



The Pennsylvania Housing Research Center

PHRC Year in Review

July 2019 – June 2020

Published September 2020

Pennsylvania Housing Research Center

Pennsylvania State University

206B Sackett Building

University Park, PA 16802

Telephone: (814) 865-2341

Facsimile: (814) 863-7304

E-mail: phrc@psu.edu

Web Site: www.phrc.psu.edu

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I. Introduction

The purpose of this document is to provide a summary of activities the Pennsylvania Housing Research Center has pursued and products that have been delivered between July 1, 2019 and June 30, 2020.

Each year, the Pennsylvania Housing Research Center (PHRC) seeks to conduct a series of projects that collectively satisfy the following criteria. Projects should:

- meet the needs of the residential construction industry and the housing consumer in Pennsylvania;
- be consistent with the mission and goals of the PHRC;
- be affordable and feasible, given the resources available and the prevailing constraints on time, expertise, and facilities; and
- be a balanced program of projects that address both the long- and the short-term needs of the industry.

The projects undertaken were developed with input and assistance from the PHRC's Industry Advisory Council (IAC). This body consists of builders, developers, design professionals, code officials, manufacturers, suppliers, remodelers, and industry associations as well as state and federal agencies. After a thorough discourse at the spring IAC meeting in April 2019, the members of the IAC voted on projects they felt were the highest priority for the industry.

The result of this input was the "*PHRC Project Plan, July 2019 – June 2020*", which outlined projects that the PHRC would undertake during this time period. The plan included only those projects that were to receive funds provided to the PHRC by the Commonwealth of Pennsylvania through Uniform Construction Code (UCC) permit fees. When appropriate, the PHRC attempts to use state funding to leverage outside support. It should also be noted that the PHRC undertook an array of additional projects that did not receive any state funds. Some of these projects are included in this report but are identified as having no support from the UCC permit funds.

Through the memorandum of understanding that Penn State University has with the Department of Community and Economic Development (Contract #27-872-0001), the PHRC is required to submit to DCED an annual work plan and an annual report summarizing the activities for the previous year with respect to the fee. This "Year in Review, 2019-2020" is submitted to meet the annual report requirement.

A. PHRC Organizational Chart

Please refer to Figure 1 for the current PHRC organizational chart.

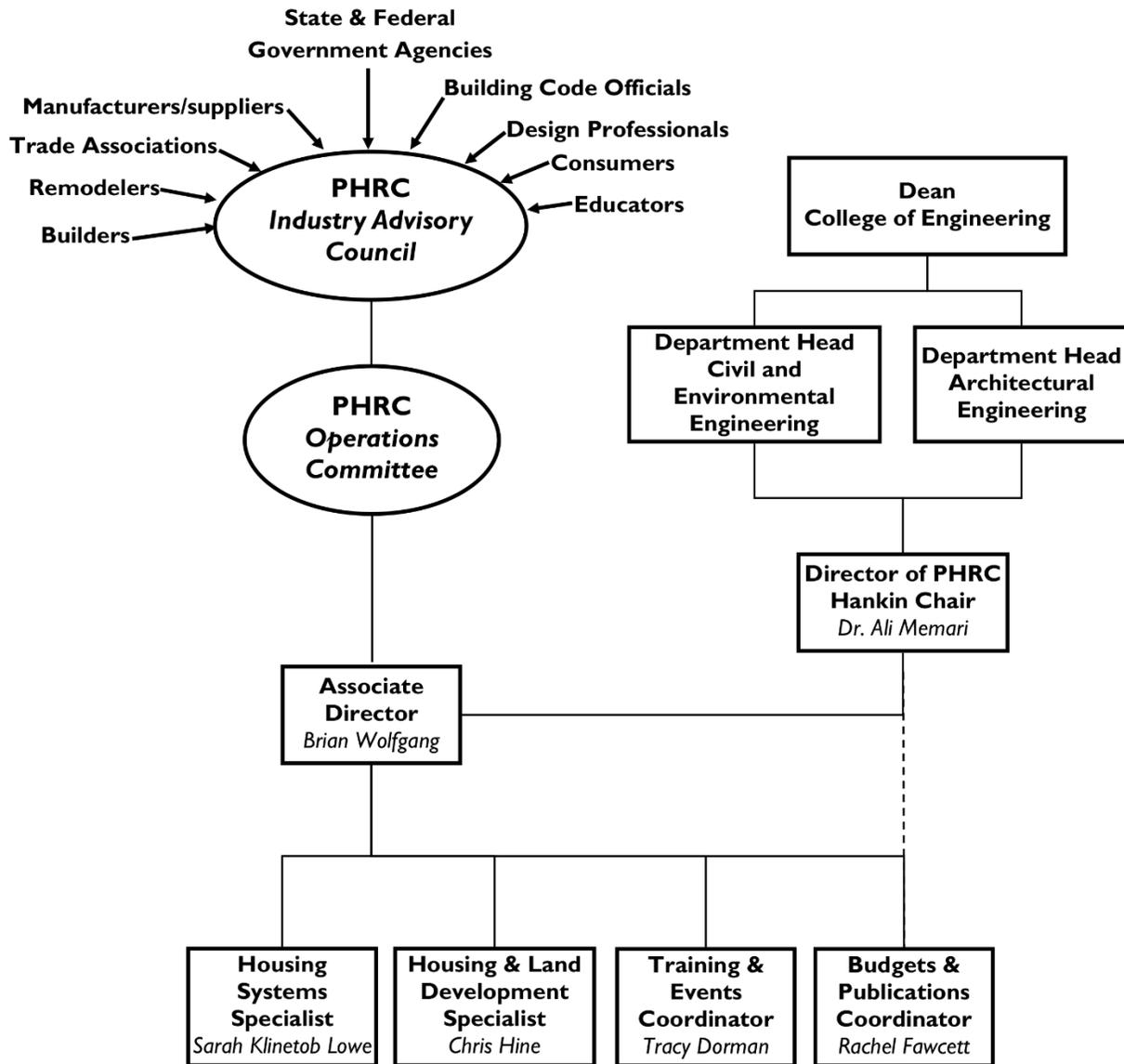


Figure 1. PHRC Organizational Chart

B. COVID-19 Impacts

The 2019-2020 project year was impacted in significant and unprecedented ways by the COVID-19 pandemic. The PHRC team's workflow was interrupted following the 28th Annual PHRC Housing Conference and 2020 Residential Building Design and Construction Conference. Beginning March 16, 2020, Penn State employees, which includes PHRC staff, in accordance with guidance from the Governor of Pennsylvania were instructed to begin working remotely for what was anticipated to be a short-term arrangement. The course of the COVID-19 pandemic certainly changed over the subsequent weeks, resulting in not only the PHRC team working remotely for the remainder of 2020 but also the cancelation of all in-person activities for the remainder of the 2019-2020 project year. While some activities were shifted to a virtual platform, others were canceled altogether.

