



The Pennsylvania Housing Research Center

PHRC Year in Review

July 2018 – June 2019

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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, 2018 and June 30, 2019.

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 2018, 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 2018 – June 2019*", 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, 2018-2019" is submitted to meet the annual report requirement.

A. PHRC Organizational Chart

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

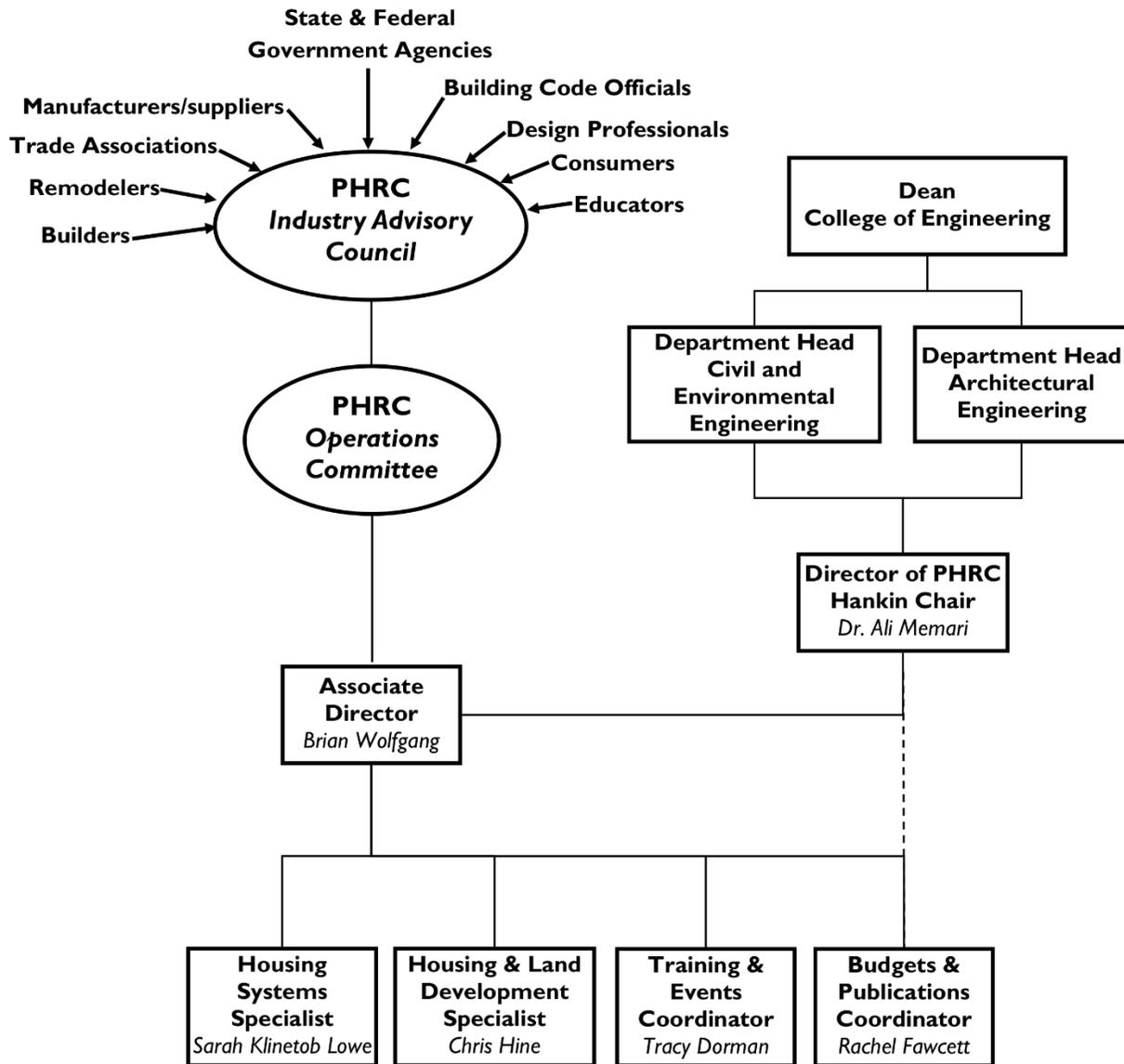


Figure 1. PHRC Organizational Chart

B. Uniform Construction Code – October 1, 2018 Code Update

The PA UCC Review & Advisory Council (RAC) conducted its re-review of the previously unadopted code provisions in the 2012 and 2015 ICC codes starting in December 2017. On May 1, 2018, the RAC submitted their report to the Department of Labor & Industry which details the results of this voting process, thus ending this review period. The code provisions that were adopted during this process took effect on October 1, 2018.

The 2018-2019 project year was primarily focused on providing the residential construction industry in Pennsylvania with the training, resources, and support needed during the transition to the code provisions adopted under the UCC. This is reflected in an increase in the frequency of speaking engagements as well as attendance at these events. A substantial portion of time was spent fielding emails and phone calls from industry professionals who had questions about complying with the new code provisions.

