B O N N E V I L L E P O W E R A D M I N I S T R A T I O N

Strategic Recommendations to Improve Energy Efficiency in Manufactured Housing

A Report to the Bonneville Power Administration

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STRATEGIC RECOMMENDATIONS TO IMPROVE ENERGY EFFICIENCY IN MANUFACTURED HOUSING

Executive Summary

This paper provides strategic recommendations from Washington State University Energy Program (WSU) to Bonneville Power Administration (BPA) on activities that could be undertaken to improve energy efficiency in manufactured homes through multiple mechanisms.

Findings and Recommendations

Market Based Findings and Recommendations

1. **While the market for manufactured homes is currently declining, it is expected to rebound as the economy recovers. The majority of the new homes are heated with electric forced air furnaces, which creates an ongoing load issue.**
   Recommendation: It is recommended that BPA stay actively engaged with this market to enhance the efficiency of electrically-heated homes as much as is cost-effectively possible.

2. **The low end of the market is becoming less energy efficient.**
   Recommendation: The current HUD Code efficiency standard is far too low, and would not meet the site-built energy code in any of the Pacific Northwest states. If the HUD Code standard does not improve, BPA should incent the manufacturers to build above the HUD Code level.

3. **The number of single section homes is increasing as a percentage of total production. These homes tend to be the least efficient produced, and are not represented as a significant portion of above-code programs like NEEM.**
   Recommendation: BPA needs to develop a long-term strategy for improving this sector of the industry that may include a direct acquisition component.

4. **About half of the electrically heated homes have heat pumps installed after market. Billing analyses of manufactured homes indicate that heat pumps perform little better than electric resistance furnaces (Baylon, Davis, & Hewes, 2009).**
   Recommendations: WSU recommends that BPA and utilities partner with Washington State's Department of Labor and Industries (L&I) to commission all heat pump and air conditioner installations on HUD Code homes in Washington State. WSU also recommends that future random sample field studies clearly identify the efficiency of the heat pump and whether or not it has been commissioned.

Technical Based Findings and Recommendations

1. **Advanced Framing can achieve a 6.8% average increase in wall performance with a 4% savings in cost on walls without foam cladding. There are, however, divergent opinions on the applicability of advanced framing in the manufactured home industry.**

Recommendation: BPA should conduct research and demonstration on the use of advanced framing to address industry concerns, and where appropriate, explore possible solutions to structural and cosmetic issues.

2. **Increasing efficiency in manufactured homes requires research and development into new measures and technologies unfamiliar to the industry.**
   Recommendation: BPA can fund rapid research and demonstration projects at manufacturing plants. Projects might include deployment of High R walls, roofs and floors, super windows, and advanced HVAC systems such as ductless heat pumps or heat pump water heaters. Convene the plant engineers and key production managers to share success stories and lessons learned.

3. **The impact of transport on insulation settling and duct leakage is unknown.**
   Recommendation: BPA can support research into attic and floor insulation levels and duct and envelope tightness in the plant and on site.

4. **The characteristics and performance of non NEEM homes have not been studied since the early 1990s.**
   Recommendation: BPA should support both baseline field studies and market assessments of non-NEEM homes.

Policy Based Findings and Recommendations

1. **The Pacific Northwest is fortunate to have individuals actively and prominently engaged at the national level with improving the HUD Code.**
   Recommendation: BPA should continue to support these efforts.

2. **The current administration of the HUD Code lacks building science input and installation training, and makes tracking and assessment of homes difficult.**
   Recommendations: Technical assistance and training to the HUD Code infrastructure should be part of any beyond code program. It is also recommended that the Northwest Power Council (Council), if it deems appropriate, include administrative reform issues in its testimony regarding new HUD Code standards. Also, any future beyond-code program should use HUD numbers for tracking purposes.

3. **Washington law allows utilities to set rates based on energy efficiency standards.**
   Recommendation: Washington utilities should be apprised of the inefficiency of low end manufactured homes and informed that they may use efficiency rates (“hookup standards”) to achieve efficiency goals for manufactured homes.

4. **Acquisition is the most expensive option and must be strategically planned.**
   Recommendation: WSU defines five principles that should guide acquisition: (1) lead to the next standard; (2) invest in maximum cost-effective efficiency to reduce lost opportunity and reduce equipment cost; (3) involve manufacturers in demonstrating before doing; (4) commission heat pumps; and (5) continue a voluntary component in any acquisition program.

Introduction

The Northwest has a strong history of energy efficiency in manufactured homes. Beginning in the late 1980s, BPA, in partnership with the State Energy Offices (SEOs) in Idaho, Montana, Oregon and Washington, began the process of reducing electric space heating use in this sector through research conducted in the Residential Construction Demonstration Program. This program identified measures that could reduce the energy use of manufactured homes. Many of these measures became the standards for the successful Super Good Cents Program for manufactured housing. In 1992 BPA, its state partners, the Northwest Power and Conservation Council and the region's utilities created the Manufactured Housing Acquisition Program (MAP). The goal of MAP was to purchase the highest cost-effective level of efficiency for all electrically-heated manufactured homes sited in the Pacific Northwest. BPA and the investor-owned utility partners invested approximately 100 million dollars, purchasing efficiency in 50,000 homes in less than three years.

The energy provisions of the code for all manufactured homes nation-wide, the Housing and Urban Development (HUD) code, is being considered for an update. These provisions have not been changed since 1994, and the base HUD code is currently highly inefficient in comparison to site-built homes in the Northwest. As manufactured homes are one of the highest users of electric space heat per square foot of any building type in the Pacific Northwest, this presents a strong opportunity to increase the baseline and lock-in energy savings in the future. The U.S. Department of Energy (DOE) is now responsible for the standard, and there is an opportunity to reduce the energy intensity of manufactured homes significantly, as manufactured homes may soon be subject to regular review of the energy standards that govern their construction.

The MAP program proved energy efficient manufactured homes could be built cost-effectively, and had a strong impact on the first upgrade in the energy efficiency standards of the HUD Code. The upgrade of the HUD Code reduced the savings associated with the MAP standards by raising the baseline, and triggered the reduction of utility incentives associated with the program about half way through the program's originally scheduled end date. After MAP ended, the region's SEOs created an ongoing manufactured home certification program called the Northwest Energy Efficient Manufactured Home (NEEM) Program under the leadership of the Oregon Department of Energy. By 1998, the NEEM program share of production dropped to 30%, and the Northwest Energy Efficiency Alliance agreed to fund a program to regain market share. This program, managed by the Energy Division of the Idaho Department of Water Resources, restored market share to 80%, and convinced many of the region's utilities to support the program with incentives. It also created an infrastructure that was self-supporting, funded by industry fees. The Power Council, along with the SEOs convinced the industry to adopt it. That first NEEA manufactured home venture ended in fall of 2001.

The NEEM program currently maintains an overall average market share of almost 60%, but manufactured home production in the Pacific Northwest has dropped dramatically—particularly with the recent economic downturn. The industry has recently started producing homes as cheaply as possible, and has, in some cases, turned to the practice of installing R-11 batts in 2x6 walls (this has become the base case wall system for some of the region's largest manufacturers.) This, coupled with the fact that the majority of manufactured homes produced still have electric resistance furnaces for space heating (even those in the NEEM program) means that site-built energy codes in the Pacific Northwest now far exceed the HUD Code in efficiency, and will soon surpass the efficiency standards of the NEEM program.

This paper provides strategic recommendations to BPA on activities that could be undertaken to improve energy efficiency in manufactured homes through multiple mechanisms. These mechanisms include participation in the HUD code revision process, working with the manufactured housing industry to innovate, and the development of voluntary programs to promote energy efficiency.

Market Analysis

WSU, on behalf of BPA, recently conducted a Cost Assessment for Manufactured Homes **(Eklund & Gordon, 2011)**. This work updated the costs that were collected 20 years ago by Ecotope, Inc. **(Baylon, Lubliner, Davis, & Kennedy, 1990).** In the earlier study, the trend was toward energy efficiency - driven by the Super Good Cents and impending MAP program in an expanding market. In the 2011 study, the trend seems to be toward reduced efficiency in the base case, driven by a shrinking market in a retracting economy.

