The Pennsylvania Housing Research Center

PHRC Year in Review

July 2020 – June 2021

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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, 2020 and June 30, 2021.

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

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

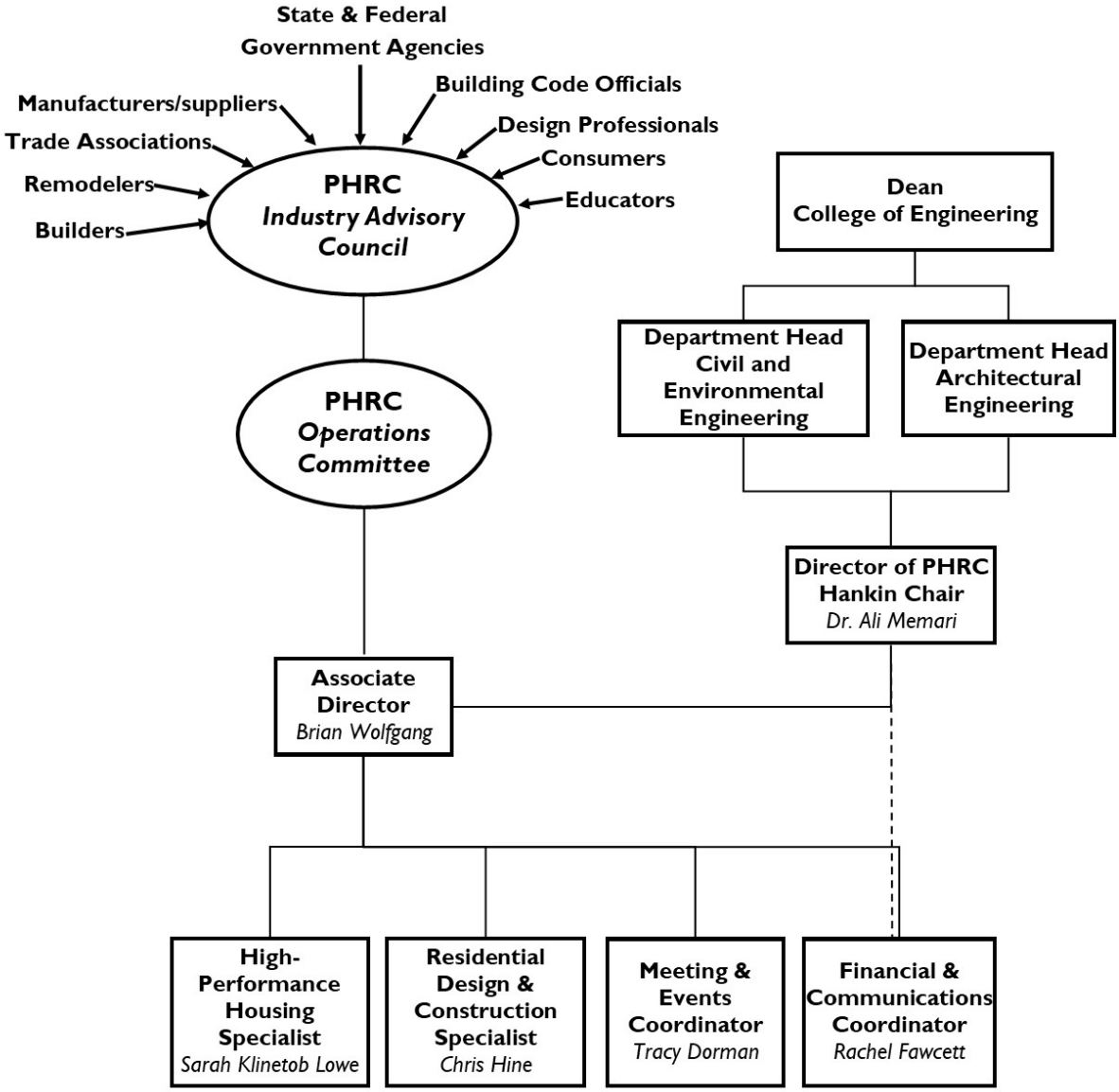
The projects undertaken were developed with input and assistance from the PHRC's Industry Advisory Council (IAC). This body consists of builders, developers, design professionals, code officials, manufacturers, suppliers, remodelers, and industry associations as well as state and federal agencies. After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

The result of this input was the "*PHRC Project Plan, July 2020 – June 2021*", 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 UCC permit fee funding to leverage outside support. It should also be noted that the PHRC undertook an array of additional projects that did not receive any UCC permit fee funds. Some of these projects are included in this report but are identified as having no support from the UCC permit fee 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, 2020-2021" is submitted to meet the annual report requirement.