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 95 educational services to 4,879 individuals during this reporting period (Table 1).

Table 1. Summary of all PHRC Educational Programs for the 2018-2019 Project Year

PROGRAM	Activities for 2017-2018	
	# of Events	# of Attendees
Workshops	20	604
Webinars	11	941
Speaker Service	60	2,953
PHRC Conference/PCCA Symposium (Central)	Day 1	127
	Day 2	112
PCCA Symposium (East)	1	101
PCCA Symposium (West)	1	41
TOTAL	95	4,879

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 will take effect on October 1, 2018. Therefore, the existing PHRC workshops that will continue to be offered are in need of an update to reflect these changes. Additionally, there is a need to make minor course material updates based on instructor feedback through the use of “Program Change Forms.” We will also 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: A substantial amount of time and resources were dedicated to updating existing PHRC workshops, including those that are typically offered through PCCA. This was accomplished through financial support from PCCA and through the use of an outside consultant to assist with file formatting.

2. Online Residential Deck Program

Description: The PHRC has developed a new online training strategy in the 2015-16 project year that is based on the successful webinar model. This new online strategy will allow for the delivery of longer workshops (up to 6 hours of instruction) over the course of a few weeks to a month. The Online Residential Deck Program will take the current full day deck program and place it into a 4-module online class. This online class will run once per week for a month. Each session will be 1 ½ hours and the total amount of instruction will be 6 hours. Note: This project is carried over from the 2017-18 project year due to the reallocation of staff time toward code updates beginning in spring 2018.

Manager/PI: C. Hine

Report: The online deck program has been developed, but due to the overwhelming need for code update training across the Commonwealth, the delivery of this project is pushed to the 2019-2020 project plan 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 2018-2019 project year, the PHRC delivered 20 workshops to 604 individuals during this reporting period. See Table 2 for detail.

Table 2. PHRC Workshops Held July 1, 2018 through June 30, 2019

Program	In-person/ Online	# of Programs	# of Attendees
2015 IRC Update	In-Person	14	507
IRC Building Code Academy – 4 days	In-Person	1	26
IRC Plumbing Code Academy – 4 days	In-Person	1	11
IRC Mechanical Code Academy – 4 days	In-Person	1	8
IRC Energy Code Academy – 2 days	In-Person	1	11
IRC Electrical Code Academy – 4 days	In-Person	1	17
Commercial Energy – 2 days	In-Person	1	24
<i>Total</i>		20	604

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. Note: Due to the high demand for code update training, the PHRC webinar series for 2018-2019 will begin a month early (August 2018) and will offer two webinars per month in August and September, 2018.

Report: The PHRC delivered eleven webinars during this reporting period to a total of 941 people. Note that the February webinar was postponed due to inclement weather. Due to the PHRC Housing Conference, no webinar was held in March. See Table 3 for the summary of webinars and attendees.

Table 3. 2018-2019 Webinar series titles and number of attendees

Webinar Series		
Month	Title/Topic	Number of Attendees
August #1	PA Residential Code Update	140
August #2	Residential Energy Code Update	144
September #1	Whole House Mechanical Ventilation	79
September #2	Blower Doors for Builders	85
October	PA Alternative Residential Energy Provisions	72
November	Air Sealing for 5ACH50	69
December	HERS and the ERI Path	96
January	Solar PV in PA	52
April	Forced Air HVAC Systems: It's More Than Just Hot Air	68
May	Manufactured Stone Veneer: Sticking to the Basics	68
June	Intro to the Passive House Standard for the PA Residential Construction Industry	68
	<i>Total</i>	941

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 27th Annual PHRC Housing Conference was held on March 13-14, 2019 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 Dr. Lynn Fisher, AEI Center on Housing Markets and Finance, entitled “Update on Housing and Mortgage Markets”.

The following tracks and sessions were offered:

- High Performance Homes
 - “Deep Dive into High Performance Windows” by Darren Macri
 - “Breathe Easy; Ventilation Best Practices” by Luke Langhals
 - “Smart Enclosures; A Pathway to Low Carbon / Net Zero Energy Single Family Housing” by Jim Muhaw, Norm Horn & Jason Grottini
- Construction & Management
 - “Advanced Framing: Maximizing the Value & Efficiency of Wood Wall Systems” by Bob Kuserk
 - “Deck Construction: Code, Design, and DCA6-15” by Matt Hunter

- “Introduction to the Structural Building Component Industry: A Metal Plate Connected Wood Truss Inspection Checklist” by Tim Reigel
- PCCA Symposium Central
 - “Testing Airtightness of the Building Enclosure” by Chaz Steffen & Michael Arblaster
 - “PA Alternative Residential Energy Provisions” by Brian Wolfgang
 - “PA UCC / Code Enforcement Q & A” by Bob Buddenbohn, Anthony Ascioffa & Douglas Meshaw

Day 2: The following tracks and sessions were offered on the second day of the conference:

