The Pennsylvania Housing Research Center

PHRC Year in Review

July 2017 – June 2018

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Pennsylvania Housing Research Center
Penn 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

Table of Contents

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, 2017 and June 30, 2018.

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 PHRC receives funds from multiple sources including funds collected under Act 157 of 2006, which established a two dollar fee collected for each building permit to support training and education for the construction industry. To assure that programs funded in whole or part with Act 157 monies meet the needs of the construction industry, Act 157 requires that education, training and other activities provided by the PHRC be approved by its Industry Advisory Council (IAC). Note that this fee structure was altered by Act 36 of 2017, however these changes do not affect the 2017-2018 Project Year.

The projects undertaken were developed with input and assistance from the PHRC's Industry Advisory Council (IAC). This body consist 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 2017, 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 2017 – June 2018*", 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 the Act 157 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 Act 157 funds.

Through the MOU 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, 2017-2018" is submitted to meet the annual report requirement.

A. Staff Changes During 2017-2018 Project Year

The PHRC experienced one change to its staff during the recent fiscal year. Rachel Fawcett started in the position of Budgets & Publications Coordinator as of September 11, 2017.

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

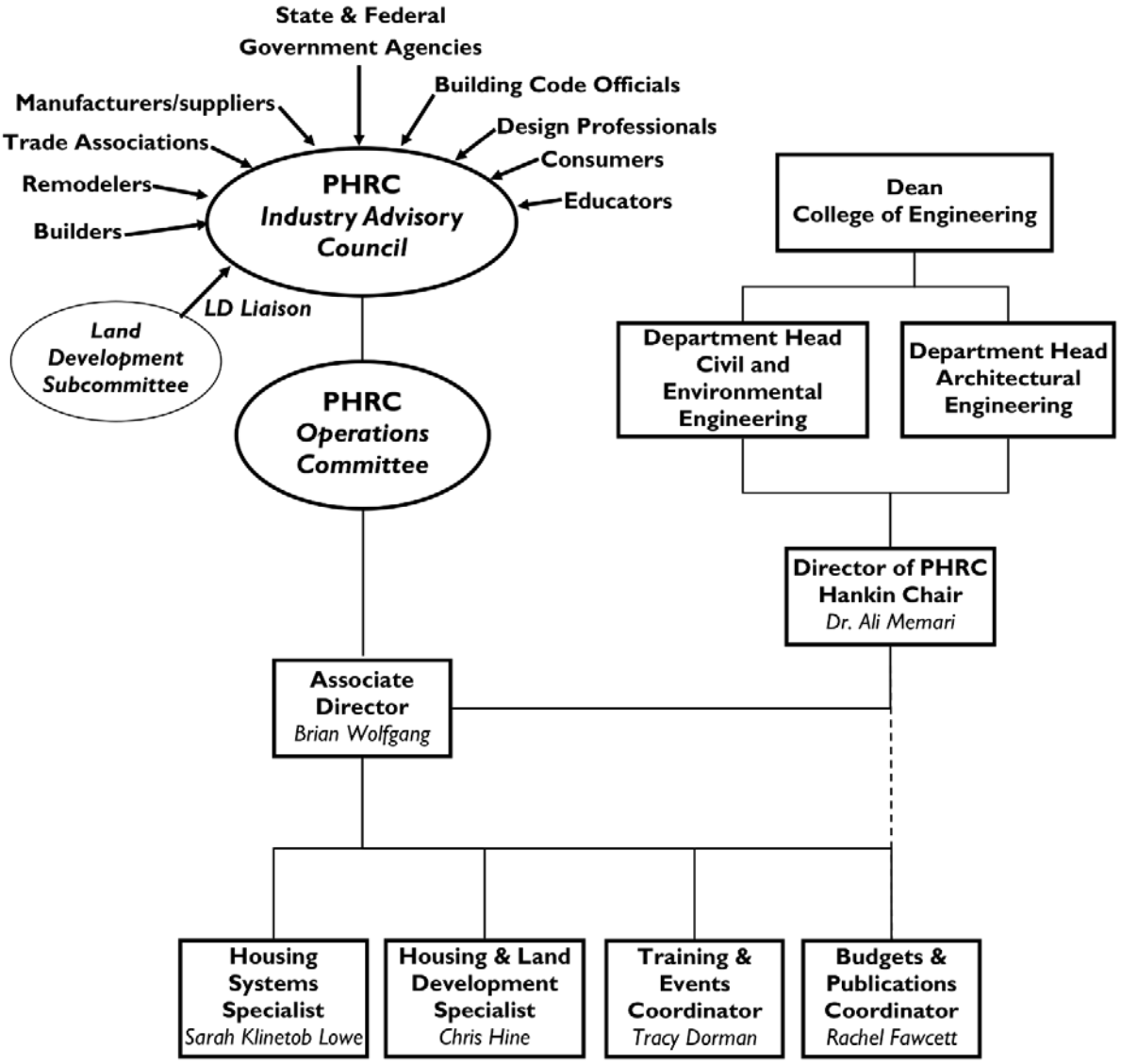

Figure 1. PHRC Organizational Chart

B. Uniform Construction Code – October 1 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 take effect on October 1, 2018.

