Getting Schooled in Passive House
TEAM PLAYERS

BARTLETT DESIGN

MAINE COAST WALDORF SCHOOL

BECKER

WARREN CONSTRUCTION GROUP

WALSH

Allied Engineering

Structural Mechanical Electrical
MCWS PROJECT GOALS

- Consolidate campus
- Energy conservation
- Sustainable Design
- Waldorf Principals
  - Anthroposophical Design
  - Flexible Spaces
  - Collaborative Teaching
  - Organic Shaped Spaces
  - High Ceilings
  - Natural Light
  - Use of Chalkboards (Low Tech)
  - Use of Color
  - Use of Natural Materials
ACCOMPLISHMENTS

PASSIVE HOUSE - PHIUS + 2015
• Healthy
• Comfortable
• Very Little Energy Needed

MAINE ADVANCED BUILDINGS CERTIFICATION
• At least 30% more energy efficient than minimum code requirements
• Maintenance and monitoring systems ensure building performs
WHAT’S DIFFERENT

PASSIVE HOUSE
1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
4. AIRTIGHT ENCLOSURE
5. BALANCED VENTILATION WITH HEAT RECOVERY
DESIGN CONSIDERATIONS

SITE PLANNING

BUILDING DESIGN

BUILDING ENVELOPE

BUILDING SYSTEMS

PERFORMANCE
SITE PLANNING
BUILDING DESIGN
BUILDING ENVELOPE

- FLOOR ASSEMBLY
- WALL ASSEMBLY
- ROOF ASSEMBLY
- WINDOWS & DOORS
BUILDING ENVELOPE

CONTINUOUS AIRTIGHT LAYER (RED)

R-61 NORTH WALL INSULATION

R-17 SLAB INSULATION

SOLAR PANELS

R-55 ROOF INSULATION

TRIPLE GLAZED WINDOWS

R-51 WALL INSULATION
SOUTH, EAST & WEST WALLS (R-51)

- siding
- ¾” strapping
- 2” foil faced rigid insulation (taped)
- 2” rigid insulation
- weather barrier (majvest by siga)
- sheathing
- 2x8 wood stud, Fill cavity with dense-packed cellulose
- 5/8” gwb
TYPICAL WALL - FOUNDATION

2X8 STUD WALL FILLED WITH DENSE PACKED CELLULOSE INSULATION
SHEATHING - TAPE AND SEALED AS AIR SEALING LAYER AND VAPOR CONTROL LAYER
SIGA MAJVEST WRB (ADDED BY CONTRACTOR)
2" RIGID POLYISO INSULATION - SEAMS TAPE
2" RIGID FOIL-FACED POLYISO INSULATION - SEAMS TAPE AND STAGGERED AS WRB
ACETYLATED WOOD SIDING (OR METAL SIDING OVER ADDED HORIZONTAL STRAPPING)
SILL PLATE TAPE SEALED TO VAPOR BARRIER
VAPOR BARRIER TO TURN UP FOUNDATION WALL AND LAP OVER TOP OF WALL AS A CAPILLARY BREAK - TURN UP AND SEAL TO SHEATHING-SEALED TO SILL PLATE
3/4" VERTICAL STRAPPING ALIGNED WITH FRAMING
FOUNDATION WATERPROOFING
4" RIGID EPS INSULATION
VAPOR BARRIER
4" REINFORCED CONCRETE SLAB - POLISHED
1" EPS THERMAL BREAK
4" MIN. CRUSHED STONE BED
INTERIOR 4" DRAIN TILE AND RADON VENT
(2) LAYERS 2" RIGID MINERAL FIBER DRAIN BOARD AND INSULATION
CEMENT BOARD FINISH
4" EXTERIOR DRAIN TILE SURROUNDED BY CRUSHED STONE AND FILTER FABRIC
REINFORCED CONCRETE FOOTING AS SCHEDULED