- Residential Systems
 - “Ductwork in Attics, One of the Last Holdouts of Inefficient Home Design” by Andrew Poerschke
 - “The Evolution of Buildings, Codes & Building Science” by Ted Winslow
 - “Polyiso CI for Code; Compliant Walls in Type V and Residential Construction” by Tom Robertson
 - “5 ACH50: Easy to Reach When You Follow the Path” by Bill Morgan
- Code Update Track
 - “2015 IRC Update Part 1: Chapters 1-3” by Bob Buddenbohn & Dave Buskirk
 - “2015 IRC Update Part 2: Chapters 4-10” by Bob Buddenbohn & Dave Buskirk
 - “2015 IRC Update Part 3: Chapters 11-16 by Bob Buddenbohn & Dave Buskirk
 - “2015 IRC Update Part 4: Chapters 24-42” by Bob Buddenbohn & Dave Buskirk
- Land Development
 - “Green Stormwater Infrastructure in Residential Communities: Best Practices & Potential Benefits” by Lauren McPhillips
 - “Zoning for Infill and Redevelopment” by John Trant
 - “Creating Housing for All” by Debra Bassert & Bill Warwick
 - “Green Infrastructure for Stormwater Management” by Katie Blansett

Table 4. Attendees at the Annual PHRC Housing Conference

Event	# of people
Day 1 (March 13)	127
Day 2 (March 14)	112

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: For the 2020 RBDCC, the PHRC kicked off the Call for Submissions in Spring 2019 and received 135 abstracts thus far with another 5 abstracts expected. Given this 25% increase in abstracts anticipated from 2018 RBDCC numbers, the PHRC is expanding the conference to three days – March 4-6, 2020 – and will stay concurrent with the Annual PHRC Housing Conference – March 4-5, 2020. The two keynote speakers have also been confirmed – Dr. David O. Prevatt from the University of Florida and Lois B. Arena, PE from Steven Winter Associates.

- 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, promote, and execute (through session presentations) each of the three PCCA Symposia in 2019, including events in Valley Forge and Monroeville. Attendee numbers are shown in Table 5.

Table 5. Attendees at the PCCA Symposia

Event	# of people
Eastern PCCA Symposium (March 27)	101
Western PCCA Symposium (April 3)	41

- 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 2018-2019 reporting period, the PHRC delivered 60 speaking engagements, reaching 2,953 people. These speaking engagements are summarized in Table 6.

Table 6. Speaking Engagements During the 2018-2019 Project Year

Organization	Topic(s)	Date	# of Attendees
Lehigh Valley Builders Association	2015 IRC Update 101 and 102	7/12/2018	45
Lebanon County Builders Association	2015 Code Update 101 and 102	7/17/2018	19
Huntingdon Rotary Club	Technology in the Connected Home	7/17/2018	32
HBA of Metro Harrisburg	2015 IRC Update 101 and 102	7/18/2018	70
Portland Cement Association (PCA)	A Review of 3D Printing of Concrete and Challenges for Construction	7/23/2018-7/27/2018	30
Pocono Builders Association	2015 Code Update 101 and 102	7/25/2018	23
York County Builders Association	2015 Code Update 101 and 102	7/26/2018	40
PA Builders Association (PBA)	PA Residential Code Update	8/3/2018	60
West Branch Susquehanna Builders Association	Code Update 101 and 201 - 2015 IRC Highlights	8/21/2018	25
Home Builders Association of Northeastern PA	101Code Update and 102 2015 IRC Highlights	8/22/2018	14
PA Manufactured Housing Association (PMHA)	Code Update 101, 102, Manuf Housing	8/23/2018	26
Pennsylvania Housing Research Center (PHRC)	Construction Drawings	8/27/2018	61
Portland Cement Association (PCA)	3D Printing of Concrete – Status, Challenges, and Opportunities	8/28/2018-8/29/2018	40
PA Manufactured Housing Association (PMHA)	2015 IRC Code Update 101, 102, Manuf Housing	8/30/2018	20
Builders Association of Northwestern PA (BANWPA)	Code Update 101, 102, Blower Door, Mechanical Ventilation	9/4/2018	60
HBA of Berks County	IRC Update 101, 102, Blower Door & Mechanical Ventilation	9/5/2018	36
YBC Your Building Center, Inc.	Code Update 101, 102, Blower Door, Mechanical Ventilation	9/6/2018	100
BIA of Lancaster	101, 102, Blower Door & Mechanical Ventilation	9/12/2018	130
Carbon Builders Association	IRC Update 101, 102	9/13/2018	28
YBC Your Building Center, Inc.	IRC Update 101, 102, Blower Door, Mechanical Ventilation	9/13/2018	52
Indiana-Armstrong Builders Association	IRC Update - 101, 102, Blower Door/Mech Vent	9/14/2018	60
Commonwealth Building Officials	2015 Code Update	9/20/2018	15
Pennsylvania Housing Research Center (PHRC)	2015 Energy Update, PA Alt, Blower Door, Mechanical Ventilation	9/27/2018	18
HBA of Bucks & Montgomery Counties	IRC Code Update - PA Alt/Mech Vent and Blower Door	9/28/2018	120
Central Keystone COG	IRC Update - 101 & 102	10/8/2018	124
YBC Your Building Center, Inc.	IRC Update - 101, 102, Blower Door/Mech Vent	10/11/2018	50
Brookside Lumber Company & H.P Starr Lumber	IRC Update - 101 and 102	10/11/2018	140
Keystone ASHI (American Society of Home Inspectors)	Code Evolution and it's Impact on the Building Enclosure	10/12/2018	125
York County Builders Association	IRC Update - Blower Doors/PA Alt	10/16/2018	24
YBC Your Building Center, Inc.	IRC Update 101, 102, Blower Door/Mech Vent	10/16/2018	46

