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Yakama Nation Housing Authority, Adams View: System Retrofit Research Report and Case Study Summary

February 23, 2004–January 15, 2005

CARB (Consortium for Advanced Residential Buildings)
Norwalk, Connecticut

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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Building Technologies Program

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Nomenclature

ACH	air changes per hour
CARB	Consortium for Advanced Residential Buildings
cfm	cubic feet per minute
CO_2	carbon dioxide
DOE	U.S. Department of Energy
HERS	Home Energy Rating System
HSPF	Heating Seasonal Performance Factor
HUD	U.S. Department of Housing and Urban Development
IECC	International Energy Conservation Code
NO_X	nitrogen compounds, such as nitric oxide (NO) and nitrogen dioxide (NO_2)
NREL	National Renewable Energy Laboratory
NASEO/RESNET	National Association State Energy Officials/ Residential Energy Services Network
PEX	Cross-Linked Polyethylene
SEER	Seasonal Energy Efficiency Ratio
SO_2	sulfur dioxide
YNHA	Yakama Nation Housing Authority

Summary

The Yakama Nation is the largest tribe in the Pacific Northwest. The Yakama Nation Housing Authority (YNHA) is working to rehabilitate single family homes (two to four bedrooms) in its Adams View project using public and tax credit financing. It is in need of a major rehabilitation as a result of wear and tear after many years of use and overcrowding. The scope for the current CARB "gut rehab" project is 25 of the 40 homes in the Adams View development, but the proposed strategies could be replicated for the remaining 15 homes as well as for several other similar developments of the YNHA. On a larger scale, the system rehabilitation strategy developed for the Adam's View project should be replicable for most of the more than 4,300 housing units that were constructed in the Northwest (Washington, Oregon, and Idaho) under the US Department of Housing and Urban Development (HUD) Housing Act of 1937.

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Background and Project Description

The National Renewable Energy Laboratory (NREL) is the technical field manager for the U.S. Department of Energy's (DOE) Building America Program. The goal of Building America is to develop innovative system engineering approaches to advanced housing that will enable the United States housing industry to deliver affordable and environmentally sensitive housing while maintaining profitability and competitiveness of homebuilders and product suppliers in domestic and overseas markets.

The Consortium for Advanced Residential Buildings (CARB), led by Steven Winter Associates, is one of five Building America teams working throughout the country to develop, test, and design advanced building energy systems for all major climate regions within the United States. To accomplish this, Building America teams partner with material suppliers, equipment manufacturers, developers, builders, designers, and state and local stakeholders. The range of innovative system concepts considered in projects includes onsite power systems, optimized envelope systems, advanced mechanical and lighting systems, high-efficiency space-conditioning systems, efficient water-heating systems, renewable-energy systems, efficient appliances, energy-control systems, and design and construction strategies.

The Yakama Nation is the largest tribe in the Pacific Northwest. The Yakama Indian Reservation is 1,371,918 acres, covering 1,573 square miles in the south-central Washington counties of Klickitat and Yakama. Located in the Yakama Valley, which is a very dry climate, the area is commonly referred to as the "Palm Springs of Washington." Tribal enrollment is more than 8,800 people, and more than 13,700 people live on or near the reservation.

The Yakama Nation Housing Authority (YNHA) is working to rehabilitate single family homes (two to four bedrooms) in its Adams View project using public and tax credit financing. Named for the spectacular 12,307-ft Mount Adams, the Adams View project was constructed in the early 1980s under the HUD 1937 Housing Act. It is in need of a major rehabilitation as a result of wear and tear after many years of use and overcrowding (Figures 1 and 2).

Figure 1. One of the boarded-up homes at Adam's View scheduled for rehabilitation

Figure 2. Another of the homes at Adam's View (shingles blown off roof)

The scope for the current CARB "gut rehab" project is 25 of the 40 homes in the Adams View development, but the proposed strategies could be replicated for the remaining 15 homes, as well as for several other similar developments of the YNHA. On a larger scale, the system rehabilitation strategy developed for the Adam's View project should be replicable for most of the more than 4,300 housing units (2,039 low-rent and 2,320 mutual-help) that were constructed in the Northwest (Washington, Oregon, and Idaho) under the U.S. Department of Housing and Urban Development (HUD) Housing Act of 1937. HUD implements and administers government housing and urban development programs including low-rent public housing, mortgage insurance for residential mortgages, equal opportunity in housing, energy-efficient mortgages, and research and technology grants. Many of these 4,300 homes that were originally built have little or no insulation and have outdated equipment. Some considerations for moisture management will also need to be considered in regions of the Northwest that receive more rainfall, such as the Seattle, Washington, area.

The Adam's View project consists of the design and construction of gut rehabs for 25 of the 40 houses in the community. Houses that are vacant are being rehabbed under the first phase of the project. All houses are to be rehabbed and occupied before the close of 2005. The first house completed has a slightly different style from the rest of the housing stock (blue triangle in Figure 3). The next three rehabs (orange squares) were finished by the end of March 2005, and an additional three houses (red circles) were completed in April 2005. Work was proceeding on two additional homes (black hexagon) during CARB's last site visit and was completed at the end of May 2005. As of the end of August 2005, 20 units have been completed. The rehabilitation project was approved and funded by the HUD Office of Native American Programs and state tax credit financing. The site/project is owned by the tribe, and there is interest and motivation to improve energy efficiency. The YNHA has adopted the 2003 International Energy Conservation Code (IECC) standards as its standard building practice. The project funds are currently in place and approximately $40,000 per unit has been budgeted.