This unprecedented disruption had a significant impact on PHRC deliverables, including:

- Fewer in-person workshops and speaking engagements held in spring 2020
- Cancelation of PCCA Symposia
- Some 2019-2020 projects will be carried over to 2020-2021 due to diverting staff resources to COVID-19 response needs

With PHRC staff working remotely in 2020, staff time was diverted, as appropriate, to supporting the residential construction industry as it navigated COVID-19 impacts. The largest impact in Pennsylvania was the shutdown of construction activity from late-March through May 2020. The PHRC team responded in the following ways:

- Initiated frequent email communication to share information from Governor Wolf's administration as it related to construction
- Worked with industry stakeholders to coordinate communication on COVID-19 safety requirements
- Shared online resources for industry stakeholders who focused on professional development during the shutdown

While the overall engagement in the latter half of the project year was stifled by the COVID-19 pandemic, the PHRC team worked diligently to support the residential construction industry in a variety of ways. The team also worked to prepare for the longer-term needs in a virtual world, such as increased online training and engagement.

II. Training, Technical Assistance & Outreach

The PHRC has a mandate to transfer knowledge by providing the necessary training and education to the wide variety of groups that make up the housing industry. To meet this expectation, the PHRC offers an array of activities to educate and transfer appropriate technologies to the industry. These activities can include the development and delivery of educational programming using a variety of media, the hosting of conferences/symposia, and the publication of reports, as well as serving as a general resource to the industry in answering questions.

Counting workshops, webinars, speaker services, and conferences, the PHRC provided 44 educational services to 2,056 individuals during this reporting period (Table 1).

Table 1. Summary of PHRC Educational Programs for the 2019-2020 Project Year

PROGRAM	Activities for 2019-2020	
	# of Events	# of Attendees
Workshops	17	319
Webinars	8	699
Speaker Service	16	677
PHRC Conference/PCCA Symposium (Central)	Day 1	121
	Day 2	97
RBDCC	1	143
PCCA Symposium (East)	N/A	-
PCCA Symposium (West)	N/A	-
TOTAL	44	2,056

The four general categories of the PHRC's work in this area include:

- A. Program Development
- B. PHRC Training Program Delivery
- C. Webinar Development and Delivery
- D. General Technical Assistance, Technology Transfer, & Outreach Activities

The following sections labeled A through D of the report will provide further details on the PHRC's accomplishments in each of these categories.

A. Program Development

The PHRC developed or updated the following training programs. These programs address issues challenging the residential construction industry (builders, developers, remodelers, building code officials, design professionals, materials suppliers, etc.).

1. Existing Program Updates & Maintenance

Description: On May 1, 2018, the PA Uniform Construction Code (PA UCC) Review and Advisory Council (RAC) submitted their report to the Department of Labor and Industry adopting the majority of code provisions contained in the 2015 International Code Council (ICC) Model Codes. These new code provisions took effect on October 1, 2018. Many core workshops have already been updated but some focused-topic workshops still need to be addressed. Additionally, there is a need to make minor course material updates based on instructor feedback. Also, we will continue work to update and improve the photos in programs, incorporate more photos or videos as appropriate, and expand active learning exercises to increase learner participation and knowledge retention.

Manager/PI: C. Hine & B. Wolfgang

Report: PHRC staff continued to update workshops to reflect administrative changes, technical additions, and other instructor-led requests.

2. Solar PV Program

Description: In 2011, a one-day solar photovoltaic system installation and inspection training program was developed by the PHRC in conjunction with several industry professionals. This project would update this program with the latest code provisions, as well as explore how or if to upgrade or enhance the program to meet the needs of solar photovoltaic installers, inspectors, and educators across Pennsylvania.

Manager/PI: S. Klinetob Lowe

Report: The update of the content of this one-day program with the latest code provisions and up-to-date Pennsylvania context is complete.

3. Training for Blower Door and Duct Tightness Testing

Description: With envelope air leakage (blower door) testing now required by the PA Uniform Construction Code, the industry is attempting to respond to the need for more third parties to conduct this test. Many consultants and other subcontractors have an interest in building this capacity in order to offer blower door testing as a service but are not sure where to turn for training. This project would allow the PHRC to partner with other organizations in the state that have a similar goal of helping the residential construction industry adapt to these code changes. This collaboration would focus on

bringing blower door and other relevant training to PA in order to provide the regional industry an opportunity to build blower door and duct testing capacity

Manager/PI: B. Wolfgang

Report: The PHRC team has made significant strides regarding the blower door and duct tightness testing training development. This effort involves a significant collaboration with the National Sustainable Structures Center (NSSC) at Penn College. PHRC and NSSC will work to develop a blended training program that will provide Infiltration and Duct Leakage (IDL) certification through the Building Performance Institute (BPI) upon completion.

The core PHRC function is to develop online asynchronous training that focuses on Pennsylvania Uniform Construction Code (UCC) requirements and International Energy Conservation Code provisions. These topics will also be covered in training developed for in-person instruction.

This effort is ongoing and will continue into the 2020-2021 project year.

B. PHRC Training Program Delivery

Description: The PHRC has developed and maintains a wide array of training for many sectors of the construction industry with a focus on residential construction. These programs are intended to address technical issues facing the industry. The intended audience for these programs includes builders, remodelers, trade contractors, design professionals, educators, and building code officials. Additionally, the PHRC can customize programs to better meet the needs of an industry partner.

The PHRC seeks to partner with relevant outside organizations whenever possible. These industry partners may include trade associations such as the Pennsylvania Builders Association or their local associations, professional associations, building code associations, as well as the Pennsylvania Construction Code Academy (PCCA).

Current PHRC training program offerings are listed below. These are broken into three categories: (1) Code Refresher, (2) Academy Programs, and (3) Focused Topics.