Builders Association of Metro Pittsburgh (BAMP)	IRC Update - Blower Door/PA Alt	10/18/2018	60
Builders Association of Cambria County	IRC Update 101: Code Update and 102: 2015 IRC Highlights	10/25/2018	55
Wayne/Pike BIA	IRC Update 101 & 102, PA Alt and Mech Vent	10/30/2018	66
Central Susquehanna Builders Association	IRC Update 101 & 102, Blower Door and Mech Vent & PA Alt	11/1/2018	9
PA Builders Association (PBA)	Code Updates in PA: What have we Learned so far?	11/2/2018	15
BIA of Lancaster	PA Alternative	11/12/2018	15
Somerset County BA	Code update 101 an 102, Blower Door and Mech Vent	11/14/2018	13
HBA of Metro Harrisburg	Blower Doors and PA Alternative	11/20/2018	14
Builders Association of Metro Pittsburgh (BAMP)	2015 IRC Update, Blower Door/PA Alt	11/29/2018	26
Pocono Builders Association	Whole House Mechanical Ventilation & PA Alternative	12/6/2018	16
Cove Lumber	Code Update 101 & 102, Blower Door and Mechanical Ventilation	12/12/2018	38
Brookside Lumber Company & H.P Starr Lumber	Code Update 101 and 102	1/10/2019	69
Pennsylvania College of Technology	PHRC Overview	1/10/2019	35
Westmoreland Professional Builders Assn	Code Update 101 & 102, Blower Door and Mechanical Ventilation	1/17/2019	16
PFS Corporation	2015 IRC Whole-House Mechanical Ventilation -	1/18/2019	75
Carbon Builders Association	Code Update Blower Doors & Mechanical Ventilation	1/22/2019	36
BIA of Philadelphia	2015 IRC Code Update (101 & 102)	2/14/2019	50
Central PA Inst of Science & Technology	2015 IRC Code Update (101 & 102)	2/26/2019	8
PABCO	PA Alt	3/8/2019	60
Pennsylvania Housing Research Center (PHRC)	Engineered Wood	3/25/2019	153
Westchester Modular Homes, Inc.	2015 IRC Whole-House Mechanical Ventilation	3/26/2019	50
Pennsylvania Housing Research Center (PHRC)	Engineered Wood	3/29/2019	153
Middle Bucks Institute of Technology	Greenbuild: Affordable Net Zero Energy	3/29/2019	125
Lawrence County Builders Association	2015 IRC Code Update (101 & 102)	4/2/2019	27
Builders Association of Metro Pittsburgh (BAMP)	Solar PV in PA	4/2/2019	9
Allensville Planning Mill	2015 IRC and RAC Amendments	4/4/2019	21
Builders Association of Central Pennsylvania (BACP)	Whole House-Mechanical Ventilation	5/8/2019	26
DelChester NARI	2015 IRC Update - Code changes	5/23/2019	34
NAHB Housing Research Working Group	An Introduction to 3D-Printing of Concrete	6/6/2019	20
Pennboc Region V	Ext Water Mgmt and Fundamental of Exterior Plaster and PA Alternative/Code Compliant Air Barriers	6/11/2019	26
Total		60	2,953

Conference Presentations: The following conference presentations were delivered during the 2018-2019 Project Year.

- Kamel, E. (Presenter) and Memari, A. M., (2019). “Review of Building Science Application in Selected DOE’s Race to Zero Student Design Competition Projects,” Presented at the ASCE AEI 2019 Conference – Integrated Building Solutions – The National Agenda, April 3-6, 2019, Washington, DC.
- Lu, X. (Presenter) and Memari, A. M., (2019). “Application of Infrared Thermography Method for In-Situ Measurement of Thermal Properties of Building Envelope Systems,” Presented at the ASCE AEI 2019 Conference – Integrated Building Solutions – The National Agenda, April 3-6, 2019, Washington, DC.

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 PHRC mailings, promotional pamphlets, articles in research or trade journals, answering phone and email questions, and the maintaining PHRC’s website, as well as various relevant technical meetings attended by PHRC staff.

