the Warehouse, sufficient airflow and ventilation are critical. The space planning of required heated and unheated locations creates efficiency of the heating and cooling systems. This example of a warehouse maintenance facility dedicated specific heating and cooling systems based on the various zoning of uses within the building. Roof top heat pump units and mini-split AC system serve offices and supportive spaces for employees. Within the warehouse maintenance spaces, radiant heaters coordinated between Warehouse racks and lighting systems were provided. Warehouse ventilation is by motorized dampers with system automation for operation when outdoor temperature and humidity is in an acceptable range.



Wall Assembly A - Metal Panel on Stud Wall

FIGURE 6 - TYPICAL WALL ASSEMBLIES



Wall Assembly B - Brick Veneer Wall

FIGURE 7 - TYPICAL WALL ASSEMBLIES

1. Wall Assembly A – Metal Panel on Stud Wall

This insulated stud wall with continuous exterior wall board insulation is used for typical conditioned spaces. The vertical metal panel acts as a rainscreen, with an air gap and drainage plane behind to block moisture infiltration before it reaches the insulation. Continuous wall board insulation is provided outboard of the wall structure. This eliminates the number of thermal breaks in the wall. Batt insulation is provided in the stud wall to increase the R-value of the entire wall assembly.

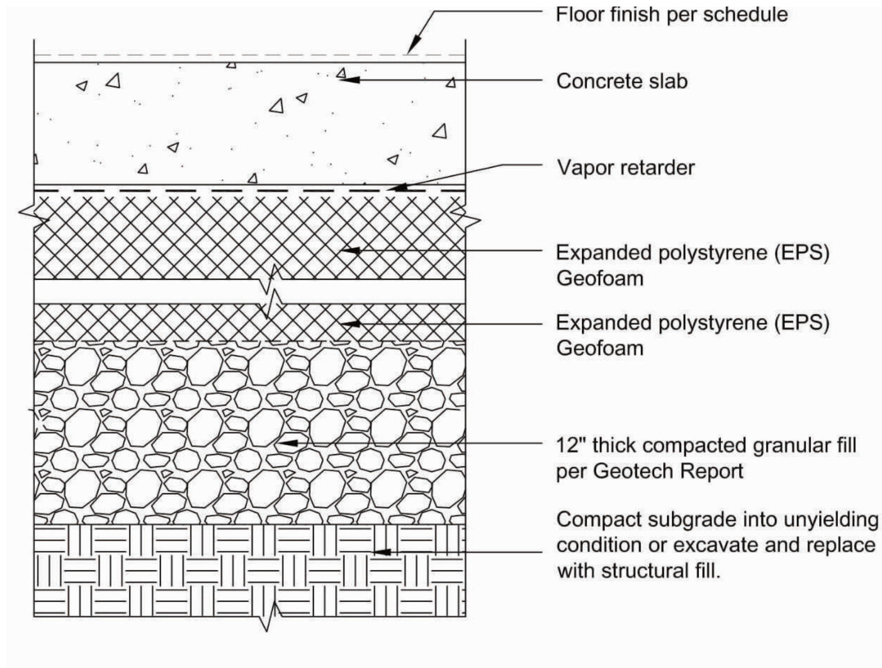
MAJOR COMPONENT	PROPERTIES/DETAILS
Metal wall panel	Capillary break
Air space	Moisture management
Wall board insulation	R-11 min.
Furring	Confirm thermal break
Batt insulation	R-19 min.
Vapor retarder	Water management

2. Wall Assembly B – Brick Veneer Wall on Stud Wall

This insulated stud wall with continuous exterior wall board insulation is used for typical conditioned spaces. The cavity wall brick assembly acts as a rainscreen, with an air gap and drainage plane behind to block moisture infiltration before it reaches the insulation. Continuous wall board insulation is provided outboard of the wall structure. This eliminates thermal breaks in the wall. Thermally broken brick ties are used to attach the face brick to the sheathing structure of the building. Thermally broken brick ties are specially designed to reduce the conduction of temperature from exterior to interior. Batt insulation is provided in the stud wall to increase the R-value of the entire wall assembly.

MAJOR COMPONENT	PROPERTIES/DETAILS
Brick	Capillary break
Air space	Moisture management
Wall board insulation	R-11 min
Brick ties (thermally broken)	Confirm thermal break
Weather resistive barrier	Water & air management
Metal stud	Confirm thermal break
Batt insulation	R-19 min.
Vapor retarder	Water management

2.3.2.2 FLOOR DESIGN



Floor Assembly B - Concrete Slab on Grade

FIGURE 8 - TYPICAL FLOOR ASSEMBLIES

1. Floor Assembly A – Concrete Slab on Grade

This insulated concrete floor is used where a first-floor height is raised above grade to maintain a continuous level height from loading dock height to warehouse area is required. This is typical for industrial functions such as manufacturing, warehousing, and maintenance areas.

MAJOR COMPONENT	PROPERTIES/DETAILS
Concrete slab	R-0.2/inch
Vapor retarder	Water management
Geofoam insulation	R-20 min.