(1) **Code Refresher** programs are 1-day programs that offer a shorter alternative to the multi-day academies and are also well-suited for anyone interested in an introduction to building codes or information to make inspections go more smoothly.

- | | |
|----------------------------------|-------|
| a. IRC Building Code Refresher | 1 day |
| b. IRC Plumbing Code Refresher | 1 day |
| c. IRC Mechanical Code Refresher | 1 day |
| d. IRC Electrical Code Refresher | 1 day |
| e. IRC Energy Code Refresher | 1 day |

(2) **Academy Programs** are typically offered 1-2 times per year through the Pennsylvania Construction Codes Academy (PCCA). These programs are geared toward beginning code officials seeking to pass their certification exams or anyone interested in a comprehensive overview of residential building codes.

- | | |
|--------------------------------|--------|
| a. IRC Building Code Academy | 4 days |
| b. IRC Plumbing Code Academy | 4 days |
| c. IRC Mechanical Code Academy | 4 days |
| d. IRC Electrical Code Academy | 4 days |
| e. IRC Energy Code Academy | 2 days |

(3) **Focused Topics** programs are designed to immerse the attendee more deeply into a particular aspect of construction. These programs are ideal for meeting continuing education requirements for certified code officials. As appropriate, AIA Learning Units (LUs) for architects, ICC credits and ICC contact hours for code officials, NARI credits for remodelers, and Professional Development Hours (PDHs) for engineers are offered.

- | | |
|--|-------|
| a. Blueprint Reading Program | 1 day |
| b. Residential Sprinkler Inspection/Installation | 1 day |
| c. Fundamentals of Exterior Plaster and Thin Stone Veneer Assemblies | 1 day |

d. Building Envelope Design and IECC Code Compliance	1 day
e. Building Code Plan Review and Inspection	1 day
f. Residential Deck Design and Construction	1 day
g. Building with Exterior Rigid Foam	1 day
h. Residential Moisture Management: The 4D's	online
i. IRC Framing Design & Code Compliance	1 day
j. Commercial Energy	2 days
k. HVAC Design & Installation	1 day
l. IRC Multifamily	1 day

Report: During the 2019-2020 project year, the PHRC delivered 17 workshops to 319 individuals during this reporting period. See Table 2 for further details. Note: Due to the COVID-19 restrictions on in-person activities, five in-person workshops had to be canceled.

Table 2. PHRC Workshops Held July 1, 2019 through June 30, 2020

Program	In-person/ Online	# of Programs	# of Attendees
2015 IRC Update	In-Person	3	51
Blueprint Reading & Understanding House Plans	In-Person	1	14
Building Envelope Design & IECC Code Compliance	In-Person	3	50
Commercial Energy Academy – 2 days	In-Person	1	15
IRC Building Code Academy – 4 days	In-Person	1	32
IRC Electrical Code Academy – 4 days	In-Person	1	17
IRC Mechanical Code Academy – 4 days	In-Person	1	16
IRC Plumbing Code Academy – 4 days	In-Person	1	25
Residential Deck Design & Construction	In-Person	4	72
Stucco & Thin Stone Veneer Design & Installation	In-Person	1	27
<i>Total</i>		17	319

C. Webinar Development and Delivery

Description: The PHRC will continue its successful monthly webinar series. Webinars are delivered live and are also archived for on-demand viewing. Proposed topics are listed below. One PA Labor & Industry contact hour is offered for each webinar for PA code officials. As appropriate, AIA Learning Units (LUs) for architects, ICC credits and ICC contact hours for code officials, NARI credits for remodelers, and Professional Development Hours (PDHs) for engineers are offered.

Report: The PHRC delivered eight webinars during this reporting period to a total of 699 people. Due to the PHRC Housing Conference, no webinar was held in March. See Table 3 for the summary of webinars and attendees.

Table 3. 2019-2020 Webinar series titles and number of attendees

Webinar Series		
Month	Title/Topic	Number of Attendees
September	Reducing Thermal Bridging with Continuous Exterior Insulation	80
October	Wall Bracing in the UCC	96
November	Pennsylvania's MS4 Programs and Its Impact on Development	62
December	High Performance Wall Systems	68
January	Ductwork in Attics	76
February	Building Science 101 for Residential Buildings	106
April	The Do's and Don'ts of Crawlspace Design and Installation	130
May	Intro to ENERGY STAR	81
	<i>Total</i>	699

D. Technical Assistance, Technology Transfer, & Outreach

Description: This initiative is a continuation or expansion of activities to get technical information, resources, and publications to builders, remodelers, design professionals, building code officials and others involved in the residential construction industry.

Report: The PHRC had organized, developed, and/or delivered the follow activities:

1. Annual PHRC Housing Conference
2. Residential Building Design & Construction Conference
3. PCCA Symposia
4. Speaking Engagements
5. General Outreach Activities
6. Annual Magazine
7. Educating the Next Generation of Tradespeople
8. Support of the UCC RAC
9. Support of Standards

1. **Annual PHRC Housing Conference:** The PHRC will continue to organize, promote and hold the annual conference. This conference has been held since 1992 and has established a reputation of being the premier program focusing on technical issues of housing and land development in PA. The conference brings together the building community (builders, remodelers, design professionals, educators) with regulators (planners, building code officials, township engineers, DEP and conservation district staff, etc.) and others involved in the residential construction industry.

Report: The 28th Annual PHRC Housing Conference was held on March 4-5, 2020 at the Penn Stater Conference Center and Hotel in State College, PA.

Day 1: Day 1 of the PHRC Conference started off with a keynote from Clayton DeKorne, Chief Editor, Journal of Light Construction, entitled “How Will Construction Solve the Skilled Labor Shortage?”.

The following tracks and sessions were offered:

- High Performance Homes
 - “Checking Your Work: Properly Installed HVAC in High-Performance Homes” by Dean Gamble
 - “Choose Your Own Adventure: Building Performance Good Better Best” by Clint Shireman
 - “BeTL & AddCon Lab Tours”
- Construction
 - “Updated PA Act 287, as Amended for the Excavator” by Mark Lipka
 - “Concrete: An Out of this World Construction Material” by Aleksandra Radlinska

- “Moisture Management: Learning from Our Experience” by Bill Dare
- Codes and Regulations (PCCA Symposium Central)
 - “Inspecting Manufactured and Industrialized Housing” by Michael Moglia
 - “Manufactured Housing Installation Under the HUD Administered Program” by Mark Conte
 - “2018 PA UCC / Code Enforcement Q & A” by Bob Buddenbohn, Douglas Meshaw & Matt Kegg
- The PHRC held an event the evening of March 4. This event was titled “Happy Hour on the Exhibit Floor”. This networking event featured 14 exhibitors ranging from student groups to product manufacturers.