A. PHRC Organizational Chart

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



B. COVID-19 Impacts

The 2020-2021 project year continued to be impacted in significant and unprecedented ways by the COVID-19 pandemic. Through July 2020 – June 2021, PHRC staff members continued to work remotely. Additionally, all events were held virtually when possible. While these circumstances certainly made many traditional PHRC activities difficult to execute successfully, the PHRC was able to leverage various online delivery modes to increase participation in specific areas, such as PHRC webinars and the inaugural PHRC Construction Summit.

This ongoing unprecedented disruption had a significant impact on PHRC deliverables during the 2020-2021 project year, including:

- Fewer in-person workshops and speaking engagements requested and scheduled,
- Cancelation of PCCA Symposia, and
- Some 2020-2021 projects will be carried over to 2021-2022, or in some instances, staff resources were redirected to attainable projects due to workflow restrictions.

While the challenges of carrying out the PHRC's mission in a remote and virtual environment are substantial, the PHRC staff continued to thrive and adapt to the needs of the residential construction industry. As the pandemic continued throughout the year, significant headwinds were present such as virtual learning fatigue and a general desire to return to in-person activity. The PHRC team anticipates more flexibility to return to some level of in-person activity in fall 2021.

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 30 educational services to 2,216 individuals during this reporting period (Table 1).

Table 1. Summary of PHRC Educational Programs for the 2020-2021 Project Year

PROGRAM	Activities for 2019-2020	
	# of Events	# of Attendees
Workshops	6	80
Webinars	12	1,435
Speaking Engagements	10	403
PHRC Conference/PCCA Symposium (Central)	Day 1	69
	Day 2	65
	Students	37
PHRC Construction Summit	1	159
TOTAL	**32**	**2,248**

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

A. Program Development
B. PHRC Training Program Delivery
C. Webinar Development & Delivery
D. Builder Briefs & Other Publications
E. Technical Assistance, Technology Transfer, & Outreach

The following sections labeled A through E 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: For many PHRC workshops, there is a need to make minor course material updates based on instructor feedback throughout the year. Also, the PHRC will continue work to update and improve the photos in programs, incorporate more photos or videos as appropriate, and expand active learning exercises to increase learner participation and knowledge retention.

Manager/PI: C. Hine

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

2. Training for Blower Door and Duct Tightness Testing

Description: With envelope air leakage (blower door) testing now required by the PA Uniform Construction Code, the industry is attempting to respond to the need for more third parties to conduct this test. Many consultants and other subcontractors have an interest in building this capacity to offer blower door testing as a service but are not sure where to turn for training. This project would allow the PHRC to partner with the National Sustainable Structures Center (NSSC) at the Pennsylvania College of Technology. The collaboration will focus on bringing blower door and other relevant training to PA to provide the regional industry an opportunity to build blower door and duct testing capacity. Note: this project began in the 2019-2020 project year and is ongoing.

Manager/PI: B. Wolfgang, S.K. Lowe, & C. Hine

Report: The PHRC team executed a significant collaborative effort with the Clean Energy Center, formerly the National Sustainable Structures Center (NSSC), at Penn College. PHRC and the Clean Energy Center worked to develop a blended training program that will provide Infiltration and Duct Leakage (IDL) certification through the Building Performance Institute (BPI) upon completion.

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

The pilot for this program is anticipated to be offered during the 2021-2022 project year.

3. PHRC Continuing Education On-Demand

Description: PHRC staff have repeatedly been asked when webinars would become available on-demand for continuing education credit. This has been difficult in the past due to ongoing

software and infrastructure changes at Penn State. The PHRC team is now working with the Office for Digital Learning (ODL) within the Penn State College of Engineering to utilize newly available software platforms for on-demand education. Note: this project began in the 2019-2020 project year and is ongoing.

Manager/PI: B. Wolfgang & R. Fawcett

Report: The PHRC team worked with ODL to develop ten on-demand courses through Penn State Extension. These courses will begin the initial offering of on-demand education for continuing education on residential construction in fall 2021.

4. Virtual Workshop Transition and Development

Description: As the PHRC team continues to adapt to the changes brought about during the COVID-19 pandemic, there will be a need to develop new and adapt existing content for virtual deployment. PCCA has indicated that most of their activities will be conducted virtually in the coming fiscal year which will also support this initiative. Many of these courses will be delivered in a half-day (3.5 hours) live virtual format using video conferencing software.