2.3.2.3 ROOF DESIGN

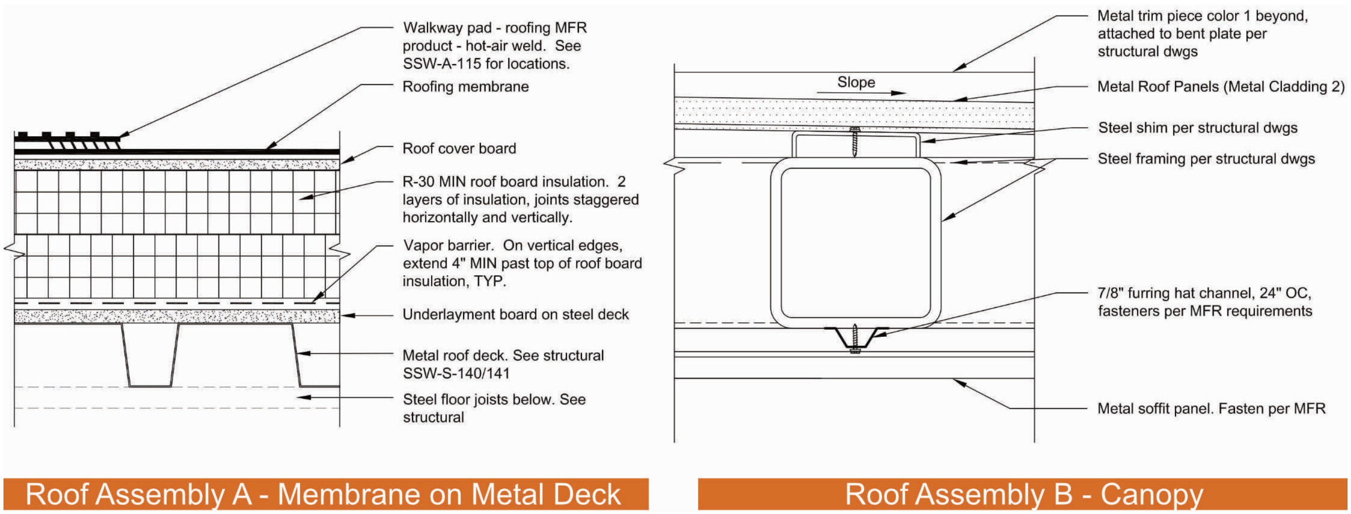


FIGURE 9 - TYPICAL ROOF ASSEMBLIES

1. Roof Assembly A – Roof Membrane on Metal Deck

This insulated roof assembly is used where long clear spans within the interior spaces are required, typical of industrial functions such as manufacturing, warehousing, and maintenance areas. Increased roof board insulation thickness can increase the exterior envelope energy efficiency. Confirm structural roof framing systems load design when green roof systems are provided on the structural roof framing system.

MAJOR COMPONENT	PROPERTIES/DETAILS
Roof membrane	Capillary break
Roof board insulation	R-30 min. staggered joints
Vapor barrier	Water management
Metal roof deck fasteners	Confirm thermal break

2. Roof Assembly B – Canopy

This roof assembly type is used at non-heated exterior applications where outdoor spaces are required to cover and protect employee working areas or storage spaces.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal roof	Capillary break
Structural framing	Confirm thermal break
Furring	Confirm thermal break
Metal soffit	Capillary break