Publications

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

- 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*, Published March 2019, Vol. 8, No. 1, pp. 1-8.
- Memari, A. M., Simmons, N. C., and Solnosky, R., (2019). “Video Capture Technique Analysis of Four-Sided Structural Sealant Glazing Curtain Wall Systems for Racking Performance,” Submitted to *International Journal of Architectural Engineering and Construction*, Published: Vol. 7, No. 4, December 2018, pp. 1-16.
- Lu, X. and Memari, A. M., (2019). “Comparative Energy Analysis and Life Cycle Assessment of innovative Residential Wall Systems,” Submitted to *ASCE Practice Periodical on Structural Design and Construction*, Published 5-7-19; Vol. 24, No. 3, pp. 04019015-1 to 04019015-17.
- Lu, X. and Memari, A. M., (2019). “Determination of Exterior Convective Heat Transfer Coefficient for Low-Rise Residential Buildings,” to Submitted to *Taylor and Francis Journal of Advances in Building Energy Research*, December 2018, Published online May 6, 2019; 19 p.
- Kamel, E. and Memari, A. M., (2019). “Review of BIM’s Application in Building Energy Simulation: Tools, Issues, and Solutions,” *Elsevier Journal of Automation in Construction*, Published: Vol. 97, January 2019, pp. 164-180.

- Kamel, E., and Memari, A. M., (2019). "State of the Art Review of Energy Smart Homes," ASCE Journal of Architectural Engineering, Special Section on Housing and Residential Building Construction, Vol. 25, No. 1, March 2019, pp. 03118001-1-26.
- Ariosto, T., Memari, A. M., and Solnosky, R. L., (2018). "Development of Designer Aids for Energy Efficient Residential Window Retrofit Solutions," Elsevier, Sustainable Energy Technologies and Assessments, Published on 3/8/19: Vol. 33, pp. 1-13.
- Kamel, E. and Memari, A. M., (2018). "BEPAT: A Platform for Building Energy Assessment in Energy Smart Homes and Design Optimization," Published October 2018 as Vol. 5, No. 4, pp. 321-339; DOI: <http://doi.org/10.12989/eri.2017.5.4.321>.
- Lu, X. and Memari, A. M., (2018). "Comparative Study of Hot Box Test Method Using Laboratory Evaluation of Thermal Properties of a Given Building Envelope System Type," Elsevier Journal of Energy and Buildings, 178, November 2018, pp.130-139.
- Jellen, A. and Memari, A.M., (2018). "Residential Vertical Expansion Using Modular Construction", ASCE Journal of Architectural Engineering, Special Section on Housing and Residential Building Construction, Vol. 24, No. 3, September 2018, pp. 04018019(1-12).
- Memari, A. M., Kuczynski, T. C. and Solnosky, R., (2018). "Review of Design, Construction, and Capabilities of an Air Bladder Load Test Facility (ABLTF) for Structural Experimental Enclosure Studies," ASTM Journal of Testing and Evaluation, Vol. 46, No. 4, July 2018, pp. 1421-1433.
- Kamel, E. and Memari, A. M., (2019). "Review of Building Science Application in Selected DOE's Race to Zero Student Design Competition Projects," Proceedings, ASCE AEI 2019 Conference – Integrated Building Solutions – The National Agenda, April 3-6, 2019, Washington, DC, 10 pages.
- Lu, X. and Memari, A. M., (2019). "Application of Infrared Thermography Method for In-Situ Measurement of Thermal Properties of Building Envelope Systems," Proceedings, ASCE AEI 2019 Conference – Integrated Building Solutions – The National Agenda, April 3-6, 2019, Washington, DC, 10 pages.
- Hojati, M., Radlinska, A., Nazarian, S., Duarte, J., Memari, A. M., and Bilen, S., (2018). "Synthesis and 3D Printing of One-Part Geopolymer Mortar," Proceedings of the 1st International Conference on Concrete and Digital Fabrication – Digital Concrete 2018, Zurich, Switzerland, September 10-12, 2018, 3p.
- Hojati, M., Radlinska, A., Nazarian, S., Duarte, J., Memari, A. M., Meisel, N., and Bilen, S., (2018). "Design and 3D Printing of Two-Part Geopolymer Mortar," Proceedings of the 1st International Conference on Concrete and Digital Fabrication – Digital Concrete 2018, Zurich, Switzerland, September 10-12, 2018, 3p.