Manager/PI: B. Wolfgang & R. Fawcett

Deliverables: The PHRC team worked with PCCA to deliver three different virtual workshops including Building Envelope Fundamentals, Building Envelope Assemblies & Code Compliance, and Residential Deck Design & Construction: The Basics. These workshops were delivered via Zoom for a total of six online workshop opportunities.

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 Codes Academy (PCCA).

Note: the types and format of programs that will be offered in the 2020-2021 project year will depend on the feasibility of in-person instruction. Many workshops will be forced to adapt to virtual deployment.

Report: During the 2020-2021 project year, the PHRC delivered 6 workshops to 80 individuals during this reporting period. See Table 2 for further details.

Table 2. PHRC workshops held during the 2020-2021 Project Year

Program	In-person/ Online	# of Programs	# of Attendees
Building Envelope Fundamentals	Online	2	18
Building Envelope Assemblies & Code Compliance	Online	1	12
Residential Deck Design & Construction: The Basics	Online	3	50
	Total	**6**	**80**

C. Webinar Development & 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 in Pennsylvania are offered.

Report: The PHRC delivered twelve webinars during this reporting period to a total of 1,435 people. Due to the PHRC Housing Conference, no webinar was held in March, and due to the PHRC Construction Summit, no webinar was held in December. See Table 3 for the summary of webinars and attendees.

Table 3. 2020-2021 Webinar series titles and number of attendees

Webinar Series		
Month	**Title/Topic**	**Number of Attendees**
August	Why Housing is Long Overdue for Disruption	92
September #1	Slab Insulation: Finding the Right Details	122
September #2	"A Range of Rainscreens: An In-Depth Look at the Variety of	95
October	It's More than "Just a Deck"	113
November	Restoring Floodplains to Manage Stormwater	118
January #1	Fire Protection of Lightweight Framing Floor Assemblies	132
January #2	Control Layers - Vapor Barriers & Retarders	134
February	Structural Insulated Panels (SIPs) for Residential Construction	121
April #1	Healthy Homes – Existing Conditions	93
April #2	Checking Your Work, Properly Installed HVAC in New Homes	83
May	Air Sealing Tips, Tricks and Details	100
June	UCC Code Update: 2018 ICC Code Adoption	232
	Total	**1,435**

D. Builder Briefs & Other Publications

Description: The PHRC will produce publications as appropriate, including its series of short technical documents called Builder Briefs that address specific issues that have been identified by builders or remodelers. These documents are intended to be quick to read with a lot of the information presented graphically or pictorially. Potential publication topics include:

- Slab-on-Grade Insulation
- Advanced Air Sealing Strategies

Manager/PI: B. Wolfgang

Report: A single page (front and back) builder brief for slab-on-grade insulation will be published near the end of 2021. The timing of this publication is strategic to align with the effective date of the new UCC code update in the first quarter of 2022.

The air sealing publication is being combined with a project from the 2021-2022 project plan which will focus on utilizing a detailed scope of work to ensure proper air sealing. This publication is anticipated to be published in early 2021.

E. 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
10. Strategic Partnerships

1. **Annual PHRC Housing Conference**: The PHRC will continue to organize, promote, and hold the conference. This conference has been held annually since 1992 and has established a reputation of being the premier program focusing on technical issues of housing and land development in Pennsylvania. 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 29th Annual PHRC Housing Conference was held on March 3-4, 2021 in a virtual format using Zoom for session delivery. The PHRC team developed a custom user interface that participants used to access sessions, session handouts, speaker bios, and overall event information. The event was a resounding success based on feedback from speakers, participants, and the experience of the PHRC team.

Day 1: Day 1 of the PHRC Housing Conference started off with a keynote from Ali Wolf, Chief Economist for Zonda, entitled "What to Expect From the Housing Market in 2021."

The following tracks and sessions were offered:

- Building Science & Construction
    - "Blower Door, Building Tightness, & Building Science – Pulling It All Together" by Jack Wilson
    - "Residential Ventilation for the Third Decade of the 21st Century" by Rick Karg
    - "Where Did All the Pressure Go?" by Gary Klein
- Codes & Regulations
    - "Pennsylvania UCC Review & Advisory Council Update: 2018 ICC Code Review" by Walt Schneider
    - "Basement Insulation in Existing Homes: Navigating the Options" by Brian Wolfgang & Chris Hine
    - "Lateral Load Path Basics" by Bob Kuserk
- Afternoon Plenary
    - "The House That SHE Built: A Showcase for Women in Homebuilding" by Kristi Allen, Natalie Miles, & Sandy Larsen
- The PHRC held a virtual happy hour on the evening of March 3rd. This happy hour included PHRC staff, conference speakers, and attendees and allowed for industry discussion on the day's sessions.