The overall result of this process as it relates to residential construction is that the 2015 International Residential Code and the residential portion of the 2015 International Energy Conservation Code were adopted with approximately 22 amendments. This represents a significant shift in enforceable residential code provisions within the UCC. This also represents a need for PHRC staff to shift their time toward program and content development near the end of the 2017-2018 fiscal year.

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 45 educational services to 1,680 individuals during this reporting period (Table 1).

Table 1. Summary of all PHRC Educational Programs for the 2017-2018 Project Year

PROGRAM	Activities for 2017-2018	
	# of Events	# of Attendees
Workshops	19	553
Webinars	7	375
Speaker Service	18	547
PHRC Conference/PCCA Symposium (Central)	Day 1	110
	Day 2	95
TOTAL	45	1,680

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. 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.

Manager/PI: C. Hine

Report: The online Residential Deck Program will be carried over into the 2018-2019 project plan year due to the need for development and deployment of training programs on the changing base residential building code in Pennsylvania during the 2017-2018 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, teachers, 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 four categories: (1) Code Refresher, (2) Code Essentials, (3) Academy Programs, and (4) 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. Code Essentials programs are 2-day programs that offer a shorter alternative to the multi-day academies but provide greater depth than the Refresher programs.

    a. International Residential Code Essentials 2 days
    b. IRC Plumbing Essentials 2 days
    c. IRC Mechanical Essentials 2 days
    d. IRC Electrical Essentials 2 days
    e. Residential Energy Essentials 2 days
    f. Commercial Energy Essentials 2 days

3. Academy 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. International Residential Codes Academy 4 days
    b. IRC Plumbing Academy 4 days
    c. IRC Mechanical Academy 4 days
    d. IRC Electrical Academy 4 days

4. Focused Topics programs are designed to immerse the attendee more deeply into an 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. International Residential Code Inspections 2 days
    c. Residential Sprinkler Inspection/Installation 1, 2 days
    d. Special Issues with Two-Family Dwellings and Townhouses 1 day
    e. Fundamentals of Exterior Plaster and Thin Stone Veneer Assemblies 1 day
    f. Residential Energy Plan Review and Inspection 1 day
    g. Building Envelope Design and IECC Code Compliance 1 day
    h. Building Code Plan Review and Inspection 1 day
    i. Residential Deck Design and Construction 1 day
    j. Building with Exterior Rigid Foam 1 day
    k. Residential Moisture Management: The 4D's online
    l. IRC Framing Design & Code Compliance 1 day

For program descriptions, visit http://phrc.psu.edu/Industry-Education/PHRC-Training-Programs/Workshops/Available%20Workshops.aspx.

Report: During the 2017-2018 project year, the PHRC delivered 19 workshops to 553 builders, remodelers, educators, code officials, design professionals, and planners during this reporting period (see Table 2 for detail).

Table 2. PHRC Workshops Held July 1, 2017 through June 30, 2018

PROGRAM	In-person/ Online	# of Programs	# of Attendees
Blueprint Reading Program	In-Person	3	69
Fundamentals of Exterior Plaster and Thin Stone Veneer	In-Person	2	60
IRC Residential Code Academy – 4 days	In-Person	1	19
IRC Plumbing Code Academy – 4 days	In-Person	1	18
IRC Mechanical Code Academy – 4 days	In-Person	1	14
IRC Framing Design and Code Compliance	In-Person	3	92
IECC Essentials – 2 days	In-Person	1	36
Residential Energy Essentials – 2 days	In-Person	1	15
IRC Electrical Academy – 4 days	In-Person	1	18
IRC Electrical Code Refresher	In-Person	1	28
Two Family-dwellings and Townhouses	In-Person	2	61
PCCA Symposium (East and West)	In-Person	2	123
	Total	19	553

C. Webinar Development and Delivery

Description: In today's economic climate, there is a need for educational programs without travel costs. 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 certification maintenance credit 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 seven webinars during this reporting period to a total of 375 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. 2017-2018 Webinar series titles and number of attendees

