

Appendix A

Lab Home A and B Construction Specifications and Alterations

Appendix A -Lab Home A and B Construction Specifications and Alterations

A.1 Lab Home A Construction Specifications and Alterations¹

A.1.1 Background

Battelle Memorial Institute Pacific Northwest Division (Battelle) operates the Pacific Northwest National Laboratory (PNNL). The lab home to be altered is sited in Richland, Washington on Battelle-owned land adjacent to 790 6th Street, just South of the Atmospheric Measurement Lab (AML) and Battelle Shipping/Receiving Facilities in Richland, Washington.

The home (“Lab Home A”) will become a research and demonstration laboratory to demonstrate and evaluate retrofit and smart grid technologies. The home will be instrumented for data collection.

A.1.2 Alteration Specifications for Lab Home A

Below are the specifications/scope of alterations work for Lab Home A.

1. Windows and Sliding Glass Doors Retrofit: (Bid Alternate #1)
 - a. At Battelle’s direction, and within ~4-8 weeks of the set up of the homes, Contractor shall perform a retrofit of all windows and sliding glass doors with double-pane, clear glass, aluminum frame with a National Fenestration Rating Council (NFRC)-certified U-factor no less than 0.60 and a solar heat gain coefficient (SHGC) no less than 0.30.
 - b. The windows and sliding glass doors in the home will be retrofitted with the same type of window (e.g., a picture window will be retrofitted with a picture window and an operable window retrofitted with an operable window). The NFRC temporary label shall remain attached to all windows and the sliding glass doors.
 - c. All operable windows shall be horizontal sliders.
 - d. All windows and sliding glass doors will be from the same manufacturer and the same product line (brand).
 - e. All windows and sliding glass doors shall be secured to the home with stainless steel screws and trimmed with the windows/sliding glass door trim-board that was removed from the home to retrofit these windows and doors. The trim board shall be attached using stainless steel screws.
 - f. All windows and sliding glass doors shall be supplied with screens.
 - g. All windows and sliding glass doors removed for this retrofit shall be preserved in as good a condition as possible and will be transferred to Battelle for storage.
2. Interior Walls.
 - a. Selected non load-bearing walls identified below shall be moved or removed to accommodate future equipment. These include moving a wall in the utility room to expand the furnace closet,

¹ Note that due to funding limitations, the alterations in Section 8: Alternative (Secondary) Hot Water Distribution System: (Bid Alternate #3) was not implemented.

building an exterior access door and wall with a door in the master bedroom closet to the water heater, and moving a wall in the kitchen to accommodate a larger refrigerator. The approximate total wall area to be modified or added as described below is 250 ft².

- i. Any walls that are replaced or constructed shall be taped, finished and painted in the original wall color.
 - b. The space for the water heater (located in the master bedroom closet) shall be expanded to approximately 4 foot deep by moving the access wall in the closet. An insulated door shall be installed across this wall to access the water heater from the closet. This access door shall be 36 inches wide by 80 inches high and have a door sweep and hardware. Contractor shall also install a 36 inch wide x 80 inch high insulated/solid core exterior access door to the water heater closet. This door shall have locking hardware with weatherstripping. All walls/wall cavities shall be insulated with fiberglass batt insulation. Wall area to be modified and insulated is approximately 112 ft².
 - c. The enclosure for the air handling unit for the heat pump shall be modified to approximately 6 foot deep x approximately 4 foot wide to allow room for the future installation of a heat recovery ventilation unit (e.g., air-to-air heat exchanger). A 36 inch wide access door with hardware shall be installed approximately midway along the (new) 6 foot wall. Note that the walls enclosing the furnace room do not need to be insulated. Wall area to be modified is approximately 112 ft².
 - d. The space for the refrigerator shall be expanded to accommodate a 36 inch wide refrigerator (as a retrofit). Therefore the short-wall adjacent to the dining room will need to be moved. Wall area to be modified is approximately 20 ft².
3. Heating/Cooling Systems and Ductwork.
- a. Home shall be equipped with two heating/cooling systems (for experimental purposes). Only the heat pump heating/cooling system will be activated at the time of setup.
 - i. Install the factory provided heating/cooling system #1: current minimum federal standard 2.5 ton heat pump (13.0 SEER/7.7 HSPF) with outdoor compressor/fan unit and inside air handler (blower) with backup strip resistance (per HUD code for Richland, Washington climate). The heat pump shall be installed during setup of the home.
 - ii. Heating system #2: Cadet Model #RMC151W 120V white-color electric resistance fan heaters. See http://www.cadetco.com/show_product.php?prodid=1001. Fan heaters shall be located in each bedroom, bathroom, and laundry room and in the kitchen/dining/living room/hallway area. The total wattage of this system shall be sized to meet the design load in Richland, Washington and shall be allocated to the areas according to their square footage. This heating system shall be separately circuited per the Electrical Panel/Electrical Wiring specifications given in Section 7 below.
 - b. The thermostat for the Cadet heaters shall be controlled by line voltage, wall-mounted thermostats for each heater.
4. Water Heater Closet
- a. The water heater closet/location shall have a water drain in the floor connected to the central wastewater drain for the home.
5. Exterior Stairs
- a. Code-compliant stairs shall be provided for the front entry, back door and the 1 sliding glass door on the end of the home.

