Narrative Final Report (Attachment E Part 3)
NCPTT 2016 Grants

Navajo Nation 'Train-the-Trainers' Traditional Hogan Retrofits and Manual Development

Prepared for: National Park Service - National Center for Preservation Technology and Training

Grant Number: P16AP00190

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September 15, 2017

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Executive Summary

iCATIS, The Forgotten People, and Purpose Focused have partnered to develop energy efficient techniques and training methods to preserve and retrofit existing traditional Navajo Hogans. Hogan retrofits centered on preservation of historic building integrity, while also increased building longevity and occupant comfort. The project developed a low-cost approach to evaluating building health, while prioritized and installed retrofit improvements to preserve Navajo Hogans. Critical to project success was development of community interaction and establishing a 'train-the-trainers' model, where two Navajo business leaders were trained to perform building assessments and install prioritized weatherization improvements. These business leaders can now direct future training and installation throughout the Navajo Nation.

iCATIS led energy audit and building health evaluations of four traditional Navajo Hogans and developed a prioritized list of critical retrofits. Hogans were evaluated for deficiencies using:

a) energy audit and building envelope evaluation techniques that include blower door tests, infrared cameras, temperature data loggers, thermocouples, and site weather data, and

b) air and water tightness testing and inspection using smoke pens to identify rim joist, windows, doors, seals, combustible exhaust, roof, envelope penetrations, and exterior/interior envelope leaks.

Air sampling assessments evaluated improvements by measuring carbon monoxide, particulate matter, and radon to determine ventilation and exhaust needs and/or grade isolation improvements.

Following, our team led instruction of two training workshops for the Navajo business leaders: 1) Hogan Envelope, Insulation, and Ventilation 'Best Practices' and 2) Solar Thermal Collector Refurbishing and Installation. Next, our team, including trained business leaders continued installation of weatherization and solar collector improvements at these four Hogans. Lessons learned were incorporated into a fifth 'model' Hogan, where trained business leaders taught two additional, identical training workshops for Navajo community members and volunteer group attendees. Improvements focused first on improving combustible exhaust, heating/ventilation, infiltration losses, and insulation, respectively. Installed improvements include chimney pipe and flashing, envelope seals, natural ventilation, solar thermal collectors, solar photovoltaic systems (powering collector blowers and basic lighting), foam insulation leak sealing, door/window seals/replacement, vapor/moisture barriers, and ceiling/wall insulation.

Two workshop training manuals are being finalized to further optimize and prioritize preservation, weatherization, and solar thermal collector improvements. The final training manuals will detail low-cost energy audit, building envelope, infiltration, ventilation, and building health evaluation techniques that utilize simplified tooling, best practices for prioritizing preservation and retrofit improvements, and guidance on solar collector refurbishment and installation. Manuals will be available for interested community members and available at: www.icatis.org

Introduction

Project Background

The International Centers for Appropriate Technology and Indigenous Sustainability – iCATIS – have partnered with the Forgotten People and Purpose Focused to develop innovative training manuals and workshops to provide low cost retrofits at existing traditional Hogans in the Navajo Nation. Framed by the Bennett Freeze paradigm – a 43 year U.S. government imposed construction hold encompassing 2 million acres of the Navajo and Hopi Nations – this congressional act denied infrastructure to fix homes, build new homes, and build drinking water systems.[1] The recent overturning of the 1966 Bennett Freeze Act has left 10 Navajo chapters with dilapidated living structures, but with freedom to now develop a holistic sustainability plan to address basic infrastructure needs of the Navajo people. Many Navajo elders continue to live in these dilapidated structures and are exposed to unbelievable living conditions that threaten their health and well-being.

In 2013, iCATIS conducted an assessment of living structures throughout the Navajo Nation. Over half of the homes throughout the Bennett Freeze area lack adequate infrastructure, including no piped water or electricity, poorly ventilated cooking and heating stoves, large open holes in the building envelope, inadequate or no building insulation, and extreme temperature swings from freezing temperatures in the winter to nearly unbearable heat in the summer.[2] During this time, Navajo chapters and community groups received over 200 used solar thermal collectors and developed initial trainings to install these solar collectors in Navajo homes (Figure 1). The Forgotten People received 50 solar collectors and has been developing a holistic plan to not only install the solar collectors, but also to address

Figure 1: Navajo Nation Solar Thermal Collector Installation Workshop

inadequate building envelope, insulation, and ventilation within traditional Navajo Nation Hogans.