Day 2: Day 2 of the PHRC Conference started off with a keynote from Lois B. Arena, Steven Winter Associates, Inc, entitled “Passive House: A Proven Path Toward Resilient, Affordable and Energy Efficient Housing”.

- High Performance
 - “Balancing Affordability, Feasibility, and Operability in High-Performance Multifamily Housing” by Ashley Wisse & Debra Hall
 - “A Couple’s Passive House—Environmental Responsibility Without City Living” by Gary Gardner
- Construction & Codes
 - “Adapt and Overcome: Hiring a Young Workforce” by Clint Shireman
 - “Panelized Passive House Multifamily Construction” by Paul Grahovac
 - “High-Performance Windows—The latest from the Lab and from the Field” by Theresa Gilbride & Katherine Cort
- Land Development & Planning
 - “The Future of New Community Development and Housing Choice” by Daniel Anderton & Michael Snyder
 - “Restoring Floodplains to Manage Stormwater” by Leslie Rhoads, Kelly Gutshall & Mark Hackenburg
 - “Circulation and Roads for your Development: Back to the Future” by Martin T. Pietrucha
 - “Zoning Beyond Land Use: New Thinking to Modernize a Zoning Ordinance and to Address Housing Needs” by AJ Schwartz & Carolyn Yagle

Table 4. Attendees at the Annual PHRC Housing Conference

Event	# of people
Day 1 (March 4)	121
Happy Hour on the Exhibit Floor (March 4)	146
Day 2 (March 5)	97

2. **Residential Building Design & Construction Conference:** The PHRC will organize, promote, and hold the Residential Building Design and Construction Conference (RBDCC), to be held in even numbered years. The RBDCC provides a unique forum for researchers, design professionals, manufacturers, and builders to keep up-to-date on the latest advancements and discuss their own findings, innovations, and projects related to residential buildings. RBDCC sessions will consist of technical paper presentations on recent research and innovations related to residential buildings. RBDCC is focused on various types of residential buildings including single- and multi-family dwellings, mid-rise and high-rise structures, factory-built housing, dormitories, and hotels/motels. Full papers be published in the conference proceedings.

Report: The PHRC held the 2020 (5th) Residential Building Design and Construction Conference on March 4–6, 2020 at The Penn Stater Hotel and Conference Center. With 136 abstracts submitted (a 25% increase from the 2018 RBDCC), the conference was expanded from 2 to 3 days. Researchers from 7 different countries were represented, and total registrations increased from 79 to 143 (an 81% increase). Fifty-six papers have been submitted for inclusion in the proceedings, which will be published once all the editorial work is complete.

Two keynote speakers were invited for the conference: David O. Prevatt, Ph.D., PE, FASCE, Associate Professor of Civil & Coastal Engineering, Associate Director NSF - NHERI Experimental Facility at University of Florida and Lois B. Arena, PE, Director of Passive House Services at Steven Winter Associates, Inc. Professor Prevatt discussed his presentation titled “Wind Hazard Resilient Residential Communities—When Engineering Isn’t Enough.” Lois B. Arena shared her presentation titled “Passive House: A Proven Path Toward Resilient, Affordable & Energy Efficient Housing.” The conference also hosted a closing plenary session by Jay Arehart, Senior Research Fellow at Project Drawdown and Tom Richard, Director of Institutes Energy & the Environment at Penn State, entitled “Buildings as a Drawdown Solution: Getting to Zero and Beyond.” The conference program and the proceedings including full papers for the past conferences can also be found online, www.phrc.psu.edu/Publications/Past-Conference-Proceedings.aspx.

3. **PCCA Symposia:** The PHRC will work with the PCCA to develop and deliver 3 one-day programs (one in the central region of the Commonwealth in conjunction with the annual PHRC Housing Conference, one in the eastern part of the Commonwealth, and one in the western part). This annual event is intended to address technical issues being faced by building code officials.

Report: PHRC staff helped to organize three symposia hosted by PCCA in spring 2020. Due to COVID-19 restrictions on in-person events, only the PCCA Symposium Central was held in conjunction with the PHRC Housing Conference. The PCCA Symposium East and West were canceled.

4. **Speaking Engagements:** The PHRC participates in talks, seminars, and conferences directed at the housing and land development industries. This may include trade and professional association functions and regional meetings, local association meetings, or state or national conferences. Over the 2019-2020 reporting period, the PHRC delivered 16 speaking engagements, reaching 677 people. Note: COVID-19 restrictions on in-person gatherings had a significant impact on spring 2020 speaking engagements. These speaking engagements are summarized in Table 5.

Table 5. Speaking Engagements During the 2019-2020 Project Year

Organization	Topic(s)	Date	# of Attendees
Pennsylvania Housing Research Center (PHRC)	Construction Drawings	9/6/2019	75
Keystone ASHI (American Society of Home Inspectors)	4 D's of Moisture Management	9/9/2019	18
Penn State University	3D Printing of Concrete Structures -- Status, Challenges, and Vision for Future	9/12/2019	18
Quality Home and Building Inspection	Air sealing and air barriers/mechanical ventilation	9/20/2019	58
Penn State University	Introduction to Infrared Thermography Method for Building Wall Thermal Resistance Determination	10/6/2019	7
Penn State University	3D Printing of Concrete – Status & Opportunities	10/15/2019	15
Penn State University	Introduction to Additive Manufacturing and 3D Printing of Concrete Methods	10/17/2019	18
DelChester NARI	Residential Moisture Management: the 4D's	10/23/2019	25
Transportation Research Board	Application of 3D printing in Transportation Structures	1/12/2020	30
West Branch Susquehanna Builders Association	Air Sealing and Air Barriers in the Uniform Construction Code	2/18/2020	25
Penn State University	Introduction to the Passive House Standard	2/28/2020	22
Penn State University	Solar Photovoltaics for Passive House	3/27/2020	22
Penn State University	Building Science Basics: Passive House Envelope Design	4/3/2020	22
Penn State University	Framing Materials: Wood as a Construction Material	4/13/2020	150
Penn State University	Framing Materials: Engineered Wood Products	4/15/2020	150
Penn State University	Intro to Passive House Wall Design	4/24/2020	22
	<i>Total</i>	16	677

Conference Presentations: The following conference presentations were delivered during the 2019-2020 Project Year.