- i. All stairs shall have a code-compliant platform/landing.
 - ii. Stairs to the front entry door and back door shall be Jack and Jill type stairs (steps on both sides of the landing) similar to those shown in http://www.mobilehomedepotmi.com/parts_pages/steps_wood.html
 - b. A code-compliant handicapped ramp shall be provided for the sliding glass door on the backside of the home. The ramp shall have a 4 foot x 6 foot platform/landing.
 - c. All stairs (including railing, treads and landing) and the handicapped ramp shall be pre-formed plastic or constructed of recycled plastic lumber in a dark color
6. Skirting
- a. Entire perimeter of home shall be covered with ‘rapid-wall’ type skirting (vinyl-clad over Styrofoam backing) of a color that is complimentary to the house color. For an example of this skirting, see <http://rustiquerapidwall.com/>. Contractor shall provide two (2) access panels with skirting: 1 in the front and 1 in the back of the home. Skirting shall also include twelve 8”x16” manual vents: 4 on front of home, 4 on back of home, and 2 on each side of the home.
7. Electrical Panel/ Electrical Wiring: (Bid Alternate #2)

The electrical panel and wiring diagram specified below are non-standard for most common manufactured homes. The electrical panel is a commercial-style panel and thus is larger than a standard residential panel. The breakers specified are of 2 types: standard and controllable. The controllable breakers are specified so that Battelle can simulate occupancy conditions in the home by turning on and off equipment remotely (via a signal) that is connected to the controllable (powered) breaker. The wiring specifications shall require significantly more wire than is common in manufactured homes given that these specifications require separating out circuits that are most times combined (e.g., lights and plugs in rooms) in standard home wiring configurations.

For the electrical panel, breakers and wiring the Contractor shall follow National Electrical Code (NEC) requirements throughout.

The following are general specifications for the electrical panels and breakers:

- a. The main electrical/breaker panel in the home shall be a Square D Powerlink G3 3000 Level System with web-enabled control. See <http://www.schneider-electric.us/products-services/products/lighting-control/powerlink/3000-level-system/3000-level-g3-controller/>. A file of a panelboard take-off sheet with a recommended circuit layout and required breakers (standard or controllable—see notations and descriptions below) is included as Attachment 2 with these specifications. It is however up to the discretion of the Contractor’s electrician on how to best balance the load on either side of the split-phase service.
- b. The labels for the circuits shall be included on the panel. The labels are given on the circuit layout and are identified in the specifications below for each circuit using an identifier following the circuit description in parentheses and bolded as shown here: **(Label)**
- c. The main electrical/breaker panel shall be ‘flush-mounted’ and located either in the location of the existing panel or adjacent to the existing panel. If possible, there shall be at least 3 feet of unobstructed wall on one side of the panel. Battelle is aware that the Square D panel is deeper than a standard residential panel and thus when this panel is ‘flush-mounted’ it will protrude

several (3 to 4) inches beyond the finished drywall. No trim around the panel is required. Panel shall have a door.

- d. The breakers for each circuit are identified by amperage and as either 'standard' or 'controllable'. These breakers shall be provided for the Powerlink G3 3000 Level System panel by Square D and thus shall be purchased from Square D.
- e. For each 15 and 20 amp breaker installed in the panel, a double loop of conductor (2 circular loops of conductor approximately 2" in diameter) shall be used prior to connection to the breaker. Loops shall be as far away from the actual breaker lug as possible, but within the confines of the panel enclosure. [Note that the panel box has been sized to accommodate this request.] These loops will be used with current transformers (CTs) installed by Battelle as part of the metering and thus are necessary to achieve higher accuracy on low-load circuits.
- f. The second panel, to be used for a future Electric Vehicle Charging Station, shall have a 200A main breaker and the panel shall be wired with a conventional two-pole 30 amp breaker and a single-pole 20A breaker. This panel shall be a small panel since only three breaker slots are needed. The load side of this panel shall include appropriately sized conductors running from the panel and terminating on the exterior of the home with two service disconnects, one for the 30A circuit and one for the 20A circuit. The service disconnect shall be a weather tight variety and located on the front of the home (same side as front door) and near the corner/end of the home. This second panel shall be flush-mounted in the utility room near the main panel.
- g. All switch plates, receptacle plates and light fixtures/ light fixture covers shall be labeled with the circuit number of the breaker controlling that circuit.

The following are the specifications for the circuits. Ground Fault Interrupter (GFI) receptacles shall be used where code requires they be used.