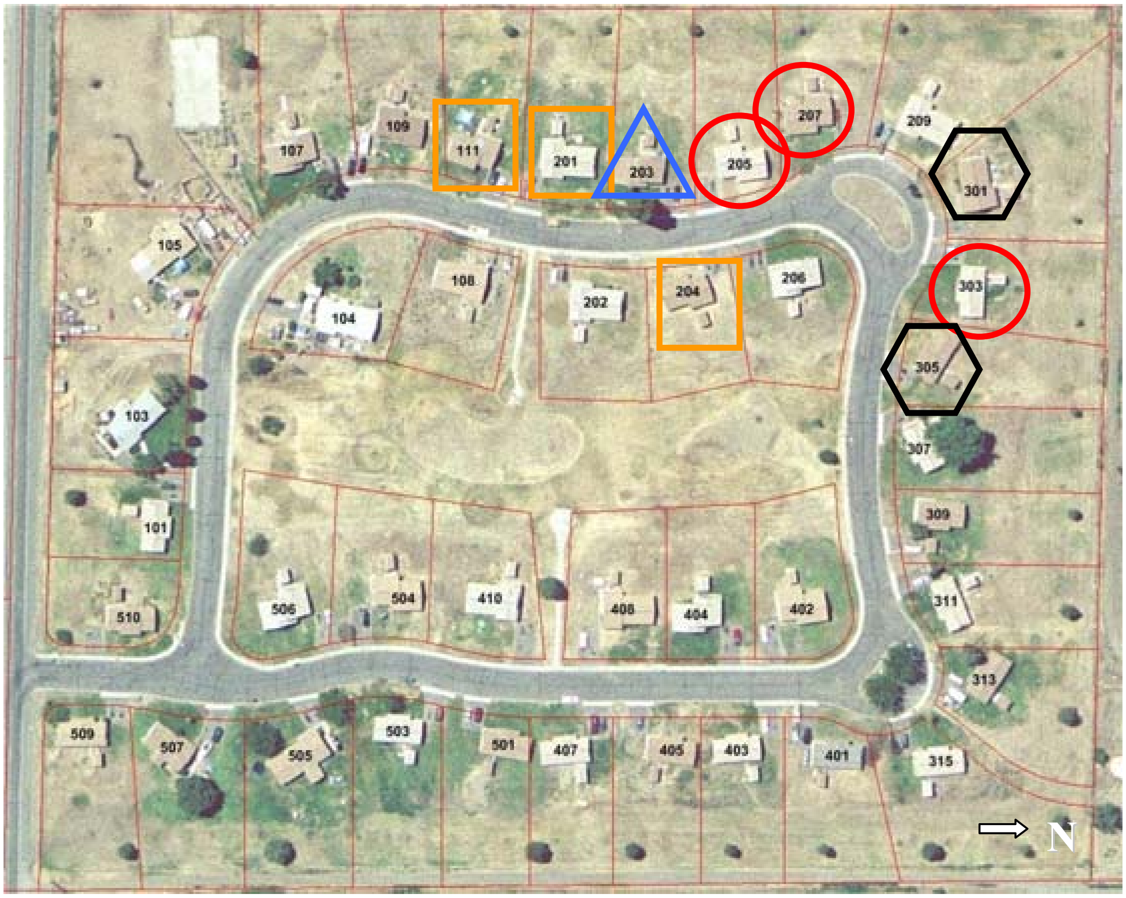


Figure 3. Overview map of the Adam's View development

CARB's Rehabilitation Strategy

After reviewing Yakama's current housing stock and performing preliminary energy modeling, CARB recommended a list of improvements for a "whole building systems" approach to design. Each of these recommendations was presented to the Yakama Nation Housing Authority and based on the discussions that arose during those meetings, CARB gave a full presentation to the Yakama Tribal Board. At that time, each of the following recommendations was presented to the board for evaluation:

- Low-e windows
- Insulation details (above-grade walls, attic, crawlspace)
- Mechanical system design and equipment upgrades
- Plumbing upgrades (PEX plumbing)
- Tight envelope and ducts
- Lighting and appliance package.

To develop a system rehabilitation strategy for the Adam's View homes, the current housing conditions were observed, energy modeling was performed, and then performance testing was performed on the initial rehabs. For the whole house energy performance analysis, a three-bedroom unit was selected as representative of the entire group. The breakdown of unit types is almost equal (nine two-bedrooms, nine three-bedrooms, seven four-bedrooms). As is shown in Figure 5, the modeled unit is a single-family detached home built on a vented crawlspace with the front entrance facing east.

For the builder basecase model, the specifications of the current building stock (pre-rehab) are being used to gauge the energy-savings benefits of the recommended rehab package. The building specifications for each model can be found in Table 1. For the purposes of this comparison, lighting and appliance loads are assumed to be equivalent to the Building America Benchmark reference house because we weren't able to obtain actual data on these categories. For the rehabilitation of the existing homes, the goal of the program is for 20% total source-energy savings over the pre-rehab home.

To allow for a more direct comparison of the models, a SEER-10 air-conditioning unit is being modeled in the builder basecase, even though the original homes did not include cooling. Still, the largest energy consumption is heating. In the pre-rehab homes, space heating represents more than 59% of the total source energy use. Because of the minimal insulation and poor sealing of the building envelope, there is not much more than a wood frame providing shelter from the elements. The focus of our rehabilitation strategy was to improve the building envelope and utilize a compact, more efficient heat pump system. Natural gas is not available and, while the homes did not have central air conditioning, the YNHA wanted to include it in the rehabilitated homes.