2.3.2.4 WALL SECTIONS AND DETAILS

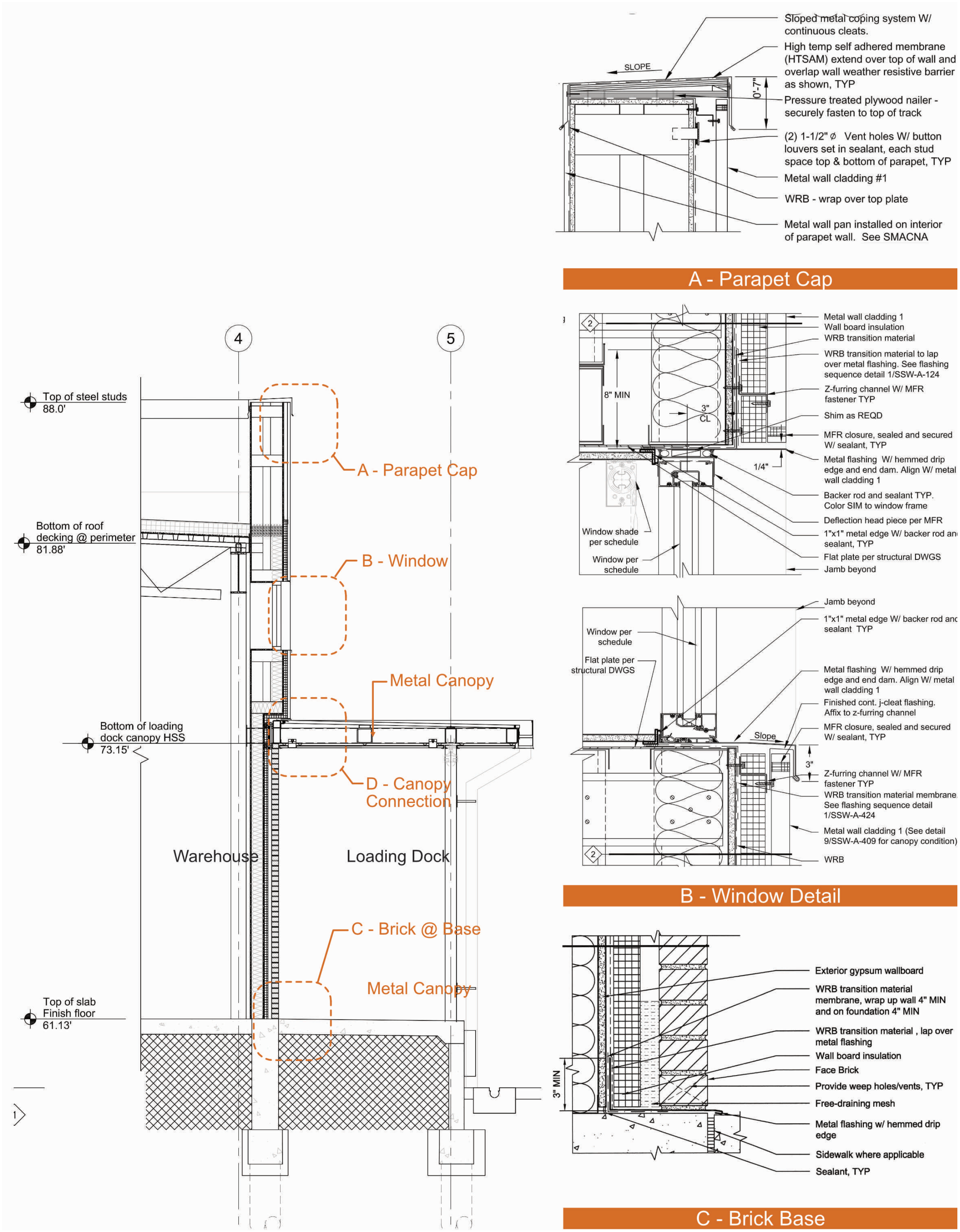


FIGURE 10 - WAREHOUSE WALL SECTION AND DETAILS

2.3.3 PRE-ENGINEERED METAL BUILDING

Pre-engineered buildings are steel structures designed by a pre-engineered building supplier or manufacturer that have a specific design and fabricate the building to have various materials and methods to satisfy different structural and aesthetics requirements. Being pre-engineered in a factory according to design specifications, pre-engineered buildings are erected on-site, requiring no welding and using bolt-together construction. If pre-designed for future expansion, the bolted connections allow the building to expand in length with additional bays or possibly in width and height as well.

The structural primary frame assembly is I-shaped steel sections which can be trusses, beams, and other structural elements. The secondary structural elements are composed of Z-shape or C-shape for purlins, girts, and eave struts. To support the steel structure, conventional concrete foundations are used. Conventional concrete can also be used for the floor. When the foundation is being built on-site, the structural members can be simultaneously fabricated in the factory. Its components, including roof and wall panels, are manufactured and sent to the construction site to be assembled on site. Each building's framed openings are pre-punched at the factory, making installing customized components such as doors, gutters & downspouts, insulation, wall lights, windows, and skylights easier.

In the following example, a one-story transportation fleet vehicle and maintenance facility has heated vehicle storage and maintenance work areas, utilizing exterior wall assembly A for exterior wall, shown in figures below. Structurally, the building takes advantage of the large open interior clear floor areas and overhead clearances for fleet vehicles.

With pre-engineered roofing systems, metal panel roofing provides optimal location for solar array photovoltaic panels. Coordination of skylight locations provide daylighting at fleet workers' maintenance areas and provide additional daylighting overall inside the building. This additional daylighting within the interior space provides daylighting without compromising security needed at the exterior walls of the facility.

Since pre-engineered buildings are made of various components built off site, highly energy efficient exterior wall and roof systems can be considered as well as triple-pane windows, insulated doors, and insulated overhead doors. The ideal locations for thermal breaks for the exterior envelope occur between the primary structure and the secondary structure for walls and roofing systems. This can be achieved with thermal break isolation systems, using fiberglass Z-girts, and pre-engineered insulated metal panels. The concrete slab on grade is an ideal mass structure for radiant floor heating and cooling for consistent temperature control for workers. Ventilation can be provided by motorized dampers with system automation for operation when outdoor temperature and humidity is in an acceptable range.