8. Bedrooms

- a. Master bedroom will have 1 dedicated 120V receptacle circuit on a separate 20 amp standard breaker. (***M_Bedroom Rcpt***)
- b. Master bedroom will have 1 dedicated 120V lighting circuit serving the single ceiling fixture on a separate 15 amp controllable breaker. (***M_Bedroom Lights***)
- c. Bedroom 2 will have 1 dedicated receptacle circuit a 20 amp standard breaker. (***Bedroom 2 Rcpt***)
- d. Bedroom 3 will have 1 dedicated receptacle circuit on a 20 amp standard breaker. (***Bedroom 3 Rcpt***)
- e. Bedrooms 2 and 3 will be combined into 1 dedicated 120V lighting circuit serving the ceiling fixtures on a separate 15 amp controllable breaker. (***2 Bedroom Lights***)

9. Master Bathroom

- a. 1 dedicated 120V receptacle circuit on a 15 amp standard breaker. This circuit shall include 1 standard receptacle installed under the sink. (***M_Bath Rcpt***)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***M_Bath Lights***)
- c. 1 dedicated 120V circuit for the ventilation fan on a 15 amp controllable breaker. (***M_Bath Vent Fan***)

10. 2nd Bathroom

- a. 1 dedicated 120V receptacle circuit on a 15 amp standard breaker. This circuit shall include 1 receptacle installed under the sink. (***Bath Rcpt***)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***Bath Lights***)
- c. 1 dedicated 120V circuit for the ventilation fan on a 15 amp controllable breaker. (***Bath Vent Fan***)

11. Kitchen

- a. 1 dedicated 120V circuit for convenience receptacles on a separate 20 amp standard breaker. (***Kitchen Rcpt***)
- b. 1 dedicated 120V circuit for the dishwasher on a 20 amp controllable breaker. (***Dishwasher***)
- c. 1 dedicated 120V circuit for the refrigerator receptacle on a 20 amp controllable breaker. (***Refrigerator***)
- d. 1 dedicated 120V circuit for the over-the-range ventilation fan on a 15 amp controllable breaker. (***Range Vent Fan***)
- e. 1 dedicated 240V circuit for the range on standard circuit breakers sized to meet NEC requirements for a residential kitchen range. (***Range***)

12. Dining Room

- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (***Dining Room Rcpt***)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***Dining Room Lights***)

13. Living Room

- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (***Living Room Rcpt***)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***Living Room Lights***)

14. Hallway

- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (***Hallway Rcpt***)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***Hallway Lights***)

15. Utility Room

- a. 1 dedicated 120V circuit for receptacles on a 15 amp standard breaker. One receptacle should be at panel height near electrical panel. (***Utility Room Rcpt***)
- b. 1 dedicated 120V circuit serving the clothes washer receptacle on a 20 amp controllable breaker. (***Clothes Washer***)
- c. 1 dedicated 240V circuit serving the clothes dryer plug on controllable breakers sized to meet NEC requirements for a standard residential-sized clothes dryer. (***Clothes Dryer***)
- d. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (***Utility Room Lights***)
- e. 1 dedicated 120V receptacle circuit located adjacent to the furnace air handler enclosure with at least 3 feet x 3 feet of wall space above the receptacle on a 15 amp controllable breaker. (***Heat Ex. Rcpt***)

16. Heating/Cooling

- a. 1 dedicated 240V circuit for air handler/back up heat unit on standard breakers sized to meet NEC requirements for the air handler/back up heat. (***Furnace***)
- b. 1 dedicated 240V circuit for the heat pump outside unit on standard breakers sized to meet NEC requirements for the heat pump unit. Install a disconnect at the heat pump outside unit per NEC requirements. (***Heat Pump***) (***Air Conditioner***)
- c. Dedicated 120V circuits for the alternative room wall heaters on 20 amp controllable breakers. 5 individual circuits are suggested:
 - i. Both bathrooms + utility room (***Bathroom/Utility Htr***)
 - ii. Master bedroom (***M_Bedroom Heater***)
 - iii. Two (2) remaining bedrooms (***2_Bedroom Heater***)
 - iv. Living room/hallway area (***Living Room/Hall Htr***)
 - v. Dining room/kitchen area (***Dining/Kitchen Htr***)

Note: If more circuits are needed for the room wall heaters per NEC requirements, contact PNNL for guidance.

17. Other Circuits

- a. 1 dedicated 120V circuit serving the whole-house ventilation fan on a 15 amp controllable breaker. (***Whole House Vent***)
- b. 1 dedicated 120V circuit serving the exterior lighting on a 15 amp controllable breaker. (***Exterior Lights***)

18. Additional (Spare) Controllable Breakers

Contractor shall supply (in a box) additional controllable breakers for the main panel as follows: 8 additional 20 amp controllable breakers; 8 additional 15 amp controllable breakers; and 2 additional controllable breakers of the same amperage for the clothes dryer circuit.