In 2014, the Forgotten People, Purpose Focused, and iCATIS partnered to develop the Indigenous Holistic Sustainable Community Development (IHSCD) task force. IHSCD is a group of regional experts addressing Navajo Nation infrastructure gaps that will improve living conditions through strategic educational and vocational trainings that lead to self-sustainability, business creation, and local economy improvements. One of the goals of the IHSCD task force is to develop a Hogan retrofit educational and training focus group within the Navajo Nation.

Included in the IHSCD's sustainable vision is preservation of existing, traditional Hogan structures, but retrofitting them to be energy efficient, safe living spaces (Figure 2). Hogans often have high infiltrative heat losses (Figure 2, middle right), inadequate stove ventilation, and lack a sustainable way to heat their homes.

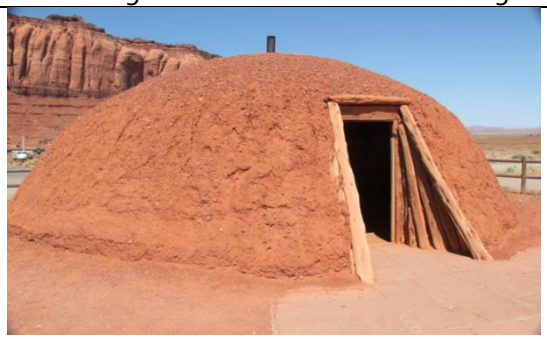
Navajo Nation traditional Hogan structure

North facing Hogan view

Modernized Hogan, no insulation

Visible large infiltrative holes inside a Hogan

Internal Hogan view: no insulation and modernized framed roof



Navajo Hogan with mud-filled walls

Photo courtesy of Bob and Karen K.

Figure 2: Different Views of Navajo Nation Traditional Hogan Living Structures

Project Approach and Goals

Our team has conducted Hogan building energy audits to evaluate retrofits needed. We used common energy audit techniques, including blower door tests, infrared thermal imaging, indoor temperatures, and indoor air quality monitoring to identify the required retrofits to each Hogan. Following, iCATIS led two instructional and training workshops to train a Navajo team to install retrofit improvements at four existing Hogans. These two training workshops include:

- **Workshop 1: Hogan envelope, insulation, and ventilation 'best practices' training workshop** – Best practice techniques were taught to seal the Hogan building envelope

to stop infiltrative losses, provide additional insulation including low cost earthen berms, and improve stove ventilation to ensure adequate indoor air quality.

- **Workshop 2: Solar thermal collector refurbishing and installation training workshop** – iCATIS led additional installation training for the unused solar thermal collectors already in possession of the Forgotten People. This included refurbishing old solar collectors with new insulation and seals, while also installing fan-assisted solar thermal collectors external and adjacent to the Hogan. The only change to the Hogan was the ductwork penetrating into the Hogan, thus preserving the historic integrity of the building.

Following workshop training and installation of the retrofits at four Hogans, our team compared pre- and post-retrofit conditions evaluated the best performing retrofits, based on cost and performance, and integrated results and instructions into two 'how-to' draft training manuals:

- Hogan Envelope, Insulation, and Ventilation Best Practices
- Solar Thermal Collector Refurbishing and Installation

Next, we repeated the previous two workshops, this time instruction was led by our trained Navajo Hogan retrofit team:

- Workshop 3: Hogan envelope, insulation, and ventilation 'best practices' training workshop
- Workshop 4: Solar thermal collector refurbishing and installation training workshop

Workshops 3 and 4 installed the best performing and least cost retrofits into a fifth 'model Hogan.' Navajo instruction was supervised and critiqued by our project team, and improvements were integrated into nearly final versions of the two training manuals.