In 2010 2,049 manufactured homes were produced in the Pacific Northwest, with 58% built to NEEM program standards. According to the NEEM database, the characteristics of the NEEM homes as they leave the factory are:

- 77% have electric, forced air furnaces
- 22% have forced air, natural gas furnaces
- About 1% have heat pumps according to statistics supplied by the factory
- The balance are propane or oil furnaces or zonal electric heat **(Northwest Energy Works, 2011)**

One area where the NEEM data is disconnected with the reality in the field is the distribution of heat pumps among homes with electric heat. Heat pumps are usually installed after the home is sited, and since the manufacturer is not usually involved in the heat pump purchase (it usually happens at the dealer-customer level soon after set-up, or between an HVAC contractor and customer some time later) the manufacturer has little ability or motivation to track which homes have heat pumps installed. This distribution of heat pumps among electrically heated homes can only be determined by examining the homes in the field. The regional has conducted five field studies, beginning with a study of MAP homes in 1995 **(Baylon, Davis, & Palmiter, 1995)**

Table 1 is derived from the most recent Pacific Northwest Manufactured Home Regional Field Study, conducted by the four Pacific Northwest states and Ecotope Inc. in 2008 **(Baylon, Davis, & Hewes, 2009)**. The table shows the distribution of heating systems for randomly sampled homes from two different field studies (dates for each sample indicate the year in which the homes were produced and sited.)

System	Distribution 2000-01	2006-07
An Electric Furnace (Elements + Fan Only)	54%	49%
A Heat Pump (HP)	24%	36%
A Furnace Fired by Natural Gas or LPG	22%	15%

Table 1: Heating system types from MH Regional Field Studies

The first observation in the most recent field data is that approximately half the NEEM homes have electric heat. The percentage of homes with heat pumps in the 2000-2001 sample is 24%, rising to 36% in the 2006-2007 sample. Note that the percentage of homes with natural gas or propane furnaces is the same in the 2000-2001 study as in the NEEM database production average (Figure 2), but decreases to 15% in 2006-2007; probably an artifact of a small sample size.

The energy usage determined from the billing analysis heat pumps and electric resistance furnaces was virtually the same in 2000-2001, and very close in the 2006-2007 sample. This indicates that the heat pumps were probably not installed properly or commissioned. **(Baylon, Davis, & Hewes, 2009)**

An interesting trend discovered during the 2008 field study is the increase in air conditioning in gas heated homes. In 2000-2001, 32% of homes heated by gas or propane had central air conditioning systems; in the 2006-2007 sample, that increased to 60%. The increase in air conditioning in gas heated homes is all the more notable given that the number of gas heated homes is 31% lower in the 2006–2007 sample.

It is not known how many of the heat pumps and air conditioners were commissioned at installation. As is shown in reports of research done in the Pacific Northwest on heat pump installations, PTCS commissioning and controls can improve system performance an average of 18%, at an average cost of 4.6 cents per kWh saved **(Eklund, 2008), (Davis & Robison, 2008).** A 1999 study assessed the impacts of proper charge and flow in air conditioning to be between 7 and 17% **(Neme, Proctor, & Nadel, 1999)**.

While the predominate source of water heat in manufactured housing is known to be electric resistance tank units, neither the NEEM field studies field studies nor the periodic field studies record this information, so assessments similar to those performed for space heat cannot be conducted. According to NTA, one of the two Design Approval Primary Inspection Agencies (DAPIA) interviewed for this project, the majority of homes throughout the country, including the Pacific Northwest, are shipped with electric water heaters (even those heated with natural gas or propane.) This is supported by cost data indicating that electric resistance water heaters cost significantly less than gas fired heaters.

Market Trends

Regionally and nationally, HUD Code home shipments have dropped overall, and are at their all time lowest. **Figure 1** shows Pacific Northwest shipments of HUD code homes from 1990 through 2010, broken down by single and multi-section, and shows the percentage of multi-family of the total shipments. Shipments are the numbers of HUD Code homes shipped into the Pacific Northwest states—mostly from factories located within those states. Note that the year 1995 marked the end of the production boom that coincided with MAP.

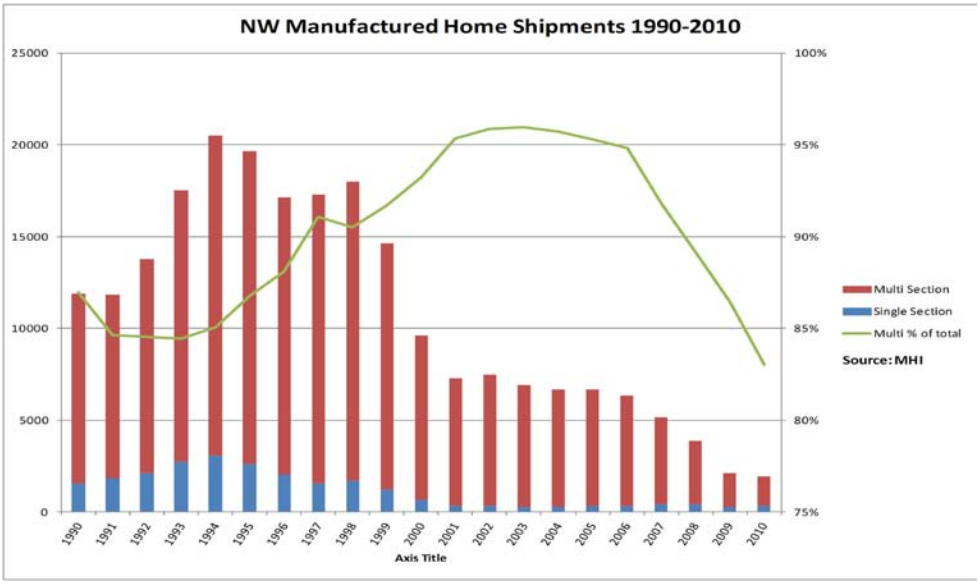


Figure 1: Nation-wide Manufactured Housing Shipments (Source: Manufactured Housing Institute)

Note that nationally the number of single-wide homes shipped is relatively constant since 2001, while the number of multi-wide homes has significantly declined. This may indicate that the lower end of the market remains viable, while the segment that competed directly with the site-built market has declined as the site-built market itself has declined. The rate of decline seems to have stabilized in 2010, but current production numbers suggest a decrease of 10 to 15% in 2011. This in part explains why two Pacific Northwest manufacturers closed down this year. Some experts believe the manufactured home market will recover to pre-recession levels by 2016 **(Grissim, 2011).**

The NEEM market continues to diminish in number of homes produced and sold, with annual production projected to be below 1,000 in 2011. **Figure 2** shows NEEM production by space heating system type from 2005 through 2011. Although NEEM production has decreased, it is directly linked to overall market conditions—the ratio of NEEM to HUD Code production in the Pacific Northwest has remained relatively constant with NEEM comprising around 60% of total HUD Code production.

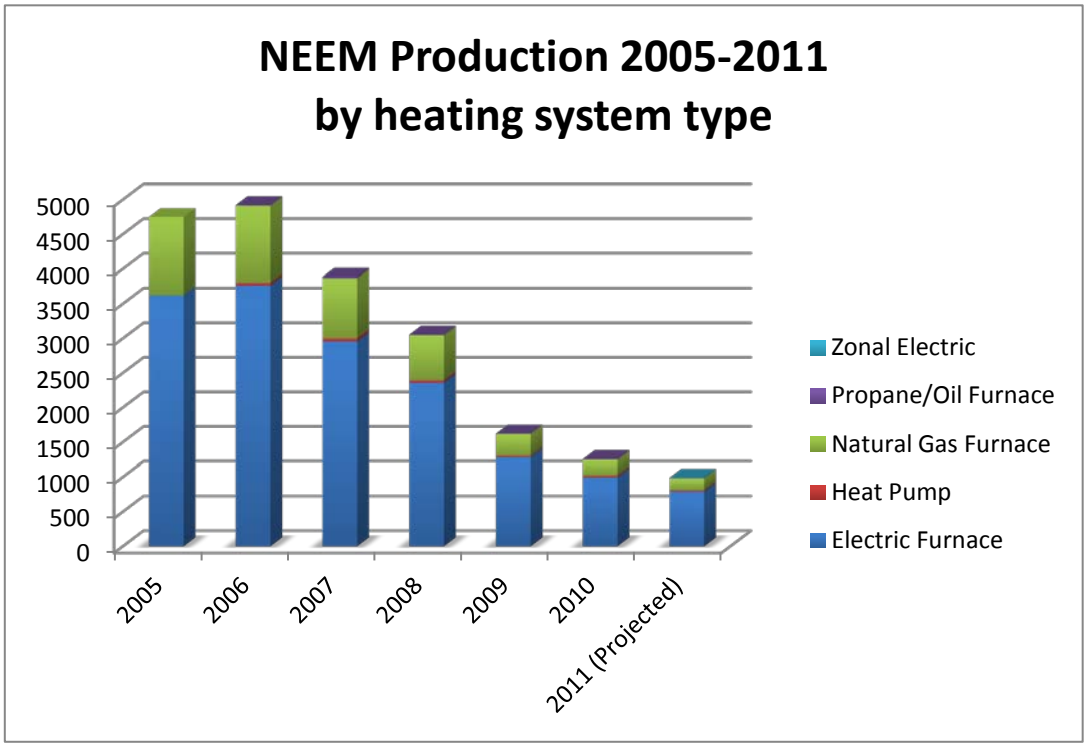


Figure 2. NEEM Production 2005 to 2011 with Percent Heating System Type (Northwest Energy Works, 2011)

