LA RES Natural Gas Reduction Subcommittee Interim Report *Draft of: 12 Jul 21*

Executive Summary

Virtually the entire Los Alamos community is heated by combustion of natural gas (NG). Space heating is the majority of that demand. Roughly 25% of NG goes to secondary uses – water heating, cooking, and pilot lights. More than 75% of total use is in residences. Both NG itself, when it escapes, and the carbon dioxide it produces, when burned, are greenhouse gasses that cause climate change. The Board of Public Utilities has adopted a strategic goal to phase out NG use in Los Alamos by 2070.

No single "silver bullet" will replace NG for space heating. Main approaches, all of which are technically and economically viable to pursue today, are:

1. New construction should utilize more compact architectures. Multi-story and multi-family dwellings lose less heat per unit living area than single-story, single-family detached homes. LA's shortage of developable land is already driving local construction in this direction,
2. For both new and existing homes, the most "bang for the buck" in reducing NG use is to reduce heat loss through their exterior envelopes (roof and outside walls) via upgrades in windows, doors, and insulation. This is particularly true of government-built homes.
3. New construction can take advantage of architecture and orientation to derive some significant fraction of heating needs directly from the sun, assuming the site has solar access.
4. NG-fired furnaces and water boilers can be replaced by modern heat pumps. These use 3-4X less electricity than traditional electric resistance heating to deliver the same heat energy. They are reversible to provide cooling (air conditioning) in hot weather. Peak electrical demand may still exceed what the present electric supply system (sources, transmission lines, and distribution system) can provide. Distributed ("rooftop") solar photovoltaic generation and storage in at least some individual homes may be necessary.

Water (for personal hygiene, clothes and dish washing, etc.) can be heated directly by the sun, by heat pumps, or by point-of-use electrical ("tankless") systems. Both NG and electric cooking ranges can be replaced by electric induction ranges that also offer superior cooking performance. NG pilot lights can and should be simply eliminated in favor of electric ignition of remaining NG appliances.

The point of this work is to show that phasing out NG is possible, even today. Technology, economics, and regulatory factors will all evolve over coming decades to make this difficult task easier. We can, and must, get started.

This is a preliminary report, intended to show directions of the subcommittee's thoughts today. Several sections are incomplete and much quantitative detail remains. Italicized entries indicate some of the areas where such further discussion or detail is intended. Except for banning installation of new NG pilot lights, all recommendations (Sec. 7.0) to support the above approaches are preliminary.

1.0 Introduction

1.1 The Challenge

Natural gas (NG) is a major contributor to global climate change. Its principal component is methane, CH_4. When methane is burned, it combines with atmospheric oxygen, to form carbon dioxide, CO_2, and harmless water vapor. CO_2 remains in the atmosphere for hundreds of years, forming a heat-trapping blanket that helps raise the temperature of the planet, hence the term "greenhouse gas." Unburned methane is also a greenhouse gas. It can be released during exploration, drilling, extraction, transmission, distribution, or incomplete combustion of NG. Compared to CO_2, it has a much greater global warming potential but lasts "only" decades in the atmosphere. It, too, is a significant contributor to climate change.

In October, 2020, the Board of Public Utilities adopted a strategic goal to "support elimination of natural gas usage by 2070." The exact date is not important. Starting on "elimination" is.

Almost all buildings in Los Alamos are heated with NG. The Department of Public Utilities DPU) supplies gas to approximately 7700 meters. In a typical year, the citizens of Los Alamos County, exclusive of the Laboratory, use about 8,600,000 therms (average for 2010-2019).

Roughly sixty homes in the La Senda area of White Rock are heated with commercially-supplied propane, C_3H_8. When burned, C_3H_8 also produces CO_2. Its use also needs to be eliminated using the same approaches as for NG, but the quantity is small enough it is not included in the statistics in this report.

NG use closely follows ambient air temperatures, as expected. It typically peaks at about 1,500,000 therms/mo. in December and January. Minimum usage is around 200,000 therms/mo. In June, July, and August. (Again, these are 2010-2019 averages.) Summer use indicates how much gas is used for purposes other than space heating – water heating, cooking, and pilot lights. Those secondary uses are undoubtedly greater in colder weather when more water heating is necessary and more cooking is done, but they cannot be separated in the data. If 200,000 therms/mo. year-round is assumed, 28% of NG is used for secondary purposes. The real percentage is higher.

At least 75% of NG goes to residential customers. About 4% is used by LA Public Schools. Close to 5% is used by County government. About 16% of use is classified by DPU as "commercial." Some "commercial" use actually also residential. A significant part of the "commercial" space in town is occupied by the Laboratory or its subcontractors and should not be attributed to LA citizens. The actual percentage of NG that goes to residences is higher than 75%.

Clearly, residential space heating is by far the single largest use for NG in Los Alamos. Hence, the NG Reduction Subcommittee has so far focused on it, while recognizing that secondary and non-residential uses will need to be addressed more completely, too.

This report outlines one general path to phasing out NG that is technically and economically viable today. Technical, economic, and regulatory environments will evolve. Other paths may open. However it is done, it will take decades. We need to get started with the tools at hand.