Webinar Series		
Month	Title/Topic	Number of Attendees
September	Hot Water Fundamentals	79
October	No Webinar was held	
November	Residential Makeup Air Systems	75
December	Radiant Floor Heating Systems	56
January	Residential Energy Auditing 101	53
February	Visitability	48
March	No Webinar, PHRC Conference	-
April	Future Proof Home Design	30
May	Greenbuild	34
	Total	375

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 Symposium
4. Speaking Engagements
5. General Outreach Activities
6. Annual Newsletter
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 technical 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 26th Annual PHRC Housing Conference was held on February 28 and March 1, 2018 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 Glenn Cottrell, Managing Director of Building Solutions, IBACOS, entitled "Understanding the Cost of Quality".

   The following tracks and sessions were offered:

   - High Performance Homes
     - "Live Simply, Safely, Sustainably" by Tracey Powell
     - "Be a Hero with Zero: Zero Energy Homes in Pennsylvania" by Scott Pusey
     - "Universal Design/Aging-in-Place: An Interactive Experience" by Dorothy Gerring & Rob Wozniak
   - Construction & Management
     - "High Performance Building – What Makes Sense & What Doesn't" by Vaughn Piccolo
     - "Drainage & Drying in the Exterior Wall" by Kaylen Handly
     - "The Do's and Don'ts of Crawlspace Design and Construction" by Chris Hine

- PCCA Symposium Central
  - "Act 36 of 2017 – Reform of Code Review & Adoption Process in Pennsylvania" by Bob Buddenbohn
  - "2015 RAC Re-Review: Residential Update" by Brian Wolfgang
  - "PA UCC / Code Enforcement Q & A" by Bob Buddenbohn, Don Forry & Douglas Meshaw

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

- Design & Technology
  - "VRF System Design in High Performance Homes" by Ryan Flynn
  - "Thermal Insulation, More Than Just Temperature Control" by Robert DeVries
  - "The Good, the Bad, and the Broken Code – The Devil is in the Details" by Wade Romberger
  - "Balancing Ventilation and Airtightness in Residential Buildings" by Sean O'Brien, P.E. and Scott Bondi, P.E.
- Construction & Management
  - "Moisture Control for Hard Coat Stucco and Thin Veneer Stone" by Steve Long
  - "Adhered Manufactured Stone Veneer: Code Requirements & Detailing Practices" by Nick Lang
  - "Disaster Response and the Building Professional" by Walt Schneider
  - "Use of Cross Laminated Timber (CLT) in Single- and Two-Family Dwellings" by Matt Hunter
- Land Development
  - "Growing Smarter: Implementing Tactical Urbanism/Placemaking, Catalyzing Better Communities. What's the Developer's Role?" by John Turack
  - "Technology and Machine Control in Earth Moving Applications" by Bruce McKown
  - "Community Planning to Accommodate Millennial & Elderly Housing Needs" by Peter Wulfhorst & Neal Fogle
  - "Managed Release Concept – An Approved Alternative for Stormwater Management" by Domenic Rocco

Table 4. Attendees at the Annual PHRC Housing Conference

Event	# of people
Day 1 (February 28)	110
Day 2 (March 1)	95

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 4th Biennial Residential Building Design and Construction Conference on February 28—March 1, 2018 at The Penn Stater Hotel and Conference Center. The 4th RBDC Conference with 109 abstracts submitted shows more than 100 percent increase in abstracts submitted to the 3rd conference. Approximately 50 papers have been submitted for inclusion in the proceedings, which will be published once all the editorial work is complete. This event brought researchers from 13 different countries to share their R&D efforts related to housing and residential construction. Besides the opportunity for exchange of ideas, this expertise forum assisted builders, designers, material manufacturers, and code officials to become more familiar with the latest developments and advancements in this field. The goal and hope continue to be that this conference series will impact the home building industry for improved health, safety, serviceability, sustainability, energy efficiency, resiliency, and cost-effectiveness. On Tuesday, February 27, a special Research & Education Night was held for a mix and mingle event with tours of the lab facilities, a demonstration of the 3D-printing concrete robot that won 2nd place in the NASA 3D-Printed Habitat Challenge, and a reception at the Hintz Family Alumni Center to highlight the current work by our graduate students.