2.3.3.1 ENVELOPE DESIGN

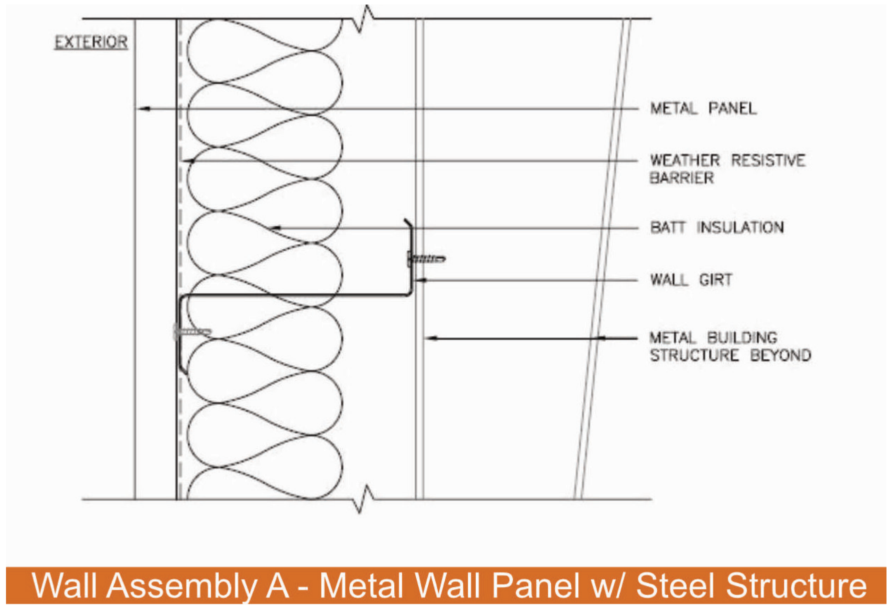


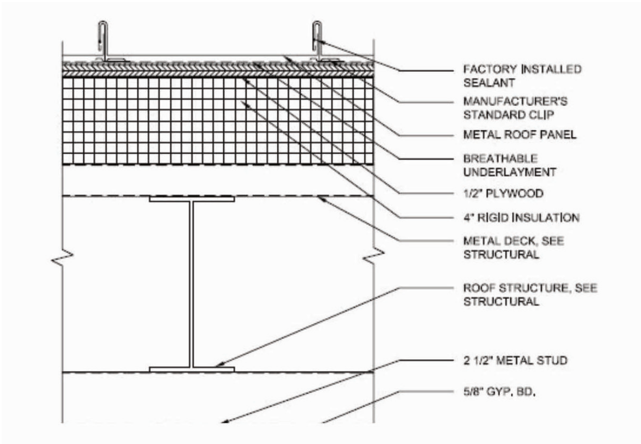
FIGURE 11 - TYPICAL WALL ASSEMBLIES

1. Wall Assembly A – Metal Panel w/ Steel Structure

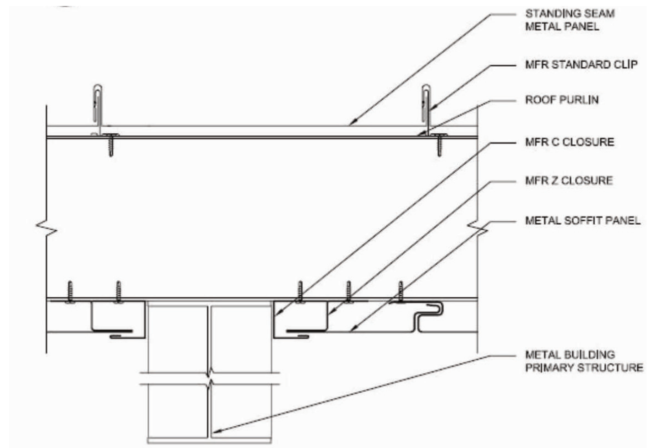
This insulated stud exterior wall is typical for pre-engineered buildings. Consider additional strategies such as additional thermal break between primary structure and Z-girts or use of fiberglass Z-girts for exterior wall systems. This decreases the energy transfer from interior to exterior wall components.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal wall panel	Capillary break
Weather resistive barrier	Water & air management
Batt insulation	R-19 min.
Wall Z-girt	Confirm thermal break
Steel structure	Confirm thermal break

2.3.3.2 ROOF DESIGN



Roof Assembly A - Standing Seam w/ Steel Structure



Roof Assembly B - Exterior Overhang (Metal Soffit)

FIGURE 12 - TYPICAL ROOF ASSEMBLIES

1. Roof Assembly A – Standing Seam with Steel Structure

Standing seam roof panels are typical for this type of structure. Provide acceptable underlayment for drainage and sheathing layer for panel attachment. Rigid insulation should be used to provide a continuous insulation barrier. Staggered joints will help to reduce air infiltration. R-30 insulation is recommended. For addition thermal performance, add batt insulation to the air cavity between steel beams.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal roof panel	Capillary break
Breathable underlayment	Water management
Rigid insulation	R-20+, stagger seams
Metal deck fasteners	Confirm thermal break
Roof structure	Confirm thermal break
Metal stud	Confirm thermal break

2. Roof Assembly B – Exterior Overhang (Metal Soffit)

Uninsulated metal soffit overhang. Typical where exterior circulation will be located outside for staff and maintenance work. Creating a thermal break connection to insulated building envelope is critical.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal panel	Capillary break
Roof purlin	Confirm thermal break with building envelope
Metal soffit panel	Capillary break