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, August 3, 2018.
- Westford Symposium on Building Science, Klinetob Lowe, S. and Wolfgang, B., Westford, MA, August 6-8, 2018.
- Passive House Institute of the US (PHIUS) Annual Conference, Klinetob Lowe, S., Boston, MA, September 21-22, 2018.
- Fall PBA Board Meetings, Hine, C. and Wolfgang, B., Harrisburg, PA, November 2, 2018.
- Passive House Institute of the US (PHIUS) Certified Passive House Consultant Training, Klinetob Lowe, S., New York City, NY, December 3-7, 2018.
- International Builders Show and NAHB Student Competition, PHRC staff, Las Vegas, NV, January 18-21, 2019.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Las Vegas, NV, January 20, 2019.
- NAHB Residential Educators Workshop, Hine, C. and Wolfgang, B., Las Vegas, NV, January 20, 2019.
- Winter PBA Board Meetings, Hine, C. and Wolfgang, B., Hershey, PA, March 1, 2019.
- ASCE Pittsburgh's 10th Annual Sustainability Conference – Smart Cities: Transforming Cities for a New Era, Klinetob Lowe, S., Pittsburgh, PA, March 6, 2019.
- PABCO Legislative Conference, Wolfgang, B., New Cumberland, PA, March 8, 2019.
- ASCE AEI 2019 Conference, Memari, A.M., Washington, DC April 3-6, 2019.
- PERC Conference, Klinetob Lowe, S. and Wolfgang, B., University Park, PA, April 9, 2019.
- 2019 Solar Decathlon Design Challenge Student Competition and Faculty Meeting, Klinetob Lowe, S., Golden, CO, April 12-14, 2019.
- PHFA Housing Forum, Fawcett, R. and Klinetob Lowe, S., Harrisburg, PA, May 8-9, 2019.
- Penn State Energy Days Conference, Klinetob Lowe, S., State College, PA, May 29-30, 2019.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Washington, D.C., June 5, 2019.

- NAHB Housing Research Working Group Meeting, Memari, A.M. and Wolfgang, B., Washington, D.C., June 6, 2019.
- PCCA's Spring Sustainability Conference, Klinetob Lowe, S., State College, PA, June 11, 2019.

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

- Klinetob Lowe, S. Centre Region Code Agency Property Maintenance Code Board of Appeals.
- Wolfgang, B. Builders Association of Central PA, Board of Directors, member.
- 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., 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 up-to-date on recent PHRC activities and to promote upcoming events. Printed magazines were also mailed to builders associations throughout the state in an effort to build recognition of PHRC and its offerings to these organizations and their members. For the 2018-2019 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 2018-2019, PHRC staff attended each RAC meeting following the recently completed 2015 code review.
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.

PA Alternative Residential Energy Provisions (PA-Alt): Based on the outcome of the PA Uniform Construction Code (UCC) Review & Advisory Council (RAC) review process of the 2015 codes, the PA Alternative Residential Energy Provisions needed to be updated to reflect the changes to the UCC that became effective on October 1, 2018.

The development of the 2018 Pennsylvania Alternative Residential Energy Provisions (PA-Alt) was led by the PHRC with guidance from a subcommittee of the PHRC Industry Advisory Council. The PHRC primarily supported this standard through delivery of training through webinars and speaking engagements that covered the 2018 PA-Alt. PHRC staff also frequently fielded questions via email and phone call that addressed the PA-Alt.

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. Retrofit of Existing Homes for Energy Efficiency according to the Passive House Standard

Description: The Passive House standard for home design is considered more stringent than other standards such as LEED and ENERGY STAR. Meeting passive house performance goals are particularly challenging when retrofitting existing construction. Examples of such challenges include hidden thermal bridges; building orientation and position and size of window openings, which affect solar heat gain; limited thickness of existing walls or floors or ceiling spaces to add insulation; and inaccessible areas with air leakage, which may yield a less than ideal airtightness. Individual home-specific challenges may also be generalizable characteristics of a given region's housing stock (e.g., common wall types or construction techniques), depending on the building history of the area. Recognizing the numerous complicating factors around retrofit building design, the international PHI standard has a designated retrofit performance path (EnerPHit) allowing for slightly relaxed performance targets relative to the new construction path (e.g., 1.0 ACH50 instead of 0.6 ACH50 envelope air leakage values). However, currently PHIUS+ 2018 requires retrofits to meet the same performance metrics as new construction (e.g., requiring 0.05 CFM50/ft² air leakage in the building envelope for both new and retrofit construction).

This project will provide a thorough review of passive house design and construction techniques when retrofitting existing construction. In particular, several case studies will be reviewed to illustrate examples of design and detailing that can be used for residential retrofit.

Manager/PI: Dr. Ali Memari

Report: The project is making progress slowly but surely, and a student assistant has been assigned to work on the project. The literature, including recent conferences, has been gathered and reviewed. In particular, some retrofit examples have been reviewed that show the breadth of possibilities including retrofitting for the following components/aspects: exterior wall framing and insulation, basement floor/wall insulation, roofing material (e.g., changing shingles to metal roofing), ceiling/attic insulation, sealing air leakage areas, window replacement, addition of external blinds or sun screens, siding replacement, thermal bridges, heating/cooling system replacement, heating/cooling distribution replacement, mechanical ventilation change, water heater change, PV solar system use, and appliances change. For each category, there are various options, which will be listed and discussed in the final report. Of course, the whole idea of

PH performance verification relies on testing. Some example studies on testing performed on retrofitted and new PH homes have been identified and summaries that indicate the effectiveness of the features used will be discussed in the final report. Example testing and evaluations include comparing whole house energy use and monitored (measured) use, solar water heating performance, ERV performance, and air tightness degree based on blower door test. The final report will also review some of the guidelines in Passive House Planning Package (PHPP), which is a tool for PH design, and EnerPHit Retrofit Plan, which provides guidelines as a “reasonable standard” for retrofit of existing homes, acknowledging that hidden thermal bridges may not all be identified and corrected and that older homes cannot be economically justified to have the same level of performance expectations as new construction. Nonetheless, EnerPHit provides specific criteria for opaque envelope, windows, heating and cooling demand, airtightness and renewable primary energy demand.