   This year's conference keynote speakers included Professor Dr.-Ing. Bohmuil Kasal, former Hankin Chair and PHRC Director of Research and current Director of the Fraunhofer Institute for Wood Research at the Fraunhofer Wilheim-Klauditz-Institut in Germany and Professor Ryan E. Smith, Associate Dean of Research & Community Engagement and Director of Integrated Technology in Architecture Center at the University of Utah. Dr. Kasal's presentation was titled "German Residential Construction: What Can We Learn From It?", while Professor Smith's talk was under the title of "Global Innovations In Residential Building: Prefabrication, Modularization & Automation". 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 Symposium: 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 2018, including events in Valley Forge and Monroeville. Attendee numbers are shown in Table 5.

Table 5. Attendees at the PCCA Symposia

Event	# of people
Central PCCA Symposium (February 28)	24
Eastern PCCA Symposium (March 28)	72
Western PCCA Symposium (April 4)	51

4. Speaker 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 2017-2018 reporting period, the PHRC delivered 18 speaker services, reaching 547 people. Speaker service and conference presentations included:

    - Klinetob Lowe, S. "2016-17 Race to Zero Project," Centre County Housing & Land Trust, State College, PA, July 12, 2017, (7 attendees)
    - Hine, C. "Construction Documents", AE 470 class, Penn State University, August 30, 2017 (60 attendees)
    - Wolfgang, B. "Introduction to Energy Codes", Arch 412 class, Penn State University, August 30, 2017 (16 attendees)
    - Wolfgang, B. "Adhered Manufactured Stone Veneer," ASHI, Homestead, PA, September 13, 2017 (48 attendees)
    - Wolfgang, B. and Hine, C. "Energy Code Implementation and Compliance in PA", PENNBOC, State College, PA, September 14, 2017 (8 attendees)
    - Klinetob Lowe, S. "Integrative Design for High Performance Habitat for Humanity Homes", State College High School, State College, PA, September 26, 2017 (10 attendees)
    - Memari, A. M. "Learning from the Performance of Residential Construction in the aftermath of Hurricanes Harvey and Irma," PBA Fall Board Meeting, Hershey, PA, October 27, 2017. (20 attendees)

- Hine, C. "PHRC, Who we are, What we do", West Branch Susquehanna Builders Association, Williamsport, PA, November 21, 2017 (42 attendees)
- Klinetob Lowe, S. "Participatory Learning through the Race to Zero Competition", National Council for Science & the Environment, Washington, DC, January 25, 2018 (13 attendees)
- Wolfgang, B. "Up to the Challenge: Evaluating Residential Building Enclosures", Tri-State ASHI, Plymouth Meeting, February 13, 2018 (45 attendees)
- Klinetob Lowe, S. "Residential Energy Auditing 101", Builders Association of Metro Pittsburgh, Pittsburgh, February 13, 2018 (16 attendees)
- Hine, C. "Residential Decks: Design, Details & Code Compliance", Central PA Institute of Science and Technology, State College, PA, February 15, 2018 (11 attendees)
- Klinetob Lowe, S., Hazel, C. "2016-2017 Race to Zero Competition: A Case Study Design for Zero Energy Ready Townhomes", Residential Building Design & Construction Conference, State College, PA February 28, 2018 (18 attendees)
- Klinetob Lowe, S., Hazel, C. "Participatory Learning through the Race to Zero Competition", Residential Building Design & Construction Conference, State College, PA March 1, 2018 (12 attendees)
- Wolfgang, B, Hine, C., Klinetob Lowe, S., Fawcett, R. "How STEM Relates to Residential Construction ", Lewistown Intermediate School, Lewistown, PA, March 13, 2018 (45 attendees)
- Hine, C. "Residential Decks: Design, Details & Code Compliance", Pocono Builders Association, Stroudsburg, PA, April 19, 2018 (11 attendees)
- Wolfgang, B. "Between a Rock and a Hard place", Keystone ASHI Membership Meeting, Reading, PA, June 4, 2018 (15 attendees)
- Wolfgang, B "2015 Code Update Overview and 2015 IRC Highlights", Builders Association of Central PA, State College, PA, June 4, 2018 (150 attendees)

Conference Presentations

- Memari, A. M. (2018). "3D Printing of Concrete for Precast Industry & Residential Construction," Quad Blocker presented at the Industry Exchange program at Penn Stater, May 14, 2018, State College, PA.
- Sagiroglu, M. (Presenter) and Memari, A. M., (2018). "Learning from the Experiences of Using Different Types of Temporary Housing Systems," Presented at the 42nd IAHS World Congress – The Housing for the Dignity of Mankind, April 10-13, 2018, Naples, Italy.