Overall, our project has established a pathway to collect much needed low cost Hogan retrofit data, implement energy efficient technologies that improved living conditions, while also ensuring preservation of traditional Hogans. In addition, our project has developed a 'train the trainers' pathway, so that the Navajo people can implement a long-term plan for Hogan retrofit expansion throughout the Navajo Nation.

Project Tasks and Deliverables

The project tasks and deliverables are detailed in Table 1, including community educational and training workshops, how-to manuals, and final reports. In Phase 1, our team conducted Hogan building energy audits to best optimize Hogan retrofits.

Table 1: Project Tasks

• Phase 1: Site Surveys and Pre-Retrofit Data Collection
○ Chapter House and stakeholder community meetings
○ Pre-retrofit energy audits and site assessments
○ Anticipated Retrofits and Benefits Report and Flyers
• Phase 2: Training Workshops at Four Existing Hogans
○ Workshop 1: Hogan envelope, insulation, and ventilation 'best practices' training workshop
○ Workshop 2: Solar thermal collector refurbishing and installation training workshop
• Phase 3: Post-Retrofit Data Collection and Manual Drafts
○ Post-retrofit energy audits and data collection
○ Draft manual creation for two workshop themes
• Phase 4: Model Hogan Retrofit, Navajo Led Workshops, and Manual Dissemination
○ Workshop 3: Hogan envelope, insulation, and ventilation 'best practices' training workshop
○ Workshop 4: Solar thermal collector refurbishing and installation training workshop
○ Finalize two manuals and make available at iCATIS website: a) Hogan Envelope, Insulation, and Ventilation Best Practices, and b) Solar Thermal Collector Refurbishing and Installation
○ Final Summary Report

Appendix 1 is intended to function as a stand-alone document – **Deliverable 1: Anticipated Retrofits and Benefits Report,** which summarizes the completion of Phase 1. Deliverable 1 will be available to the Navajo community and includes:

- Energy audit results at the four Hogans,
- Lists of the retrofits needed at each of the four Hogans, and
- Anticipated benefits of these retrofits.

Next, iCATIS led two 'train the trainers' workshops and installed retrofits at four existing Hogans. We then composed two draft manuals: a) Envelope, Insulation, and Ventilation Best Practices, b) Solar Thermal Collector Refurbishing and Installation. Training manuals document:

- Pre-retrofit performance data for each Hogan,
- Summary of the best performing and recommended retrofits for Hogans,
- Retrofit details of how-to install, costs, suppliers, and sources for additional information,
- Contact details of the trained Navajo Hogan retrofit team.

Following, we supervised Navajo led instruction and installation of the best performing retrofits at a fifth 'model Hogan retrofit.'

Because the pre-retrofit energy audit was completed in late winter, 2017, our team has determined that delaying the post-retrofit energy audit until late fall/early winter, 2017 will maximize the usefulness of these data comparisons. This approach will allow our team to compare pre- and post-retrofit energy audit data 'apples-to-apples.' Our team has requested and obtained approval from the NPS for this modification to the project schedule. Once the post-retrofit energy audit is complete, Deliverables 1 (above) and 2 (below) will be updated, resubmitted as final versions to the NPS, and made available to the trained retrofit leads and the Navajo community.

Deliverable 2: Two Training Manuals [Envelope, Insulation, and Ventilation Best Practices; Solar Thermal Collector Refurbishing and Installation] are enclosed as Appendices 2 and 3 in this report and also as a stand-alone document. These draft manuals will be finalized following completion of the post-retrofit energy audit and resubmitted to the NPS, as detailed above. Final manuals will be at www.icatis.org and made available to the Navajo community.

All findings and summarized approaches are detailed in this report, **Deliverable 3: Narrative Final Report - Navajo Nation 'Train-the-Trainers' Traditional Hogan Retrofits and Manual Development**, which will be available to the Navajo Nation and to the public at www.icatis.org. This report summarize all phases of the project, including but not limited to work performed, project effectiveness and success, results, pre- and post-retrofit performance, training manuals, community outreach event findings, expansion of Hogan retrofits throughout the Navajo Nation, and further retrofit expansion to other historical and traditional structures. Project expenses are summarized in a separate report entitled Administrative Summary.