The final prototype performance will also be compared to the Building America Research Benchmark Definition v3.1[1] specifications. This Benchmark home is fairly consistent with the 1999 HERS Reference Home as defined by NASEO/RESNET, with additions that allow for the evaluation of all home energy end uses including lighting, appliances, and plug loads. Using these specifications, a model was constructed using EnergyGauge v2.3. The results of that modeling (Table 2) indicate that the Benchmark home consumes an annual source energy total of 176 MMBtu. Most of the energy consumption is heating at 32% of the overall total. If only considering heating, cooling, and hot water, the Benchmark model achieves a HERS rating of 79.7. Note the Building America Benchmark home is a significant improvement over the pre-rehab homes.

CARB visited the Adam's View community during the first week of May 2005 to do performance testing on three of the six completed rehab units. Unit #303 (two-bedroom; Figure 4) and units #207 and #204 (three-bedroom) were inspected and tested to quantify the benefit of the improvements being made to these rehabs.

Figure 4. Finished Unit #303

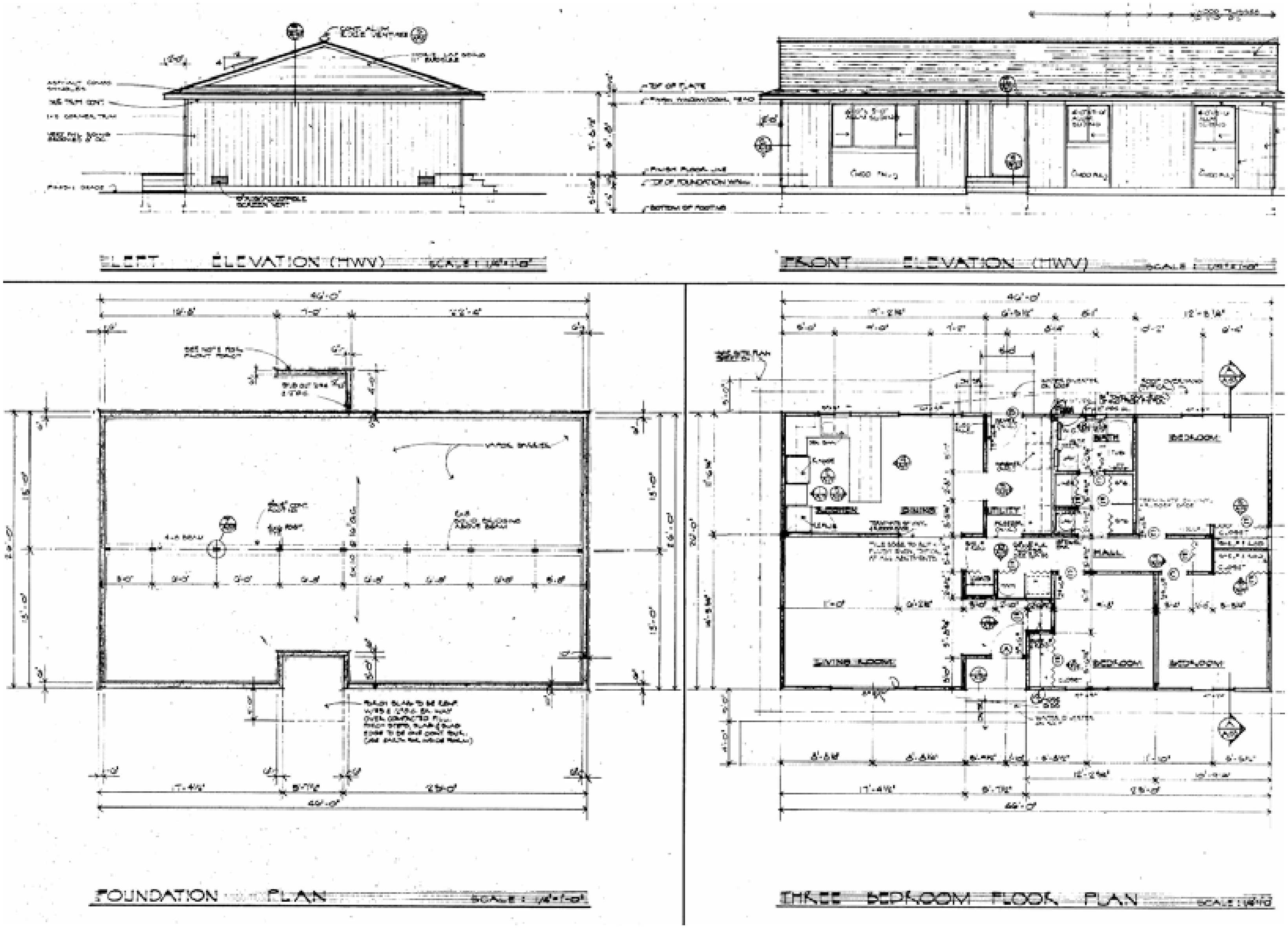


Figure 5. Three-bedroom unit elevation and floor plan

Table 1. Building America Benchmark/Builder/Prototype Specifications

Project name: Adam's View Rehab Project
Model name: 3-Bedroom Unit
Location: Toppenish, WA

General Description	
Area of living space = 1,176 ft^2	Floors above grade = 1
Glazing Area = 100 ft^2	Attached Garage = N/A
Conditioned Basement Area = N/A	TMY site: Yakima, WA