Figure 2 indicates that the two major heat sources installed at the factory in NEEM homes are electric forced air furnaces and natural gas furnaces. Table 1, based on a randomly selected sample, indicates that a significant number of electrically heated NEEM homes acquire heat pumps after they leave the factory.

Non NEEM Home Characteristics

The following characterizations of the non-NEEM market are based on information learned in the cost study, coupled with the production trends discussed earlier in this section.

After MAP, the majority of non NEEM homes had 2x6 R-19 walls with vinyl frame windows—most commonly with Low E glass. They also had at least R22 floors and ceilings, and standard, residential type doors. Several manufacturers used advanced framing, with 24 inch on center construction, and reduced framing members throughout the wall assembly. Many manufacturers used box beam headers (foam sandwiched between wood – more efficient than a solid wood header).

In contrast, the most recent cost survey indicated some trends away from energy efficiency. The industry appears to be building more inexpensive options in order to sell homes, and it is likely that to remain cost-competitive other manufacturers could start using less costly, inefficient features. Because the current HUD Code enforces safety related rules, but has outdated energy requirements, the temptation is to reduce cost through reducing energy efficiency.

This is of concern because non-NEEM homes are more likely to be heated with electric forced air furnaces, as their purchase decisions are driven by cost, and both heat pumps and gas/propane furnaces are more expensive options **(Northwest Power and Conservation Council, 2010)**. Thus, the non NEEM market breakdown probably resembles Figure 2 much more than the NEEM field distribution represented in Table 1. This is informed speculation at best; the market reality can only be positively determined through a robust sample of non-NEEM homes.

It is a disturbing trend that some of the region's manufacturers are moving toward decreasing consumer costs at the expense of energy efficiency. In June, cost study field inspectors found that one of the region's largest manufacturers was utilizing a 2x6 wall with an R-11 batt (U value of .09) as a base case offering. This is an inherently flawed and inefficient system, utilizing code minimum insulation that doesn't even fill the wall cavity (potentially contributing to additional convective heat loss) and in the absence of a sensible mechanical fastening system, risking failure of the insulation to remain in contact with the sheathing (meaning there may be significant insulation voids in the wall cavity at the top where the highest temperature difference is likely to be).

In August, 2011, NEW also discovered that one of the region's manufacturers recently introduced a "Super Saver" option for single-section homes with a dual pane aluminum frame window (U.7), the 2x6 R-11 wall and an outswing "trailer" door (with half the thermal value of the residential type door.) The "Super Saver" package is being offered by the region's largest builder of single-section homes—in 2010 this amounted to 28% of the region's single section production.

While the market penetration of these inefficient homes are not easy to determine (since they are not tracked as part of the NEEM program, and they are a relatively recent re-entry to the market), the numbers of single-section homes are rising from an all-time low of 4% of total regional shipments in 2002 to an all-time high of 17% in 2010. While the numbers of NEEM single section homes have increased from 2% historically to 7% in 2010, they have not kept up with the overall trend; in other words, single-section homes are much less likely to be efficient than multi-section homes. Add to these trends the fact that the least energy efficient package of measures is being offered for single-section homes by the region's largest single-section producer (28% of all single wide homes produced in the Pacific Northwest in 2010), and the implication is that these low efficiency measures are likely to spread to other manufacturers who compete for this market segment, and may even spread to low end multi-section construction.

In some cases, declines in energy efficiency are not driven by cost, but by perceptions of quality. One example is the use of advanced framing, a building practice that produces a 6.8% average increase in wall performance with a 4% savings in wall cost. The percent of both energy and cost savings from advanced framing decrease when foam is added to an advanced frame wall, because foam masks the frame heat loss and increases overall costs. According to Northwest Energy Works (NEW), no Pacific Northwest manufacturers currently use advanced framing, and most now use solid headers due to increased installation of sliding glass doors, resulting in a degradation of thermal performance from that found in the 1990 study by Ecotope[1].

According to NEW, the move away from advanced framing is because of experience with (or fears of) drywall popping, wavy siding and reduced roof loading capacity. If these problems are documented,

[1] Energy savings estimates were determined from the reduction in wall studs only, and are conservative in that they do not include insulated headers.

technical fixes for them will need to be developed and demonstrated as feasible before the industry will return to advanced framing. On the other hand, the DAPIA consulted for the project noted that the HUD Code allows advanced framing in all areas but those in high wind zones and notes that the nation's largest manufacturer routinely uses advance framing. According to these sources, the main issue is some additional tape and texture work onsite, and the marketing used by competitors who claim that standard framing is "solid construction" and "equivalent to site-built". During investigation of this issue, Fleetwood of Oregon offered use of its wall testing facility at the nominal cost of materials and a charge for the operator's time. Resolving this issue will take research, demonstration and education.

Current issues with market characterization

While the cost survey was instructive as to the nature of the base case and insulation upgrade options and costs, it does not inform us as to what happens to non NEEM homes after they are sold and set up. This is because the HUD-code base case has not been subject to field evaluations since the 1994 HUD Code went into effect. Among the significant unknown factors in the base case:

- Heat pump and central air conditioner installation quantity, and quality (whether commissioned or installed properly)
- Heat pump and central air conditioner name plate efficiency
- Type of home—meaning single-wide or multi-section—and specify number of sections
- Envelope tightness
- Insulation condition (both in-plant and onsite)
- Duct tightness
- Cross-over duct type and condition of insulation, sealing and mechanical fastening
- Lighting wattage and lamp type
- Energy use assessments, either via direct measurement or utility billing analysis

It is difficult to properly assess the impact of efforts like NEEM and other beyond HUD Code programs without knowing more about the base case.

Technology Analysis

There are a number of envelope, HVAC and lighting technologies that have potential in manufactured homes. The most cost effective of these are probably envelope measures that are not significant variances from current practice. For example, advanced framing cuts production cost and increases efficiency. Blown in Blanket (BIB) type insulation systems are efficient and require little clean up. Rigid foam on the exterior of walls does not require special equipment or safety measures in plants. High efficiency windows may compare well to more dynamic measures such as Structural Insulated Panels.

Envelope Technologies

High R walls

Advanced Framing: As noted above, the manufactured industry has moved away from 24 inch on center framing and insulated headers. The concerns identified by industry need to be addressed before this approach sees wide adoption, via direct technical assistance, and where needed, research and demonstration to identify issues with (and corrections for) construction processes, preservation of roof loading capability and avoidance of material failures that might lead to uneven siding or "nail pops." In addition, even where manufacturers have used 24 inch on center framing and fully insulated headers, these construction practices may fall short of fully optimized advanced framing approaches, using more framing lumber at corners or interior walls than is necessary.

Structural Insulated Panels (SIPs): In 2000, Champion Industries constructed the first HUD code home using SIPs. While there were challenges associated with design of an all-SIPs house, the DAPIA approval process, and training of plant staff to accommodate new processes and materials, the home was successfully constructed in-plant, experienced fewer transportation-related complications compared to other factory built homes, and was found to be more airtight than a typical HUD code home **(Baechler, Hadley, Sparkman, & Lubliner, 2002)**. In addition, the manufacturer concluded that SIPs construction could be easily incorporated into the HUD code construction process, and could even increase production capacity, helping to offset increases in production costs.

In spite of these advantages, it's important to note that no HUD code home has been built with SIPs since. In one case, NEEM staff working in Idaho was actively engaged with a manufacturer that also owned a SIP plant to construct their homes with SIPs; even with that vertically integrated structure, the use of SIPs was not perceived as economically feasible.