- Habibi, S. (Presenter) and Memari, A. M., (2018). "Review of Smart Envelope Systems for Multi-story Residential and Commercial Buildings," Presented at the 42nd IAHS World Congress – The Housing for the dignity of Mankind, April 10-13, 2018, Naples, Italy.
- Ko, M., Memari, A. M., Duarte, J. P., Nazarian, S. (Presenter), Ashrafi, N., Craveiro, F., and Bilen, S., (2018). "Preliminary Structural Testing of a 3D Printed Small Concrete Beam and Finite Element Modeling of a Dome Structure," Presented at the 42nd IAHS World Congress, April 10-13, 2018, Naples, Italy.
- Solnosky, R. (Presenter), Memari, A. M., and Kremer, P. A., (2018). "Racking Testing Facility to Evaluate In-Plane Performance of Structural Insulated Panels," Presented at the 4th Residential Building Design and Construction Conference -- The Housing for the dignity of Mankind, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Jellen, A. C. (Presenter) and Memari, A. M., (2018). "Concept Paper: MODs – Next Generation Mobile Housing," Presented at the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Kamel, E. (Presenter) and Memari, A. M., (2018). "Software Tool for Automation in Residential Building Energy Simulation and Monitoring," Presented at the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Zahabi, M. (Presenter), Said, A., and Memari, A. M., (2018). "A Brief Literature Study of Nanoparticles Supplementation in Civil Cementitious Materials," Presented at the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Lu, X. (Presenter) and Memari, A. M., (2018). "Thermal Resistance Simulation of Different Conventional and Innovative Insulation Technologies," Presented at the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Habibi, S. (Presenter) and Memari, A. M., (2018). "Role of BIM in Designing Zero-Net Energy Homes," Presented at the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018.
- Lu, X. (Presenter) and Memari, A. M., (2017). "Energy Performance Evaluation and life-Cycle Assessment of Different Types of Residential Building Wall Systems," Presented at Energypath 2017, July 27, 2017, Desales University, Center Valley, PA.

5. General Outreach Activities: The general outreach activities of the PHRC include activities 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.

- Ramaji, I. J. and Memari, A. M., (2018). "Extending the Current Model View Standards to Support Multi-Story Modular Building Projects," Taylor & Francis Architectural Engineering and Design Management, Vol. 14, Issue 1-2, pp. 158-176; DOI: 10.1080/17452007.2017.1386083.
- Memari, A. M., Kremer, P. A., Solnosky, R., and Hartman, K., (2018) "Racking Test Evaluation of Unitized Curtain Wall System with Structural Glazing Tape," ASCE Journal of Architectural Engineering, Vol. 24, No. 2, June 2018, pp. 04018006 (1-25).
- Kamel, E. and Memari, A. M., (2018). "Automated Building Energy Modeling and Assessment tool (ABEMAT)," Elsevier Journal of Energy, Vol. 147, March 15, 2018, pp. 15-24, https://doi.org/10.1016/j.energy.2018.01.023.
- Hojati, M., Radlinska, A., Nazarian, S., Duarte, J., and Memari, A. M., (2018). "3D-Printing of Geopolymer Concrete Cylinders and Beams," Proceedings of the 9th Advances in Cement-Based Materials (Cements 2018) Conference, June 11-12, 2018, Penn State University, State College, PA.
- Hojati, M., Radlinska, A., Nazarian, S., Duarte, J., and Memari, A. M., (2018). "Additive Manufacturing of Cementitious Materials for NASA's Centennial Challenge," Proceedings of the 9th Advances in Cement-Based Materials (Cements 2018) Conference, June 11-12, 2018, Penn State University, State College, PA.
- Sagiroglu, M. and Memari, A. M., (2018). "Learning from the Experiences of Using Different Types of Temporary Housing Systems," Proceedings of the 42nd IAHS World Congress – The Housing for the dignity of Mankind, April 10-13, 2018, Naples, Italy, pp. 1-12.
- Habibi, S. and Memari, A. M., (2018). "Review of Smart Envelope Systems for Multi-story Residential and Commercial Buildings," Proceedings of the 42nd IAHS World Congress – The Housing for the Dignity of Mankind, April 10-13, 2018, Naples, Italy, pp. 1-13.
- Ko, M., Memari, A. M., Duarte, J. P., Nazarian, S., Ashrafi, N., Craveiro, F., and Bilen, S., (2018). "Preliminary Structural Testing of a 3D Printed Small Concrete Beam and Finite Element Modeling of a Dome Structure," Proceedings of the 42nd IAHS World Congress – The Housing for the Dignity of Mankind, April 10-13, 2018, Naples, Italy, pp. 1-17.
- Solnosky, R., Memari, A. M., and Kremer, P. A., (2018). "Racking Testing Facility to

Evaluate In-Plane Performance of Structural Insulated Panels," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 16p.