- Muthumanickam, N. K. (Presenter), Duarte, J. P., Nazarian, S., Bilén, S., and Memari, A. M. (2020). “BIM for design generation, analysis, optimization, and construction simulation of Martian habitat,” ASCE Earth & Space Conference – Engineering for Extreme Environments, April 20-23, 2020, Seattle, Washington.
- Muthumanickam, N. K. (presenter), Park, K., Duarte, J. P., Nazarian, S., Memari, A. M., and Bilén, S. (2020). “BIM for Parametric Problem Formulation, Optioneering and 4D Simulation of 3D Printed Martian Habitat: A Case Study of the NASA 3D Printed Habitat Challenge,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Nazarian, S. (presenter), Duarte, J. P., Bilén, S., Memari, A. M., Muthumanickam, N. K., Watson, N., Radlinska, A., Ashrafi, N., and Hojati, M., (2020). “An Overview of the Execution of 3D-Printed Subscale Habitat on Mars: A Case Study to Exemplify the Automated Construction Process,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Hindman, D. (presenter) and Memari, A. M., (2020). “Mass Customized Cross-Laminated Timber Elements for Residential Construction,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Amini, M. (presenter) and Memari, A. M., (2020). “Performance of Residential Buildings in Hurricane Prone Coastal Regions and Lessons Learned for Damage Mitigation,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Amini, M. (presenter) and Memari, A. M., (2020). “Evaluation of Various Retrofit Strategies for Existing Residential Buildings in Hurricane Prone Coastal Regions,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Bates, J. (presenter) and Memari, A. M. (2020). “Conceptual Geometric Design for U.S. Costal Homes to Resist Hurricane Surge Forces,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Park, K. (presenter), Memari, A. M., Hojati, M., Nazarian, S., and Duarte, J. P. (2020). “Structural Analysis of Full-Scale and Sub-Scale Structure for Digitally Designed Martian Habitat,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.
- Park, K. (presenter), Memari, A. M., Hojati, M., Zahabi, M., Nazarian, S., and Duarte, J. P. (2020). “Experimental Testing and Finite Element Modeling of 3D-

Printed Reinforced Concrete Beams,” *5th Residential Building Design and Construction Conference*, Penn State University, University Park, PA, March 4-6, 2020.

- Nazarian, S. (presenter), Duarte, J. P., Bilén, S. G., Memari, A., Radlinska, A., Meisel, N., and Hojati, M., (2019). “Additive Manufacturing of Architectural Structures: An Interplay between Materials, Systems, and Design,” Proceedings of the CIAC 2019 Conference on Automation Innovation in Construction, Leiria, Portugal, Nov. 7-8, 2019
- Klinetob Lowe, S. (Presenter). (2019). “From Zero Energy to Energy+: Community-University-Industry Partnerships for Sustainable Housing.” Presented at the 2019 Association for the Advancement of Sustainability in Higher Education (AASHE) Conference, October 28-30, 2019, Spokane, WA.

5. **General Outreach Activities:** The general outreach activities of the PHRC include efforts to let builders know about the PHRC and the services and publications it provides. These activities may include creating PHRC mailings and promotional pamphlets; writing articles in research or trade journals; answering phone and email questions; and the maintenance of the PHRC’s website and social media, as well as relevant technical meetings attended by PHRC staff.

Publications

The following list includes the scholarly publications published during the reporting period.

Journal Papers

- Ramaji, I. J.* and Memari, A. M., (2020). “Interpreted Information Exchange: Implementation Point of View,” *Journal of Information Technology in Construction*, Published February 2020; ITcon Vol. 25 (2020), pp. 123-139; <https://dx.doi.org/10.36680/j.itcon.2020.008>; https://www.itcon.org/papers/2020_08-ITcon-Ramaji.pdf.
- Habibi, S., Obonyo, E., and Memari, A. M., (2019). “Design and Development of Energy Efficient Re-roofing Solutions,” Elsevier *Renewable Energies*, Published online November 2019; 11p. <https://doi.org/10.1016/j.renene.2019.11.128>.
- Lu, X. and Memari, A. M., (2019). “Comparative Analysis of Energy Performance for residential wall systems with conventional and innovative insulation materials: A Case Study,” *Open Journal of Civil Engineering*, Vol. 9, No. 3, September 2019, pp. 240-254. DOI: [10.4236/ojce.2019.93017](https://doi.org/10.4236/ojce.2019.93017); <https://www.scirp.org/Journal/paperinformation.aspx?paperid=95034>.
- Lu, X.* and Memari, A. M., (2019). “Comparative Study of Indoor Infrared Thermography Method to Estimate the Overall Thermal Resistance for Building Envelope Systems,” *International Journal of Architectural Engineering and*

Construction, Vol. 8, No. 3, September 2019, pp. 14-21;
<http://dx.doi.org/10.7492/IJAEC.2019.014>.

- Hindman, D. P. and Memari, A. M., (2019). “Mass Customized Cross-Laminated Timber Elements for Building Construction,” Forest Product Society, *Wood Design Focus*, Volume 29, No. 2, Summer 2019, pp. 27-34.
- Memari, A. M., Iulo, L. D., and Griffin, C., (2019). “Study of Vulnerability of Air Barrier Membranes and Sealant Joint Tapes Applied over Wood Sheathing Panel Joints Due to Racking Movement in Passive House Designed Residential Buildings,” Forest Product Society, *Wood Design Focus*, Vol. 29, No. 1, Spring 2019, pp. 10-17.
- Ariosto, T.*, Memari, A. M., and Solnosky, R. L., (2019). “Comparative Study of Energy Efficiency of Glazing Systems for Residential and Commercial Buildings,” *International Journal of Architectural Engineering and Construction*, Vol. 8, No. 2, pp. 1-18 June 2019; DOI: <http://dx.doi.org/10.7492/IJAEC.2019.007>.
- Ariosto, T.*, Memari, A., and Solnosky, R. (2019). “A Comparative Thermal Properties Analysis Evaluation for Residential Window Retrofit Solutions,” Taylor and Francis, *Advances in Building Energy Research*, Published online October 19, 2018, 30p.; DOI: [10.1080/17512549.2018.1528885](https://doi.org/10.1080/17512549.2018.1528885).
- Lu, X. and Memari, A. M., (2019). “Performance Evaluation of Wall Panels Incorporating Conventional and Innovative Materials Developed with High Insulation Properties,” *International Journal of Architectural Engineering and Construction*, Vol. 8, No. 1, March 2019, pp. 1-8.
- Lu, X. and Memari, A. M., (2019). “Application of Infrared Thermography on In-Situ Determination of Building Envelope Thermal Properties,” Elsevier *Journal of Building Engineering*, Vol. 26, November 2019, 100885, pp. 1-12; <https://doi.org/10.1016/j.jobbe.2019.100885>.