Spray foam: In 2002, WSU and the Idaho Energy Division worked with Kit Homes to construct the Zero Energy Manufactured Home on the Nez Perce reservation in Lapwai, Idaho. The project specifications called for the use of spray foam (Icynene) in the walls, floors and ceiling. Kit's experience with using spray foam within the factory setting was that using foam requires significant modification of the production process, with additional needs for worker safety, and a significant amount of cleanup post-installation. The foam industry has expressed interest in working with the manufactured housing industry and other interested parties to overcome these issues.

Blown in Blanket Type Systems (BIBs): These systems are widely used in site-built housing and produce better quality installation and higher R values. Most of the systems are designed so preparation is quick

and there is no significant cleanup. No extraordinary measures are required to ensure worker safety beyond those needed for batt insulation. Many manufacturers already use blown insulation for ceilings and even floors, and should be able to adapt to blowing insulation into walls.

Exterior foam walls: While exterior foam sheathing has made inroads into the site built market, and has even been used in some modular homes, this building practice has not, to our knowledge, been used in manufactured housing. According to WSU's interviews with the DAPIAs, there are no structural issues with the use of foam sheathing in manufactured housing, when used in conjunction with the current shear system. Additional research may be required as to the maximum thickness of the foam, given transportation and on-site setup considerations.

High R Roofs

SIPs: As noted in the walls section, other than for demonstration purposes, SIPs have not been adopted by the manufactured housing industry, largely because of cost considerations. SIPs applications in attics can provide a conditioned space for HVAC duct chases and other mechanical systems, and can eliminate the house to exterior leakage related with the use of a vented attic. Also, for single section homes, SIPs can provide higher R-value throughout the roof assembly, including at the eaves, and may accordingly reduce the overall height of the home, avoiding transport height restrictions.

Spray foam under roof decking: Application of spray foam to the roof deck could potentially provide similar benefits to the SIPs roof noted above, allowing for inclusion of mechanical systems in an unvented attic, and reducing house leakage. DAPIAs noted that the use of foam would require a change to the HUD requirements for attic venting (unless the assembly was fully enclosed.)

Foam at eaves: Since polyurethane foam is already used for gluing the bottom of the truss chord to drywall, it may be that this foam could be extended to the first 12" of the eaves. Typical insulation at eaves is about R-12. Use of high density foam at the eaves would double this.

Foam blocks at eaves: Similar to the strategy noted above, this approach would use a foam wedge to baffle blown roof insulation, and add high density foam insulation to the eaves to significantly increase the R value. This product is currently unavailable, but could be developed if program standards included a requirement for full insulation value at the eaves.

High R floors

SIPs: When Champion constructed their all SIP home in 2000, they chose to locate the duct system in the crawlspace. If used in conjunction with a SIP cathedralized attic, the duct system could be brought into conditioned space.

Spray foam: In the Zero Energy Manufactured Home constructed in 2002, the manufacturer needed to apply the foam to an R-11 belly blanket, because the foam wouldn't adhere to the belly fabric. The research team working on the home also determined that the trunk ducts should not be foamed, to allow for beneficial conductive heat loss from the ducts to the home (regain).

High Efficiency Windows

Production windows are now approaching U factors below .2. An issue with these windows is whether they employ multiple panes that may make them too heavy or fragile for transport in a HUD Code home. This should be investigated and tested. If they work, they may be at the top of the list for acquisition, as they are likely to be a part of future versions of the IECC.

HVAC Equipment and System technologies

Ductless heat pumps: Ductless heat pumps (DHPs) have become a popular option in the site built industry, in new construction and retrofit applications. Manufactured homes, because of their layout, may be good candidates for this technology, utilizing a central DHP, in conjunction with zonal resistance heating in bedrooms. Multi-head systems may allow for further reductions in zonal electric heating, at higher cost, and with some penalty to DHP system efficiency. Another approach that needs further research is the use of transfer fans to move conditioned air from the central zone into the back rooms (HUD's heat loss calculations may be in conflict with this approach.) Further investigations are also needed into any potential HUD listing or code conflicts which may need to be revised to allow for DHPs.

Variable refrigerant flow central heat pumps: Variable refrigerant flow (VRF) heat pumps utilize technology similar to the ductless heat pump noted above, achieving significantly higher efficiencies than traditional air source heat pumps. Nordyne has recently begun producing a VRF system that will work in manufactured housing – additional research is needed to determine viability of this system in the Pacific Northwest.

Heat Pump system commissioning and controls: Heat pumps need to meet specifications for charge, flow, thermostat setup and outdoor lockout to operate correctly. Heat pumps meeting the Northwest's PTCS specification are estimated to achieve an average of 900 kWh annual savings over heat pumps without commissioning.

Electric furnaces with improved blowers and good duct design: Given that the majority of manufactured homes are shipped with electric furnaces, it would be useful to examine how this technology could be improved. The use of a blower with an Electrically Commutated Motor (ECM) can result in savings of 30% and upwards, when compared with a standard blower motor. The use of ECMs also introduces opportunities to mix air from a centralized DHP system, and may also allow for use of the blower fan as an efficient ventilation system. It's important to note that ECMs are very sensitive to high static pressure, requiring intelligent duct design that keeps the static pressure to .5 inches of water column (125 Pa) or less.

Electric Zonal heating and cooling: The use of zoned heating and cooling systems has the benefit of eliminating the need for a ducted distribution system. The disadvantages cited by the industry are higher costs, and eliminating the option of post setup installation of a heat pump or central air conditioner (this argument holds less weight given the increased availability of ductless heat pumps).

Other systems: Other technologies with wide deployment throughout the United States, but with less use in the Pacific Northwest, include residential economizers and evaporative coolers. Evaporative coolers have long been used to cool manufactured homes in southwest Idaho and eastern Washington. Demonstration of new technologies incorporating these methods of cooling may expand their use in manufactured homes.

Domestic Hot Water technologies

Heat Pump Water Heaters: Heat pump water heaters (HPWHs) are a high visibility technology being heavily promoted throughout the country. In the heating dominated Pacific Northwest, extracting heat from the conditioned space is problematic, providing space cooling during the many months of the year when it may not be desired. HPWH configurations that may be appropriate for the Pacific Northwest include placing the HPWH in a sectioned-off utility room where colder temperatures are not a significant issue, or using the HPWH to exhaust cooled air to the exterior, which has the added benefit of providing heat recovery ventilation. When used in conjunction with a ductless heat pump, the combined system acts in effect as a two stage heat pump. If HPWHs are to be promoted, they should meet and be installed to the Northern Climate Specification **(Northwest Energy Efficiency Alliance, 2009)** to ensure savings are obtained and the units are installed properly.

Plumbing system design: "Structured plumbing" systems, which reduce energy and water losses through designs that limit trunk and branch runs, insulate all pipe, incorporate circulation loops and a recirculation pump, have the potential to save 80% or more of the waste water and hot water in a "typical" home. Manufactured housing, with single story layouts, has the potential for a lot of wasteful design (distances of 60 feet from water heater to appliance are not unheard of in multi-wide homes. WSU has had discussions with Gary Klein of Affiliated International Management on the potential of structured plumbing approaches in both the IECC and HUD codes, as well and energy and water conservation programs.

Lighting Technologies

Compact and other fluorescents: While compact fluorescent lighting (cfl) is widely available in retail, and cfls are widely used in energy efficiency programs for site built homes, WSU's survey of the northwest manufacturers only identified one case where the manufacturer shipped cfls with the home, and then only when the customer selected the Eco-Rated option. Manufactured housing has a lot of untapped potential in this regard. Alternative design strategies for fluorescent technologies, such as dimmable T8 and T5 lamps in wall and ceiling valances, have proved to be effective and aesthetically pleasing in demonstration homes such as the WSU Energy House **(Lubliner, 2000).**

LEDs: LED technology has progressed significantly in the last decade, though costs remain high, especially for lamps with higher color rendering. A demonstration home using LEDs might be the best strategy for deploying this technology in the manufactured housing marketplace.