- Jellen, A. C. and Memari, A. M., (2018). "Concept Paper: MODs – Next Generation Mobile Housing," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 20p.
- Kamel, E. and Memari, A. M., (2018). "Software Tool for Automation in Residential Building Energy Simulation and Monitoring," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 9p.
- Zahabi, M., Said, A., and Memari, A. M., (2018). "A Brief Literature Study of Nanoparticles Supplementation in Civil Cementitious Materials," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 17p.
- Lu, X. and Memari, A. M., (2018). "Thermal Resistance Simulation of Different Conventional and Innovative Insulation Technologies," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 17p.
- Habibi, S. and Memari, A. M., (2018). "Role of BIM in Designing Zero-Net Energy Homes," Proceedings of the 4th Residential Building Design and Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 15p.
- Hazel, C., Klinetob Lowe, S., Hanna, T. & Copeland, S. (2018). "2016-2017 Race to Zero Competition: A Case Study Design for Zero Energy Ready Townhomes", Proceedings of the 4th Residential Building Design & Construction Conference, Penn State University, University Park, PA, February 28 to March 1, 2018, 15p.

Conferences/Meetings Attended

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

- Dorman, T., C. Hine, A.M, Memari, and B. Wolfgang. International Builders Show and NAHB Student Competition, Orlando, FL, January 7-12, 2018.
- Memari, A. M., (2018). Attended HUD Technology Innovation Workshop, Arlington, VA, March 29, 2018.
- Memari, A. M., (2017). Attended 2017 Building Systems Housing Summit, Hershey, PA, October 9, 2017.
- Hine, C., A.M. Memari, and B. Wolfgang. PBA Fall Board Meeting and PHRC-PBA Breakfast Meeting, Hershey, PA, October 27, 2017.
- Hine, C. and B. Wolfgang, NAHB Residential Educators Workshop, Orlando, FL, January 10, 2018.

- Hine, C. and B. Wolfgang, PBA Summer Board Meeting and PHRC-PBA Breakfast Meeting, Camp Hill, PA, July 21, 2017.
- Klinetob Lowe, S. New Gravity Housing Conference, Philadelphia, PA, August 3-4, 2017.
- Fawcett, R. and Klinetob Lowe, S. Homes Within Reach Conference, Harrisburg, PA, December 4-6, 2017.
- Klinetob Lowe, S. Race to Zero Student Design Competition, National Renewable Energy Laboratory, Golden, CO, April 21-22, 2018.
- Fawcett, R. and Klinetob Lowe, S. Energy Days Conference, University Park, PA, May 30-31, 2018.
- Wolfgang, B., NAHB Student Chapter Advisory Board Meeting, Orlando, FL, January 10, 2018.
- Wolfgang, B. PABCO Legislative Conference, New Cumberland, PA, October 17, 2017.
- Wolfgang, B. PBA Winter Board Meeting and PHRC-PBA Breakfast Meeting, Reading, PA, February 23, 2018.
- Wolfgang, B. Westford Symposium on Building Science, Westford, MA, July 30-August 2, 2017.

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., Earthquake Engineering Research Institute, 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 Newsletter: The PHRC Annual Newsletter was sent electronically to PHRC members and stakeholders to keep them up-to-date on recent PHRC activities and to promote upcoming events. Printed newsletters 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 2017-2018 project year, the PHRC newsletter 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 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 tradespeople 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 established for the 2015 Annual PHRC Housing and Land Development Conference and this program will continue to provide an opportunity for students to attend the conference at no charge.

   A scholarship program was offered for the Annual PHRC Conference. Students from across the state were able to attend the conference at no fee 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. Throughout 2017-2018, PHRC staff attended each RAC meeting during the re-review of the 2015 code provisions. Information obtained during these meetings will be used to provide training to the industry on the code changes that will become enforceable on October 1, 2018.
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 will become effective on October 1, 2018.

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. 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 was done by Rachel Fawcett, budgets & publications coordinator of the PHRC.

III. Applied Research

A very 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.