Conference Proceedings Papers

- Muthumanickam, N. K., Duarte, J. P., Nazarian, S., Bilén, S., and Memari, A. M. (2020). “BIM for design generation, analysis, optimization, and construction simulation of Martian habitat,” Proceedings of the ASCE Earth & Space Conference – Engineering for Extreme Environments, April 20-23, 2020, Seattle, Washington, 12p.
- Muthumanickam, N. K., Park, K., Duarte, J. P., Nazarian, S., Memari, A. M., and Bilén, S. (2020). “BIM for Parametric Problem Formulation, Optioneering and 4D Simulation of 3D Printed Martian Habitat: A Case Study of the NASA 3D Printed Habitat Challenge,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 15p.

- Nazarian, S., Duarte, J. P., Bilén, S., Memari, A. M., Muthumanickam, N. K., Watson, N., Radlinska, A., Ashrafi, N., and Hojati, M., (2020). “An Overview of the Execution of 3D-Printed Subscale Habitat on Mars: A Case Study to Exemplify the Automated Construction Process,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 6p.
- Hindman, D. and Memari, A. M., (2020). “Mass Customized Cross-Laminated Timber Elements for Residential Construction,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 7p.
- Amini, M. and Memari, A. M., (2020). “Performance of Residential Buildings in Hurricane Prone Coastal Regions and Lessons Learned for Damage Mitigation,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 14p.
- Amini, M. and Memari, A. M., (2020). “Evaluation of Various Retrofit Strategies for Existing Residential Buildings in Hurricane Prone Coastal Regions,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 12p.
- Park, K., Memari, A. M., Hojati, M., Nazarian, S., and Duarte, J. P. (2020). “Structural Analysis of Full-Scale and Sub-Scale Structure for Digitally Designed Martian Habitat,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 18p.
- Park, K., Memari, A. M., Hojati, M., Zahabi, M., Nazarian, S., and Duarte, J. P. (2020). “Experimental Testing and Finite Element Modeling of 3D-Printed Reinforced Concrete Beams,” Proceedings of the 2020 Residential Building Design and Construction Conference, Penn State University, University Park, PA, March 4-6, 2020, 15p.
- Habibi, S., Obonyo, E., and Memari, A. M., (2020). “A New Concept for the Integration of Bamboo in Contemporary Vernacular Architecture,” Proceedings of the 43rd IAHS World Housing Congress – Housing in the Third Millennium between Tradition and Innovation, International Association for Housing Science, March 16-17, 2020, Cochabamba, Bolivia, 9p.
- Habibi, S., Obonyo, E., and Memari, A. M., (2019). “Design and Development of Energy Efficient Re-roofing Solutions,” Proceedings of the Building Simulation 2019 Conference, Rome, Italy, September 2-4, 2019, 7p.
- Habibi, S., Obonyo, E., and Memari, A. M., (2019). “A Bamboo Design Concept for Low Income Housing in Kenya,” *Proceedings of the 18th International Conference on Non-Conventional Materials and Technologies “Construction Materials & Technologies for Sustainability” (18th NOCMAT 2019)*, July 24-26, 2019, Nairobi,

Kenya, 14 pages.

Conferences/Meetings Attended

The following is a list of the housing industry-related conferences and meetings attended by the PHRC personnel.

- Summer PBA Board Meetings, PHRC staff, University Park, PA, July 26, 2019.
- New Gravity Housing Conference, Klinetob Lowe, S. and Memari, A., Philadelphia, PA, August 1-2, 2019.
- Westford Symposium on Building Science, Hine, C. and Wolfgang, B., Westford, MA, August 5-7, 2019.
- PA Home Performance Conference, Wolfgang, B., State College, PA, October 1, 2019.
- PA Build My Future, PHRC Staff, Williamsport, PA, October 17, 2019.
- Association for the Advancement of Sustainability in Higher Education (AASHE) Conference, Klinetob Lowe, S., Spokane, WA, October 28-30, 2019.
- Fall PBA Board Meetings, Hine, C. and Wolfgang, B., Harrisburg, PA, November 1, 2019.
- North American Passive House Conference, Klinetob Lowe, S., Crystal City, VA, December 6-7, 2019.
- International Builders Show and NAHB Student Competition, PHRC Staff, Las Vegas, NV, January 20-23, 2020.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Las Vegas, NV, January 22, 2020.
- 2020 Conference on Health, Environment, and Energy (CHEE), Klinetob Lowe, S., New Orleans, LA, January 21-23, 2020.
- Winter PBA Board Meetings, Dorman, T., Hine, C., and Wolfgang, B., Valley Forge, PA, February 21, 2020.
- 2020 Reinventing Our Communities Cohort with the Philadelphia Federal Reserve Bank, Fawcett, R., March 27 - October 2020.
- Solar Decathlon Design Challenge Student Competition, Klinetob Lowe, S. and Memari, A., Online, April 17-19, 2020.
- Housing Innovation Alliance Conference, Hine, C. and Wolfgang, B., Online, April 22, 2020.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Online, June 17, 2020.

Service in Professional Societies

The PHRC staff and faculty are involved in a variety of organizations at both the state and national level.

Pennsylvania Committees and Organizations

- Dorman, T., Professional Women in Building Council of Central PA, Chair.
- Fawcett, R., Professional Women in Building Council of Central PA, Member.
- Klinetob Lowe, S., Centre Region Code Agency Property Maintenance Code Board of Appeals.
- Klinetob Lowe, S., Professional Women in Building Council of Central PA, Vice Chair.
- Wolfgang, B., Builders Association of Central PA, Board of Directors, Secretary.
- Wolfgang, B., Builders Association of Central PA, Education Committee Chair.
- Wolfgang, B., State College Area School District Building Construction Technology Program Occupational Advisory Committee Member.