Solar technologies

Solar ready: Given the high first costs for both solar thermal and PV systems, neither technology is a cost effective option for the mainstream manufactured home buyer. However, including a "solar ready" option facilitates the after-market installation of solar technologies by implementing in-plant provisions such as roof load calculations, roof penetration flashing and mounting systems, pre-installed piping and conduit chases, and mechanical room design. Incremental costs are estimated at $300-$2100 (in climates with reduced snow loads, the existing roof design can accommodate the weight of the panels, reducing the need for a roof upgrade) **(Lubliner, Hadley, Gordon, & Nelson, 2003)**. Overall these

elements improve installation logistics and ensure consistent performance, while saving on after-market installation costs.

Transportation Impacts

Another technical issue, unrelated to new technologies, is the impact of transportation on energy efficiency features of the home. In 2011, one NEEM home tested by WSU failed to meet the program's duct leakage requirement; it had onsite tested leakage rates of 14% of conditioned floor area, compared to 5% of conditioned floor area in the factory. This particular home was a single wide, so there were no cross-over duct related issues; WSU and NEW staff concluded that the failure was transportation-related. While the NEEM field studies do evaluate duct leakage, no rigorous comparisons of in-plant and on-site duct leakage have been performed, which would help assess the impact of transportation on duct leakage.

Another area which has not received attention in recent years is the impact of transportation on insulation in ceilings. In the 1980s, RADCO performed some assessments of rockwool insulation settling in attics; results of these assessments were not available from RADCO at the time of this paper's release. To our knowledge, experiments with settling of blown cellulose have not been conducted. The impact of settling is probably less severe with higher ceiling insulation levels seen in NEEM homes, but may have a significant impact on the base-case.

Transportation could potentially also affect the distribution of insulation in the floor, especially for manufacturers using loose fill or "hybrid" floor systems (combination of batts and loose fill.) Settling, or other unintended redistribution of loose fill insulation (due to a belly blanket that isn't tight, or has tears) could lead to higher heat loss through the floor (and potentially through the duct system). To our knowledge, this issue has never been researched.

Policy Analysis

Overview of federal standards process

The National Manufactured Housing Construction and Safety Standards Act of 1974 **(United States Congress, 1974)** was passed in order to pre-empt conflicting state standards that threatened the viability of the industry. The U.S. Department of Housing and Urban Development (HUD) was given jurisdiction to develop and implement new regulations for the industry, resulting in the Federal Manufactured Home Construction and Safety Standards (FMHCSS) **(United States Code, 1974)**.

HUD created the FMHCSS and amendments to it in consultation with the Manufactured Housing Consensus Committee. In 1992 Congress, impatient with the inaction of HUD to address the inadequacy of the FMHCSS energy standards, passed Section 104(c) of the Energy Policy Act of 1992 providing that if HUD did not adopt updated energy standards within one year of enactment that the states could adopt energy standards for manufactured homes **(United States Congress, 1992).** This was incentive for expedited action by HUD resulting in the current HUD Code energy standards in 1994.

The process prior to the latest direction by Congress is that the Consensus Committee makes "periodic" recommendations to HUD for adoption, revision or interpretation of the FMHCSS. HUD then goes through the standard rule-making process with public input.

The fact that this process takes place an average of once every 18 years only after intervention by Congress indicates its ineffectiveness. The Consensus Committee is dominated by the manufactured housing industry which has an apparent conflict of interest in recommending any changes that will increase first-time cost.

The current round of rule-making was precipitated by Section 413 of the Energy Independence and Security Act of 2007, which mandated that the Secretary of Energy establish by rule energy efficiency standards for manufactured homes not later than four years after the date of enactment of the EISA (2011) **(United States Congress, 2007)**. Section 413 provides that the Secretary of DOE consult with the Secretary of HUD, who may consult with the Consensus Committee. It also provides that the energy standards will be updated no later than 1 year after IECC revision in the future.

Although the EISA was passed by a Democratic congress and signed by George W. Bush, the process is ultimately a political one. In fact, the Manufactured Housing Institute (MHI) is pushing legislation in the current Congress to repeal Section 413 and return the authority to promulgate manufactured home energy standards to HUD.

Revising the HUD code is an occasional, highly political process, subject to resistance from industry and the regulatory agency, and resulting in standards that are the result of compromise. It remains to be seen what impact Section 413 of the EISA and U.S. DOE will have on the process, or whether MHI will be successful in returning the system to its pre EISA status quo.

The advantages of the HUD code process are that the improvements made impact all homes produced, and all measures are paid by the ultimate purchaser (which is why the EISA requires they be cost effective.) If the requirements of the EISA stand, and U.S. DOE proves effective at implementing the IECC into HUD Code standards, and the IECC standards remain consumer cost effective then the HUD

Code could become a highly effective way to improve the efficiency of manufactured homes. Implementing the 2006 IECC will make some of the most energy inefficient cost reduction strategies unavailable by decreasing the overall heat loss rate up to 30% in HUD climate zone three.

Figure 3: IECC Climate Zones (Int. Codes Council)

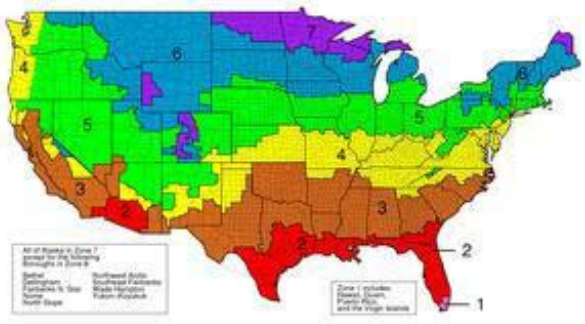
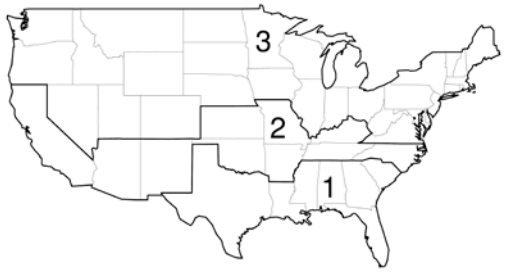


Figure 4: HUD MH Climate Zones (WSU)



The HUD Code does not affect heating and cooling, appliance or lighting efficiencies. Standards for heating and cooling systems and appliances are under the National Appliance Efficiency and Conservation Act of 1987 **(United States Congress, 1987).** In addition, HUD has required that heating, cooling and water heating equipment be specially licensed to be used under the HUD Code. While this requirement may have value for gas-fired appliances, it has no benefit in regard to electrically powered systems; indeed, it acts as an unnecessary regulatory burden, and should be changed.

Changing the HUD Code requires active engagement by experts with credibility, understanding of the process, and subject matter expertise. The Pacific Northwest is fortunate to have a leading expert on federal standards and representation on both the Manufactured Home Consensus Committee (MHCSS) and the 501 Committee that considers and recommends HUD Code changes to the MHCSS. Support for these ongoing efforts may be something that BPA and its regional partners should consider.

Administrative Enforcement Processes

Current implementation of the FMHCSS is through rules that establish a system of Design Approval Primary Inspection Agencies (DAPIA) which are private businesses, and Independent Primary Inspection Agencies (IPIA) which are state government agencies as in Idaho, Oregon and Washington (but may be private businesses elsewhere.) Because the design approval and inspection agencies are paid by the manufactured housing industry, they're subject to the influence of the industry—particularly where they may be replaced by a competitive business. In addition, the inspection agencies are paid by the inspection unit, and may have an interest in facilitating production rather than hindering it with enforcement requirements. This is not, of course, to say that actual conflicts exist in all cases. There is also an inherent inertia in the system, as a number of businesses and agencies have formed to participate in the FMHCSS implementation system—they naturally have an interest in seeing the system continue in a form that ensures their existence.

Since 1976, HUD Code Homes have been tracked by the Institute for Building Technology and Safety (IBTS), a private institution contracted by HUD to provide this service. IBTS supports itself by providing information related to the label (HUD number, serial number, manufacturer, date of construction and

location of first delivery—usually a dealer) for a fee. Results are faxed to the requesting party in 5 to 10 business days on a one-by-one basis. A reformed process would provide better tracking information so homes with defects could be more easily and cheaply found, and statistical information could be mined without archaic restrictions on information use. That said, using HUD numbers for tracking is far superior to serial numbers for tracking purposes, since HUD numbers are used by both factory and the IPIA at all stages of construction.

Problems with homes after purchase and installation are handled by the State Administrative Agencies (SAAs) in 38 states. In other states the consumer is referred to HUD. The HUD data base on SAA contacts is out of date. The SAA process is only for problems created or connected to construction in the plant, and includes high bill and comfort issues. Life threatening emergencies have priority.