A.2 Lab Home B Construction Specifications and Alterations²

A.2.1 Background

Battelle Memorial Institute Pacific Northwest Division (Battelle) operates the Pacific Northwest National Laboratory (PNNL). The lab home to be altered is sited in Richland, Washington on Battelle-owned land adjacent to 790 6th Street, just South of the AML and Battelle Shipping/Receiving Facilities in Richland, Washington.

The home (“Lab Home B”) will become a research and demonstration laboratory to demonstrate and evaluate retrofit and smart grid technologies. The home will be instrumented for data collection.

² Note that due to funding limitations, the alterations in Section 8: Alternative (Secondary) Hot Water Distribution System: (Bid Alternate #3) was not implemented.

A.2.2 Alteration Specifications for Lab Home B

Below are the specifications for Lab Home B alterations.

1. Windows and Sliding Glass Doors Retrofit (Bid Alternate #1)
 - a. At Battelle's direction, and within ~4-8 weeks of the setup of the homes, Contractor shall perform a retrofit of all windows and sliding glass doors with triple-pane low-e vinyl framed windows with a National Fenestration Rating Council (NFRC)-certified U-factor no greater than 0.22 for operable windows and the sliding glass doors, no greater than 0.20 for fixed (picture) windows, and a solar heat gain coefficient (SHGC) of no less than 0.20.
 - b. The windows and sliding glass doors in the home will be retrofitted with the same type of window (e.g., a picture window will be retrofitted with a picture window and an operable window retrofitted with an operable window). The NFRC temporary label shall remain attached to all windows and the sliding glass doors.
 - c. All operating windows shall be single-hung type windows with white vinyl frames.
 - d. All windows and sliding glass doors will be from the same manufacturer and the same product line (brand). The recommended vendor for the triple pane windows and sliding glass doors is Jeld-Wen Premium ESMK Vinyl White. The NFRC certified products directory number (CPD #) for these windows and sliding glass doors is: JEL-A-543-09065-00001 retrofit single hung windows; JEL-A-757-01694-00001 retrofit fixed windows; and JEL-A-697-03919-00001 retrofit sliding glass doors. These windows shall be purchased from the vendor (Jeld-Wen) through the DOE windows volume purchase web site (www.windowsvolumepurchase.org)
 - e. All windows and sliding glass doors shall be secured to the home with stainless steel screws and trimmed with the windows/sliding glass door trim-board that was removed from the home to retrofit these windows and doors. The trim board shall be attached using stainless steel screws.
 - f. All windows and sliding glass doors shall be supplied with screens.
 - g. All windows and sliding glass doors removed for this retrofit shall be preserved in as good a condition as possible and will be transferred to Battelle for storage.
2. Interior Walls.
 - a. Selected non load-bearing walls identified below shall be moved or removed to accommodate future equipment. These include moving a wall in the utility room to expand the furnace closet, building an exterior access door and wall with a door in the master bedroom closet to the water heater, and moving a wall in the kitchen to accommodate a larger refrigerator. The approximate total wall area to be modified or added as described below is 250 ft².
 - i. Any walls that are replaced or constructed shall be taped, finished and painted in the original wall color.
3. The space for the water heater (located in the master bedroom closet) shall be expanded to approximately 4 foot deep by moving the access wall in the closet. An insulated door shall be installed across this wall to access the water heater from the closet. This access door shall be 36 inches wide by 80 inches high and have a door sweep and hardware. Contractor shall also install a 36 inch wide x 80 inch high insulated/solid core exterior access door to the water heater closet. This door shall have locking hardware with weatherstripping. All walls/wall cavities shall be insulated with fiberglass batt insulation. Wall area to be modified and insulated is approximately 112 ft².