R-17 SLAB
R-51 WALL

TYPICAL WALL - FOUNDATION

2X8 STUD WALL FILLED WITH DENSE PACKED CELLULOSE INSULATION

SILL PLATE TAPE SEALED TO CAPILLARY BREAK/VAPOR BARRIER

SILL SEAL GASKET - TAPED AND SEALED TO VAPOR BARRIER

VAPOR BARRIER TO TURN UP FOUNDATION WALL AND LAP OVER TOP OF WALL AS A CAPILLARY BREAK - TURN UP AND SEAL TO SHEATHING-SEALED TO SILL PLATE

1" EPS THERMAL BREAK

4" REINFORCED CONCRETE SLAB - POLISHED VAPOR BARRIER

4" TYPE IX RIGID EPS INSULATION

INTERIOR 4" DRAIN TILE AND RADON VENT

4" MIN. CRUSHED STONE BED
THERMAL BRIDGE MODEL – TYPICAL FOUNDATION WALL

PSI VALUE = 0.077 BTU/HR/FT
THERMAL BRIDGE MODEL – INTERIOR FOOTING

PSI VALUE = 0.025 BTU/HR/FT
TYPICAL WALL – AT FLOOR

- GYPSUM WALL BOARD
- BASE TRIM AS SCHEDULED
- 2X8 STUD WALL FILLED WITH DENSE PACKED CELLULOSE INSULATION
- SILL PLATES - SEALED TO DECK
- FLOORING FINISH AS SCHEDULED
- 3/4" FLOOR SHEATHING
- 1 3/4" X 7 1/4" LVL RIM JOIST
- CAVITIES BETWEEN AND AROUND JOISTS FILLED WITH DENSE PACKED CELLULOSE
- TOP BEARING OPEN WEB WOOD JOISTS
- FIELD APPLIED SHEATHING TO CONTAIN CELLULOSE AT TOP OF WALL
- 3/4" STRAPPING
- GYPSUM WALL BOARD FINISHED CEILING
TYPICAL WALL – ROOF EXTERIOR
R-55 ROOF

24 GA. PREFINISHED STANDING SEAM METAL ROOF

FIRESTONE UNA-CLADGUARD SELF ADHERED ROOF UNDERLAYMENT - LAP OVER FASCIA

5/8" ZIP SYSTEM ROOF SHEATHING

PLYWOOD BLOCKING AND INSULATION STOP

ROOF FRAMING, 16" TJI SPACED PER STRUCTURAL REQUIREMENTS. CAVITIES FILLED WITH DENSE PACKED CELLULOSE

2x WEB STIFFENER OVER BEARING LOCATIONS

TAPERED TOP PLATE

WRB WRAPS OVER WALL AND IS TAPE SEALED TO CEILING SHEATHING

TYPICAL WALL – ROOF INTERIOR
Location: Boston, MA (cold year)

WUFIPassive, Component 20: Walls, North (A350°, 835.27 ft²)

Composite Wood Siding
Air Layer 20 mm
vapour barrier
Polyisocyanurate Insulation
vapour barrier
Oriented Strand Board
Polyisocyanurate Insulation

Cellulose Fibre Insulation
Interior Gypsum Board

HYGROTHERMAL WUFIP MODEL
NORTH WALL (R-61)

- siding
- ¾” vertical strapping
- weather barrier (majvest by siga)
- 9 ½’ I-joist, fill cavity with dense-packed cellulose
- Weather barrier (majvest by siga)
- sheathing
- 2x8 wood stud, fill cavity with dense-packed cellulose
- 5/8” gwb
NORTH WALL - FOUNDATION

- 2x8 Stud wall filled with dense packed cellulose insulation
- Sheathing - taped and sealed as air sealing layer and vapor control layer
- 9-1/2" Engineered wood I-joists fastened through to studs - cavities filled with dense packed cellulose
- SIGA MAJVEST weather resistance barrier
- SIGA MAJVEST weather resistance barrier added by contractor. Lap over vapor barrier
- 3/4" Vertical strapping aligned with framing
- Acetylated wood siding (or metal siding over added horizontal strapping)
- Sill plate tape sealed to capillary break/vapor barrier
- Foundation waterproofing
- Plywood sheathing as sill cap
- 2" EPS thermal break
- Cement board finish
- 3/4" Rigid insect screen and rainscreen vent
- (2) layers 2" rigid mineral fiber drain board and insulation
- 4" Rigid EPS insulation
- Vapor barrier to turn up foundation wall and lap over top of wall as a capillary break - turn up and seal to sheathing-sealed to sill plate
- 4" Reinforced Concrete slab - polished
- Interior 4" drain tile and radon vent
- 1" EPS thermal break
- Reinforced concrete footing as scheduled
- 4" Exterior drain tile surrounded by crushed stone and filter fabric