Installation is not regulated by HUD, and is left to states and local jurisdictions to regulate. When BPA and the State Energy Offices of the Pacific Northwest began working with the HUD Code system in the region in the late 1980s, it was found that marriage lines were "sealed" with carpet pad or insulation, and cross over ducts were hanging temporarily connected with duct tape and routinely bent so air could not easily move through them. Between 1989 and 1995, the SEOs worked with the state IPIAs, manufactured housing associations and state and local code jurisdictions to develop and implement energy efficient installation standards with annual training. That training is no longer occurring in Idaho, and may not be taking place in the other states. This is a significant issue, since with a high turnover rate in the industry, it is unlikely that the knowledge promulgated through these past training efforts remains in the workforce.

There are a number of possibilities for improving the current FMHCSS enforcement process. They include:

1. Revising the process for determining u-factors to account for challenging geometries, compression of insulation, added conduction of metal framing (where applicable), and effects of convection channels in insulated cavities.
2. Providing feedback on insulation installation, including a grading metric similar to that adopted by the Residential Energy Services Network (RESNET.)
3. DOE quality assurance on the design approval process and the inspection process for energy and ventilation measures.
4. DOE training of DAPIA, IPIA and SAA staff in building science topics such as air leakage, thermal bypass and moisture movement in building assemblies. WSU has been working with Washington's IPIA to investigate training their staff in heat pump commissioning and duct testing, set-up issues, and thermography.
5. Consultation of DOE on severe SAA complaints dealing with mold, carbon monoxide and building failure due to moisture.
6. Uniform HUD Code installation standards in regard to marriage lines and cross-over duct installation.
7. Make problems due to improper marriage line seal, cross-over duct installation and structural failure impacting air seal and insulation specifically part of HUD Code process. Under this improvement, for example, the DAPIA would look at marriage line sealing strategies, and the IPIA would make sure those strategies are carried out. Thus, the Manufacturer's quality assurance process is responsible, and installation failures are captured by the SAA process.
8. Require annual training and re-licensing for manufactured home installers with mandatory curriculum elements on proper structural support, very basic building science, marriage line sealing and cross-over duct installation.

Making these changes on a national basis requires DOE to engage in the implementation process of the HUD Code. The Northwest Power and Conservation Council can advocate for these changes in its testimony and suggest they be included in the FMHCSS. Opposition from the industry, HUD and possibly DOE can be expected.

In the past, BPA made progress in some of these areas on a regional basis. Idaho, Oregon and Washington still have installation standards that are a legacy of the work of the state energy offices working in conjunction with the local manufactured housing industry and agencies involved with HUD Code homes to develop and implement efficient installation standards. And accurate component U factors were developed and used in qualifying manufacturer's designs to the standards of regional programs. BPA's support for this work was critical to its success.

As part of any new manufactured home programs, BPA is advised to consider funding annual installation training as part of the certification process for installers with the understanding that the state agencies will continue these efforts after the funding is over. It should also structure any new acquisition program to require voluntary implementation of as many of the features stated above as possible for the homes impacted by the program with BPA or its contractor(s) taking the role of DOE.

Utility Hookup Standards

There are two dimensions to setting rates based on minimum energy efficiency standards. The first is the wholesale rate surcharge authorized by the Northwest Power Act **(United States Congress, 1995)** to enforce the Model Conservation Standards, and the second is utility hookup standards based on minimum end use efficiencies. The first has been considered, but never used, and the second has been established in Washington State.

Mason County Public Utility District Number 3 adopted a connection standard where homes, including manufactured homes, could either be certified to the Super Good Cents standard or pay a substantial connection fee. This was challenged by the Washington Manufactured Housing Association, and the Washington Supreme Court ruled in favor of the utility stating in part "We agree the new facilities charge is a valid rate and not a construction standard" **(Washington State Supreme Court, 1994).** The Washington State Supreme Court specifically ruled that a valid utility rate was not a building standard and thus was not preempted by the National Manufactured Housing Construction and Safety Standards Act of 1974.

In an era where site-built codes far exceed the HUD Code efficiency requirements, the question arises as to who should pay for the extra cost for the utility to serve inefficient electrically-heated homes. Should it be the rate payer or the homeowner?

The hookup standard remains as a viable promotional tool for energy efficiency—at least in Washington State. It is not currently recommended as a regional strategy, because it has not been established as a viable option in states other than Washington. It is as an alternative to paying for efficiency measures that cannot be implemented through standards, and should be left to utilities to decide whether to use this tool or not to meet regional and state efficiency goals.

Acquisition

The purchase of energy efficiency resources has a distinguished history in the manufactured housing arena. As mentioned in the introduction, the original MAP Program was a massive effort that purchased efficiency wholesale from over 50,000 manufactured homes built at the height of historic manufactured home sales. The cost of the MAP efficiency purchase was approximately 1.7 to 2 cents per kWh saved **(Lee, Taylor, Schrock, Sandahl, Chin, & Kavanaugh, 1995).**

Acquisition can be used for several purposes. One is to acquire efficiency as cheaply as possible by dealing directly with manufacturers. Another is to move the industry standards which may result in upgrade of the HUD Code as it did in 1994. Another result is to create a long-lasting program such as the NEEM Program that grew out of MAP, and continues to this day, allowing continued utility and tax investment.

The regional base case has slipped since the MAP program. It may be time for a new acquisition program for all of the reasons stated above.

Acquisitions do not have to be a cash payment per complying home. They could also be a system whereby an aggregator such as BPA makes bulk purchases of materials such as foam board and efficient windows and equipment such as mini-split ductless heat pumps and heat pump water heaters and provides them to manufacturers who agree to install them.

WSU recommends that BPA and the region adopt the following five principles in the design of any regional acquisition effort.

Principle 1: Anticipate potential HUD Code changes and prove them through acquisition.
For example, if the HUD Code is amended to incorporate the 2006 International Energy Conservation Code (IECC) standards, the next target is the next version of the IECC expected to be adopted—the 2012 IECC. New technologies in that code would be first on the list to drive the HUD code adoption process to the next level in the time period before the new rules. Just as MAP demonstrated that energy efficient windows and doors, and added insulation in ceilings, walls and floors were feasible and cost effective to HUD, it is clear that actually doing it takes away the argument that it can't be done.

Some of the primary advanced features of the 2012 IECC are:

- Foam on walls in IECC Climate areas 6 and higher—these zones comprise about half of HUD Climate Zone 3
- Very tight air sealing of the envelope and ductwork, requiring very careful in-plant construction and onsite testing
- High percentage of energy efficient lighting, installed by the builder

Principle 2: Maximize efficiency
Designing and constructing homes to reduce heating energy is a long-term investment with at least twice the life expectancy of most equipment solutions such as heat pumps. While technology is part of any acquisition program, the improvement of envelope efficiency is almost always the most cost-effective choice.

A two-pronged approach is to have the basic efficiency increases made through the HUD Code process, and then acquire efficiency improvements above that designed with the objective of making the envelope as efficient as cost-effectively possible to avoid lost opportunities.

Resulting loads should be in the neighborhood where equipment strategies such as heat recovery ventilators and mini-split ductless heat pumps can make a big contribution to maintaining comfort in the home at the lowest possible cost.

Principle 3: Engage the industry in research and demonstration

Research and demonstration provide a pathway into new technologies that saves cost in the long run by ensuring that implementation occurs in a way that actually saves energy and is integrated into the production process that it is likely to continue. Several examples of near term projects are listed below. Each is designed to fit into the other principles. These projects should be done with industry where appropriate, and key participants brought together to share success and trade information.

1. An exploration of advanced framing's possible issues and cost-effective solutions for any that are found to be valid and time-limited incentives to manufacturers who agree to build all homes with advance frames for a certain period.
2. A demonstration of blown-in-blanket wall systems in interested manufacturers' plants.
3. A demonstration of foam on walls working with several plants and solving detail issues maturing into incentives to add foam on walls for IECC climate zones 6 or higher.
4. A research and demonstration project for eliminating ducts or bringing them all inside the thermal shell of a manufactured home.
5. Research into high R attic construction that solves the issues of low heels and the fact that a great number of HUD Code homes have slanted roofs—once these issues are solved. BPA should consider incenting high R attics where a future IECC will require them for site built until that standard becomes part of the HUD Code.
6. That BPA conduct research into whether very high efficiency windows (triple or more panes) are light enough for manufacturers to use and durable enough to withstand transport and setup.
7. A program to train and support IPIA staff to conduct commissioning of heat pumps, as well as duct and envelope testing.
8. Provide linkage between IPIA alteration permit database and future potential research activities.