Comparative Energy Analysis and Life Cycle Assessment of Innovative Residential Wall Systems

Description: In an effort to develop a better understanding of energy efficient wall system options available to home builders, innovative wall systems such as advanced 2x6 framing and double stud systems (with cellulose, fiberglass, or spray foam insulation, and with or without exterior rigid insulation), SIPs, ICF, EIFS, and other innovative (including some proprietary) systems need to be evaluated further. While there is significant amount of thermal performance data available on conventional 2x4 wood-frame systems, better understanding of newer systems as well as emerging ones is needed not only with respect to annual operational energy performance where the insulation system significantly impacts, but also from the life-cycle assessment (LCA) perspective that informs of the embodied energy and carbon footprint from the materials manufacturing stage to completion of the construction and end of life demolition, i.e., cradle-to-grave analysis. This project intends to provide a side by side comparison of various types of residential wall systems assumed to be used to construct a model home for operational annual energy performance using software such as THERM and BEOPT and carry out LCA using software such as ATHENA. In order to develop a better understanding of the thermal properties of the wall systems, efforts will be made to test selected systems in the BeTL lab climate chamber as well. In particular, some prefabricated wall panel manufacturers will be invited to contribute to the project if they wish their wall system tested. The result will be a complete research report, a builder brief, a conference paper, and a journal paper.

Manager/PI: Dr. Ali Memari

Report: The research has been completed and a final report is due to be submitted in fall 2018. In this report, using energy simulation, comparison of energy performance for several types of building envelope systems such as ICF, SIP, EIFS and advanced framing is presented. The results show that all of these types of wall systems turn out to effectively reduce the annual energy consumption compared to the standard 2*4 wood-frame wall, with ICF showing the best performance. The study also discusses the “anti-insulation” effect, which means that in some cases increasing the insulation beyond a certain level will actually increase the cooling energy use. The approach for modeling wood-stud walls considering the thermal bridge effect is also explained in detail. Life cycle assessment is also conducted to evaluate the long-term behaviors of these building envelope systems.

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. 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: This project effectively adapted to the circumstances surrounding the October 1 code change as part of the UCC. Because of the regulatory changes, there was a more immediate need to make our audience aware of the UCC, UCC Review and Advisory Council, and the code change recommendations that came out of the 2015 re-review process. The tangible result of this effort has been a single-page handout that summarizes code provisions that were amended, online locations of UCC regulations, and ICC online references.

2. Exterior Plaster Assemblies in Pennsylvania (continuation)

   Description: This project would include activities such as providing technical support and assistance in the development of general outreach to builders, design professionals, code officials, and home inspectors as the housing industry in PA continues to address issues related to stucco and manufactured stone installation.

   Manager/PI: B. Wolfgang

   Report: The PHRC continued to support the building industry and the Pennsylvania Builders Association and their technical needs related to exterior plaster assemblies through speaking engagements and other support. Many of these speaking engagement focused on manufactured stone veneer assemblies.

3. Residential Ventilation Systems in PA

   Description: As the building enclosure on residential projects becomes tighter, it becomes increasingly important to consider the ventilation requirements for the project. Current enforceable code requirements in PA allow for the use of operable glazing to satisfy air exchange requirements. However, there are scenarios that warrant consideration of mechanical ventilation through exhaust or balanced systems. Available technology

continues to expand, and guidance from industry standards does not always agree. This project would look at the existing requirements, design guidelines, and available ventilation systems to provide PA builders with a reference should they consider the installation of a mechanical ventilation system on a project.

Manager/PI: B. Wolfgang

Report: PHRC worked with Chris Hazel from the Hamer Center for Community Design within the Stuckeman School of Architecture and Landscape Architecture to produce a document titled "Ventilation Requirements and Code Changes." This publication summarizes new whole-house ventilation requirements included in the 2015 IRC, outlines common ventilation strategies, and provides example calculations for various home sizes. This publication will be available electronically in fall 2018.

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

Description: A Community Land Trust (CLT) is a general term for a type of non-profit affordable housing organization that is designed to meet the specific affordable housing needs of its host community. As of 2017 there are ten (10) CLTs in the state of PA, and 316 in the United States. While each have a common mission to provide affordable housing to its host community, each have unique characteristics, including:

- strategies to meet their perpetually affordable housing goals (e.g., dual or shared ownership arrangements, affordable resale requirements, etc.),
- various and unique funding arrangements (e.g. private donations, grant funding, etc.)
- spectrum of client types, including homeowners, renters, or a combination of both,
- focus on utilizing existing housing stock, building new construction, or a combination of both, and
- utilization of single family, attached, and/or multifamily homes.

The purpose of this project is to evaluate the initial and current quality and energy affordability of the homes that the ten (10) CLTs in Pennsylvania are utilizing in their respective programs, and to explore feasible strategies to improve their housing stock in a way that enables them to continue their mission of perpetually affordable housing.