R-17 SLAB
WINDOWS

- INTUS triple glazed European tilt-turn
- Installed R6.2, U value = 0.1604

DOORS

- REYNAERS triple glazed European
- Installed R5.0, U value = 0.1995
TYPICAL WINDOW HEAD - NORTH WALL

- **5/8" THICK WALL SHEATHING**
- **HEADER, SEE STRUCTURAL DRAWINGS**
- **LOW-EXPANSION SPRAY FOAM INSULATION**
- **1/2" THICK RIGID INSULATION**
- **VAPOR IMPERMEABLE INTERIOR TAPE SEALANT OVER WINDOW FRAME ONTO WOOD FRAMING**
- **DRYWALL RETURNS AT HEAD AND JAMB**
- **CORRUGATED METAL PANEL SIDING (VERTICAL)**
- **1X HORIZONTAL WOOD STRAPPING FASTENED THROUGH INSULATION**
- **FLASHING TAPE OVER TOP EDGE OF METAL DRIP CAP**
- **3/4" THICK PLYWOOD WINDOW BUCK, APPLY SELF ADHERED WATERPROOF MEMBRANE OVER FRONT EDGE**
- **METAL DRIP CAP FLASHING/HEAD TRIM PREFINISHED TO MATCH SIDING COLOR**
- **PREFINISHED METAL RETURN TRIM, HEM BACK EDGE AGAINST WINDOW AND TURN DOWN FRONT EDGE TO RECEIVE LOWER EDGE OF HEAD TRIM**
- **FLASHING TAPE OVER FACE OF WINDOW FRAME AT EDGE OF WALL SHEATHING**
- **FACE OF WINDOW FRAME ALIGNED WITH OUTSIDE FACE OF WALL SHEATHING**
TYPICAL WINDOW SILL - NORTH WALL

VAPOUR IMPERMEABLE
INTERIOR TAPE SEALANT OVER WINDOW SILL FRAME ONTO FLASHING TAPE BELOW

LOW EXPANSION SPRAY FOAM INSULATION

VAPOUR PERMEABLE WINDOW FLASHING TAPE, LAP OVER 3/4" THICK BLOCKING TO FORM BACK DAM, EXTEND OVER OUTER FACE OF EXTERIOR RIGID INSULATION. FOR ANY LAP JOINTS, INTERIOR TAPE SHOULD LAP OVER EXTERIOR

HARDWOOD SILL AND APRON TRIM

FACE OF WINDOW FRAME ALIGNED WITH OUTSIDE FACE OF WALL SHEATHING

SELF-ADHERING WATERPROOF MEMBRANE APPLIED FROM FACE OF WINDOW SILL, WRAP OVER PLYWOOD SUBSILL AND ONSO FACE OF RIGID INSULATION BELOW

3/4" PLYWOOD BUCK/ SUBSILL SET AT 5° SLOPE

METAL SILL TO TURN UP AT JAMBS MIN 1", JAMB TRIM TO LAP OVER AND HOLD MIN 1/4" ABOVE SILL SURFACE

PREFINISHED METAL SILL WITH BACK EDGE TURNED UP INTO WINDOW FRAME, FRONT EDGE WRAPPING PLYWOOD SUBSILL WITH DRIP EDGE

PRIOR TO INSTALLING PLYWOOD SILL FOLD WRs OVER TOP OF 9 1/2" TJI, LAP WINDOW SILL FLASHING OVER WRs

CORRUGATED METAL PANEL SIDING (VERTICAL)