Engaging industry is a strategy to establish buy-in, build enthusiasm and inspire innovation. This principle was proven in the industrial sector where sparsely attended training by technical experts was replaced by industries telling their efficiency success stories to a packed room with hundreds of industry attendants.

Principle 4: Commission heat pumps

As noted above, over a quarter of all new NEEM homes have an air source heat pump installed after market. Manufacturers rarely install heat pumps, because they require placement of an outdoor unit and connection of refrigeration lines. It is not known how many of these site-installed heat pumps meet any commissioning and control requirements, though the results of the Ecotope billing analysis cited above indicates the vast majority do not.. Even more uncertain are the number of existing and non NEEM manufactured homes that have heat pumps installed.

At least in Washington State this problem can be easily solved and establish a model for the region and perhaps the nation. Washington's Department of Labor and Industries already permit and inspect all heat pump installations on manufactured homes in Washington State. They currently determine that a

heat pump was installed, that the indoor and outdoor units match, and that the requirements of the permit are met. The data base currently shows that a home has a heat pump installed. The division that performs this service is interested in having its field staff trained in heat pump commissioning and performing it on the systems they permit and inspect. It would require a nominal flat payment.

Under this approach, the heat pump would receive basic commissioning, with focus on presence of backup heat lockout, and check for documentation by the installer of proper charge. Inspectors would collect the following data:

- Date of commissioning,
- Whether installer had provided lockout and documentation,
- Type, size and efficiency of equipment,
- Evidence of utility program participation, and
- Vintage, sections and certification (if any) of the home.

Principle 5: Maintain and support a voluntary efficiency program

Almost sixty per cent of Pacific Northwest manufactured home buyers choose to purchase NEEM homes. This investment averages $1,300 on a single section home and $1,800 on a double section. This consumer choice, with modest utility support, has persisted throughout the market decline for HUD Code homes. To leverage this investment, avoid free ridership, and build in an exit strategy, every acquisition program design should maintain a voluntary option to purchase extra efficiency measures. These can include specific items such as blown-in-blanket walls, super efficient windows and advanced lighting packages plus options like Eco Rated.

Key Findings and Recommendations

It remains to be seen whether the manufactured housing market will revive as the general housing market picks up. The re-emergence of low efficiency construction is somewhat of a surprise, given the long-term success of MAP and NEEM. That plus what are still a sizeable number of electrically-heated homes per year added to the grid make efficiency in this sector still worth pursuing.

The primary means to attain increase in HUD Code efficiency is through improvement in the HUD Code. To date opportunities to do this are rare, and must be given priority when they occur. Hence all available means to retain the current Section 413 of the EISA of 2007 and to demonstrate the cost-effectiveness of at least the 2006 IECC should be pursued.

Upgrading the standard is only half the battle. Research and demonstration provides a pathway into new technologies that saves cost in the long run by ensuring that implementation occurs in a way that actually saves energy and is integrated into the production process so that it is likely to continue.

Measures to improve enforcement and installation are also necessary. It is also important to advocate for any possible changes in the HUD Code that will improve efficiency, such as a reformed U factor calculation procedure. A regional effort should be made to continue design, in-plant and installation technical assistance and training, and advocate its adoption by DOE and HUD. This should include training in basic building science so installers and perhaps line foremen know the reasons behind the changes being made.

Acquisition is the most expensive but also the most controllable energy efficiency vector. It can be used to purchase efficiency and also to aim toward upgrade of the HUD Code. There are a host of technologies available, and many of them are currently cost-effective or soon will be. Most or all of them become cost effective when viewed on a life-cycle cost basis, because of the lost opportunity if they are not acquired during construction.

WSU staff present the following key findings and recommendations:

Market Related Findings and Recommendations

1. **While the market for manufactured homes is currently declining, it is expected to rebound as the economy recovers. The majority of these homes are heated with electric forced air furnaces, which creates an ongoing load issue**:
   - 1,936 manufactured homes were sited in the Pacific Northwest during 2010.
   - Of the homes sited in 2010, 83% were multi-section and 17% were single section.
   - Approximately half of NEEM homes have electric forced air furnaces for heating; the remainder is heated by natural gas furnaces or heat pumps. It is likely that non NEEM homes have a higher percentage of electric forced air heating, because NEEM homeowners are probably more likely to invest in a heat pump.

   Recommendation: Although the market is currently declining, it still produces a significant number of electrically-heated homes, and will probably rebound to higher output as the economy recovers. It is therefore recommended that BPA stay engaged with this market, and is to be commended for its investment in updating the regional cost information in preparation for informed participation in the DOE rulemaking on upgraded HUD Code energy efficiency standards.

2. **The low end of the market is becoming less energy efficient.**
   The cost research conducted by WSU found that the low end offerings included metal frame windows, R-2 trailer doors, and R-11 in 2x6 walls. This is the first time this type of construction has been widely available in the Pacific Northwest since before MAP. Our research found a package with these features offered for single section homes by the largest manufacturer of single section homes in the region. It is likely that these features will also be used in multi-section homes without some kind of significant standard upgrade or market intervention.

   Recommendation: This demonstrates that the current HUD Code efficiency standard is far too low, as these features would not meet the site-built energy code in any of the Pacific Northwest states. If the HUD Code process does not improve the standard to eliminate these inefficient practices, BPA will have to decide 1) whether it will pay manufacturers to upgrade these homes; and 2) if so, where will the benchmark level be?

3. **The number of single section homes is increasing as a percentage of total production.**
   - Single section homes generally represent the low end of the market.

- Historically less than 2% of NEEM homes are single section. This percentage increased to as much as 7% in the past two years—still significantly lower than the 17% share that single section homes comprised of the total Pacific Northwest market in 2010.
- Single section homes are very likely to have electric resistance space heat with no heat pump installed on site.
- Single section homes are most likely to have the least energy efficient construction.

Recommendation: This sector of the market deserves particular attention by BPA, as it is growing, is not as susceptible to the NEEM strategy, is likely to have electric resistance heat, and usually has the least efficient construction without direct market intervention. This may indicate a need for an ongoing acquisition program for single-section homes.

4. **The majority of HUD Code homes are shipped with electric resistance furnaces. NEEM field data shows that about half of these homes have heat pumps installed after market.**
   - The NEEM field study cited in this paper does not indicate whether systems are commissioned or not, and it does not indicate heat pump name plate efficiency.
   - The field study report does show that average heat pump and electric resistance energy use are the same in climate zone 1 and almost the same in climate zone 2, indicating that most of the heat pumps are probably not commissioned or properly installed.
   - Half of the region's HUD Code production is sited in Washington State with the other half divided between Oregon, Idaho, Montana and other states.
   - The Washington Department of Labor and Industries (L&I) enforces the HUD requirement that all modifications to HUD Code homes be done consistently with the HUD Code through a system of alteration permits. Its expert staff conducts field inspections of all after-market heat pump and air conditioner installations on HUD Code homes sited in Washington.

   Recommendations: WSU recommends that BPA partner with L&I to commission all heat pump and air conditioner installations on HUD Code homes in Washington State. L&I field staff are already cross trained in a number of disciplines and are enthusiastic about being trained in commissioning. This partnership will include access to the L&I data base and modifications expanding the information collected and allowing homeowners to indicate they are interested in their home being a subject of research when they apply for a permit. The L&I field staff can also conduct informational audits to increase knowledge about the non NEEM sample. For a nominal cost per unit, this partnership will serve as a case study and can be replicated elsewhere.

   WSU also recommends that future random sample field studies note the name plate efficiency of the heat pump and whether or not it has been commissioned. The performance analysis should segregate the commissioned and noncommissioned system performance.

Technical Based Findings and Recommendations

1. **Advanced Framing achieves a significant increase in wall performance, with reduced cost. However, there is significant resistance to its adoption in manufactured housing.**
   The Incremental Cost Study showed that manufacturers could probably achieve a 6.8% average increase in wall performance with a 4% savings in wall cost. There are, however, many divergent opinions on advanced framing in the manufactured home industry:
   - Reports from the industry in the Pacific Northwest that advanced framing is not favored because it reduces roof load ratings and leads to nail pops and increased stress cracking, particularly above window and door frames.
   - DAPIA reports that there is no HUD restriction, except in Wind Loading Zone 3, and that the nation's largest manufacturer uses advanced framing.
   - Marketing concerns that standard framing is more solid, and "just like site-built".