National and International Committees and Organizations

- Memari, A.M., American Society of Civil Engineers, member.
- Memari, A.M., American Society of Civil Engineers, Editor-in-Chief, Journal of Architectural Engineering.
- Memari, A.M., American Society of Civil Engineers, Architectural Engineering Conferences, National Conference Steering Committee, member.
- Memari, A.M., The Masonry Society, member.
- Wolfgang, B., ASTM International, member and C11 Committee Gypsum and Related Building Materials and Systems member.
- Wolfgang, B., National Association of Home Builders Student Chapter Advisory Board member.

6. **Annual Magazine:** The PHRC Annual Magazine was sent electronically to PHRC members and stakeholders to keep them updated on recent PHRC activities and to promote upcoming events. For the 2019-2020 project year, the PHRC magazine was published in the fall to provide timely updating of the audience with the outcome of the previous year's projects and with what to expect in the coming year.
7. **Educating the Next Generation of Tradespeople:** Educating the "next generation" of residential trade contractors and industry professionals is essential for the future of residential construction. With the support of the IAC, the PHRC will consider the education of the next generation of tradespeople as an ongoing project. The ultimate

goal is to increase the detailed knowledge of future industry professionals through this general outreach and provide students with professional development opportunities within the residential construction industry. This project includes relationship building, sharing of resources, speaking at school events, leveraging resources and contacts to bring opportunities to students, and getting feedback from instructors and administrators to better address their needs. Other outreach activities include trying to increase participation of vocational students and instructors in the PHRC conference, PCCA Symposia, and PHRC webinars.

A scholarship program was offered for the Annual PHRC Conference. Students from across the state were able to attend the conference at no cost due to the scholarship. PHRC staff are also involved with outreach through speaking to and interacting with various groups including students in other classes at Penn State, the State College Building Construction Technology Program, and the Central PA Institute of Technology Carpentry Program.

8. **Support of the UCC RAC:** The PHRC continues to support the RAC and the public by serving as a general technical resource upon request and by sharing updates on RAC activities to the general PHRC audience. Throughout 2019-2020, PHRC staff attended each in-person and telephone RAC meeting.
9. **Support of Standards:** The PHRC has developed three standards to respond to industry demand. Each of these standards requires training and timely technical assistance for local governments, builders/developers, design professionals, and contractors. These standards are available electronically for free.

III. Applied Research

An important function of the PHRC is to undertake or stimulate research and development on materials, products, procedures, and processes. These efforts may have a longer-term or a more fundamental focus than other projects. Projects in this category foster partnerships and draw on the expertise and strengths of the people and facilities available at The Pennsylvania State University.

1. Comparative Study of Suitability of Different Types of Wall Systems for Passive House Design Based on Construction System, Energy, Building Science, and Life Cycle Assessment

Description: With growing interest in Passive House (PH) Design approach based on Passive House Institute (PHI) or Passive House Institute United States (PHIUS), home designers and builders are encouraged to explore the possibility of considering such design/construction, but they are faced with the challenge of choosing the appropriate wall system configuration. Besides conventional site-built approach, panelized wall systems and modular construction are now options for construction systems. Additionally, PH can be employed in many climates. As a result, some preliminary comparison of all the options is necessary to help designers and builders see merits of each option. This proposed project will review wall system types that have been used for PH design in the United States and Europe. It will evaluate them side by side based various criteria including thermal resistance, air tightness, moisture permeability, embodied energy (life cycle assessment / LCA), overall energy performance, and suitability for site-built stick-frame, panelized construction, and modular construction.

Manager/PI: Dr. Ali Memari

Report: The project has made some progress with two papers under development involving graduate and undergraduate students. Progress has been made in the following areas: a) identification of candidate wall systems suitable for passive house design, including pros and cons, b) review of appropriate air barrier systems and tape types appropriate for different sheathing types suitable for selected wall systems, c) detailed review of the difference between passive house design criteria based on Passive House Institute (PHI) and Passive House Institute U.S. (PHIUS), d) review of computational tools for energy analysis of passive house designed building, e) appropriateness of the passive house wall systems for performance under lateral loading conditions, and f) their appropriateness for use in historic preservation projects. It is expected that the two current journal papers will be completed by the end of the year. Further work is planned on comparison of selected wall systems for LCA and energy analysis as well as review of their suitability for modular construction.

IV. Applied Projects

The Applied Project category refers to projects that are application-oriented and have a direct need by the residential construction industry. This may also include longer term initiatives.

1. Training for Secondary and CTC Instructors

Description: The PHRC has pursued an initiative for the past few years that involved outreach to the “next generation” of the residential construction industry. This outreach included interaction with secondary instructors at Pennsylvania schools and career and technology centers. Some feedback during this outreach was that many of the instructors themselves need training. This project would focus on obtaining approval to provide continuing education to secondary instructors through the PA Department of Education. This would also open the potential to hold a standalone event in future years catered to secondary instructors and their need for professional development.

Manager/PI: B. Wolfgang

Report: The PHRC team continues to advance this ongoing effort to support trade education. In 2019-2020, the PHRC collaborated with the Endorsed Trade Program at the Pennsylvania Builders Association to distribute a survey regarding the interests and needs of instructors at trade programs throughout Pennsylvania. The results of this survey were used to develop new concepts for the 2020-2021 project year with a new event due to launch in late 2020.

2. A Deeper Dive into Mechanical Ventilation

Description: This applied project will take whole-house mechanical ventilation a step beyond standard code compliance. We will look at the performance characteristics of each method and look into hybrid, high performance ventilation strategies.

Manager/PI: C. Hine

Report: This project has been postponed for the 2019-2020 project plan year and will be completed during the 2020-2021 project plan year.

3. Energy Retrofits

Description: Nearly 80% of Pennsylvania’s existing housing stock was built before modern building codes, resulting in higher than necessary energy bills and occupant comfort issues. This project would focus on studying the potential impacts and challenges associated with energy retrofits through local case studies. Data extracted through this project would lead to future webinars and conference presentations.

Manager/PI: S. Klinetob Lowe

Report: The PHRC wrote a successfully funded external grant to support this project. Together with several affordable housing partners, the Energy+ initiative is systematically addressing residential energy efficiency towards “permanent affordability” of existing affordable housing in State College, PA. Program goals include lessening residents’ energy burdens, reducing the environmental impact of the affordable housing stock, and enhancing public investment in housing affordability. The PHRC is following the timelines set by the external grant and will be completed in the 2020-2021 project year.