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. Summary of 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.

Manager/PI: B. Wolfgang

Report: Due to the primary focus of the PHRC team's UCC activity involving the unusually high demand for training, this project will be completed in the 2019-2020 project year. Draft language was developed for this UCC summary document and deliverable options (length, paper size, overall format) were discussed. In the 2019-2020 project year, this project will be completed through direct input from the PHRC Industry Advisory Council.

2. Exterior Plaster Mockup Construction

Description: The exterior plaster workshop has been very popular recently due to the need for additional education on the principles of stucco and manufactured stone installation and overall moisture management. To enhance this workshop, the PHRC will work with PHRC instructors to construct mockups of exterior plaster assemblies and flashing details to better demonstrate the challenges of exterior plaster design and installation.

Manager/PI: B. Wolfgang

Report: Two PHRC instructors that focus on exterior plaster designed a classroom mockup for use in the revamped Stucco and Thin Stone Veneer Design and Installation workshop. This mockup uses a series of constructed materials on hinges to represent the different control layers in the building enclosure. This mockup was constructed by a regional stucco remediation contractor and will be debuted in fall 2019.

3. PA Community Land Trusts (CLT): Quality and Energy Affordability of Homes in Non-Profit Affordable Housing Models

Description: From Community-Wealth.org, Community Land Trusts (CLTs) are nonprofit, community-based organizations designed to ensure community stewardship of land. Community land trusts can be used for many types of development (including commercial and retail) but are primarily used to ensure long-term housing affordability. As of 2017 there are seven housing-based CLTs in the state of Pennsylvania and 316 total CLTs in the United States. This applied project to document PA-based housing CLTs will be a continuation from the 2017–2018 fiscal year.

Manager/PI: S. Klinetob Lowe

Report: For the 2018-2019 project year, the PHRC took a deep dive into the needs of one Pennsylvania community land trust - the State College Community Land Trust (SCCLT) - to explore the impact and challenges of long-term housing affordability in the land trust model. Work included exploring the details of a new “Energy+” program to address long-term housing affordability through energy retrofits, providing information and language on low-income housing energy burdens for a successfully funded SCCLT application to the Pennsylvania Housing and Rehabilitation Enhancement Fund (PHARE) grant, and the development of educational posters on residential energy retrofits for single-family homes during a public open house.

In the next fiscal year, the PHRC will expand the results of the work completed for a broader audience.

4. PA Residential Code Update Marketing & Communication

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 will take effect on October 1, 2018. This project will focus on getting the word out regarding these updates to builders, contractors, and design professionals across the Commonwealth. This effort would include electronic communication, development of flyers, and other initiatives.

Manager/PI: C. Hine

Report: The PHRC reviewed the report and compiled a modular based training platform to be delivered to the residential industry. These training sessions were delivered as speaking engagements and all delivered sessions are listed under “Speaking Engagements” in this document.

5. PA Alternative Residential Energy Provisions Update and Publication

Description: The Pennsylvania Alternative Residential Energy Provisions were developed with the intent of being: simpler to build and easier to enforce; more rational and flexible; focused on Pennsylvania in terms of climatic and other conditions; and, equivalent to the provisions of the International Energy Conservation Code (IECC) in terms of energy efficiency. Based on the outcome of the PA Uniform Construction Code (UCC) Review & Advisory Council (RAC) review process of the 2015 codes, the PA Alternative Residential Energy Provisions will need to be updated to reflect the changes to the UCC that will become effective on October 1, 2018.

Manager/PI: B. Wolfgang

Report: The PHRC developed the PA-Alt for consideration by the Pennsylvania Department of Labor & Industry (DLI) to meet their legislated mandate to consider the development of alternative prescriptive methods for energy conservation that account for the various climatic regions within the Commonwealth per Act 45 of 1999. The PA-Alt was developed with the intent of being simpler to build to and easier to enforce; more rational and flexible; focused on Pennsylvania in terms of climatic and other conditions; and equivalent to the provisions of the International Energy Conservation Code (IECC).

The development of the 2018 Pennsylvania Alternative Residential Energy Provisions (PA-Alt) was led by the PHRC with guidance from a subcommittee of the PHRC Industry Advisory Council. The PHRC would like to recognize the following members of the PA-Alt Subcommittee for their contribution of time and knowledge: Bob Hart, John Holahan, Jon Kautz, Jerry Leach, Gary Lenker, Robin Loughran, R. Clem Malot, Amy Martino, Tom McCosby, Sarah Miller, Chad Owens, Tommy Songer, Jon Sukonik, and Mike Turns.