Methods and Materials

Technical Soundness of Proposed Methods

All methods utilized industry standards for energy audits and weatherization and solar thermal collector improvements and are well documented by the building and historic preservation communities. All retrofits had minimal impact to the look and feel of these historic and culturally significant buildings. Regarding the retrofit workshop, infiltrative losses, insulation, and improved stove ventilation are standard practices to improve indoor comfort and air quality, while reducing energy consumption.[3] Standard energy audit approaches will quantify the best performing retrofits. Pre-/post-retrofit energy audits have/will use common practice blower door tests, infrared cameras, data logging thermocouples, and air velocity/flowrate meters.[4]

Solar thermal collectors are a well-established technology that has minimal impact on the preservation of the existing structure. When adequately sized, solar thermal collectors can offset up to 50% of typical household heating requirements.[5] Because of a one year project timeline, it is not possible to collect heat and energy savings to compare to the baseline year. Consequently, our trained business leads plan to continue to track solar collector energy savings for years to come, and compare post-retrofit performance to pre-retrofit performance to determine energy savings after completion of this project. Our trained business leads aim to continue data collection and to optimize approaches well beyond the completion of this project.

Methods and Materials Used

Hogan Energy Audits and Indoor Air Quality Assessments

Hogan energy audit and building health evaluations began with iCATIS led assessments of four traditional Navajo Hogans. Hogans were evaluated for deficiencies using:

a) energy audit and building envelope evaluation techniques that include blower door tests, infrared cameras, temperature data loggers, thermocouples, and site weather data, and

b) air and water tightness testing and inspection using smoke pens to identify rim joist, windows, doors, seals, combustible exhaust, roof, envelope penetrations, and exterior/interior envelope leaks.

Air sampling assessments evaluated improvements by measuring carbon monoxide, particulate matter, and radon before and after weatherization improvements. When initial carbon monoxide and particulate matter readings were high relative to the local atmosphere, retrofits focused on improving stove and combustion source exhausting and ventilation. When radon readings were high relative to the local atmosphere, retrofits focused on improved ventilation and proposed future improvements in the indoor flooring that isolated the floor from the surrounding soils, such as installing a concrete slab or wood floors.

The Hogan energy audit and indoor air quality assessment results are detailed in Appendix 1: Hogan Anticipated Retrofits and Benefits (i.e., Deliverable 1). Appendix 1 is intended to function as a stand-alone document that covers: a) the materials used and the methods used for Hogan energy audits and indoor air quality assessments, b) details the results of the pre- and post-weatherization energy audits, and c) summarizes the anticipated retrofits to be installed at each Hogan and anticipated benefits at each Hogan.

Solar Thermal Collectors

Solar thermal collectors collect the sun's rays and trap them inside the collector, much like a greenhouse. When connected to a blower and ducting, air flows through the solar collector from the outside, flows through the collector and heats up, and then this hot air is blown into a home or Hogan. When properly designed, solar collectors can significantly reduce the amount of supplemental heat needed for a home or Hogan. The Navajo Nation has nearly 200 solar collectors, and nearly 50 of these are under the care and responsibility of The Forgotten People for future installation into Navajo homes and Hogans.

Nine solar collectors were refurbished during Workshops 1 and 3 of this project for future installation at Navajo Hogans. The specifications for these solar collectors can be found in Appendix 2: Solar Thermal Collector Refurbishing and Installation.

Each solar collector was refurbished with new insulation, seals, and mounted with heat sensors (i.e., snap discs) and blowers. The solar collectors were then mounted to exterior wooden frames that are independent of the Hogan structure. Ducting and electrical wiring were connected from the solar collector to the Hogan and then to a thermostat inside of the Hogan. Appendix 2 details the materials and methods used to refurbish the solar collectors and install the collectors at Hogans.

Results and Discussion

Appendix 1 details the Anticipated Retrofits and Benefits for each of the five Hogans assessed during this project. Appendix 2 details the Solar Thermal Collector Refurbishing and Installation process and provides detailed step-by-step instructions. Appendix 3 details all weatherization improvements installed at the five Hogans and summarizes Hogan Envelope, Insulation, and Ventilation Best Practices.

