HABITAT FOR HUMANITY PHILADELPHIA / PHC DP2020 SUMMARY

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Introduction

The purpose of Green Building United Passive House Community's 2020 Demonstration Project was to explore the feasibility of furthering Habitat for Humanity Philadelphia's goal of providing health-promoting, affordable, high performance housing by adopting Passive House Institute United States (PHIUS) Certified design. Through this project, the Passive House Community holistically explored ways to achieve Passive House designs using Habitat for Humanity Philadelphia's project Oxford Green as a model. The specific charge of the Demonstration Project was to evaluate if earning PHIUS performance benchmarks was feasible at low or no cost within HFHP's existing financial and project delivery model.

Passive House is a building framework that combines low energy usage with high indoor air quality to dramatically improve a building's energy performance and occupant health and comfort. Originally "passivhaus" or "Passive building" in German, Passive House today is applicable to all building types – single-family, multi-family, commercial, and industrial. There are several strategies that can be implemented to achieve Passive House performance levels, but the main principles are the following:

Airtightness and continuous insulation: A very airtight envelope prevents infiltration, energy losses, and creates a more durable building. Continuous insulation prevents thermal bridging, which can also be a major source of energy loss through building envelopes.

High-performing openings: High-performing windows manage solar gains, while high-performing doors and other envelope openings limit thermal bridging and air leakage.

Balanced ventilation: Continuous, balanced ventilation is important for occupant health, comfort, and durability. Ventilation systems are combined with energy or heat recovery to reduce energy needed to run these systems while maintaining interior comfort.

Reduced heating and cooling systems: Through implementation of the above principles, building loads should dramatically decrease, limiting operational energy used from space conditioning systems and help pave the way toward zero energy buildings.

The Demonstration Project was organized around community charrettes, focused on the Passive House principles and their connections back to the Oxford Green model. Over the course of six charrettes throughout 2020 and 2021, the Passive House Community explored design, construction, and systems improvements to identify how Oxford Green could meet the Passive House standard.

The charrette schedule was as follows:

- Charrette #1: Demonstration Project Kick-off
- Charrette #2: Systems Review
- Charrette #3: Design Opportunity-Seeking
- Charrette #4: Design Report Back and Construction Opportunity-Seeking
- Charrette #5: The Importance of Airtightness
- Charrette #6: Findings Review

Scope and Project Team

In early 2020, Green Building United's (GBU) Passive House Community (PHC) and Habitat for Humanity Philadelphia (HFHP) initiated a Demonstration Project using the ISA (Interface Studio Architects) designed Oxford Green affordable housing project. Oxford Green is a multi-phase construction project of 20 affordable single-family rowhomes in 2 phases on the 2300 block of Oxford Street in the Sharswood neighborhood of Philadelphia. The project was completed in June 2021.

The Demonstration Project (DP2020) team included Habitat for Humanity Philadelphia (HFHP) and Green Building United's Passive House Community (GBU/PHC). In addition to this team, DP2020 volunteers – architects, contractors, building scientists, and building enthusiasts – helped overlay Passive House principles to the design and the construction process, got hands-on building experience in the field (before being halted due to Covid-19), and presented the work publicly during the charrette series to showcase the entire process.

This collaboration represented an exciting opportunity for GBU/PHC to engage HFHP, to learn from each other, and to expand the GBU/PHC outreach. The DP2020 was also an opportunity for GBU/PHC to work with the HFHP community to understand how high-performance projects are created within practical financial constraints of a non-profit housing developer and financier. The partnership joined technical expertise and practical expertise, with the goal of assisting HFHP to realize Passive House performance within their financial and project delivery model.

Approach: Opportunity-Seeking, Modeling, Budgeting

It became clear that HFHP represents a unique player in the design and construction world, as they are the Owner, Developer, and Builder of their projects. Additionally, HFHP has partnerships with several manufacturers who sponsor certain materials or products for HFHP's projects. It should be noted that construction delivery is not traditional. Projects are completed using a combination of non-technical volunteers, professional builders, and homeowner "sweat equity." This unique position has several advantages for executing projects but also has challenges.