2.3.3.3 WALL SECTIONS AND DETAILS

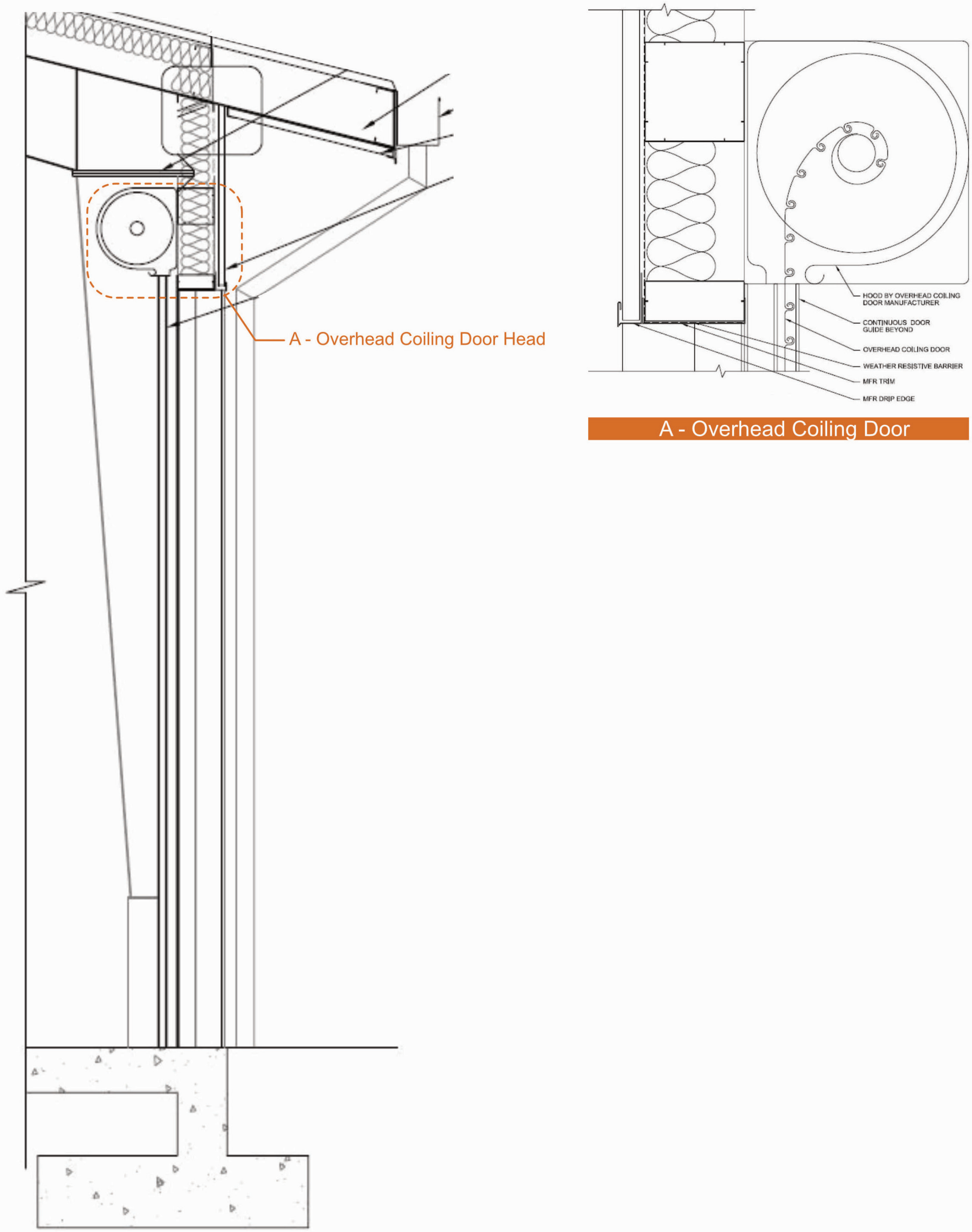


FIGURE 13 - PRE-ENGINEERED BUILDING WALL SECTION AND DETAILS

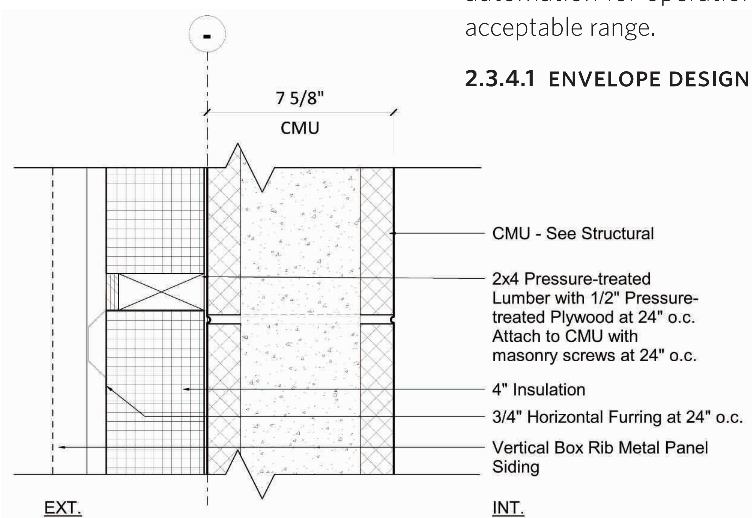
2.3.4 UNOCCUPIED SERVICE BUILDING

Unoccupied service buildings meet various service needs for commercial industrial businesses. These types of buildings need to accommodate an interior temperature range of below freezing point to not-to-exceed 90 degrees. These temperature ranges address the demands of various equipment and utilities and maintains their function within the building.

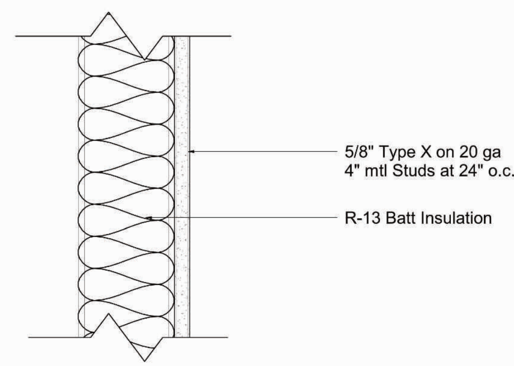
In the following example, a one-story unoccupied service building utilizing exterior wall assembly A for exterior wall envelope, is shown. Structurally, the building takes advantage of concrete masonry units to provide additional perlite loose-fill insulation within their cavities as well as providing another continuous interior insulation and additional exterior insulation.

The metal panel roofing is an optimal location for solar array photovoltaic panels. Without compromising security needed on exterior walls for equipment locations, skylights provide daylighting into a potentially large footprint interior space. Design for specific equipment heating and cooling needs, the concrete slab on grade is an ideal mass for radiant floor heating and cooling. Based on interior temperature and moisture levels, ventilation can be provided by motorized dampers with system automation for operation when outdoor temperature and humidity are in an acceptable range.

2.3.4.1 ENVELOPE DESIGN



Wall Assembly A - Insulated CMU Wall



Wall Assembly B - Interior Furr Wall

FIGURE 14 - TYPICAL WALL ASSEMBLIES

1. Wall Assembly A – Insulated CMU Wall

This insulated concrete wall is used where Type I or II fire-resistive construction is required. This is typical for industrial functions such as manufacturing, warehousing, and maintenance areas. A layer of continuous rigid insulation is provided behind the exterior concrete wall for thermal resistance.