Side-by-Side Study of Homes
Specifications of Standard and Energy Construction

Characteristic	Benchmark Home	Builder Home	Prototype Home
Foundation Construction	vented crawlspace - concrete	vented crawlspace - concrete	vented crawlspace - concrete
Foundation Insulation	uninsulated	uninsulated	uninsulated
Framed Floor Construction	standard framing @ 16" o.c.	standard framing @ 16" o.c.	standard framing @ 16" o.c.
Framed Floor Assembly	U-0.05	uninsulated	R-30 batt insulation
Wall Construction: 1st Floor	2x4 wood framing - 16" o.c.	2x4 wood framing - 16" o.c.	2x4 wood framing - 16" o.c.
Wall Assembly: 1st Floor	U-0.058	R-11 batt insulation	R-13 (R-11 batt insulation + insulated siding)
Ceiling/Roof Construction	wood trusses @ 24" o.c.	wood trusses @ 24" o.c.	wood trusses @ 24" o.c.
Ceiling Assembly	U-0.026 (R-35.35)	R-19 insulation	R-38 cellulose insulation
Window Type	benchmark	aluminum double	vinyl double low-e
Window U-Value	0.40	0.69	0.31
Window SHGC	0.58	0.65	0.33
Interior Shading	interior shading multiplier = 0.7 in cooling season and 0.85 in heating season	interior shading multiplier = 0.7 in cooling season and 0.85 in heating season	interior shading multiplier = 0.7 in cooling season and 0.85 in heating season
Doors	U-0.20	U-0.40	U-0.40
Infiltration	0.40 natural ACH	0.80 natural ACH	0.31 natural ACH
Heating System	heat pump 6.8 HSPF	Electric Baseboard 1.0 Btu/Btu	Heat Pump 6.8 HSPF
Cooling System	heat pump SEER 10	air conditioner * SEER 10	Heat Pump SEER 10
Water Heater	electric water heater EF 0.88	electric water heater EF 0.88	electric water heater EF 0.90
HW Tank Size	40 gals	40 gals	40 gals
Water Heater Location	interior	interior	interior
Duct R-value	R-3.3	R-0.0	R-6.0
Supply Duct Area	317.5 ft^2	235.2 ft^2	235.2 ft^2
Return Duct Area	58.8 ft^2	58.8 ft^2	58.8 ft^2
Supply Duct Location	100% attic	100% attic	100% attic
Return Duct Location	100% attic	100% attic	100% attic
AHU Location	interior	outside	outside
Duct Leakage to Outside	10.0%	10.0%	7.0%
Leakage Fraction [1]	return:35%	return:30%/AHU:5%	return:30%/AHU:5%
Temperature	cooling: 78°F	cooling: 78°F	cooling: 78°F
	heating: 68°F	heating: 68°F	heating: 68°F
Lighting	10% fluorescents (100 W / 30 W)	0% fluorescents (100 W / 30 W)	22% fluorescents (60 W / 40 W)
Energy Star Appliances	--	--	--

** an air conditioner is assumed in the modeling to allow for a better comparison*

[1] leakage fraction is the amount of the duct leakage to the outside that is contributed by the return and AHU. The remaining % is from the supply side

Benchmark version: Building America Benchmark Definition version 3.1
Software version: Energy Gauge USA - USResRatePro - version 2.3

Table 2. Building America Benchmark Analysis Results

Summary of Energy Consumption by End-Use

	Annual Site Energy						Annual Site Cost		
	Benchmark		Builder		Prototype		Benchmark	Builder	Prototype
End-Use	kWh	Therms	kWh	Therms	kWh	Therms	$	$	$
Space Heating	5236	0	15783	0	4153	0	$ 298	$ 900	$ 237
Space Cooling	1391	0	1198	0	609	0	$ 79	$ 68	$ 35
DHW	3596	0	3600	0	3473	0	$ 205	$ 205	$ 198
Lighting	1746		1746		1397		$ 100	$ 100	$ 80
Appliances	2419	0	2419	0	2419	0	$ 138	$ 138	$ 138
Plug Load	1964		1964		1964		$ 112	$ 112	$ 112
OA Ventilation	0		0		0		$ -	$ -	$ -
Total Usage	16352	0	26710	0	14015	0	$ 932	$ 1,522	$ 799
Site Generation					0				
Net Energy Use	16352	0	26710	0	14015	0	$ 932	$ 1,522	$ 799

Summary of End-Use Source-Energy and Savings

	Annual Source Energy			Source Energy Savings				Component %	
				Percent of End-Use		Percent of Total			
	Benchmark	Builder	Proto	Builder	Prototype	Builder	Prototype	Builder	Prototype
End-Use	MBtu/yr	MBtu/yr	MBtu/yr						
Space Heating	56.5	170.2	44.8	**-201%**	**21%**	**-65%**	**7%**	**102%**	**46%**
Space Cooling	15.0	12.9	6.6	**14%**	**56%**	**1%**	**5%**	**-2%**	**33%**
DHW	38.8	38.8	37.4	**0%**	**3%**	**0%**	**1%**	**0%**	**5%**
Lighting	18.8	18.8	15.1	**0%**	**20%**	**0%**	**2%**	**0%**	**15%**
Appliances	26.1	26.1	26.1	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Plug Load	21.2	21.2	21.2	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
OA Ventilation	0.0	0.0	0.0	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Total	176.3	288.0	151.1	**-63%**	**14%**	**-63%**	**14%**	**100%**	**100%**
Site Generation			0.0						
Net Energy Usage	176.3	288.0	151.1	**-63%**	**14%**	**-63%**	**14%**		

Notes: The "Percent of End-Use" columns show how effective each building is in reducing energy use over the Benchmark in each end-use category.
The "Percent of Total" columns show how the energy reductions in each end-use category contribute to the overall savings.

energy costs	$0.0570	/kWh for electricity	Washington Average
	$1.40	/therm for natural gas	Washington Average

	equipment sizing		
Benchmark	30.0 kBtu/hr for heating		
	25.4 kBtu/hr for sensible cooling	-->	3.5 nominal tons
Builder	46.0 kBtu/hr for heating		
	20.9 kBtu/hr for sensible cooling	-->	2.5 nominal tons
Prototype	21.5 kBtu/hr for heating		
	11.3 kBtu/hr for sensible cooling	-->	1.5 nominal tons