Day 2: Day 2 of the PHRC Conference started off with a keynote from Karen Parolek, Principal at Opticos Design, entitled "Missing Middle Housing: Thinking Big and Building Small."

- High-Performance Housing
    - "Are Healthy Homes Features the New Granite Countertop? Priority Health Upgrades & Healthy Labeling Programs" by Ellen Tohn
    - "Turning the Corner in 2021 – Building & Selling Indoor airPLUS Homes" by Nick Hurst & Paul Raymer
    - "Variable Capacity Heat Pumps for Cold Climates: Get the Basics Right & Good IAQ Will Follow" by Kimberly Llewellyn
    - "Introduction to Life Cycle Analysis for Housing" by Corey Griffin
- Land Development & Planning
    - "Restoring Hydrologic Function in Suburban Pervious Landscapes" by Stu Schwartz
    - "Land Banks' Approach to Residential Construction" by Winnie Branton, Hallie Chatfield, & An Lewis
    - "Community Land Trusts in Pennsylvania" by Ed Nusser, Anna Kochersperger, & Rachel Fawcett
    - "Elder Cottage Housing Opportunity (ECHO): An Innovative Housing Solution" by Helen Kelly & Julie Fenton

Table 4. Attendees at the Annual PHRC Housing Conference

Event	# of people
Day 1 (March 3)	69
Day 2 (March 4)	65
Student Participants	37

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. The 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 will be published in the conference proceedings.

   Report: For the 2022 RBDCC, the PHRC kicked off the Call for Submissions in spring 2020 and received 118 abstracts. The 2022 RBDCC will stay concurrent with the Annual PHRC Housing Conference – March 2-3, 2022. The two keynote speakers have also been confirmed – Dr. Wil V. Srubar III from the University of Colorado Boulder and Rusty Smith from Auburn University.

3. **PCCA Symposia:** The PHRC will work with the PCCA to develop and deliver three 1-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: Due to pandemic restrictions on in-person activities, PCCA did not host independent symposia in the East or West. PCCA did support the delivery of the virtual PHRC Housing Conference which includes the PCCA Symposium Central as a part of the conference.

4. **Speaking Engagements:** The PHRC will hold and/or participate 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 regional, state, or national conferences.

   Report: Despite the inability to host or participate in in-person activities and events, the PHRC was still able to deliver 8 speaking engagements to a total of 371 individuals.

Table 5. Speaking engagements during the 2020-2021 Project Year

Organization	Topic(s)	Date	# of Attendees
Penn State University	Construction Drawings	9/2/2020	101
Penn State University	Structural Behavior and Reinforcement Solutions for 3D-Printed Concrete Structures	9/4/2020	12
Modular Home Builders' Association	Presentation from Tony Jellen	10/9/2020	50
Penn State University	Introduction to Structural Engineering and Sustainable Building Design	11/18/2020	20
Penn State University	Introduction to the Passive House Standard	12/7/2020	101
Penn State University	Introduction to Building Science	1/29/2021	29
Keystone ASHI	A Breath of Fresh Air: Ventilation in Single-Family Homes	2/1/2021	11
Penn State University	Dive into Building Science	2/1/2021	29
Tri-State ASHI	Crawlspaces	2/9/2021	20
University of Denver	Career Panel	3/10/2021	30
	Total	**10**	**403**

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

Publications

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

Journal Papers

- Zahabi, M., Said, A., and Memari, A.M., (2021). "Cold Sintering of Calcium Carbonate for Construction Materials Application," Journal of ACS Omega, Published January 12, 2021 by American Chemical Society, 13p.; https://doi.org/10.1021/acsomega.0c04617.
- Zuabi, W. and Memari, A. M., (2021). "Review of Hempcrete as a Sustainable Building Material," International Journal of Architecture, Engineering and Construction, published January 2021; Vol. 10, No. 1, pp. 1-17, DOI: http://dx.doi.org/10.7492/IJAEC.2021.004
- Memari, A. M., Simmons, N. C., and Solnosky, R., (2021). "Unitized Curtain wall Systems Joint Performance with Re-entrant Corners under Seismic Racking Testing," Elsevier Journal of Building Engineering, Published 5/27/21; Vol. 40, August 2021, 18p. https://doi.org/10.1016/j.jobe.2021.102715.
- Amini, M. and Memari, A. M., (2021). "CFD-Based Evaluation of Elevated Coastal Residential Buildings under Hurricane Wind Loads," Published Vol. 27, No. 3, pp. 04021014-1-19. DOI: 10.1061/ (ASCE)AE.1943-5568.0000472.