4. The enclosure for the air handling unit for the heat pump shall be modified to approximately 6 foot deep x approximately 4 foot wide to allow room for the future installation of a heat recovery ventilation unit (e.g., air-to-air heat exchanger). A 36 inch wide access door with hardware shall be installed approximately midway along the (new) 6 foot wall. Note that the walls enclosing the furnace room do not need to be insulated. Wall area to be modified is approximately 112 ft².
5. The space for the refrigerator shall be expanded to accommodate a 36 inch wide refrigerator (as a retrofit). Therefore the short-wall adjacent to the dining room will need to be moved. Wall area to be modified is approximately 20 ft².
6. Heating/Cooling Systems and Ductwork
 - a. Home shall be equipped with two heating/cooling systems (for experimental purposes). Only the heat pump heating/cooling system will be activated at the time of setup.
 - i. Install the factory provided heating/cooling system #1: current minimum federal standard 2.5 ton heat pump (13.0 SEER/7.7 HSPF) with outdoor compressor/fan unit and inside air handler (blower) with backup strip resistance (per HUD code for Richland, Washington climate). The heat pump shall be installed during setup of the home.
 - ii. Heating system #2: Cadet Model #RMC151W 120V white-color electric resistance fan heaters. See http://www.cadetco.com/show_product.php?prodid=1001. Fan heaters shall be located in each bedroom, bathroom, and laundry room and in the kitchen/dining/living room/hallway area. The total wattage of this system shall be sized to meet the design load in Richland, Washington and shall be allocated to the areas according to their square footage. This heating system shall be separately circuited per the Electrical Panel/Electrical Wiring specifications given in Section 7 below.
 - b. The thermostat for the Cadet heaters shall be controlled by line voltage, wall-mounted thermostats for each heater.
7. Water Heater Closet
 - a. The water heater closet/location shall have a water drain in the floor connected to the central wastewater drain for the home.
8. Exterior Stairs
 - a. Code-compliant stairs shall be provided for the front entry, back door and the 1 sliding glass door on the end of the home.
 - i. All stairs shall have a code-compliant platform/landing.
 - ii. Stairs to the front entry door and back door shall be Jack and Jill type stairs (steps on both sides of the landing) similar to those shown in http://www.mobilehomedepotmi.com/parts_pages/steps_wood.html
 - b. A code-compliant handicapped ramp shall be provided for the sliding glass door on the backside of the home. The ramp shall have a 4 foot x 6 foot platform/landing.
 - c. All stairs (including railing, treads and landing) and the handicapped ramp shall be pre-formed plastic or constructed of recycled plastic lumber in a dark color

9. Skirting

- a. Entire perimeter of home shall be covered with 'rapid-wall' type skirting (vinyl-clad over Styrofoam backing) of a color that is complimentary to the house color. For an example of this skirting, see <http://rustiquerapidwall.com/>. Contractor shall provide two (2) access panels with skirting: 1 in the front and 1 in the back of the home. Skirting shall also include twelve 8"x16" manual vents: 4 on front of home, 4 on back of home, and 2 on each side of the home.

10. Electrical Panel/ Electrical Wiring: (Bid Alternate #2)

The electrical panel and wiring diagram specified below are non-standard for most common manufactured homes. The electrical panel is a commercial-style panel and thus is larger than a standard residential panel. The breakers specified are of 2 types: standard and controllable. The controllable breakers are specified so that Battelle can simulate occupancy conditions in the home by turning on and off equipment remotely (via a signal) that is connected to the controllable (powered) breaker. The wiring specifications shall require significantly more wire than is common in manufactured homes given that these specifications require separating out circuits that are most times combined (e.g., lights and plugs in rooms) in standard home wiring configurations.

For the electrical panel, breakers and wiring the Contractor shall follow National Electrical Code (NEC) requirements throughout.

The following are general specifications for the electrical panels and breakers:

- a. The main electrical/breaker panel in the home shall be a Square D Powerlink G3 3000 Level System with web-enabled control. See <http://www.schneider-electric.us/products-services/products/lighting-control/powerlink/3000-level-system/3000-level-g3-controller/>. A file of a panelboard take-off sheet with a recommended circuit layout and required breakers (standard or controllable—see notations and descriptions below) is included as Attachment 2 with these specifications. It is however up to the discretion of the Contractor's electrician on how to best balance the load on either side of the split-phase service.
- b. The labels for the circuits shall be included on the panel. The labels are given on the circuit layout and are identified in the specifications below for each circuit using an identifier following the circuit description in parentheses and bolded as shown here: (**Label**)
- c. The main electrical/breaker panel shall be 'flush-mounted' and located either in the location of the existing panel or adjacent to the existing panel. If possible, there shall be at least 3 feet of unobstructed wall on one side of the panel. Battelle is aware that the Square D panel is deeper than a standard residential panel and thus when this panel is 'flush-mounted' it will protrude several (3 to 4) inches beyond the finished drywall. No trim around the panel is required. Panel shall have a door.
- d. The breakers for each circuit are identified by amperage and as either 'standard' or 'controllable'. These breakers shall be provided for the Powerlink G3 3000 Level System panel by Square D and thus shall be purchased from Square D.
- e. For each 15 and 20 amp breaker installed in the panel, a double loop of conductor (2 circular loops of conductor approximately 2" in diameter) shall be used prior to connection to the breaker. Loops shall be as far away from the actual breaker lug as possible, but within the confines of the panel enclosure. [Note that the panel box has been sized to accommodate this request.] These loops will be used with current transformers (CTs) installed by Battelle as part of the metering and thus are necessary to achieve higher accuracy on low-load circuits.

- f. The second panel, to be used for a future Electric Vehicle Charging Station, shall have a 200A main breaker and the panel shall be wired with a conventional two-pole 30 amp breaker and a single-pole 20A breaker. This panel shall be a small panel since only three breaker slots are needed. The load side of this panel shall include appropriately sized conductors running from the panel and terminating on the exterior of the home with two service disconnects, one for the 30A circuit and one for the 20A circuit. The service disconnect shall be a weather tight variety and located on the front of the home (same side as front door) and near the corner/end of the home. This second panel shall be flush-mounted in the utility room near the main panel.
- g. All switch plates, receptacle plates and light fixtures/ light fixture covers shall be labeled with the circuit number of the breaker controlling that circuit.