   Recommendation: That BPA conduct research and demonstration on advanced framing to explore possible solutions and obtain solid information to address concerns. Fleetwood has offered its wall test facility for this purpose for the cost of materials plus a nominal fee for sample assembly and testing. On road testing may also be necessary.

2. **Increasing efficiency in manufactured homes requires new measures and technologies unfamiliar to the industry.**
   One of these, advanced framing, has been discussed in its own right. Other technologies include: blown in blanket wall insulation, foam on walls, bringing ducts into conditioned space, high R attic construction, and high efficiency window integration with HUD Code transportation limits.
   Recommendation: Fund rapid research and demonstration at manufacturing plants in these areas with several manufacturers doing each type of project and each one doing at least one project. Then convene the plant engineers and key production managers to share success stories and lessons learned. NEW and WSU can provide technical assistance.

3. **The impact of transport on insulation settling and duct leakage is unknown.**
   Do ducts stay tight and insulation at full loft during transportation from plant to home site? Duct tightness at the plant versus onsite was called into question by a chance Building America test at a single-section home where a wide discrepancy was found between in-plant and field measurements.
   Recommendation: Conduct random tests on pre and post duct testing and attic insulation.

4. **The characteristics and performance of the non NEEM homes have not been studied since the early 1990s.**
   A long-term strategy toward non-NEEM homes cannot be developed without data about these homes; a robust field study and market assessment of these homes is long past due.
   Recommendation: BPA should support both baseline field studies and market assessments of non-NEEM homes.

Policy Related Findings and Recommendations

1. **The Pacific Northwest is fortunate to have individuals actively and prominently engaged at the national level with improving the HUD Code.**
   - Changing federal standards requires credibility, experience with the process and expertise.
   - The Pacific Northwest has a noted expert on standards for appliances and the HUD Code; it is also represented on the Manufactured Housing Consensus Committee (MHCC) and the 501 Committee that recommends changes to the MHCC.

   Recommendation: BPA and utilities should continue to support these efforts.

2. **The current administration of the HUD Code lacks building science input and installation training, and makes tracking and assessment of homes difficult.**
   - The HUD Code enforcement system lacks independent building science expertise.
   - The State Administrative Agency (SAA) system for solving problems is limited to issues related to manufacturing, and generally lacks building science technical capability.
   - The current tracking system is expensive, cumbersome, and withholds data based on confidentiality for production and sales numbers that is against the public interest.

   Recommendations:
   - Technical assistance and training to the HUD Code infrastructure should be part of any beyond code program.
   - It is also recommended that the Northwest Power Council (Council), if it deems appropriate, include administrative reform issues in its testimony regarding new HUD Code standards.
   - Also, any future beyond-code program should use HUD numbers for tracking purposes.

3. **Washington law allows utilities to set rates based on energy efficiency standards.**
   - Washington State has a high court ruling upholding a rate structure that required customers to bring manufactured homes to specific efficiency standards.
   - Where the HUD Code lags significantly behind site built codes, the question arises as to who should pay the extra cost to serve inefficient homes—ratepayers or home buyers.

   Recommendation: Washington utilities should be apprised of the inefficiency of low end manufactured homes and informed that they may use efficiency rates ("hookup standards") to achieve efficiency goals for manufactured homes to bring them into parity with site-built new homes.

4. **Acquisition is the most expensive option and must be strategically planned.**
   Acquisition has been successfully used in the Pacific Northwest to produce ongoing savings at low cost—and it has had national impact. With that success and the maintenance of a robust manufactured home program throughout the intervening years, it is important to take the lessons learned and use them to design the next generation of acquisition programs.

   Recommendation: WSUEP recommends that BPA and the region invest in above HUD Code and NAECA energy efficiency improvements guided by these five principles.

- Implement the changes needed to move from whatever HUD Code energy standard is in place to the next substantial revision of the standard;
- Reduce heating loads to the point where even if the source is electric resistance the load is manageable;
- Research, demonstrate and encourage the use of energy efficiency practices and technologies that will produce long-term change in the way manufactured homes are built and installed; and
- Optimize the performance of the heat pumps and air conditioners that are installed in both new and existing HUD Code homes through incentives for highly efficient equipment and commissioning.
- Continue a voluntary efficiency investment opportunity such as NEEM as part of any acquisition program in order to leverage consumer investment, reduce free ridership, and build in a viable exit strategy.

Sources

Baechler, M., Hadley, A., Sparkman, R., & Lubliner, M. (2002). Pushing the Envelope: A Case Study of Building the First Manufactured Home Using Structural Insulated Panels. ACEEE Summer Study on Energy Efficiency in Buildings Conference. Pacific Grove, CA: American Council for an Energy Efficient Economy.

Baylon, D., Davis, B., & Hewes, T. (2009). Summary of NEEM Manufactured Home Field Data and Billing Analysis. Ecotope, Inc.

Baylon, D., Davis, B., & Palmiter, L. (1995). Manufactured Home Acquisition Program: Analysis of Program Impacts. Ecotope, Inc. and Washington State Energy Office.

Baylon, D., Lubliner, M., Davis, B., & Kennedy, M. (1990). Manufactured Homes Cost Data Analysis Report. Ecotope Inc. and Washington State Energy Office.

Davis, B., & Robison, D. (2008). High Efficiency Heat Pump Heating and AC Monitoring Project. Ecotope, Inc. and Stellar Resources.

Eklund, K. (2008). Residential Heat Pump and Air Conditioner Research, Demonstration, and Deployment Improving Pacific Northwest Utility and State HVAC Programs. Idaho Energy Division.

Eklund, K., & Gordon, A. (2011). Cost Assessment for Manufactured Homes. Prepared for the Bonneville Power Administration.

Grissim, J. (2011, Fall). The Current Industry Landscape – and a Few Predictions. Grissim Perspective .

Lee, A. D., Taylor, Z. T., Schrock, D. W., Sandahl, L. J., Chin, R. I., & Kavanaugh, D. C. (1995). Impact Evaluation for the Manufactured Housing Acquisition Program (MAP). Richland, Washington: Pacific Northwest Laboratory.

Lubliner, M. (2000, October). WSU Energy House. Automated Builder Magazine .

Lubliner, M., Hadley, A., Gordon, A., & Nelson, M. (2003). Introducing Solar Ready. American Solar Energy Society Annual Conference. ASES.

Lubliner, M., Hadley, A., Gordon, A., & Nelson, M. (2003). Introducing Solar Ready. American Solar Energy Society Annual Conference. ASES.

Neme, C., Proctor, J., & Nadel, S. (1999). Energy Savings Potential from Addressing Residential Air Conditioner and Heat Pump Installation Problems. Washington, DC: American Council for an Energy Efficient Economy (ACEEE).

Northwest Energy Efficiency Alliance. (2009). A Specification for Residential Heat Pump Water Heaters Installed in Northern Climates, Version 3.0.

Northwest Energy Works. (2011). Northwest Energy Efficient Manufactured Housing Program Database.

Northwest Power and Conservation Council. (2010). Sixth Northwest Conservation and Electric Power Plan.

United States Code. (1974). National Manufactured Housing Construction and Safety Standards Act of 1974. Title 42 United States Code, sections 5401-5426 .

United States Congress. (2007). An Act To move the United States toward greater energy independence...and to improve the energy performance of the Federal Government, and for other purposes. (PL 110-140) Stat. 1492 United States Statutes at Large .

United States Congress. (1992). An Act to provide for improved energy efficiency. (Brief Title: Energy Policy Act of 1992). United States Statutes at Large PL 102-486, 106 Stat. 2776 .

United States Congress. (1987). National Appliance Efficiency and Conservation Act of 1987. Public Law 100-357 .

United States Congress. (1974). National Manufactured Housing Construction and Safety Standards Act of 1974. Title 42 United States Code, sections 5401-5426 .

United States Congress. (1995). Pacific Northwest Electric Power Planning and Conservation Act. United States Statutes at Large. (PL 96-501) 94 Stat. 2697.

Washington Manufactured Housing Association v. Public Utility District No. 3 of Mason County, 124 (Washington State Supreme Court August 25, 1994).