Manager/PI: S. Klinetob Lowe

Report: Preliminary research into the community land trust (CLT) housing model has begun, as well as conversations with three Pennsylvania land trusts – State College Community Land Trust, Centre County Community Land Trust, and Lawrenceville Community Land Trust. With the adoption of new building code provisions in PA, work on this project will shift to the 2017-2018 project year.

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 to the government during the 2017-2018 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:

- National Association of Home Builders, National Housing Endowment, 2019 HELP Grant RFP Application, January 2019-December 2022, $100,000, PI.
- Penn State Institute of Energy and Sustainability (IEE), Design and Development of an Innovative Re-roofing Solution that Demonstrates the Feasibility of Retrofitting a Leaky Vacant Building to a Watertight and Energy Producing System, January 2018-December 2019, $10,000, Co-PI.
- PSU Material Research Institute (MRI) [Humanitarian Engineering Topics], Advanced Ceramic Shelters: Durable, Cost Effective, and Impermeable, January 2018 – December 2019, $10,000, Co-PI.
- DOE, Cost-effective and Transferable High-Performance Envelope and HVAC Design Strategies for U.S. Residential New Construction and Retrofit Applications, August 2018-July 2021, $1,450,957, PI.
- Penn State University Strategic Plan opportunity RFP, Digital Innovation through Additive Manufacturing Technologies: developing a new paradigm for building construction on Earth and beyond, January 2018 – December 2019 $250,000, Co-PI.
- DOE BENEFIT, Development of Infrared Thermography Technique and Interoperability of BEM Tools for Real-Time Measurement of Thermal Properties of Building Envelope Systems, August 2018-July 2020, $500,000, PI
- National Science Foundation (NSF), Collaborative Research: Development of Experimentally and Computationally-Supported Fragility Functions for Performance Based Hurricane Design of Building Envelope Systems, May 1, 2018 – April 31, 2021, $386,552, PI.
- PSU-COE Grand Challenges Workshop - Supporting Competitive ERC Teams, A Living Lab for an Adaptive Circular City, February 2018 – January 2020, $70,000, 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.

Act 157 of 2006 funds are collected through a $4 fee on every building permit issued in the Commonwealth and are dispersed through the Department of Community and Economic Development. PHRC receives 50% of the collected permit fees minus a 7.5% administrative fee. Funds for the 2017-2018 Project Year are based upon funds received from July 2016-June 2017. Table 6 below shows the amount received during the July 2016-June 2017 time period.

Table 6. Summary of Act 157 Funds received during the 2016-2017 fiscal year used for the 2017-2018 PHRC Project Year.

Collection Period	Amount Received
Q3: July 2016 - September 2016	$124,177.55
Q4 October 2016 - December 2016	$129,512.95
Q1: January 2017 - March 2017	$100,836.10
Q2: April 2017 - June 2017	$133,603.30
Total	$488,129.90

Expenses for the Act 157 account ($435,275.64) were lower than the revenues ($488,129.90) for the 2017-2018 fiscal year. This difference is primarily due to the salary cost savings during the Budgets & Publications Coordinator vacancy (July 2017-September 2017), as well as budgeted code update costs that were instead expended in the 2018-2019 Project Year. All carryover funds will be utilized in future fiscal years. Table 7 shows a breakdown of PHRC expenses for the 2017-2018 Project Year.

Table 7. PHRC Expenses for the 2017-2018 PHRC Project Year.

Category	Act 157	Combined Non-Act 157 Funds	Total
Total Salaries	$254,296.70	$26,714.75	$281,011.45
Total Wages	$2,440.00	$0.00	$2,440.00
Total Student Wages	$10,012.00	$0.00	$10,012.00
Fringe Benefits	$104,989.46	$11,113.37	$116,102.83
Supplies and Materials	$1,455.78	$3,283.67	$4,739.45
Communications Services	$106.26	$425.37	$531.63
Travel	$21,854.48	$54,380.28	$76,234.76
Publications	$369.50	$1,058.92	$1,428.42
Maintenance	$197.32	$69.77	$267.09
Consulting & Prof Svc	$30,200.00	$1,139.58	$31,339.58
Copies and Photographic Services	$4,810.14	$3,156.76	$7,966.90
Computer Services	$0.00	$925.87	$925.87
Purchased Services	$1,100.00	$200.00	$1,300.00
Equipment	$0.00	$55.96	$55.96
Computer Equipment	$0.00	$31.80	$31.80
Miscellaneous	$3,444.00	$2,040.00	$5,484.00
Total	**$435,275.64**	**$104,596.10**	**$539,871.74**