During the project, our team got additional support from a Pittsburgh non-profit, called Amizade, who provided many volunteers that attended training workshops and assisted field installation efforts for solar collectors and weatherization improvements. iCATIS and our team are shown in Figure 3.

Hogan owner names and longitude and latitude were omitted from the following results to protect the identity of the participants.

Figure 3: iCATIS and the Amizade Team at Hogan 1

Retrofits Installed at the Four Hogans

Hogan 1: Family Residence

Hogan 1 was located at a family residence. Tremendous infiltration occurred both through the exterior and interior building envelope, and most noticeably where the heating stove chimney pipe exited through the Hogan roof. Daylight was visible through multiple locations within the Hogan.

To remedy, our team began by spraying expandable liquid foam insulation into envelope holes, noted during the initial energy audit. This included holes from cable line access and where the roof rafters met the vertical walls. Next, our team caulked the spacing between all logs used to make up the vertical walls, both on the interior and exterior. Next, we caulked and sealed all windows and door. Following, we installed ceiling insulation and overlaid the insulation with Tyvek building wrap as an additional infiltrative barrier. Homeowners plan to add stucco or drywall to preserve the internal historic integrity of the Hogan. To remedy the excessive infiltrative losses surrounding where the stove pipe exited the Hogan, new stove chimney pipe was installed, including triple wall insulated stove pipe and interior and exterior flashing (Figure 4). Lastly, the stove chimney continued over three feet above the highest nearby roof surface and a spark arrestor was installed. As a final measure, a solar thermal collector was installed to provide a supplemental heat source (Figure 4).

Figure 4: Hogan 1 Solar Thermal Collector (Left) and Stove Chimney Exhaust, Insulation, Tyvek Weatherization (Right)

Hogan 2: Family Residence

Hogan 2 was located at a family residence (Figure 5). Similar to Hogan 1, tremendous infiltration occurred both through the exterior and interior building envelope. Hogan 2 also had large missing interior walls and large cracks and broken windows. Daylight was visible through multiple locations within the Hogan.

Figure 5: Hogan 2 – Family Residence

Our team began with spraying expandable liquid foam insulation to locations noted during the initial energy audit, including spraying foam insulation into envelope holes, cracks in the plaster, and along where the roof rafters met the vertical walls. We also noted significant infiltration surrounding the window frame and consequently, sprayed liquid foam insulation there as well. We also added clear plastic infiltration barriers to any window with cracks. Next, our team caulked along all windows and doors, along gaps where the vertical walls met the

roof rafters and along any other noticeable joints, both on the interior and exterior. Following, we installed plywood and framing over the large hole of the original door frame and on multiple large holes near the main entrance. As a final measure, a solar thermal collector was installed to provide a supplemental heat source (Figure 6).

Figure 6: Hogan 2 Solar Thermal Collector

Hogan 3: Family Residence

Hogan 3 was located at a family residence. Tremendous infiltration occurred where the heating stove chimney pipe penetrated through the Hogan roof. Additional infiltration was noted in some exterior and interior locations along the building envelope and where roof rafters met the vertical wall, where daylight was visible. Hogan 3 also had cracked and broken windows.

Weatherization improvements began with using spray expandable liquid foam insulation along exterior roof rafters, along with caulking interior and exterior cracks as well as surrounding windows and doors. We also added clear plastic infiltration barriers to any window with cracks. Like Hogan 1, to remedy the excessive infiltrative losses surrounding where the stove pipe exited the Hogan, new stove chimney pipe was installed, including triple wall insulated stove pipe and interior and exterior flashing. Lastly, the stove chimney continued over three feet above the highest nearby roof surface and a spark arrestor was installed. As a final measure, a

solar thermal collector was installed to provide a supplemental heat source. Figure 7 shows the Amizade volunteer support team during the installation of the solar collector wooden frame.