- Li, Z., Hojati, M., Piasente, J., Ashrafi, N., Duarte, J. P., Nazarian, S., Bilen, S., Memari, A., and Radlinska, A. (2020). "Fresh and Hardened Properties of Extrusion-Based 3D-Printed Cementitious Materials: A Review," Published July 13, 2020, Vol. 12, No. 14, 5628, 33p. https://doi.org/10.3390/su12145628
- Amini, M. and Memari, A. M., (2020). "Review of Literature on Performance of Coastal Residential Buildings under Hurricane Conditions and Lessons Learned," ASCE Journal of Performance of Constructed Facilities, Published online August 19, 2020; Vol. 34, No. 6, pp. 04020102-1-26. DOI: 10.1061/(ASCE)CF.1943-5509.0001509; ORCID: https://orcid.org/0000-0003-1000-7129.
- Lu, X. and Memari, A. M., (2020). "Evaluation of Selected Dynamic Models in Comparison with Hot Box Test Results for Measurement of Building Envelope Thermal Properties," Published July 2020, Vol. 15, No. 2, pp. 29-43. https://doi.org/10.3992/1943-4618.15.2.29.
- Nazarian, S., Duarte, J. P., Bilén, S. G., Memari, A., Radlinska, A., Meisel, N., and Hojati, M., (2021). "Additive Manufacturing of Architectural Structures: An Interplay Between Materials, Systems, and Design," in Sustainability and Automation in Smart Constructions; Editors: Leiria, Portugal; Editors: H. Rodrigues, F. Gaspar, P. Fernandes, and A. Mateus;
- Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham., pp. 111-119, September 2020, https://doi.org/10.1007/978-3-030-35533-3_15.
- Muthumanickam, N. K., Duarte, J. P., Nazarian, S., Memari, A. M., and Bilén, S., (2021). "Combining AI and BIM in the design and construction of a Mars habitat," Chapter 13 in The Routledge Companion to Artificial Intelligence in Architecture, Editors: Imdat As and Prithwish Basu, May 5, 2021, ISBN 9780367424589.

Conferences/Meetings Attended

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

- Summer PBA Board Meetings, PHRC staff, Online, July 22-24, 2020.
- New Gravity Conference, PHRC staff, Online, August 5-7, 2020.
- 2020 Innovations in Naturally Affordable Housing Conference, Fawcett, R., Online, August 11-12, 2020.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Online, October 22, 2020.
- Fine Homebuilding Summit, PHRC staff, Online, October 26, 2020.
- Fall PBA Board Meetings, PHRC staff, Online, October 28-30, 2020.
- Housing Innovation Summit, PHRC staff, Online, November 10-11, 2020.
- Homes Within Reach, Fawcett, R., Online, January 12-14, 2021
- NAHB Student Competition, PHRC staff, Online, February 2, 2021.

- International Builders Show, PHRC staff, Online, February 9-11, 2021.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Online, February 12, 2021.
- Winter PBA Board Meetings, PHRC staff, Online, February 24-36, 2021.
- Solar Decathlon Design Challenge Student Competition, Klinetob Lowe, S., Online, April 15-17, 2021.
- Solar Decathlon Design Challenge Faculty Meeting, Klinetob Lowe, S., Online, April 15, 2021.
- Better Buildings Summit, Wolfgang, B., Online, May 17-19, 2021.
- Penn State Energy Days 2021, Klinetob Lowe, S., Online, May 19-20, 2021.
- NAHB Student Chapter Advisory Board Meeting, Wolfgang, B., Online, June 2, 2021.

Service in Professional Societies

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

Pennsylvania Committees and Organizations

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

National and International Committees and Organizations

- Memari, A.M., American Society of Civil Engineers, member.
- Memari, A.M., American Society of Civil Engineers, Editor-in-Chief, Journal of Architectural Engineering.
- Memari, A.M., American Society of Civil Engineers, Architectural Engineering Conferences, National Conference Steering Committee, member.
- Wolfgang, B., National Association of Home Builders Student Chapter Advisory Board member.