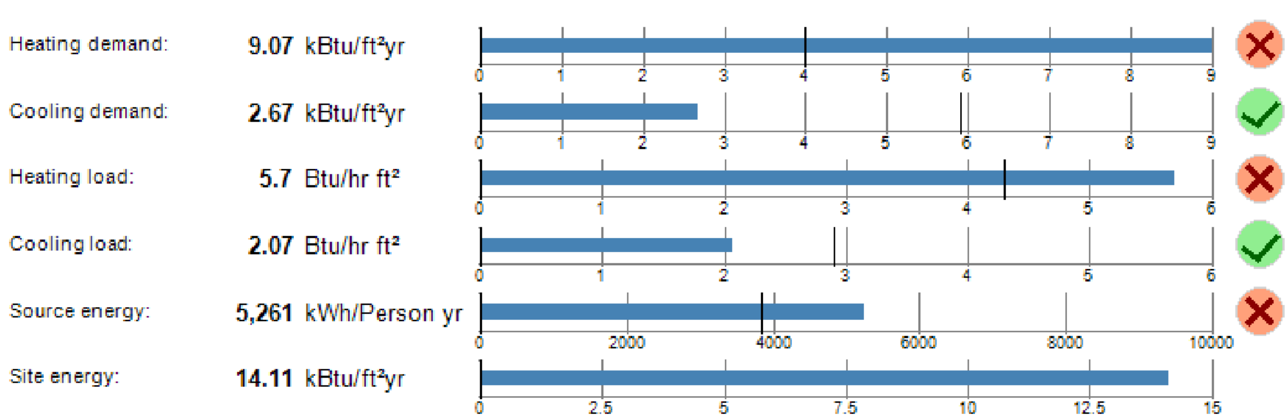
Information was presented by HFHP related to development costs and homeowner finances that played a role when evaluating design and construction changes. First, HFHP calculates actual project cost as the cost of all material, labor, contractors, permits, and overhead, regardless of whether or not materials or services were donated. The actual purchase price of each home is equal to the third-party appraised price and is lower than the total development cost. Second, homeowners who qualify for these homes earn between 30% to 60% area median income (AMI), which equates to approximately $13,500 to $27,000 per year per family.

To maximize the opportunities and utility of this project, the Passive House Community outlined the following steps:

- Understand the current Oxford Green design, approach, and limitations
- Outline design and construction opportunities as well as potential barriers to achieve Passive House standards
- Prioritize identification of areas for airtightness improvements in current design
- Prioritize alternatives that are volunteer-friendly and/or use donated materials
- Create a benchmark energy model using the existing Oxford Green design
- Evaluate changes to the benchmark model to obtain Passive House-level standards
- Coordinate monthly Wednesday charrettes to use as educational opportunities, with Saturday on-site volunteering
- Catalog substitutions made to the energy model and associated cost changes
- Evaluate cases that yield the greatest cost savings while meeting Passive House standards

The energy model was completed using WUFI software and modeled Block 2 as an 11-unit multi-family building. This approach not only simplified solutions related to Passive House (reduced certification costs and reduced construction costs related to insulation at party walls) but could more easily translate to other HFHP projects. PHIUS benchmarks include climate-specific annual heating and cooling demand limits and peak heating and cooling loads per project. Specifically, the maximum values permitted are:

Annual heating demand: 4.0 kBtu/sf/yr
Annual Cooling Demand: 5.9 kBtu/sf/yr
Peak Heating Load: 4.3 Btu/sf/yr
Peak Cooling Load: 2.9 Btu/sf/yr



The following as-designed information from Oxford Green was used to compare and budget against:

- Building Type: 11 single-family attached dwelling units
- Location: 23rd and Oxford Streets, Philadelphia, PA
- Orientation: Generally south-facing
- Foundation: R-12, Superior Walls, 2” XPS insulation, no sub-slab insulation
- Walls: R-26, 5/8” drywall, 2x6” studs @ 24” oc, 5.5” blown-in fiberglass insulation, ½” OSB sheathing, house wrap, 1” XPS insulation, hardie lap siding/panels
- Roof: R-40, 5/8” drywall, truss, ¾” sheathing, 8” XPS insulation
- Windows: Anderson 200, U=0.29, SHGC=0.29
- Air Leakage: 1,000 cfm per dwelling unit, or approximately 3 ACH (air changes per hour)
- Ventilation: Renewaire EV90, 130 CFM, 70% efficiency ERV (energy recovery unit)
- Heating & Cooling: Mitsubishi, 15 SEER heat pumps
- Water Heating: 2.3 COP heat pump hot water heater

Findings

After discovery via energy model updates and cost analyses, three cases stood out as the most feasible and cost-effective to implement Passive House standards. These three cases were:

Case #1: **Improve airtightness to Passive House levels**

This case resulted in a total additional investment of $22,000, or $1.10/sf, for the whole of Block 2. This equates to an additional investment of $2,000 per home and a potential annual savings of $96 for a family of four.

Case #2: **Improve airtightness to Passive House levels and install better-performing south-facing windows**

This case resulted in a total additional investment of $28,394, or $1.42/sf, for the whole of Block 2. This equates to an additional investment of $2,581 per home and a potential annual savings of $150 for a family of four.

Case #3: **Improve airtightness to Passive House levels, install even better-performing south-facing windows, install sub-slab insulation, add 1” insulation on the basement walls, and increase roof R-value to R-49.**

This case resulted in a total additional investment of $47,847, or $2.39/sf, for the whole of Block 2. This equates to an additional investment of $4,349 per home and a potential annual savings of $192 for a family of four.

It should be noted that the modeled electricity cost per year per dwelling unit is approximately $1,100. Therefore, a savings of $192/year represents more than a 17% savings in utility costs for homeowners. Given that homeowners fall between 30% to 60% area median income (AMI), this cost savings could be critical.

The details of each case are shown below:

Airtightness

- Most cost effective
- Estimated cost using price from Aero-Barrier
- Testing whole building vs individual units

Case	Component	Parameters	Delta from Habitat Base	Total Investment/ 11 units	Investment/SF	Potential Annual Savings for Family of 4 @ $0.14/kWh
Base Case + PH Airtightness	Roof	R-40 Continuous		$22,000.00	$1.10	**$96.02**
	Walls	R-21+5				
	Foundation	R-12				
	Slab	N/A				
	ACH @50Pa	0.06	-2.4			
	Windows	U = 0.29				

Better South-facing windows

- Take advantage of southern exposure
- Adds complexity for onsite teams and purchasing
- Price came from window manufacturer
- Other benefits of better windows

Case	Component	Parameters	Delta from Habitat Base	Total Investment/ 11 units	Investment/SF	Potential Annual Savings for Family of 4 at $0.14/kWh
Base Case + South Windows U=0.19, SHGC=0.4 + PH Airtightness	Roof	R-40 Continuous		$28,394	$1.42	**$150.33**
	Walls	R-21+5				
	Foundation	R-12				
	Slab	N/A				
	ACH @50Pa	0.06	-2.4			
	Windows	U=0.19, SHGC=0.4	u+0.10			