This document was developed by Brian Wolfgang, associate director; Christopher Hine, housing & land development specialist; and Sarah Klinetob Lowe, housing systems specialist of the PHRC. Energy equivalence analysis was performed by Sarah Klinetob Lowe. The document design and formatting were done by Rachel Fawcett, budgets & publications coordinator of the PHRC. The 2018 Pennsylvania Alternative Residential Energy Provisions were developed by the PHRC as a service to the Pennsylvania Department of Labor and Industry on behalf of all the consumers of housing in Pennsylvania.

With the 2018 PA Alternative Residential Energy Provisions presenting an energy code compliance path in the PA Uniform Construction Code since October 1, 2018, the PHRC team received numerous questions and inquiries related to its use and implementation. To respond to these ongoing questions, the PHRC published a two-page worksheet to assist with the permit application process.

The 2018 PA-Alt and the PA-Alt Worksheet are both available for download on the PHRC website.

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 2018-2019 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: April 2019 – May 2020
Title: Infrared Thermography Technique for Building Envelope Thermal Resistance Measurement
Sponsor: Penn State Institute of Energy and Sustainability (PSIEE)
Amount: \$10,000 (Candidate's share of funding – 80%)
(PI)
- Date: June 2019-June 2020
Title: Development of Bamboo Reinforced Hempcrete for Home Construction
Sponsor: Penn State Institute of Energy and Sustainability (PSIEE) and Material Research Institute (MRI)
Amount: \$40,000 (Candidate's share of funding – 55%)
(PI)
- Date: August 1, 2019 – July 31, 2022
Title: Collaborative Research: Experimentally and Computationally-Supported Fragility and Recovery Models for Performance Based Hurricane Design of Building Envelope Systems"
Sponsor: National Science Foundation (NSF)
Amount: \$400,129 (Candidate's share of funding – 75%)
(PI)
- Date: July 2019-June 2022
Letter of Intent Title: Next Generation of Smart Buildings
Sponsor: NSF LEEP HI
- Date: May 1, 2020 – April 30, 2023
Title: Cold Sintering to enable New Composites as Phase Change Materials for Building Applications
Sponsor: DOE
Amount: \$2,041,348 (Candidate's share of funding – 30%)
(Co-PI)

- Date: June 1, 2020 – May 31, 2024
Title: Development of Bamboo Reinforced Hempcrete for Home Construction
Sponsor: USDA
Amount: \$645,883 (Candidate's share of funding – 30%)
(Co-PI)
- Date: January 2019-December 2019
Title: Development of Sustainable Concrete for 3D printing
Sponsor: PSU COE ENGINEERING for Innovation & Entrepreneurship (ENGINE) Grants 2019
Amount: \$75,000 (Candidate's share of funding – 30%)
(PI)
- Date: April 2019 – May 2020
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%)
(Co-PI)
- Date: January 2019-December 2019
Title: Development of Cement-Free Concrete for 3D Printing of Homes
Sponsor: Material Research institute (MRI)
Amount: \$10,000 (Candidate's share of funding – 20%)
(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 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 to cease on October 25, 2018.

Funds for the 2018-2019 Project Year are based upon funds received from July 2017 through June 2018. Table 7 below shows the amount received during the July 2017 through June 2018 time period.

Table 7. Summary of Act 157 Funds received during the 2017-2018 fiscal year used for the 2018-2019 PHRC Project Year

Collection Period	Amount Received
Q3: July 2017 - September 2017	\$103,028.25
Q4: October 2017 - December 2017	\$159,267.93
Q1: January 2018 - March 2018	\$53,002.66
Q2: April 2018 - June 2018	\$114,152.75
Total	\$429,451.59

Expenses for the Act 157 Account (\$459,589.53) were higher than the revenues (\$429,451.59) for the 2018-2019 fiscal year. This difference was planned for due to costs associated with the code update beginning in October 2018 and made up for by cost savings in the previous year due to a staff vacancy. Table 8 shows a breakdown of PHRC expenses for the 2018-2019 Project Year allocated to the Act 157 Account.

Table 8. PHRC Expenses for the 2018-2019 PHRC Project Year

Category	Act 157
Total Salaries	\$254,413.58
Total Wages	\$2,185.60
Total Student Wages	\$13,040.00
Fringe Benefits	\$95,831.89
Supplies and Materials	\$189.24
Communications Services	\$249.52
Travel	\$22,286.36
Publications	\$1,484.00
Maintenance	\$0.00
Consulting & Prof Svc	\$45,755.00
Copies and Photographic Services	\$8,334.34
Computer Services	\$0.00
Purchased Services	\$24,800.00
Equipment	\$0.00
Computer Equipment	\$0.00
Miscellaneous	\$0.00
Total	\$459,589.53