*Sizing of cooling nominal tons is based on a SHR of 0.7, 0.7, 0.7, respectively

	HERS rating
Benchmark	79.7
Builder	59.3
Prototype	84.0

Building Envelope Rehabilitation Strategy

CARB recommended that major upgrades be made to the building envelope, starting with improving the insulation value of walls, floor, ceiling, and windows and tightening the envelope by foam-sealing joints and other possible bypasses. These recommendations target the space-heating load, because it is the largest energy end use in these homes. This project is a complete gut rehab; therefore, close attention to sealing of cracks, joints, and cut-outs needed to be followed during initial construction because it is a lot easier to do this up front rather than trying to seal things after the drywall has been finished. The various trades were instructed in proper techniques to seal the space around windows and door frames with a foam sealant that won't become too rigid and shift the windows out of square. In addition, foam or gaskets were recommended for all penetrations to the attic and crawlspace.

Energy-efficient low-e glazing replaced the old windows, which were mostly broken and boarded up. Metal roofing material was recommended to replace the old shingles that were being damaged (pulled off) by strong winds that occur occasionally in the valley.

If a tight building envelope is not achieved, then there is a large increase in the overall energy consumption of the homes. For modeling purposes, CARB initially assumed that a natural infiltration rate of 0.2 ACH could be achieved through careful sealing of the envelope. A blower door was used to determine the building envelope tightness. The results of that testing are shown in Table 3. Testing of the completed rehabs averaged infiltration rates of 0.3 ACH or higher. The overall source energy savings would increase by 2.6% if the target infiltration rate of 0.2 $ACH_{natural}$ was met.

Because these are gut rehabs, air sealing the building envelope can be tricky. The YNHA was initially unfamiliar with air-sealing techniques, so a learning curve was expected. Some problem areas identified by CARB were the

- crawlspace hatch,
- attic hatch,
- exhaust fans,
- duct leakage.

Placing a strip of weather-sealing foam on the rim of the crawlspace and attic hatches will provide a tighter seal of the hatch (Figure 6). The hole cut-out for the dryer exhaust should also be properly sealed to minimize leakage to the crawlspace. The holes through which the supply and return ducts penetrate the exterior wall should be properly sealed. In some cases this was done, but in others (unit #303, in particular) it wasn't.

Table 3. Results of Blower Door Testing to Determine the Building Envelope Tightness

	Infiltration	
House	cfm_{50}	$ACH_{natural}$
Unit #303	1,111	0.42
Unit #207	988	0.30
Unit #204	1,071	0.33

Figure 6. Crawlspace hatch

Figure 7. Looking up kitchen exhaust

There was also significant leakage through the exhaust fans. Up to 80 cfm was being drawn through the kitchen exhaust fans during the blower-door depressurization test. A backdraft damper should be installed in the flue or as a part of the fan housing, but these are either missing or improperly installed in the units tested. Figure 7 shows a picture looking up the kitchen exhaust for unit #303. Though difficult to see in the picture, there was no damper as is evident by the light penetration down the flue.

The YNHA have recently purchased a blower and have a trained crew for the installation of blown cellulose (Figure 8). Since our last visit, they have switched to blown cellulose for the wall insulation. This switch from fiberglass batts to blown cellulose could tighten the building envelope by as much as 20% as was shown to be the case in a recent Conservation Services Group study[2]. In addition, the blown cellulose will provide a slightly higher R-value to the building envelope (R-13) versus the R-11 fiberglass batts that are currently being used in the wall cavity. This would bring the overall wall R-value to R-15 when accounting for the insulated siding.

Figure 8. Blown Cellulose Insulation

HVAC Mechanical System Rehabilitation Strategy

The Friedrich Insider, a single-package heat pump (SEER 10/ 6.8 HSPF) to be located in the interior with an outdoor air circulation duct, was initially recommended. It was originally selected for this project based on several issues: the desire for cooling, the need for more efficient heating, and the desire to not have a split system because of vandalism concerns. Certainly a higher efficiency unit is preferred, but a suitable, cost-effective alternative has not been found. Friedrich, the makers of the Insider heat pump, had previously sold a SEER 12/7.5 HSPF unit, but discontinued it because market demand wasn't sufficient. The Building America Benchmark has equipment with similar efficiency, so the prototype's 21% savings in heating over the Benchmark home is a result of improvements to the building envelope and duct system. The use of the discontinued SEER 12/7.5 HSPF heat pump would further increase the overall annual source energy savings by 2.2% or further reduce annual consumption by 3.9 MMBtu.

The YNHA had problems with the performance of the Insider heat pump in a previous project, and Friedrich is currently swapping out those systems with the newer Vert-I-Pak B. Because of a supply backlog of these units, the YHNA has decided to go with Frigidaire external single-package heat pumps for the Adam's View rehabs (Figure 9). These units have the same performance values as the Insider heat pump (SEER 10 / HSPF 6.8), but the unit sits outside the house. This doesn't address the concerns of vandalism, but does provide more living area, as there is no longer a mechanical closet. Because air-handler cabinets are typically not air tight, locating the unit on the exterior will likely lead to a larger duct leakage to the outside. CARB is currently pushing for all future units to have higher performance ratings (SEER 13+ / HSPF 7.0+). Frigidaire's 13 SEER packaged heat pumps also have a variable-speed brushless permanent-magnet DC motor, which will reduce fan energy consumption of the heat pump unit. This system would increase the overall annual source energy savings by 4.3% or reduce annual consumption by 7.6 MMBtu over the current prototype.