Increased insulation & Even better windows

- Under slab
- Roof
- Donated Materials and Volunteer labor

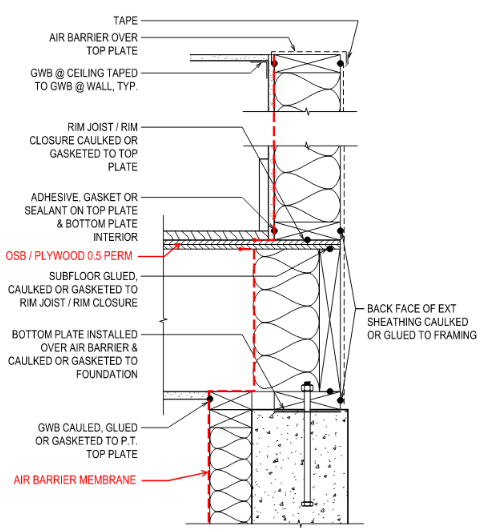
Case	Component	Parameters	Delta from Habitat Base	Total Investment/ 11 units	Investment/SF	Potential Annual Savings for Family of 4 at $0.14/kWh
Better window U-0.17; 2" slab insulation; Basement w/1" XPS interior; R49 roof	Roof	R-50	R-10	$47,847	$2.39	**$192.07**
	Walls	R-21+5				
	Foundation	R-27	R-15			
	Slab	R-10 Continuous	R-10			
	ACH @50Pa	0.06	-2.4			
	Windows	U=0.17, SHGC=0.4	u+0.12			

Design Review

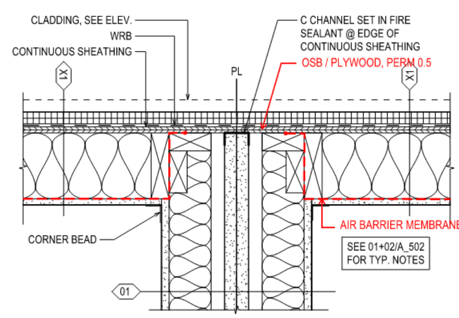
An overarching item of paramount importance to Passive House is airtightness. With air leakage comes significant energy losses, not to mention building durability and thermal comfort issues. The Passive House Community and project volunteers identified areas to improve airtightness. In addition to these individual details, it is important to maintain a continuous air barrier between all transitions. Completing a “red pencil test” is an important exercise to do early to verify the building’s control layers are intact.

Please see sketched general recommendations for the following details:

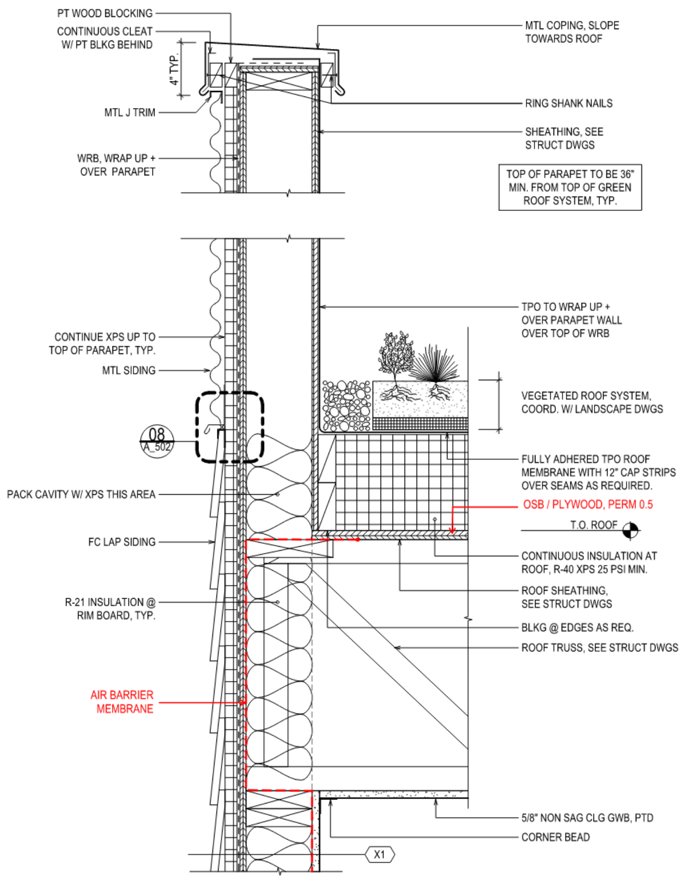
- Parapet installation — Detail 7/A501
- Floor to wall connection — Detail 1/A502
- Party wall detail — Detail 3/A501
- Window air/vapor barrier detail, — Detail 1/A403
- General enclosure penetrations — Detail 6/A502