The following are the specifications for the circuits. Ground Fault Interrupter (GFI) receptacles shall be used where code requires they be used.

11. Bedrooms

- a. Master bedroom will have 1 dedicated 120V receptacle circuit on a separate 20 amp standard breaker. (*M_Bedroom Rcpt*)
- b. Master bedroom will have 1 dedicated 120V lighting circuit serving the single ceiling fixture on a separate 15 amp controllable breaker. (*M_Bedroom Lights*)
- c. Bedroom 2 will have 1 dedicated receptacle circuit a 20 amp standard breaker. (*Bedroom 2 Rcpt*)
- d. Bedroom 3 will have 1 dedicated receptacle circuit on a 20 amp standard breaker. (*Bedroom 3 Rcpt*)
- e. Bedrooms 2 and 3 will be combined into 1 dedicated 120V lighting circuit serving the ceiling fixtures on a separate 15 amp controllable breaker. (*2 Bedroom Lights*)

12. Master Bathroom

- a. 1 dedicated 120V receptacle circuit on a 15 amp standard breaker. This circuit shall include 1 standard receptacle installed under the sink. (*M_Bath Rcpt*)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (*M_Bath Lights*)
- c. 1 dedicated 120V circuit for the ventilation fan on a 15 amp controllable breaker. (*M_Bath Vent Fan*)

13. 2nd Bathroom

- a. 1 dedicated 120V receptacle circuit on a 15 amp standard breaker. This circuit shall include 1 receptacle installed under the sink. (*Bath Rcpt*)
- b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (*Bath Lights*)
- c. 1 dedicated 120V circuit for the ventilation fan on a 15 amp controllable breaker. (*Bath Vent Fan*)

14. Kitchen

- a. 1 dedicated 120V circuit for convenience receptacles on a separate 20 amp standard breaker. (*Kitchen Rcpt*)
- b. 1 dedicated 120V circuit for the dishwasher on a 20 amp controllable breaker. (*Dishwasher*)
- c. 1 dedicated 120V circuit for the refrigerator receptacle on a 20 amp controllable breaker. (*Refrigerator*)

- d. 1 dedicated 120V circuit for the over-the-range ventilation fan on a 15 amp controllable breaker. (**Range Vent Fan**)
 - e. 1 dedicated 240V circuit for the range on standard circuit breakers sized to meet NEC requirements for a residential kitchen range. (**Range**)
15. Dining Room
- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (**Dining Room Rcpt**)
 - b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (**Dining Room Lights**)
16. Living Room
- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (**Living Room Rcpt**)
 - b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (**Living Room Lights**)
17. Hallway
- a. 1 dedicated 120V circuit for receptacles on a separate 20 amp standard breaker. (**Hallway Rcpt**)
 - b. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (**Hallway Lights**)
18. Utility Room
- a. 1 dedicated 120V circuit for receptacles on a 15 amp standard breaker. One receptacle should be at panel height near electrical panel. (**Utility Room Rcpt**)
 - b. 1 dedicated 120V circuit serving the clothes washer receptacle on a 20 amp controllable breaker. (**Clothes Washer**)
 - c. 1 dedicated 240V circuit serving the clothes dryer plug on controllable breakers sized to meet NEC requirements for a standard residential-sized clothes dryer. (**Clothes Dryer**)
 - d. 1 dedicated 120V lighting circuit on a 15 amp controllable breaker. (**Utility Room Lights**)
 - e. 1 dedicated 120V receptacle circuit located adjacent to the furnace air handler enclosure with at least 3 feet x 3 feet of wall space above the receptacle on a 15 amp controllable breaker. (**Heat Ex. Rcpt**)
19. Heating/Cooling
- a. 1 dedicated 240V circuit for air handler/back up heat unit on standard breakers sized to meet NEC requirements for the air handler/back up heat. (**Furnace**)
 - b. 1 dedicated 240V circuit for the heat pump outside unit on standard breakers sized to meet NEC requirements for the heat pump unit. Install a disconnect at the heat pump outside unit per NEC requirements. (**Heat Pump**) (**Air Conditioner**)
 - c. Dedicated 120V circuits for the alternative room wall heaters on 20 amp controllable breakers. 5 individual circuits are suggested:
 - i. Both bathrooms + utility room (**Bathroom/Utility Htr**)
 - ii. Master bedroom (**M_Bedroom Heater**)
 - iii. Two (2) remaining bedrooms (**2_Bedroom Heater**)
 - iv. Living room/hallway area (**Living Room/Hall Htr**)

v. Dining room/kitchen area (*Dining/Kitchen Htr*)

Note: If more circuits are needed for the room wall heaters per NEC requirements, contact PNNL for guidance.