Figure 7: Amizade Team During Installation of Solar Collector Frame at Hogan 3

Hogan 4: Family Residence

Hogan 4 was located at a family residence. Significant infiltration was noted in some exterior and interior locations along the building envelope and where roof rafters met the vertical wall, where daylight was visible. Overall, Hogan 4 was in fairly good shape, with insulation already existing in ceilings and exterior walls. While cracking of the exterior stucco is visible (Figure 8), no cracking penetrated through the exterior building envelope. The Hogan 4 family was advised to monitor the exterior stucco and recoat the stucco when cracking penetrates through the exterior building envelope.

Weatherization efforts began by using spray expandable liquid foam insulation along roof rafter gaps and caulking interior and exterior gaps, windows, and doors. As a final measure, a solar thermal collector was installed to provide a supplemental heat source (Figure 8). Because of the remoteness of Hogan 4, the Hogan does not have grid supplied electricity. Consequently, to power the blower in the solar collector, a solar photovoltaic (PV) system was installed. The PV system provides battery backup to run the solar collector blower during cloudy and overcast conditions, as well as after the sun goes down when still some stored heat

remains in the collector. In addition, the PV system also provides power for basic household lighting.

Figure 8: Hogan 4 Solar Thermal Collector and Solar Photovoltaic Systems

Lessons Learned

Many lessons were learned after completion of the solar collector and weatherization improvements at the first four Hogans. These lessons learned include:

- Execute a signed agreement with the home owners well in advance of site work, which includes agreed schedules for work completion.
    - Although this was developed in advance, improved follow up is necessary to ensure scheduling changes haven't occurred. Because of home owners at Hogan 3 and despite multiple iCATIS visits to Hogan 3, we were not able to complete all of the site assessment data collection at Hogan 3, including the energy audit and indoor air quality measurements.
- Complex energy audits are far too complex and time consuming for practical replication on a low cost budget
    - As a result, a simplified blower door testing procedure was developed that uses a box fan and creates a door seal with low cost plastic sheeting
- Smoke pens and puffer air flow indicators were used to identify infiltrative leaks during blower door testing.
    - Navajos did not appreciate the chemicals used in the smoke pens and the puffer air flow indicator.

- As a result, sage smudge incense sticks (smudge sticks) were used to identify infiltrative leaks. Smudge sticks are more culturally appropriate, as smudge sticks are used during ceremonial practices and are part of a 'cleansing' process for the Hogan.

- Hogans with clay floors should cover all furniture with plastic before blower door testing
- Local chimney kits are sold seasonally.
  - Business leads are being advised of on-line purchasing options, which are sold year round and often at discounted prices
- A generator is required for business leads for future site assessments and retrofits
- A very detailed description of payment terms and processing times is required well in advance with all stakeholders involved.
  - While our team did utilize payment agreements that detailed typical payment processing time periods, Navajo community members are used to very short turnaround times of one to two weeks for payments. More typical in the consulting world is net payment in 30 to 45 days.
- Small amounts of rain prevents access to remote Hogans.
  - Future project planning must schedule backup days for potential rain-outs at remote sites. Coordination of project work at non-remote sites to fill in for rainy days is critical for maximizing staff utilization and billability
- To maximize the effectiveness of volunteers, upfront training and capability assessments are critical, along with upfront planning of tasks that can split volunteers into different teams to maximize their skillsets.
- Site assessments must consider the need for structural and roof assessment experts to assist evaluation. Some Hogan improvements cannot proceed until this is address, such as the weatherization improvements to the roof of Hogan 5 and an additionally evaluated Hogan that was not part of the 5 Hogans evaluated in this report.
- The most critical lesson learned, which may be refined following our post-weatherization energy audit data analyses, is the estimated quantity of solar collectors needed per Hogan. Our current projections are based off of the floor area of each Hogan, as detailed in Table 2.
  - Because of this refinement, Hogan 5 utilized two solar thermal collectors.
  - Hogans 1 through 4 could be fitted with an additional solar collector with fairly minimal additional cost, aside from staff labor and collector refurbishing costs.