6. **Annual Magazine:** The PHRC Annual Magazine was sent electronically to PHRC members and stakeholders to keep them updated on recent PHRC activities and to promote upcoming events. For the 2020-2021 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 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. The PHRC also prioritizes gender equity in the residential construction industry through involvement with the NAHB Professional Women in Building (PWB) activities and initiatives. This project includes relationship building, sharing of resources, speaking at school events, leveraging resources and contacts to bring opportunities to students, and soliciting 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 Housing Conference, PCCA Symposia, and PHRC webinars.

   Report: The PHRC Construction Summit was launched in December 2020 and sought to bring together students, educators, and industry experts. Additionally, PHRC staff are 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.

   Report: Throughout 2020-2021, including the RAC code review process, PHRC staff attended each RAC meeting via Zoom.

9. **Support of Standards:** The PHRC has developed 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. All these standards are available electronically for free. Education on these standards will continue to be provided through various training programs as requested and technical assistance will be provided through telephone and email support by the PHRC.

   Report: PHRC staff fielded numerous inquiries via email and telephone regarding the PA Alternative Residential Energy Provisions.

10. **Strategic Partnerships:** The PHRC will continue to seek out new relationships and partnerships with peer organizations with activity in the residential construction industry. These partnerships are leveraged for the benefit of the PHRC audience and stakeholders. PHRC staff time will continue to be allocated in support of this overall initiative.

    Report: PHRC staff continued to work with critical partners and stakeholders, especially as pandemic-related challenges confronted the homebuilding industry. These partnerships allowed for an expanded reach with marketing programs, the PHRC Housing Conference, and awareness of the PHRC overall.

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. Cross Laminated Timber Home Design

Description: There is a growing interest in the use of Cross Laminated Timber for multistory building construction. According to a 2018 Zion Market Research report, the demand for CLT in 2017 was $130M and the overall growth is estimated to be 15% per year until 2024. Besides all advantages of prefabrication (e.g., factory environment quality, quick job site assembly), CLT is also favored because of being a low carbon, renewable, and cost effective construction material that can be produced in the USA, helping job growth in rural timber rich areas. Aside from such advantages, CLT has proven to perform well under fire (acceptable fire resistance rating) due to 1) its panel nature and compartmentalization, which reduces the risk of fire spread (separating function) and 2) the formation of char that allows the major part of the member to continue carry loads. This makes CLT suitable for single-family home building as well as the currently favored multi-family construction. However, at this time, there is a shortage of design examples for single-family CLT homes. This project will undertake a complete structural design (e.g., gravity, snow, wind) of a CLT home for PA as well as developing practical wall and roof details for acceptable energy performance and moisture management. The project will also provide a cost comparison with a conventionally designed wood-frame example. The results will be presented as a conference paper and/or a more extended report.

Manager/PI: Dr. Ali Memari

Report: The project is nearly completed with all the structural calculations completed and all the drawings prepared. Currently, the final report is being drafted. The project has been successful in developing a unique set of calculations using Tekla Tedds structural analysis software considering all applicable loads based on ASCE7. RISA-3D software in addition to WoodWorks Sizer software have been used to design CLT members and connections of different panel types (walls, floor, roof), as well as the foundation design. The full report will be available as a PHRC report, while shorter versions will be developed as publications. The report will provide an example for designing typical CLT homes.

IV. Applied Projects

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

1. Training for Secondary and CTC Instructors

Description: The PHRC has pursued an initiative for the past few years that involved outreach to the "next generation" of the residential construction industry. This outreach included interaction with secondary instructors at Pennsylvania schools and career and technology centers. Some feedback during this outreach was that many of the instructors themselves need training. This project would focus on obtaining approval to provide continuing education to secondary instructors through the PA Department of Education. This would also open the potential to hold a standalone event in future years catered to secondary instructors and their need for professional development. Note: this project began in the 2019-2020 project year and is ongoing.

Manager/PI: B. Wolfgang

Report: The PHRC launched an inaugural event on December 10, 2020 titled the PHRC Construction Summit. This event was intended to bring together secondary students, post-secondary students, educators, and industry experts through six in-depth sessions (list of sessions shown below). The PHRC team developed the user interface from scratch and utilized Zoom for session delivery.

- Keynote, The Future of Work: What Can We Do About the Construction Skilled Labor Shortage?, by Tadar Muhammad
- Wall Water Management by Doug Horgan
- Systematic Approach to Jobsite Health & Safety by Bryan Seal
- Framing for Success by Bob Kuserk
- Building Code Knowledge: Is It in Your "Toolbox"? by Shawn Strausbaugh
- A Breath of Fresh Air: Ventilation in New Single-Family Homes by Brian Wolfgang

A total of 159 individuals participated in the PHRC Construction Summit, including 14 instructors and 97 students.