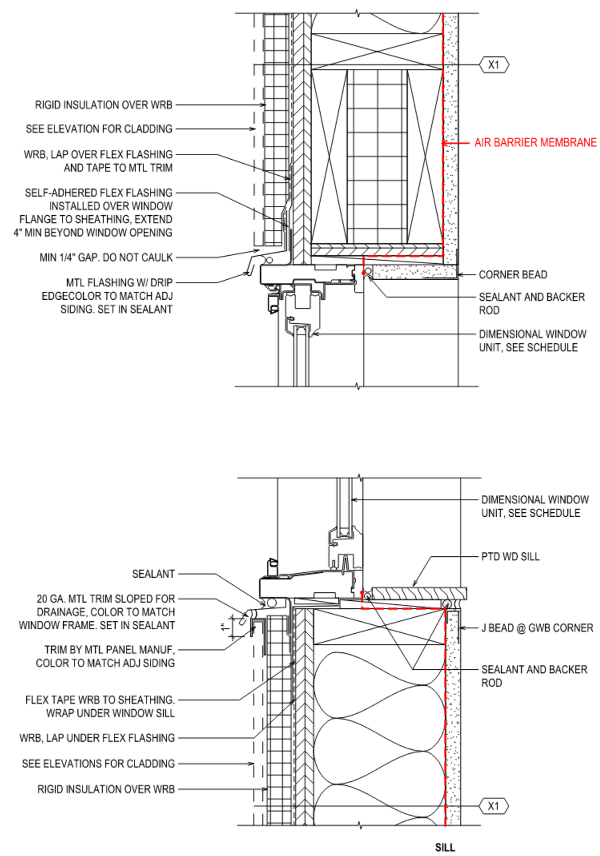
1/A502 Floor to Wall Connections



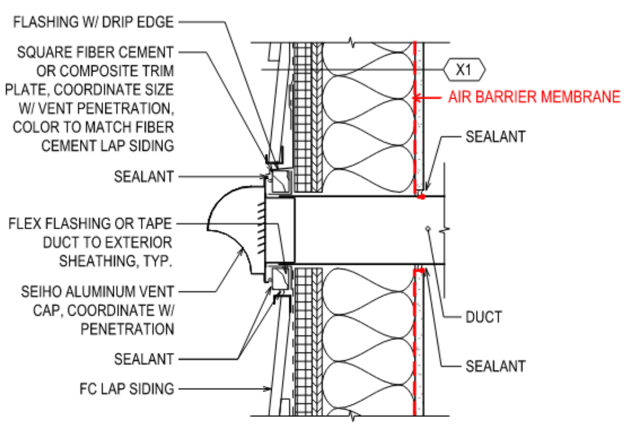
3/A501 Party Wall Detail



7/A501 Parapet Installation



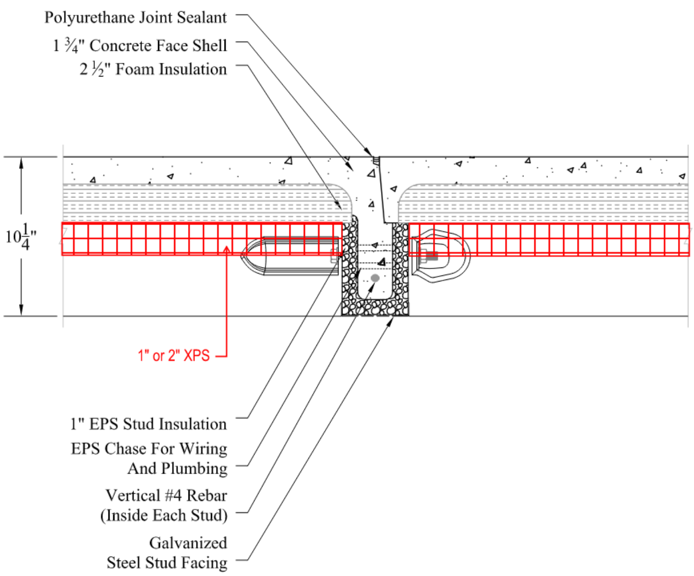
1/A403 Window Air/Vapor Barrier

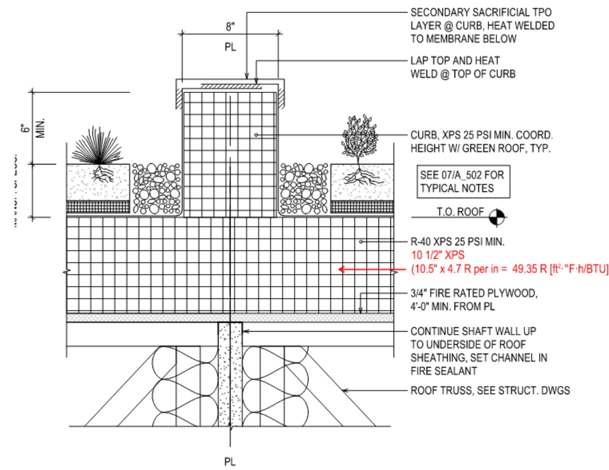


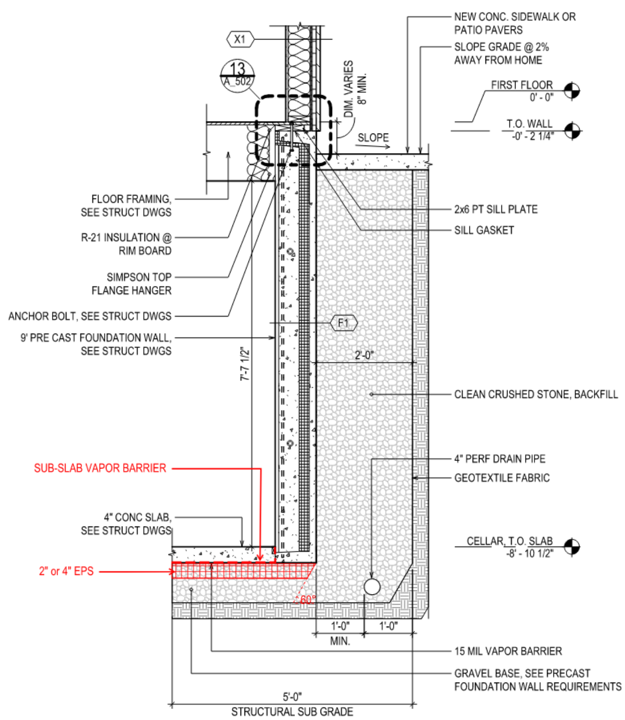
6/A502 General Enclosure Penetrations

Recommendations based on suggestions made via modeling are also provided for consideration in future construction and/or assemblies. Sketched recommendations for these details/areas are included below:

- Installation of sub-slab insulation (2" and 4")
- Superior Wall with 1" rigid insulation and built wall
- Additional XPS roof insulation to achieve R-49







Lastly, a design review log was started as part of the Project process. The log outlines potential strategies for issues, and is organized by airtightness, insulation, openings, constructability, or 'other'. This can act as a prompt for HFHP for future project thinking. Please see these comments within this report:

Item #	Sheet	Issue	Proposed Strategy	Airtightness	Insulation	Openings	Systems	Constructability	Other?
1	G_001	Describe /define air-tightness strategy - all homes in row / individual homes / party wall / include basement, etc.	Include in OPR	X					
2	A_001	Air-tightness at penetrations in partitions	Describe / spec products - backboxes, hosebibs, pipes	X					
3	A_001	Air-tightness at party wall	Define air barrier location - included in WRB?	X					
4	A_001	Air-tightness at exterior partitions	Define air barrier location - included in WRB?	X					
5	AF 120	Cellar floor consists of 4" concrete + 15 mil vapor barrier, with no sub-slab insulation	Install sub-slab insulation; Model a few thicknesses : 3-6"; Evaluate if this is something that can be donated by Dow or others		X				
6	06/A502	Sidewall vent needs gasket	Install gasket.	X					
7	A_401	Window frame insulation	Over-insulate frame at fixed windows		X	X			
8	A_401	Door gaskets	Spec perimeter door gaskets for air-tightness	X					
9	03/A502 -4/502	Plumbing vent gasket needed. Exhaust fan gasket needed	Install gasket.	X				X	
10	A_402	Door frame insulation	Over-insulate door frames		X				
11	A_402	Door sealant joints	Review detail - add expanding tape seal (Hanno)	X					
12	A_402	Thermal bridge at plywood subfloor / foundation wall	Add continuous insulation layer at wood sill plate- inside or outside		X				
13	A_402	Air barrier location	Define air barrier location - included in WRB?	X					
14	A_403	Rough openings	Use high-strength rigid insulation instead of shims?		X				
15	11,12/A_501	Show all wood nailers and blocking req	Identifies potential thermal bridge and th	X	X				
16	1/A_502	Insulation continuity	Show insulation as part of thermal / air-ti	X	X				
17	1/A_502	Vent sealing	Spec insulated vent as appropriate	X	X				
18	07/A501 07/A502	There may be a thermal bridge between the roof and the wall	Establish continuous insulation		X				
19	01/A502	No construction instructions for sealing the seams in the rigid insulation	Need to verify that the seams are taped during construction.	X				X	
20	10/A601	Air sealing notes state: Glued/Caulked or Gaasketed for connections. Should be specific.	Specify gasket	X				X	
21	10/A601	Bottom plate needs gasket and is thermal bridge at floor.	Specify gasket and establish continuous insulation	X	X			X	
22	A601/07	Metal door overhang - with snow backup may penetrate house and the 4 connections may be a thermal bridge.	Connectors should have insulators to avoid thermal bridge. Delete overhang or straighten end of overhang to avoid ice/water back-up.		X				

Item #	Sheet	Issue	Proposed Strategy	Airtightness	Insulation	Openings	Systems	Constructability	Other?
23		Basement walls R12.5 but PH R20; Exterior Walls R21 plus R5 but PH R40; Roof R40 but PH R60	Need identify a way to increase R-values		X				
24	A-210/02	The compressor is designed to be hung above the window line of the 2nd floor bedroom. In practice it is being installed at about 8-10" off of the roof surface.	Raise the height of the installation					X	
25	A111W	The drawings call for the washer and dryer to be installed in the front of the building with the dryer exhausting to the street but the units are being installed to the rear which interferes with the rear space being used as a bedroom	Units should be installed in the front. Dryer vent needs gasketing. Dryer vent should be insulated. Installations should be consistent.	X	X			X	
26		As the house is further tightened, the effect of the non-ducted exhaust fan in the kitchen will become more pronounced.	Consider kitchen exhaust scenarios in modeling.	X					
27	A111E. A111W, A121E, A121W	Sump pump and sump pump discharge will need to be carefully detailed with subslab insulation, air barrier		X	X			X	
28	A401	Windows: Energy Star. Black frames can have long term maintenance issues			X	X			**Resiliency**
29	8, 9,10/A502	Drainage plane location is unclear	Recommend clarifying drainage plane location for shedding water		X				**Resiliency**
31	AF 120	Superior walls provided with 2.5" rigid insulation only	Can add'l insulation be added to foundation walls?		X				
32	A 001	Need to increase wall assembly R-value	Can we look at wall assmelby option - e.g. 2x6 with mineral wool (~R-26), plywood/OSB, WRB, 3" polyiso @ ~5.5/inch. This would increase wall width about 2". Other insulation options can be evaluated, but may add wall thickness.		X				
33	A 001	Need to increase roof R-value. CUrrency R-40	Can 10" of rigid insulation be installed instead of 8"?		X				
34	01 / A502	Discontinuous air barrier at foundation/first floor	Can we include a sheet applied air barrier at the cellar/1F transition to connect superior wall with OSB sheathing?	X					
35	A501	Discontinuous air barrier at second floor/roof	Can we include a sheet applied air barrier at the 2F/roof transition? Around sill plate and exclude parapet from airtight boundary	X					