1X HORIZONTAL WOOD STRAPPING FASTENED THROUGH INSULATION

5/8" GWB

2X6 WALL FRAMING WITH DENSE PACKED CELLULOSE INSULATION

5/8" WALL SHEATHING
TYPICAL WINDOW HEAD - SOUTH WALL

- 2" THICK RIGID INSULATION
- 2" THICK FOIL FACED RIGID INSULATION
- HORIZONTAL WOOD SHIPLAP SIDING
- 1X VERTICAL WOOD STRAPPING FASTENED THROUGH INSULATION
- 2" THICK NAILER FOR ATTACHING WOOD HEAD TRIM
- FLASHING TAPE OVER TOP EDGE OF METAL DRIP CAP
- METAL DRIP CAP FLASHING
- FLASHING TAPE OVER FACE OF WINDOW FRAME AT EDGE OF WALL SHEATHING
- 5/4 THICK WOOD HEAD EXTENSION TRIM
- FACE OF WINDOW FRAME ALIGNED WITH OUTSIDE FACE OF WALL SHEATHING

- HEADER, SEE STRUCTURAL DRAWINGS
- LOW-EXPANSION SPRAY FOAM INSULATION
- 1/2" THICK RIGID INSULATION
- VAPOR IMPERMEABLE INTERIOR TAPE SEALANT OVER WINDOW FRAME ONTO WOOD FRAMING
- DRYWALL RETURNS AT HEAD AND JAMB
TYPICAL WINDOW SILL - SOUTH WALL

FACE OF WINDOW FRAME ALIGNED WITH OUTSIDE FACE OF WALL SHEATHING

SELF-ADHERING WATERPROOF MEMBRANE APPLIED FROM FACE OF WINDOW SILL, WRAP OVER PLYWOOD SUBSILL AND ONTO FACE OF RIGID INSULATION BELOW

3/4" PLYWOOD SUBSILL, 7" DEEP, SET AT 5" SLOPE

METAL SILL TO TURN UP AT JAMBS MIN 1", JAMB TRIM TO LAP OVER AND HOLD MIN 1/4" ABOVE SILL SURFACE

PREFINISHED METAL SILL WITH BACK EDGE TURNED UP INTO WINDOW FRAME, FRONT EDGE WRAPPING PLYWOOD SUBSILL WITH DRIP EDGE

HORIZONTAL WOOD SHIPLAP SIDING

1X VERTICAL WOOD STRAPPING FASTENED THROUGH INSULATION

2' THICK FOIL FACED RIGID INSULATION

2' THICK RIGID INSULATION

2" THICK NAILER FOR ATTACHING PLYWOOD SUBSILL, BEVEL TOP EDGE 5"

5/8" GWB

2X8 WALL FRAMING WITH DENSE PACKED CELLULOSE INSULATION

5/8" WALL SHEATHING

VAPOR IMPERMEABLE INTERIOR TAPE SEALANT OVER WINDOW SILL FRAME ONTO FLASHING TAPE BELOW

LOW-EXPANSION SPRAY FOAM INSULATION

VAPOR PERMEABLE WINDOW FLASHING TAPE, LAP OVER 3/4" THICK BLOCKING TO FORM BACK DAM, EXTEND OVER OUTER FACE OF EXTERIOR RIGID INSULATION. FOR ANY LAP JOINTS, INTERIOR TAPE SHOULD LAP OVER EXTERIOR

HARDWOOD SILL AND APRON TRIM
EXTerior

DOOR / STOREFRONT 101A
DOORS 109D, 108A & 121D SIM.

PEMKO DOOR THRESHOLD W/ THERMAL BREAK @ DOOR ONLY
1/8 SADDLES CONTINUOUS UNDER FRAMES
3x3 FIBERGLASS TUBE, FILLED W/ INSUL
PT BLOCKING
1" RIGID INSULATION

VESTIBULE

4" CONC. SLAB

EXISTING 8" CONCRETE WALL

4" FOAM INSUL

EXISTING 8" CONCRETE WALL

4" FOAM INSUL

INTERIOR

DOOR / STOREFRONT 102A

REYNERS DOOR THRESHOLD
1" RIGID INSULATION
REBAR

PT BLOCKING, SILL FASTENING

1 1/2" = 1'-0"

WARREN
CONSTRUCTION GROUP

FRONT ENTRY DOOR TRANSITIONS
7/17/17

6" = 1'-0"
ELECTRICAL & LIGHTING

- LED lighting
- Occupant sensors
- Separate switches at exterior walls
HVAC FUNDAMENTALS

Reduce the load!