4. Residential Deck Builder Brief

Description: This applied project will take and consolidate the majority of the residential deck provisions along with best practice construction details and assemble them into either a one page “jobsite document” or a multiple page instruction flyer for contractors.

Manager/PI: C. Hine

Report: This one page builder brief style document is in final development stages with a publication date of fall 2020.

5. PHRC Continuing Education On-Demand

Description: PHRC staff have repeatedly been asked when webinars would become available on-demand for continuing education credit. This has been difficult in the past due to ongoing software and infrastructure changes at Penn State. This project will dedicate more resources to making more PHRC content available on-demand, including working with Penn State to obtain software training as appropriate.

Manager/PI: B. Wolfgang

Report: Progress is ongoing regarding this multi-year effort. Most recently, PHRC staff have established a relationship with the Penn State College of Engineering Office for Digital Learning. This relationship will help the PHRC to gain access to Penn State Extension’s on-demand learning platform for future on-demand program deployment.

On-demand PHRC webinars will be deployed in the new on-demand format during the 2020-2021 project year.

6. Summary of Changes to the PA Uniform Construction Code

Description: The Uniform Construction Code in PA has been in place for over a decade. During that time, it has been altered numerous times through various legislative actions. Similar to the UCC Quick Guide, this project would focus on summarizing the basics of the UCC, including common exemptions, significant amendments, and a summary of the original Act 45 requirements. Most recently, Act 36 of 2017 significantly altered the code review and adoption process. The result of this project would be a short publication in the form of a Builder Brief so that it could be tucked into a code book or similar reference. Note: this project is carried over from the 2018-2019 project plan.

Manager/PI: B. Wolfgang

Report: This project evolved into a much larger effort to engage the PHRC team with the PA UCC. Chris Hine and Brian Wolfgang completed the Building Code Official (BCO) training in spring 2020. Regarding the goal to deliver UCC-related information to the PHRC audience, efforts have been initiated to create a separate page on the PHRC website that is dedicated to UCC-related information and links.

V. Proposals & Contracts

The PHRC continuously seeks to leverage funding from the Commonwealth with funds from other sources. The following is a list of major grant proposals submitted during the 2019-2020 project year. Several other smaller proposals were also submitted, and some are under review/negotiation but those not are reported here.

The following research proposals were submitted during this reporting period:

- Date: January 2020 – April 2021
Title: Energy+ Program: Residential Energy Stewardship for Regenerative Communities
Sponsor: West Penn Power Sustainable Energy Fund (WPPSEF) via the State College Community Land Trust (SCCLT)
Amount: \$25,000
Status: Funded
- Date: September 2020-August 2022
Title: “FMSG: Continuous remanufacturing of building composite”
Sponsor: National Science Foundation
Amount: \$500,000 (Candidate’s share of funding – 33%) (Proposal submitted 6/5/20)
(Co-PI: Memari, Enrique Gomez; PI: Bryan Vogt)
- Date: January 2020-June 2020
Title: Development of Cross Laminated Timber Shelters for Tornado and Hurricane Wind Resistance
Sponsor: PSU MRI
Amount: \$10,000 (Awarded 10/31/19) (Candidate’s share of funding –100%) (AMM PI)
- Date: April 2019 – May 2021
Title: Resilient and Energy Efficient Envelopes for Passive House Standard Buildings
Sponsor: Penn State Institute of Energy and Sustainability (PSIEE)
Amount: \$50,000 (Candidate’s share of funding – 30%) (Awarded May 2019, continuing)
(AMM Co-PI)

VI. Act 157 Funds

The PHRC receives funding from diverse sources, including contracts, grants, membership fees, fees for services, and the funds collected under Act 157 of 2006 and amended by Act 36 of 2017. To fulfill PHRC's annual mission, the organization must raise additional revenue outside of Act 157 funds in order to complete its annual project load.

Act 157 of 2006 funds were collected through a \$4 fee on every building permit issued in the Commonwealth and are dispersed through the Department of Community and Economic Development (DCED). PHRC received 50% of the collected permit fees minus a 7.5% administrative fee.

Beginning on October 25, 2018, Act 36 of 2017 amended building permit fees to be \$4.50 with PHRC being allocated 43.5% of the collected permit fee minus a 3% administrative fee to DCED. DCED interpreted Act 36 to mean that from October 24, 2017 through October 24, 2018 they could assess the previous 7.5% administrative fee and the new 3% administrative fee with the 7.5% fee ceasing on October 25, 2018.

Funds for the 2019-2020 Project Year are based upon funds received from July 2018 through June 2019, which can be seen in Table 6 below.

Table 6. Summary of Act 157 Funds received during the 2018-2019 FY (2019-2020 PHRC Project Year)

Collection Period	Amount Received
Q3: July 2018 - September 2018	\$104,764.90
Q4 October 2018 - December 2018	\$168,767.41
Q1: January 2019 - March 2019	\$92,670.01
Q2: April 2019 - June 2019	\$130,192.26
Total	\$496,394.58

Expenses for the Act 157 Account (\$439,604.00) were less than the revenues (\$496,394.58) for the 2019-2020 project year. The PHRC began to limit spending and travelled less beginning in March 2020 due to the COVID-19 pandemic. Unsure of the long-term effects of the pandemic on the residential construction industry in Pennsylvania, the PHRC will continue to be fiscally conservative. Table 7 shows a breakdown of PHRC expenses for the 2019-2020 Project Year allocated to the Act 157 Account.

Table 7. PHRC Expenses for the 2019-2020 PHRC Project Year

Category	Act 157
Total Salaries	\$268,996.55
Total Wages	\$237.60
Total Student Wages	\$1099.00
Fringe Benefits	\$101,836.62
Supplies and Materials	\$3,295.64
Communications Services	\$229.28
Travel	\$19,478.39
Publications	\$890.17
Maintenance	\$0.00
Consulting & Prof Svc	\$34,735.00
Copies and Photographic Services	\$4,035.75
Computer Services	\$0.00
Purchased Services	\$0.00
Equipment	\$4,198.16
Computer Equipment	\$571.84
Miscellaneous	\$0.00
Total	\$439,604.00