20. Other Circuits

- a. 1 dedicated 120V circuit serving the whole-house ventilation fan on a 15 amp controllable breaker. (*Whole House Vent*)
- b. 1 dedicated 120V circuit serving the exterior lighting on a 15 amp controllable breaker. (*Exterior Lights*)

21. Additional (Spare) Controllable Breakers

Contractor shall supply (in a box) additional controllable breakers for the main panel as follows: 8 additional 20 amp controllable breakers; 8 additional 15 amp controllable breakers; and 2 additional controllable breakers of the same amperage for the clothes dryer circuit.

22. Alternative (Secondary) Hot Water Distribution System: (Bid Alternate #3)

The alternative (second) hot water distribution system (See Figure A.1 below) is a parallel hot water supply system for all of the home's hot-water water-using fixtures and will be used in a future experiment in this home (Lab Home B). The purpose of the alternative hot water supply system is to test out a hot water delivery system that minimizes the use of hot water in the home and thus saves water and energy. Battelle will install a circulation pump in the system when this experiment is undertaken. The goal of this system is to draw no more than ½ to 1 cup of water at each fixture until there is hot water available at the given fixture at the water heater set temperature and to have as little flow resistance as possible to minimize circulation pumping energy.

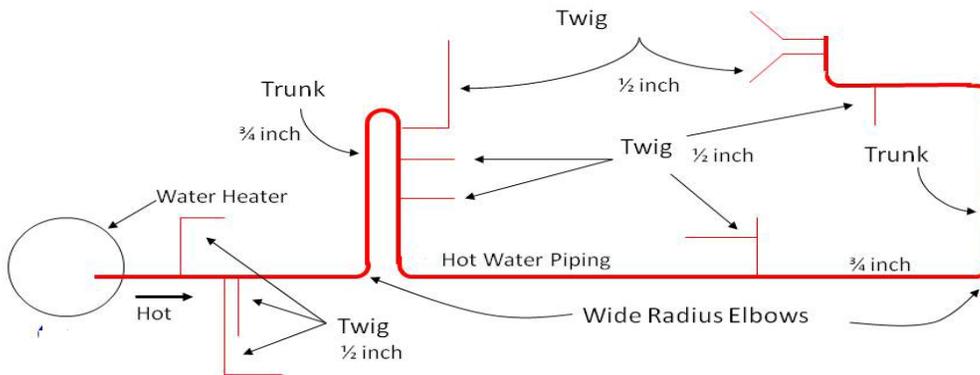


Figure A.1. Diagram of Alternative Hot Water Supply Distribution System

In the description below and in Figure A.1 above, the hot water supply lines are referred to as “trunk” and “twigs”. The trunk carries the hot water from the water heater to locations where the twigs branch out from the trunk to serve the individual fixtures.

For both the trunk and twigs, the material used shall be PEX tubing because this tubing is highly flexible, and Contractor shall use this flexibility to make wide radius bends that minimize the use of

fittings and reduce flow restrictions, especially 90 degree elbows wherever feasible—see detailed specifications below under **Hot Water Distribution System**.

The trunk shall be ¾ inch PEX (cross-linked polyethylene) tubing.

The twigs shall be ½ inch PEX tubing unless applicable standards require that ¾ inch PEX be used throughout.

This alternative hot water supply system shall be inactive (not connected) and dry at the time the home is delivered. At a later time for experimental purposes, Battelle will attach the alternative hot water supply line to the water heater and turn on the valves at those fixtures.

There is only one ‘standard’ cold water distribution system and this should be run with the ‘standard’ primary hot water distribution system (see **13** above), as it is typically configured in a manufactured home.

23. At the Water Heater

An easily accessible 2-way ball valve shall be installed at the water heater on the hot water supply from the water heater. The hot water supply system for the ‘standard’ hot water distribution system (see **13** above) shall be connected to the outlet of this 2-way ball valve.

The alternative hot water supply tubing will run from the water heater location to the fixtures as shown in Figure A.1 and described below. An additional length of the hot water “trunk” ¾ inch tubing ~8 feet long shall be coiled and secured near the water heater for later connection by Battelle. The end of this pipe will have a brass PEX connection for (later) connection to the 2-way ball valve at the water heater and be sealed after the system is commissioned (tested for leaks)— see **System Commissioning** below.

24. Alternative Hot Water Distribution System (Figure A.1)

- a. The alternative hot water supply tubing shall supply hot water to all the same fixtures in the home that are connected to the ‘standard’ hot water distribution system.
- b. The alternative hot water supply tubing shall be run separately from the ‘standard’ hot and cold water system tubing.
- c. For all the alternative hot water supply tubing, keep the flow restrictions to a minimum by limiting the number of connections, particularly the number of 90 degree elbows.
 - i. Use wide-sweeping turns where possible rather than elbows and particularly 90 degree elbows.
 - ii. Minimize the use of couplings.
 - iii. Minimize the use of insert fittings.
 - iv. Use an open style manifold (or mini-manifold)³ without valves from the trunk for the twigs to serve hot water fixtures that are close together.