There are inherent problems with an external heat pump; for example, uninsulated ductwork might be a concern (Figure 9). However, the supply duct is actually insulated and has an external metal sleeve to protect the insulation from rain and snow. One issue that was mentioned previously was concerns of vandalism. The heat pump in Figure 9 is actually the second heat pump installed at house #303. The first one was stolen from the site a few days before CARB's testing. The units are typically bolted down to the concrete pad, but the stolen unit had not been. In addition, the testing revealed higher duct leakage to the outside values than we initially anticipated with an internal air handler. Performance testing (Table 4) resulted in duct leakage to the outside of 55.5 cfm25 (7%; with a 2-ton heat pump and assuming 400 cfm/ton).

A major design detail that is usually ignored is the proper sealing of ductwork. CARB recommends that all ductwork connections be properly sealed using mastic and that the ductwork then be completely buried in the attic insulation to provide additional thermal resistance to the ductwork and minimize losses of the distribution system. The Yakama climate is dry, making ducts buried in attic insulation a viable measure.

Figure 9. Packaged heat pump unit for house #303

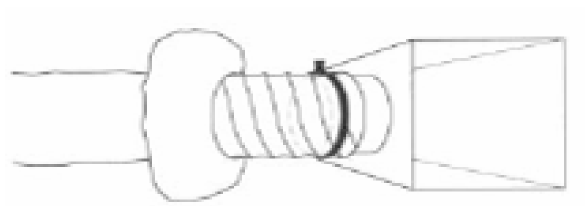
Table 4. Results of Duct Blaster Testing Used to Quantify the Leakage of the Air-Distribution System

	Total Duct Leakage		Duct Leakage to Outside	
House	cfm_{25}	%	cfm_{25}	%
Unit #303	112	14%	92	12%
Unit #207	66	8%	50	6%
Unit #204	80	10%	61	8%

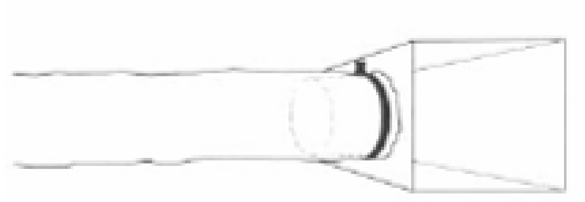
Mechanical ventilation had been recommended to maintain adequate indoor air quality. The ASHRAE 62.2 ventilation standard recommends a minimum of 42 cfm of continuous ventilation based upon floor area and the number of bedrooms. However, because of the high occupancy levels, CARB recommended a continuous ventilation rate of 60 cfm. This can be met using a local exhaust fan (bathroom or laundry room) rated at 80 cfm with a timer set for a 75% run-time. No active ventilation system is currently being utilized, but CARB continues to stress the importance of ventilation, especially if the units are better air sealed in the future.

The overall results of these specifications are an annual source energy of 44.8 MMBtu for heating and 6.6 MMBtu for cooling for the post-rehab homes. In addition to the energy savings, the cooling-unit equipment size can be reduced from an estimated 2.5 nominal tons for the pre-rehab house to a 1.5 nominal ton unit for the Prototype house. The heating equipment sizing is also 24.5 kBtu/hr less for the prototype when compared to the pre-rehab house.

It is difficult to minimize duct leakage to the outside when your air handler is located on the exterior, but use of mastic on the main supply and return sheet metal ducts would help. The circular supply registers are one-size-fits all, meaning that they have a multi-sized collar to allow for various supply duct diameters. As standard practice, a single compression strap/wire-tie is used to attach the flexduct to the boot. For the connection of the flexduct to the supply registers, CARB recommends the procedure illustrated in Figure 10 to improve duct tightness.



Retract outer insulation layer. Slide inner liner over connector. Install compression strap.



Slide insulation back into place. Secure outer liner with compression strap.

Figure 10. Recommended procedure for connecting flexduct [3]

Figure 11. Ductwork partially buried in attic

CARB also recommends that the flexduct in the attic be buried under the cellulose insulation (Figure 11). Burying the flexduct in the cellulose, decreases heat loss and gains between the ducts and the attic space. This was successfully implemented except where the flexduct needed to cross the ceiling joists to get to the outer rooms.

From CARB's evaluation of the Adam's View project, it is evident there are additional opportunities to increase performance of these units through further air sealing and the installation of tight ductwork. The test values for air infiltration and duct leakage were inputted into the energy modeling software to assess the impact of air and duct sealing on the design loads for these homes. The pie charts (Figure 12) show that air leakage (through the building envelope and ductwork) still accounts for 44% (25% infiltration + 19% ducts) of the winter heating design load and 28% (9% infiltration + 19% ducts) of the summer cooling design load.

Winter Heating Design Load - 21,484 Btu/hr   Summer Cooling Design Load - 12,334 Btu/hr