Table 2: Quantity of Solar Collectors for Various Floor Areas

Maximum Floor Area	Quantity of Solar Collectors Needed
325 ft^2	1
650 ft^2	2
975 ft^2	3

Model Hogan Retrofits Installed

Hogan 5: Grey Hills Academy High School

Hogan 5 was located at the Grey Hills Academy High School (GHAHS). This Hogan was chosen to be the model Hogan because the Hogan itself was in very good initial condition and because of its location it naturally will lead to significant public exposure and educational tours. This Hogan had exemplary window and door seals, chimney exhaust and no visible cracking of the exterior and interior envelopes. Further, this Hogan had extremely low leakage during the blower door energy audit testing. Consequently, there were no visible signs for weatherization improvements, except for the need for ceiling insulation. Because of the need to replace the roof shingles and some roofing boards, GHAHS and the business leads will integrate future roof replacement and insulation into a future course project. Hogan 5 did need an alternate heat source and as a result, solar thermal collectors were installed. Because the floor area exceeded 300 ft^2, two solar thermal collectors were needed (Figure 9). In order to protect the solar collector when not in use, and to keep the solar collector from overheating in the summer months, our team also built a cover that is placed over the glass of the solar collector when not in use.

Figure 9: Model Hogan 5 Solar Thermal Collectors (Top) and the Amizade Team (Bottom)

Conclusions

All project tasks and goals proposed to the NPS NCPTT were completed; the only exception is the final post-weatherization energy audits will be completed in late Fall/early Winter, as previously discussed, to ensure comparison of similar seasonal data and to draw the most

meaningful conclusions. Once post-weatherization energy audits are completed, Appendices 1, 2, and 3 will be updated to incorporate these data.

Our team has completed the proposed four workshops, trained Navajo retrofit business leads to achieve expert-level proficiency, and installed weatherization and solar collector improvements at five Navajo Hogans. Improvements focused first on improving combustible exhaust, heating/ventilation, infiltration losses, and insulation, respectively. Installed improvements include chimney pipe and flashing, envelope seals, natural ventilation, solar thermal collectors, solar photovoltaic systems (powering collector blowers and basic lighting), foam insulation leak sealing, door/window seals/replacement, vapor/moisture barriers, and ceiling/wall insulation.

Appendices 1, 2, and 3 are being finalized to further optimize and prioritize preservation, weatherization, and solar thermal collector improvements. The final training manuals (Appendices 2 and 3) will detail low-cost energy audit, building envelope, infiltration, ventilation, and building health evaluation techniques that utilize simplified tooling, best practices for prioritizing preservation and retrofit improvements, and detailed guidance on solar collector refurbishment and installation. Manuals will be available for interested community members and available at: www.icatis.org

Advancement of the Field of Preservation

Over the past several decades, Navajo Hogans have been gradually abandoned since the living spaces were extremely prone to infiltration, extreme seasonal temperatures, and lacked a low cost heating and cooling source. Further, the local community lacked the skillsets to identify what building problems there were, and what low cost solutions could be used to address the issues. Once abandoned as a living space, the Hogans were no longer maintained, conditions rapidly deteriorated, and soon the Hogans were no longer inhabitable. Over the past 50 years, the number of Hogans within the Navajo Nation has significantly decreased.

Our team has developed a low cost approach to enable traditional Navajo Hogans to be comfortable, livable dwellings. This includes problem identification with low cost, simplified energy audits and implementation of solutions including weatherization, natural ventilation, and solar thermal collectors. Most critically, we've established a Navajo led team who has been trained to perform these evaluations and installations independently. We've built partnerships with Grey Hills Academy High School that has a machine shop and more than adequate tooling to complete any solar collector and weatherization project. Our team has successfully integrated lessons learned from four Hogans into a fifth model Hogan that is also local at Grey Hills Academy, which can be toured by the community for continued knowledge generation and training while also serving a model for future Hogan preservation

improvements. In the upcoming months, our team will continue to work with the trained business leads to refine their business approach, marketing, and identify funding sources to expand Hogan retrofit improvements throughout the Navajo Nation.