- Super insulation, air tight construction, high performance windows
- Fault detection & diagnostics
- Extra insulation – piping and water heater (3” non-CFC foam)
- LED lighting
- No process exhaust (kitchen, science)
- All HVAC inside the thermal envelope
HEATING & COOLING

Little “h” and Little “c”

- Mitsubishi MXZ H2i “hyper heat”
- 19.0 SEER, 3.75 COP @ 47F, 2.7 COP @ 17F
- Variable speed compressors
- Full heating to -13°
- 20 zones; grouped by exposure
- Wall mounted indoor units – less friction
VENTILATION

The big “V”

- Balanced ventilation that delivers fresh air and removes stale air
- Three energy recovery units, 1st fl, 2nd fl & great room
- Ventilation per ASHRAE 62.1-2013
- Air diffusion – thermal core high induction – no heat in ERV system
DIDN’T MAKE THE CUT

IDEAS CONSIDERED BUT NOT AFFORDABLE

- ERU for each classroom for better demand control
- Higher efficiency ERU’s, such as Zehnder
- Building automation system
- Heat recovery VRF (multi-splits were more affordable)
- Geothermal
- Daylighting controls
PLUMBING

- Low flow / low water use fixtures
- Automatic sensors
- Insulated piping
- 120 gallon storage tank, insulated
RENEWABLES

- Designed to be Net Zero
- 110 Q-Cell solar panels 300W each
- 33 kW system
- Projected use = 34,000± kWh/yr.
- Installed by Maine Solar Solutions

Building use = 3 houses, 5X less than a high school of same size
### Periodic AC Energy Report for Site Maine Coast Waldorf High School

- **Report Period:** From 09/20/2017 to 09/19/2018
- **Location:** Freeport, United States
- **Peak Power:** 33 kWP
- **Installation Date:** 09/19/2017
- **Revenue calculation:** Flat rate

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PERFORMANCE
### Passive House Requirements

**Certificate criteria:** PHIUS+ 2015 Standard

#### Heating Demand

- **Specific:** 5.48 kBtu/ft²yr
- **Target:** 6.4 kBtu/ft²yr
- **Total:** 55,977.07 kBtu/yr

#### Cooling Demand

- **Specific:** 0.75 kBtu/ft²yr
- **Latent:** 0.03 kBtu/ft²yr
- **Total:** 7,942.54 kBtu/yr

#### Heating Load

- **Specific:** 4.42 Btu/hr ft²
- **Total:** 45,152.73 Btu/hr

#### Cooling Load

- **Specific:** 2.28 Btu/hr ft²
- **Total:** 23,262.09 Btu/hr

#### Source Energy

- **Total:** 103,494.57 kWh/yr
- **Specific:** 34.57 kBtu/ft²yr

#### Site Energy

- **Total:** 114,368.19 kBtu/yr
- **Specific:** 11.2 kBtu/ft²yr

#### Air Tightness

- **ACH60:** 0.39 1/hr
- **CFM50 per envelope area:** 0.03 cfm/ft²
- **Target:** 0.58 1/hr
- **Target CFM50:** 0.05 cfm/ft²
BLOWER DOOR TEST RESULTS

First Test Results:
- average CFM50 = 0.040
- Average ACH50 = 0.47

Final Test Results:
- average CFM50 = 0.035
- Average ACH50 = 0.40
COST OF CONSTRUCTION

*Including sitework:*

Construction cost: $3,332,000
Cost per ft\(^2\): $292/sf

*Building Only:*

Construction cost: $2,842,000
Cost per ft\(^2\): $249/sf

Building Size: 11,400 sf