MAJOR COMPONENT	PROPERTIES/DETAILS
Concrete masonry unit	Cavity infill insulation
Weather barrier	Water & air management
Rigid insulation	R-19 min.
Furring	Confirm thermal break
Metal panel siding	Capillary break

2. Wall Assembly B – Interior Furr Wall

Use with insulated CMU wall where greater R-value is required.

MAJOR COMPONENT	PROPERTIES/DETAILS
Studs	Confirm thermal break
Batt Insulation	R-19 min.

2.3.4.2 FLOOR DESIGN

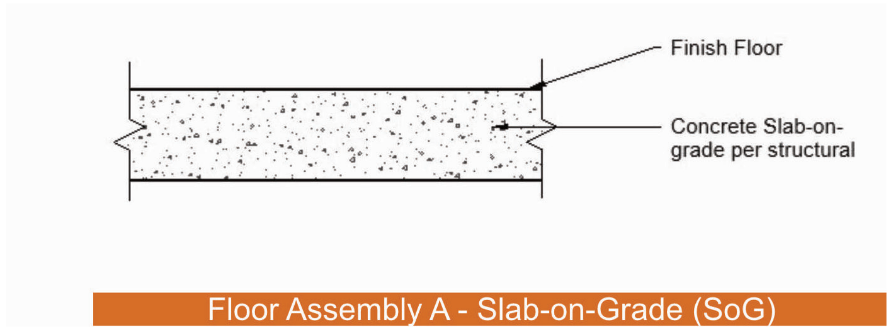


FIGURE 15 - TYPICAL FLOOR ASSEMBLY

1. Floor Assembly A – Concrete Slab on Grade (Uninsulated)

This concrete floor has the opportunity to consider additional insulation for thermal massing for radiant floor heating and cooling of spaces for workers.

MAJOR COMPONENT	PROPERTIES/DETAILS
Concrete slab	R-0.2/inch
Vapor retarder	Water management

2.3.4.3 ROOF DESIGN

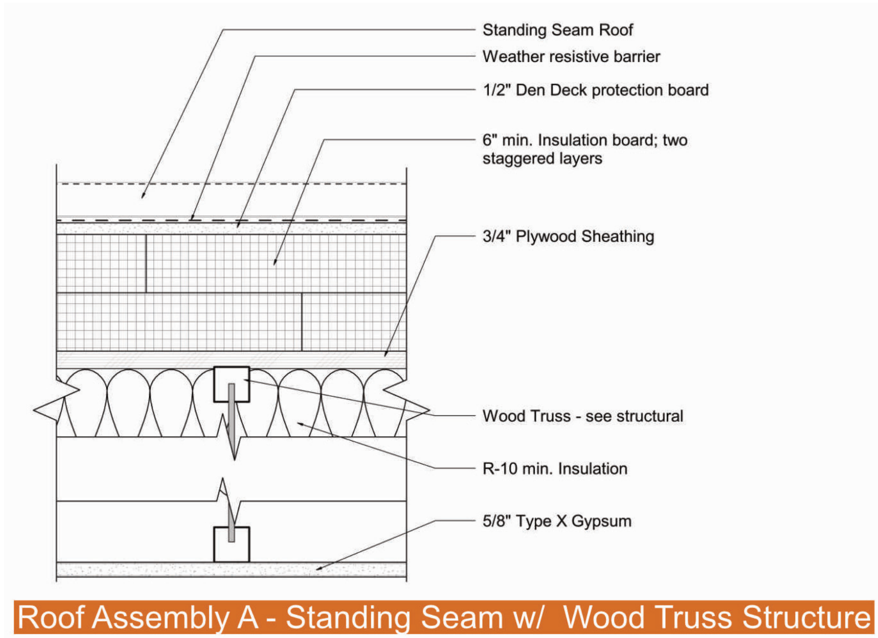


FIGURE 16 - TYPICAL ROOF ASSEMBLY

1. Roof Assembly A – Standing Seam with Wood Truss structure

The roof structure for this building is wood trusses. A weather barrier is provided above the structure, as well as 8 inches of rigid insulation with staggered joints. The staggered joints help to prevent air and moisture infiltration. Rigid insulation allows this roof to reach R-48. A metal standing seam roof is attached to the structure with Z-girts. A solar array is mounted on the standing seam and allows the building to produce 110% of its own energy.

MAJOR COMPONENT	PROPERTIES/DETAILS
Metal roof	Capillary break
Weather resistive barrier	Water & air management
Rigid insulation	R-20+, stagger seams
Batt insulation	R-10+
Wood trusses	Confirm thermal break