Project Effectiveness

The following project effectiveness metrics were defined at the beginning of the project, followed by the results of this project:

- Navajo community members engaged in Hogan preservation discussions
    - Over 200 community members have been engaged in discussion of Hogan preservation, solar collector and natural ventilation improvements, as well as weatherization improvements,
- Individuals that received training
    - 27 Navajo community members have received detailed solar collector refurbishment and installation training, as well as weatherization improvement training
    - 14 Amizade volunteers received training for Workshops 1 and 2
    - 10 Amizade volunteers received training for Workshops 3 and 4
    - Two business leads have demonstrated expert-level proficiency to be able to repeat these trainings and successfully install these retrofits independent of our project team
- Navajo Hogans that received retrofits
    - As proposed, five Hogans have received retrofits, benefiting 22 inhabitants of Hogans 1-4, plus the High School's curriculum and students
- Navajos and individuals that tour the 'model Hogan retrofit'
    - The Model Hogan was installed at the Grey Hills Academy High School.
        - To date, approximately 150 Navajos and individuals have toured the Model Hogan
        - Over the course of the next year, all 240 high school students will tour the model Hogan
        - The High School and trained retrofit business leads are developing a program for regular tours to expand touring of the Model Hogan to the outside community
- Individuals that are aware of Hogan preservation and retrofit solutions
    - Our team has found this metric to be the most difficult to quantify. We know there is a small group that is keenly aware of all of the project components that have occurred – our estimate would be 50 people in total, including Hogan owners and immediate family. However, we estimate that there is a very large number of Navajos and other individuals that are aware of at least one component of the project – our estimate would be well over 1000 people. This

includes Navajos and other individuals that have received at least one 'touch' with one of the following activities: We have posted flyers for community engagement, advertised for qualifications-based selection of the retrofit business leads, held community meetings at local Chapter Houses, assessed improvements at six Hogans, instructed four training workshops, installed improvements at five Hogans, and met with the Navajo Nation Weatherization Program and HUD program leads to discuss long-term financing of continued improvements.

To quantify energy savings of installed metrics, comparison of seasons in two years is required. For example, the energy used during the winter of Year 1 must be compared to the energy used in the winter of Year 2. Given the one year project duration, energy savings of Hogan retrofits could not be determined during this project timeframe. Nevertheless, our team will continue to follow up with the Hogan owners and trained Hogan retrofit leads, far beyond the completion of this project, to determine average annual savings realized for winter heating, and the improvement of comfort during the summer.

The project has been deemed a success, since:

- Navajo community members have received training and can perform all retrofits independent of the project team's assistance.
- Retrofitted Hogan owners have confirmed improved indoor temperatures during the summer months, largely because of improved Hogan air tightness and insulation. Consequently, it is anticipated significant energy reductions will be seen for winter time heating, because of the weatherization improvements and also because they now have a supplemental solar thermal collector heat source.
- The 'model Hogan retrofit' has already been used for tours and community education.
- The historic look and feel of the Navajo Hogans has been preserved.

Acknowledgements

Our team and the Navajo people are thankful for the funding support provided by the National Park Service's NCPTT grant program. We would like to thank all that participated, including but not limited to Tad Britt, Dr. Robert Marquez, Michael Sapp, Dr. Mark Pitterle, Don Yellowman, JoAnn Armenta, Jason Begay, Robert Blackhat, Melton and Paddy Martinez, and Valerie Kenneth. Our team is also thankful for the active community engagement including installation of the fifth 'model' Hogan at the local Grey Hills Academy High School and use of Grey Hills Academy for our Solar Thermal Collector Workshop refurbishment, as well as high school student, community member, and volunteer partnerships. We are incredibly grateful for the extensive participation and support from the Amizade team. Amizade is a Pittsburgh

non-profit that provided many volunteers to assist our installations of solar thermal collectors and Hogan weatherization improvements.

Following this project, the two business leaders – Jason Begay and Robert Blackhat – aim to establish a business that expands Hogan preservation and weatherization training and installation throughout the Navajo Nation. Our team looks forward to continued involvement to assist these efforts and we aim to work diligently with the Navajo Nation and Navajo Chapter governments to identify funding mechanisms to assist these efforts and preserve countless Hogans in the future.

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