2. A Deeper Dive into Mechanical Ventilation

Description: This applied project will take whole-house mechanical ventilation a step beyond standard code compliance. We will look at the performance characteristics of each method and look into hybrid, high performance ventilation strategies. Note: this project began in the 2019-2020 project year and is ongoing.

Manager/PI: C. Hine

Report: This project resulted in a special conference session at the 29th Annual PHRC Housing Conference, delivered by Rick Karg. Additionally, a builder brief that focuses on mechanical

ventilation will be published toward the end of 2021. The timeline is intentional to align with the PA UCC code update that will become effective in the first quarter of 2022.

3. Energy Retrofits

Description: Nearly 80% of Pennsylvania's existing housing stock was built before modern building codes, resulting in higher than necessary energy bills and occupant comfort issues. This project focuses on studying the potential impacts and challenges associated with energy retrofits through local case studies. Data extracted through this project will lead to future webinars and conference presentations. Note: this project began in the 2019-2020 project year and is ongoing.

Manager/PI: S. Klinetob Lowe

Report: The PHRC wrote a successfully funded external grant to support this project. Together with several affordable housing partners, the Energy+ initiative is systematically addressing residential energy efficiency towards "permanent affordability" of existing affordable housing in State College, PA. Program goals include lessening residents' energy burdens, reducing the environmental impact of the affordable housing stock, and enhancing public investment in housing affordability. Due to the COVID-19 pandemic, the grant timeline was officially extended by one calendar year and will be completed by April 2022.

4. Deck Flashing Lab Testing

Description: The vision for the deck flashing project takes us into the labs. The goal is to use the spray rack which will apply water to different deck ledger installations. We will then monitor moisture accumulation in various materials and address how each configuration performed.

Manager/PI: C. Hine

Report: Due to limitations on in-person activities, specifically work in a laboratory setting, this project has been tabled and can be revisited in future project years as appropriate.

5. Slab-on-Grade Insulation Details

Description: Slab on grade foundation systems present unique challenges when designing the building envelope and the thermal control layer. Insulation detailing at the slab edge can present design and constructability challenges that extend beyond minimum code.

Manager/PI: B. Wolfgang

Report: A single page (front and back) builder brief for slab-on-grade insulation will be publish near the end of 2021. The timing of this publication is strategic to align with the effective date of the new UCC code update in the first quarter of 2022.

6. Advanced Air Sealing Details

Description: This project would be developed in conjunction with the air sealing webinar. Details developed for the webinar will be compiled and added into the Details that Work guide.

Manager/PI: C. Hine

Report: The air sealing publication is being combined with a project from the 2021-2022 project plan which will focus on utilizing a detailed scope of work to ensure proper air sealing. This publication is anticipated to be published in early 2021.

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 2020-2021 project year. Several other smaller proposals were also submitted, and some are under review/negotiation but those are not reported here.

The following research proposals were submitted during this reporting period:

- Date: June 2020-December 2021
  Title: PA Hemp Home
  Sponsor: DON Services funded by PA Department of Agriculture, Commonwealth Specialty Crop Program
  Amount: PSU share $39,000 [funded]
  (PI: Memari; Co-PIs: Corey Griffin, Hojae Yi)

- Date: November 2020-March 2021
  Title: Building Enclosure Performance Training Development for Pennsylvania Contractors
  Sponsor: Pennsylvania College of Technology
  Amount: $10,500 [funded]
  (PI: Brian Wolfgang, Co-PI: Christopher Hine)

- Date: February 2021-May 2022
  Title: "Analyses of concrete samples with ingredients and engineering analysis of concrete 3D printed box shaped housing structure"
  Sponsor: Alaska Housing Finance Corporation via Xtreme Habitat Institute
  Amount: $54,000 [funded]
  (PI: Memari, Co-PIs: Jose Duarte, Shadi Nazarian, Ming Xiao, Nathan Brown, Aleksandra Radlinska, Sven Bilen)

- Date: August 2021-July 2022
  Title: "An Open-Source Design and Build-It-Together Sustainable Housing System"
  Sponsor: Pennsylvania State University – Department of Architecture, Stuckeman Center for Design Computing
  Amount: $6,000 [funded]
  (Co-PI: Memari, PI: Benay Gursoy)