2.3.4.4 WALL SECTIONS AND DETAILS

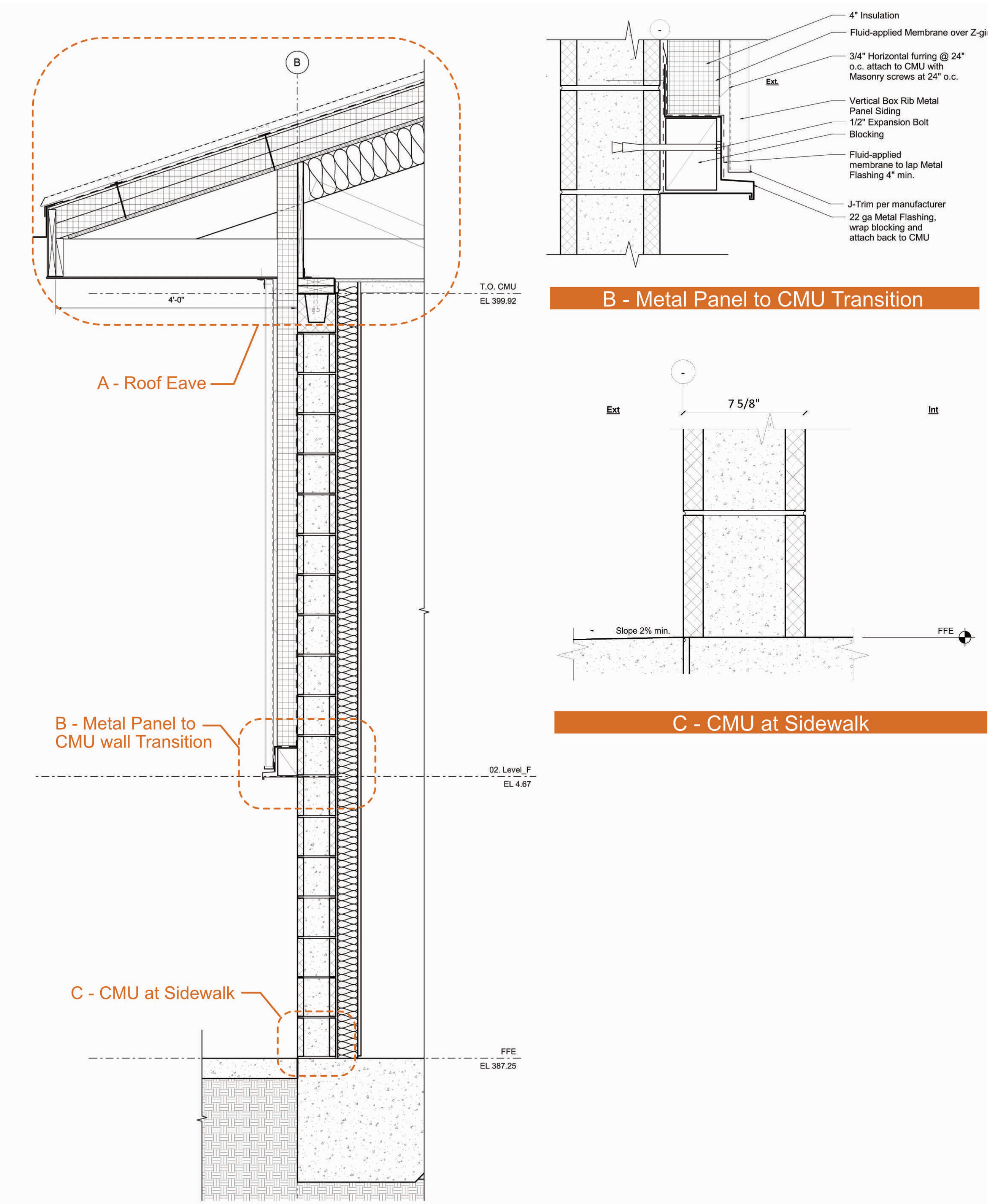
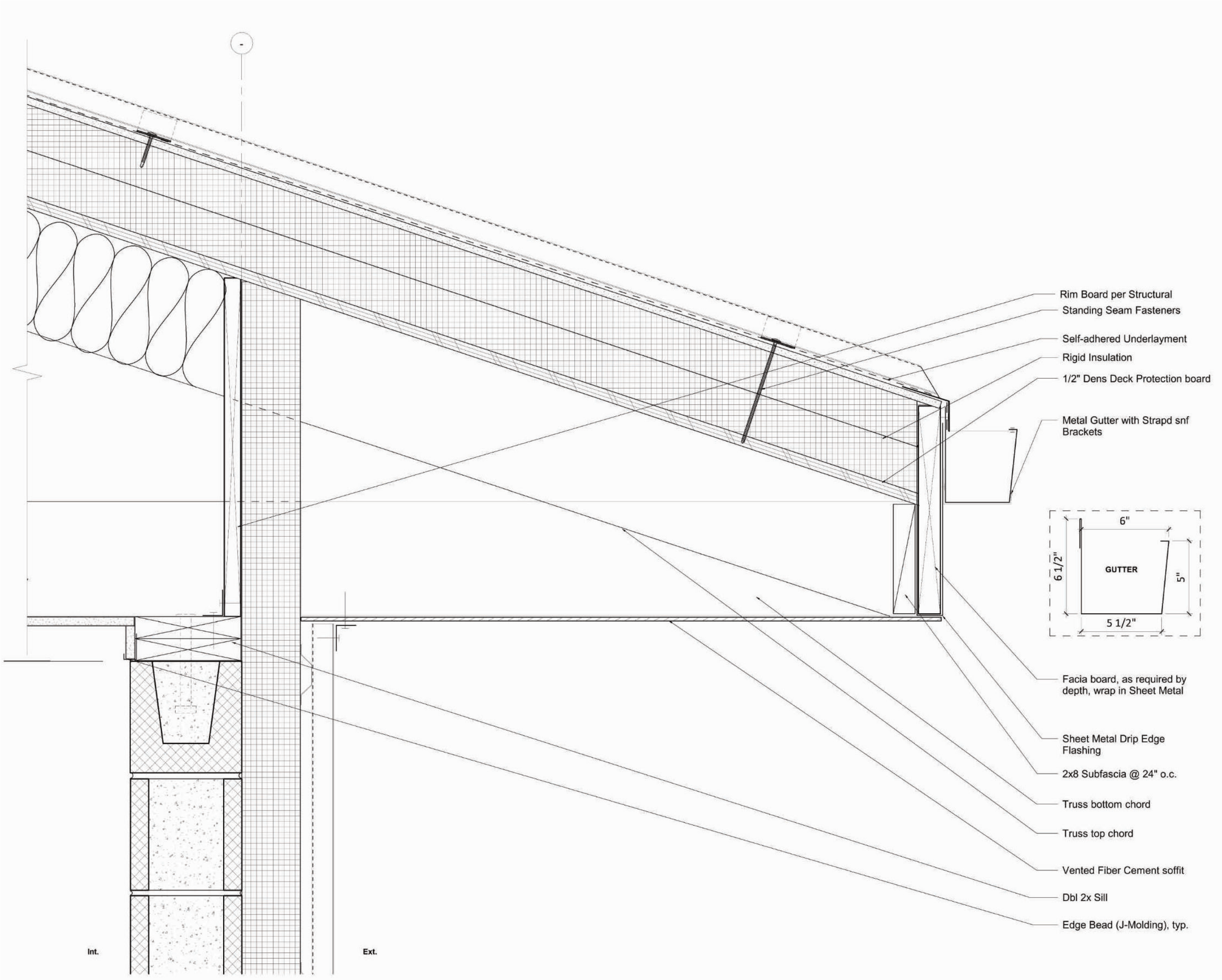