³ An example of an open-style ¾ x ¾ x ½ manifold/mini-manifold can be found at <http://www.pexuniverse.com/store/product/434>. Note that this example is not an endorsement of this particular brand of manifold.

- v. For the trunk $\frac{3}{4}$ inch tubing, minimize the number of fittings. In particular, minimize the use of any elbow fittings.
- d. The supply lines (twigs) to the fixtures shall be plumbed in the following way:
 - i. The length of the tubing to each fixture should be as short as possible and thus the $\frac{3}{4}$ inch hot water trunk tubing should be run as close as possible to the fixture or group of fixtures.
 - ii. To serve a single fixture (e.g., clothes washer), a $\frac{3}{4}$ x $\frac{3}{4}$ x $\frac{1}{2}$ tee connection shall be used (with the $\frac{1}{2}$ inch line (twig) serving the clothes washer).
 - iii. To serve multiple fixtures, a manifold (or mini-manifold) without valves shall be used on the trunk line to reduce the number of field joints. The length of an individual hot water supply twig to the fixture should not exceed 6-8 feet to the valve or angle stop. In some locations, primarily where fixtures in a group are supplied with twigs from a manifold, some of these supply lines may need to be longer than others. If more than 8 feet, Contractor will consult with Battelle staff who will be on-site during the installation of the hot water distribution systems.

25. Connections of the Alternative Hot Water Supply Lines at the Fixtures

- a. Upstream of the standard and alternative hot water supply tubing (trunk line) to each bath/shower fixture and to the clothes washer hot water supply, ball valves shown in Figure A.2 shall be installed. These ball valves shall be accessible through a panel with dimensions of approximately 16 inches wide x 12 inches above the valves and 12 inches below the valves. The opening shall be covered with a removable (screwed) cover. The ball valves shall be set to provide hot water to the bath/shower and clothes washer from the standard hot water supply system when the home is delivered.
- b. The alternative and standard hot water supply (trunk) lines to each bathroom sink shall be connected under the sinks using ball valves as shown in Figure A.2 upstream of the standard shut off (angle) valves. Both valves must be accessible through an opening in the wall under the sinks. The wall opening shall be covered with a removable (screwed) door.
- c. The alternative and standard hot water supply (trunk) lines to the kitchen sink shall be under the sink as shown in Figure A.2. The line after the T will go on to serve both kitchen hot water tap and the dishwasher. The sink and dishwasher hot water lines shall also be provided with standard shut off (angle) valves. Both ball valves must be accessible through an opening in the wall under the sinks. The wall opening shall be covered with a removable (screwed) door.
- d. The ball valves for the clothes washer and under the bathroom and kitchen sinks shall be set to provide hot water from the standard hot water system when the home is delivered.

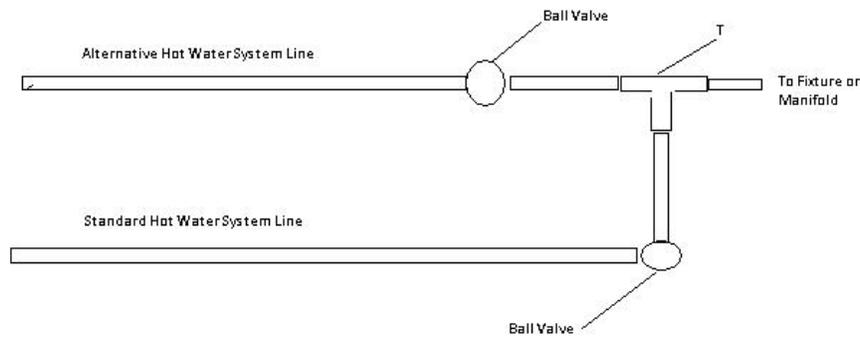


Figure A.2. Diagram of Alternative Hot Water System Fixture Connection

26. Tubing Insulation

- a. All hot water tubing (trunk and twigs) of the alternative hot water delivery system shall be insulated. This includes the fittings/manifolds where possible.
- b. Self-sealing closed-cell polyethylene (PE) pipe insulation shall be used. Use $\frac{3}{4}$ inch thick PE insulation for $\frac{3}{4}$ inch tubing and $\frac{1}{2}$ inch PE insulation shall be used for $\frac{1}{2}$ inch tubing. Tape end-to-end joints and around fittings with acrylic tape appropriate for PE pipe.
- c. The tubing (twigs) to the fixtures should be insulated as near as possible to the fixture.
- d. The extra/coiled tubing at the water heater shall not be insulated.

27. System Commissioning

The alternative system shall be tested for leaks in a similar manner to how the 'standard' water distribution system is tested.