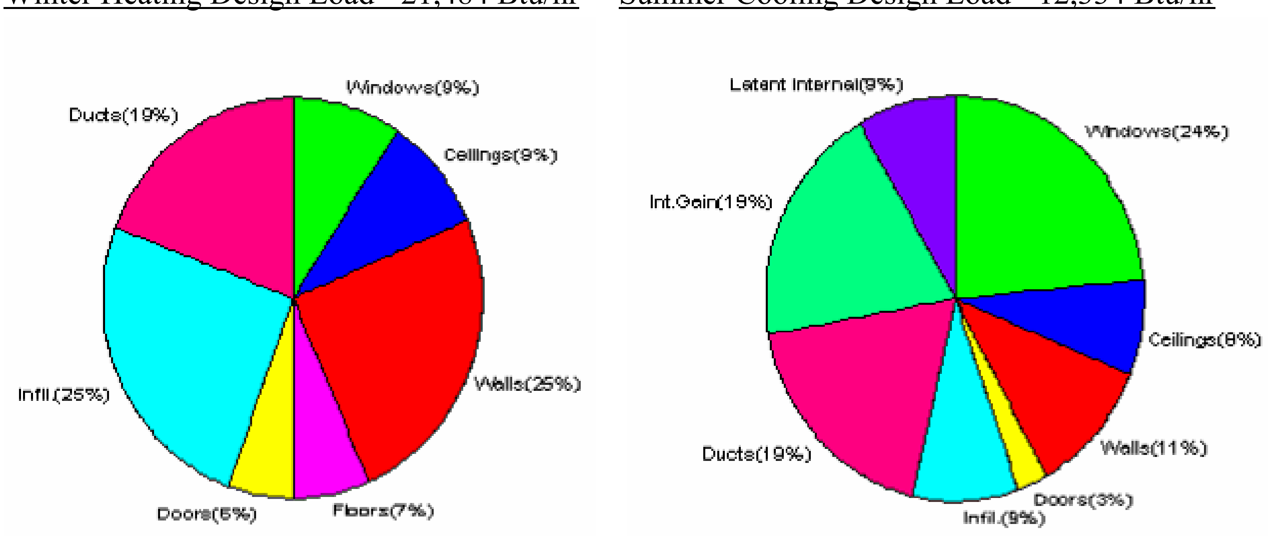


Figure 12. Air leakage in winter and summer

Water Distribution Rehabilitation Strategy

PEX piping was used to replace the old plumbing that contains lead solder. This not only improves the water quality, but also helps minimize standby losses because PEX piping has a lower heat transfer coefficient than copper pipe. In an attempt to further reduce the heat loss of the distribution system, all plumbing was recommended to run through the interior walls. This would reduce the losses of the hot water distribution system associated with running plumbing in the crawlspace. This recommendation was not implemented in the current rehabilitations.

Though the energy modeling doesn't take into account the reduced distribution losses obtained from switching to PEX plumbing, the post-rehab annual source energy for hot water is 37.4 MMBtu. Domestic hot water energy use is nearly as large as space heating; therefore, we wanted to improve the efficiency of the hot water heater. But with vandalism issues still a concern, having a propane tank outside the house was not an option. An electric tankless water heater may be a possibility in future units, but the impact on electrical service requirements needs to be examined. For now, the YNHA continues to install electric tank water heaters.

Whole House Energy Performance

The total source energy savings of the post-rehab house over the pre-rehab house is 47% (136.9 MMBtu/year). Perhaps most important is that the annual utility costs for the families will be cut nearly in half when compared to the current construction (based upon the modeling results). If replicated across the 4,300 HUD 1937 Housing Act homes in the Northwest, this whole-house strategy could save an estimated 588,670 MMBtu/year. That equates to more than 3.1 million dollars worth of savings per year (assuming $0.057/kWh). In terms of emission savings, it is estimated that 72,885 lbs. of SO_2, 21,328 lbs. of NO_X, and 31,304 tons of CO_2 could be avoided. The emission rates associated with the energy savings are based on information from the Environmental Protection Agency and differ by state.

Other Opportunities for Further Improvement

There were some problems with the performance of the exhaust fans (other than the backdraft dampers). Because of excessively high static pressures, exhaust fan performance is being derated. Specifically in unit #303 (Table 5), essentially no air was being exhausted (less than 10 cfm) through the local exhaust fans. Either a duct is blocked, the backdraft damper may have been reversed, or the duct length is simply too long. For the range hoods, a complete seal around the balometer inlet could not be obtained as a result of the hood shape, but measured values are still significantly different from the 190 cfm (high speed) at which the hoods are rated. CARB has made recommendations to the YNHA about ways to reduce static pressure drop and improve fan performance.

Table 5. Exhaust Fan Performance

	Kitchen Range Exhaust		Other Local Exhaust	
House	low speed (cfm)	high speed (cfm)	Laundry (cfm)	Bathroom (cfm)
Unit #303	54	78	11	9
Unit #207	26	52	40	87
Unit #204	49	81	68	76

A filter was located at the central return; CARB has recommended that the grille cover be changed to allow for easy replacement of the filter. Having a cover that needs to be unscrewed will likely cause the filter not to be replaced regularly, which will reduce the effectiveness of the HVAC system and the indoor air quality. Filter grilles with flush levers would be preferred.

CARB has some concerns with the quality control of the floor truss insulation installation. It was observed in several of the crawlspaces that batt insulation placed in the floor is falling out in various places. This will allow for greater heat transfer through the floor and will derate the overall U-value of the floor. During the winter months, this poor installation will be more noticeable as homeowners will likely have comfort issues because of the cold spots and potential condensation problems.

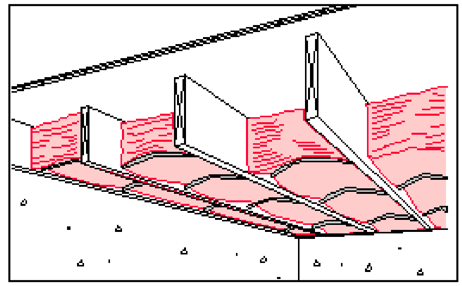


Figure 13. Spring rod installation [4]

Either greater care needs to be taken in placing these batts or something like spring rods/batt hangers should be used during the installation (Figure 13). In addition, the PEX piping should have continuous insulation wrap on it. Exposed piping in the crawlspace will greatly increase hot water distribution losses (Figure 14).

There were some issues with the wiring of the heat pump units and the programmable thermostats while CARB was testing the homes. This issue seems to have been resolved. A look at the flow rates at each supply register didn't show any significant issues. The adjustment pins for the diffuser dampers were not installed in the units tested, so all dampers were in the fully open position.