- Date: June 2021-May 2022
  Title: "Framework for Application of Machine Learning in Multi-Objective Design Optimization of Coastal Residential Buildings Under Multiple Natural Hazards"
  Sponsor: Institute for Computational and Data Sciences Seed Grant
  2021-22
  Amount: $25,000 [funded]
  (PI: Memari, Co-PI: Nathan Brown)

- Date: May 2021-August 2022
  Title: "Enhancing Hempcrete for Structural Strength Properties"

Sponsor: PA Department of Community and Economic Development
Manufacturing PA Innovation Program
Amount: $70,000 (sponsor) + $82,094 (Cost Share)
(PI: Memari, Co-PI: Corey Griffin; Industry Partner: Coexist LLC)

- Date: June 2021-December 2022
  Title: "Next Generation Bio-based Materials for Living Homes"
  Sponsor: Pennsylvania State University and University of Freiburg
  Amount: $100,000 (50% PSU, 50% UF)
  (PSU: PI: Memari, Co-PI: Corey Griffin; Hojae Yi;) (UF: Co-PI: Marie-Pierre Laborie)

- Date: July 2021-June 2024
  Title: "Developing low-cost and low-technology seismic isolation system for implementation in elevated residential buildings in Puerto Rico"
  Sponsor: National Science Foundation
  Amount: $400,000
  (PI: Memari; Co-PI: Kostas Papakonstantinou)

- Date: 2021-2022
  Title: Incorporation of Machine Learning AI Tools to Advance Automated Robotic Additive Construction of Concrete Structures on Earth and Beyond
  Sponsor: Advanced Robotics for Manufacturing (ARM) Institute
  Amount: $1000,000 (50% cost share)
  (PI) (Collaborating institutes: Xtreme Habitats Inst. (XHI), Inst. For Human Machine Cognition (IHMC), Big Sun Holding-Black Buffalo (BSH-BB)

- Date: June 2021-December 2022
  Title: "Industrial Hemp Value Added Sustainable Building Products and Systems"
  Sponsor: US Department of Agriculture
  Amount: $10,000,000
  (Candidate's share of funding – 10%)
  (PSU: Co-PI: Memari, PI: Jude Liu; Other Co-PIs: Corey Griffin, Hojae Yi, Jeff Catchmark, Stephen Chmely, Dan Ciolkosz, Christine Costello, Long He, Juliana Vasco-Correa, Brittany Clark, Miranda Harple, Carla Snyder, Terrence Bell, Alyssa Collins, Paul Esker, Louis Bengyella, Carolyn Lowry, Michael Hamel)

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 to complete its annual project load.

Prior to October 25, 2018, 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 to DCED.

Beginning on October 25, 2018, Act 36 of 2017 amended building permit fees to be $4.50 with PHRC being allocated 43.5% of the collected permit fee minus a 3% administrative fee to DCED. As of April 2020, DCED changed their fee collection process to only accept online payments by credit card or check for UCC permit fees, which allows for more expedient reporting to the PHRC.

Funds for the 2020-2021 Project Year are based upon funds received from July 2019 through June 2020, which can be seen in Table 6 below.

Table 6. Summary of Act 157 Funds received during the 2019-2020 FY (2020-2021 PHRC Project Year)

Collection Period	Amount Received
Q3: July 2019 - September 2020	$114,084.09
Q4 October 2019 - December 2020	$174,422.51
Q1: January 2020 - March 2021	$133,211.32
Q2: April 2020 - June 2021	$44,341.86
Total	**$466,059.78**

Expenses for the Act 157 Account ($378,324.32) were less than the revenues ($466,059.78) for the 2020-2021 project year. The PHRC began to limit spending and travelled less beginning in March 2020 due to the COVID-19 pandemic. Unsure of the long-term effects of the pandemic on the residential construction industry in Pennsylvania, the PHRC will continue to be fiscally conservative. Table 7 shows a breakdown of PHRC expenses for the 2020-2021 Project Year allocated to the Act 157 Account.

Table 7. PHRC Expenses for the 2020-2021 PHRC Project Year

Category	Act 157
Total Salaries	$268,383.00
Total Wages	$0.00
Total Student Wages	$817.53
Fringe Benefits	$93,772.17
Supplies and Materials	$119.88
Communications Services	$488.81
Travel	$0.00
Publications	$0.00
Maintenance	$0.00
Consulting & Prof Svc	$10,960.00
Copies and Photographic Services	$232.78
Computer Services	$99.00
Purchased Services	$117.70
Equipment	$546.46
Computer Equipment	$351.99
Miscellaneous	$2,435.00
Total	**$378,324.32**