FIGURE 17 - UNOCCUPIED BUILDING WALL SECTION AND DETAILS



C - Roof Eave

FIGURE 18 - UNOCCUPIED BUILDING ROOF / WALL DETAIL

3. Scaling Solutions

The Research Report (Part 1) applied a framework to three regional examples, collecting the following information for net zero commercial-industrial projects:

- Climate and geological data
- Cultural and political trends
- Regulatory information

In Part 2 the Design Guide dives into the details of net zero detailing common to commercial industrial projects. Although this Design Guide presents information well known to net zero design across building types, the details herein are the result of following the framework and refining designs specifically for commercial-industrial projects. Another refinement to consider is scale.

Commercial-industrial development can be unique buildings, repeated buildings across a region or a collection of buildings on a campus. These developments differ in scale and offer a variety of opportunities for net zero design. The following addresses how designers and agencies can adopt scaled solutions to reduce barriers in this development typology.

3.1 UNIQUE BUILDINGS

Individual commercial-industrial buildings typically are large, such as warehouses or central utility plants on college campuses. These buildings require large, open spaces, often with tilt-up construction and flat roofs or pre-engineered metal buildings that come with proprietary detailing. Access needs include overhead vehicular doors that can be high energy-loss openings.

Barrier to net zero design: Concrete construction and proprietary systems manufacturers charge a premium to customize to exceed minimum code requirements.

- Solution: Consider integrating only structural components into the development project. Builders can then do the work they are familiar with, and the general contractor can complement that work with the level of insulation and opening detailing needed to meet net zero (See Section 3 Design Guidelines, paragraph 3.3.1, 3.3.2 and 3.3.3). Include in the specification for the structure, the dead loads expected for rooftop solar energy generation panels. This also clarifies roles and responsibilities, which yields more accurate bids. Agencies should ensure this is included in RFPs when seeking design solutions (See Research Report, Section 5 Cultural and Political Climate).

3.2 REPEATED BUILDINGS

Commercial-industrial developers often need to develop a single concept building and repeat it across a region. An example is wastewater pump stations. These are often smaller (less than 10,000 square feet) buildings and typically unoccupied (See Section 3 Design Guidelines, paragraph 3.3.4). This means that they are visited by operations and maintenance personnel but no personnel work at these buildings regularly.

Barrier to net zero design: These facilities face funding difficulties as they aren't often 'seen' and do not present an opportunity to show off innovations.

- Solution: Establish a program with net zero goals for these facilities where they can have greater impact individual facilities. Set up these facilities to remotely report on net zero performance to save time and illustrate their contribution to energy use reduction. Establish a map of regional climate and geotechnical opportunities to guide site selection (see Research Report, Section 3 Regional Climate Context). Agencies can leverage this design guide to set standards for design detailing for these buildings.

3.3 CAMPUS BUILDINGS

Industrial campuses are a result of zoning practices that separate activities harmful to human health from residential and retail commercial areas. These collections of buildings often are a cross-section of what might be expected of a small town: Office building, electrical building, pre-treatment facilities for wastewater, warehouse, shops, and a high demand for (fleet) parking (See Section 3 Design Guidelines, paragraph 3.3.1, 3.3.2, 3.3.3 and 3.3.4).

Barrier to net zero design: With a mix of building types, campus commercial-industrial developments consist of many components. This mix of components expands by organic growth over time under different codes. These campuses are separated from basic needs by zoning, so personnel must drive or go without services such as restaurants, salons, shopping and medical assistance, which is an equity and social justice issue.

- Solution: Look at scaled-up and remote solutions to power generation, water collection and/or treatment, plus campus scale heating and cooling systems. Although most campuses have developed over time, they typically have utility paths that can be reinvented to support campus scale solutions. These can be utilidors, large-scale underground tunnel systems or overhead racked pathways. Use this design guide to equitably select detail solutions across a range of building types while identifying campus-wide opportunities. Agencies can identify campus-type facilities and set a path to net zero for the entire campus incrementally with each building design or renovation, and in geothermal, ground source heat pumps, or solar power generation (see Research Report, Section 3 Regional Climate Context, paragraphs 3.1.3, 3.2.3, 3.3.3).

3.4 CONCLUSION

Commercial-industrial development can be net zero. The solutions often look a lot like common net zero designs, however once the building types, scaling and replication opportunities are considered, the possibility emerges. By using the framework presented in Part 1 Research Report to collect regional data, and detailing illustrated in this Part 2 Design Guide commercial-industrial building design and development can get back on track for inclusion in our net zero future.