Thoughts and Takeaways

Overall, Habitat for Humanity Philadelphia has done a good job of designing and constructing this project, the HFHP status-quo is significantly above code and because HVAC systems have been optimized, major cost savings have already been realized and the energy efficiency delta between HFHP status quo and Passive House is not substantial. This is fantastic for the occupants of the homes. It also means that bringing the project up to Passive House certification performance levels would be at an additional expense. It should be noted that this study looked at an already designed, under construction building with baked-in costs; the costs of individual investments or changes that were modeled were in effect retrofit costs. If Passive House techniques were instituted at the onset, the incremental costs would be less and the potential savings per homeowner greater.

That said, two key levers were identified that would have significant impact on the energy consumption of future Habitat projects:

- **Passive House-level airtightness:** As shown in the above details, it is key to focus attention on air sealing with the designers and site personnel when planning the next project with the goal of reducing blower door results approaching 0.06 CFM per SF of enclosure area @ACH50.
- **Sourcing and installing better windows tailored to the solar exposure:** As the model results indicate, it is important to understand that improved windows can have a significant effect on project energy efficiency.

This exercise outlined these key levers and quantified the investment against the savings – and it is meant as a guide for planning. To effectively and realistically meet the Passive House benchmarks, HFHP should prioritize the following:

- Active, on-site quality control for air sealing details and sequencing of construction assemblies
- Seeking donations or deep discounts on the highest performing windows possible
- Thorough window installation training

HFHP is well-positioned to solicit additional on-site training from experts as well as material donations. With Passive House as a goal early on in the project, moving from current design to Passive House design could be perfectly achievable with limited lift.

Beyond Passive House Benchmarks

Monitoring

HFHP would benefit from monitoring occupant energy usage via Wi-Fi-enabled equipment and using the gathered data to benchmark performance of the various Habitat neighborhoods to inform design decisions for and improve the energy performance of future developments. For monitoring to be useful, operations and maintenance training for homeowners must also be implemented to verify actual performance reflects modeled intent.

Embodied Carbon

HFHP may benefit from calculating and benchmarking embodied carbon and evaluating the impacts of different material selections. In addition to operational energy, Habitat could review ways to reduce embodied carbon in their projects by evaluating different material or manufacturer choices. Embodied carbon is defined as the CO2 emissions associated with materials and construction processes throughout the lifecycle of a product, including CO2 created during manufacturing, transportation, installation, maintenance, and end of life stages. Additionally, as building codes and best practices continue to drive operational carbon down, embodied carbon becomes a bigger slice of the metaphorical carbon pie. In addition to reducing embodied carbon, alternative material selections may be desired for improved indoor air quality, durability, location of manufacture, and/or toxicity. Habitat is encouraged to use the Embodied Carbon in Construction Calculator (EC3) (https://www.buildingtransparency.org/), a free database of embodied carbon information for use in design and material procurement.

Owner's Project Requirements

HFHP would also benefit from having a documented Owner's Project Requirements (OPR) for each project or similar projects. HFHP currently has a baseline spec that outlines general requirements per division. As HFHP's intent is to build as many homes per year as possible, a more defined OPR may be helpful to streamline future projects. It is recommended, at the minimum, HFHP outline the following for their projects: Purpose and Function, Mission, Team, Codes; Sustainability Vision, included but not limited to energy efficiency goals, materials requirements, indoor air quality standards; Envelope, systems, and site/infrastructure expectations; Performance criteria and validation; and operational requirements.

Appendices

- Backup Pricing Calculations
- Energy Model Case Results
- Charrette Presentation Information
- Volunteer and Team Information

Appendices

DP2020 Volunteer and Team Information

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Kitchen & Associates
Magrann Associates
McDonald Group
Siga
Stego Industries

And Thanks to all Attendees and Participants for helping make this Demonstration Project a success!