Though T12 fluorescent lighting is used in some spaces of the home (family room, laundry room, and kitchen), CARB is pushing for a complete switch from incandescent lighting to all fluorescent lighting. There is no need to switch the lighting fixtures to pin ballasts because the

Figure 14. Crawlspace of Unit #303

fixtures have already been purchased, but residents may tend to replace burnt screw-in fluorescent bulbs with incandescent bulbs simply because they are cheaper. Installing screw-in compact fluorescent bulbs can cut the cost of lighting by 50% or more. This will also minimize internal gains, thereby reducing the cooling load in the summer (winter heating load will increase slightly).

Summary

In working with YNHA, CARB developed a system retrofit package that could be replicated across more than 4,300 HUD 1937 Housing Act homes in the Northwest. Space heating is a predominant load for these homes. The system retrofit package focuses on a high performance envelope through air sealing, insulation, and high performance windows.

When applied to the homes in the Adam's View project, this package achieved a total energy savings over the pre-retrofit homes of 47%. More importantly, the annual utility costs for the families will be cut nearly in half.

Opportunities for further improvement include higher space and water heating efficiencies and reduced duct leakage.

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[1] Hendron, Robert. 2004. Building America Benchmark Definition v3.1 http://www.nrel.gov/docs/fy05osti/36429.pdf

[2] "Fiberglass-Insulated Homes Are the Leakiest," Conservation Services Group study in *Energy Design Update*, April 2005.

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[4] http://oikos.com/esb/38/floorinsulation.html

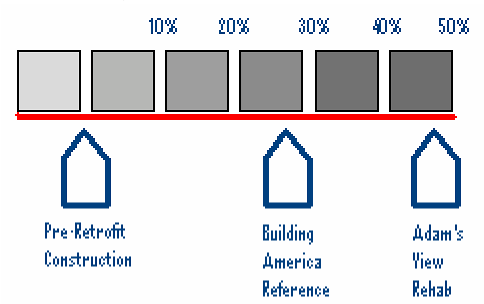
A Building America Case Study Summary
Yakama Nation Housing Authority – Wapato, Washington

The Yakama Nation Housing Authority (YNHA), working with technical support from the U.S. Department of Energy's Building America Program, is rehabilitating 25 single family homes (two to four bedrooms) in its Adam's View development. The Adam's View project was constructed in the early 1980s under the HUD 1937 Housing Act. It is in need of a major rehabilitation as a result of wear and tear after many years of use and overcrowding. The YNHA pursued the following energy-efficient features to meet the Building America goal of 20% total source-energy savings over the pre-rehabilitated housing stock.

- Wall Construction – As these are gut rehabs, the original 2x4 wood framing was used. Fiberglass batts were properly installed to ensure that the rated performance was maintained. To improve the overall thermal performance of the wall assemblies and to minimize thermal bridging at the wall studs, insulated sheathing was used on the exteriors.
- Windows – All windows were replaced with double-pane low-e windows with vinyl frames to reduce heat loss in the winter and to minimize solar heat gain in the summer.
- Roof/Attic – The ceiling plane was insulated with an equivalent of R-38 blown cellulose. Cellulose was chosen because studies have shown improved air tightness of the house as compared to fiberglass because of the density of cellulose. The asphalt shingle roofs, which were damaged from the severe winds in the valley, were replaced with metal roofs.
- Crawlspace – R-30 fiberglass batts where installed into the floor of the vented crawlspaces. PEX piping replaced the old plumbing that contained lead solder. This will not only improve the water quality but will also help minimize standby losses, because PEX piping has a lower heat transfer coefficient than copper pipe.
- Air Distribution System – The air distribution systems were tightly sealed. Typical attic installations have duct leakage to the outside as high as 15%. When tested, these systems were less than half of that duct leakage. Flexduct in the attic was buried under the blown cellulose to reduce conductive losses. The Yakama climate is dry, making attic insulation buried ducts a viable measure.
- Heating and Cooling System – Although no cooling systems were included in the original homes, the YNHA wanted to upgrade the homes and provide cooling. Because of space limitations, external single package heat pumps were used. As a result of improved air-tightness and the other energy efficiency measures, overall system sizing for each unit was reduced by a ton for cooling and cut in half for heating.

The total energy savings over the pre-rehab house is 47% or 136.9 MMBtu/year. Perhaps most important is that the annual utility costs for the families will be cut nearly in half when compared to the current homes. If replicated across the 4,300 HUD 1937 Housing Act homes in the Northwest, this whole-house strategy could save an estimated 588,670 MMBtu/year. That equates to over 3.1 million dollars worth of savings per year.

The YNHA has been working with the Consortium for Advanced Residential Buildings (CARB), one of the Building America industry teams, to rehabilitate existing housing and construct new housing that incorporates whole-house design.



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14. ABSTRACT *(Maximum 200 Words)*
The Yakama Nation is the largest tribe in the Pacific Northwest. The Yakama Nation Housing Authority (YNHA) is working to rehabilitate single family homes (two to four bedrooms) in its Adams View project using public and tax credit financing. It is in need of a major rehabilitation as a result of wear and tear after many years of use and overcrowding. The scope for the current CARB “gut rehab” project is 25 of the 40 homes in the Adams View development, but the proposed strategies could be replicated for the remaining 15 homes as well as for several other similar developments of the YNHA. On a larger scale, the system rehabilitation strategy developed for the Adam’s View project should be replicable for most of the more than 4,300 housing units that were constructed in the Northwest (Washington, Oregon, and Idaho) under the US Department of Housing and Urban Development (HUD) Housing Act of 1937.

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