1.2 Administrative Notes & Caveats

Members of the Natural Gas Reduction Subcommittee are: Lia Brodnax, Elizabeth Daly, Robert Gibson, Ben Hill, and Greg White. In May, 2021, the subcommittee was temporarily combined with the Community Planning and Zoning Subcommittee, which also includes Skip Dunn. This report includes only the NG part of the combined subcommittee's work.

This is a preliminary report to indicate the general direction of the subcommittee's thinking and work. It is incomplete. Almost all numbers are subject to verification and refinement.

The County Assessor's office kindly supplied reports on all taxed properties in the county. This data includes year originally constructed, occupied square footage, basic architectural type, type of heat, and whether or not the space is air-conditioned. DPU supplied NG usage data for all meters in the county for every month in calendar year 2018. That year was chosen as the most representative year in the past decade. 2020 data is available, but it is not clear how COVID-related issues may have changed some usage patterns. All information is public and obtained either directly or through Inspection of Public Records Act (IPRA) requests. The two datasets were correlated, to the extent possible, through street addresses.

2.0 Residential Space Heating without Natural Gas

2.1 Compact Architectures

Heat energy is lost from buildings through external surfaces – outside walls and roofs (and crawl spaces, where applicable) and through windows and doors. The less exterior surface area for each square foot of internal living area, the more energy-efficient the home can be. Single-family, single-story, detached (ranch style) homes are the least energy-efficient. Multi-story, multi-family units are more efficient.

Three simple examples demonstrate this point. Heat loss is proportional to surface area.

1. Significantly more heat is typically lost through roofs than walls. A two-story building has half the roof area of a single-story building with the same living area, although it does have more wall area.
2. A rectangular duplex has 75% of the wall area of two detached homes with the same living area.
3. A quad of rectangular units has 62% of the wall area of detached homes for the same living area.

This will be confirmed through analysis of data on existing buildings.

Los Alamos housing is already being forced in this direction by limitations on available land.

2.2 Minimize Heat Loss

After basic structural style, heat loss can be minimized through insulation and modern window and doors. Some fresh outside air does need to be admitted into any occupied building. It should be in a controllable fashion (e.g., open windows) not just through random leaks.

New Mexico has adopted, with some modifications, the 2018 International Energy Conservation Code (IECC 2018) as the NM Residential Energy Code, which applies to new construction and changes substantial enough to require permits. Where its provisions are not binding, it is still useful as guidance for any property upgrades.

Simply put, IECC 2018 requires windows in LA to have a U-Factor no more than 0.3, ceiling insulation of R-49, and wall insulation of R-20. Foundations and crawl spaces have insulation requirements, too.

Windows represent the biggest heat loss in most home envelopes. Their heat loss is rated in "U-Factor," or BTU/hr•sq.ft•deg F. Single-pane windows typically have a U-Factor around 1. Double-pane windows can vary from about 0.8 to 0.3 depending on frame and what gas is between the panes. Triple-pane windows may have U-factors as low as 0.15. For rough comparison, the more familiar R-value of a window is the reciprocal of the U-Factor. Even a window with a U-Factor of 0.3 has an R-value of only 3.3, much less than walls should be. How much heat is lost through windows depends both on the U-Factor of the windows and the total window area. Doors can be similarly large heat loss points.

Depending on the individual existing home, the easiest and most "bang for the buck" improvement is likely from adding insulation in the attic if the home has one. Insulation can be added to walls cost-effectively, too. Window and door upgrades can have the largest effect, but are also the most expensive. (See. Sec. 2.6.1)

Quantitative estimates, of both energy savings and costs, for typical Los Alamos homes will be included in Sec. 2.8 of the final report.

2.3 Heat Sources

Heat lost through walls, windows, and doors must be made up. Living occupants (humans and four-legged friends), appliances, other equipment, and lights all produce heat. So does solar radiation through glass into the home's interior.

2.3.1 Solar Thermal Heating

This issue will be addressed in the final report..

Of course, solar thermal heating only works if sunlight hits the building or at least most of it.
All newly constructed buildings should have solar access, i.e., at least the roof and as much of the rest of the building as possible should experience direct solar radiation most, if not all, of the day

at all times of the year, particularly during the colder months. (Roofs and other overhangs may be designed to shield walls from solar radiation during the warm months.) Solar access must become a factor in designing new neighborhoods or subdivisions. Orientation of individual buildings, especially their roofs, to most effectively utilize solar energy must also be a factor in neighborhood and subdivision design. Trees present a particularly sensitive political challenge, especially in established housing areas.

Solar access is also needed for any rooftop electrical generation, whether to power heat pumps (See Sec. 2.7) or for other electrical needs in the house.

2.3.2 Artificial Heat Sources – Heat Pumps

The second source of heat is some sort of artificial heater. Today's sources are NG-fired furnaces (for air) and boilers (for water). (Despite the name, boilers do not heat water nearly to boiling temperature). A few places may use electric heat. There are no known sources of geothermal heat on the east side of the Jemez mountains.

Traditional electric resistance heat has a well-deserved reputation as being very expensive. It is. At current nominal rates in Los Alamos ($0.55/therm for NG and $0.115/kWh for electricity in March, 2021) electricity costs about six times as much as NG for the same amount of heat energy.

Heat pumps are a well-established technology that makes far more efficient use of electricity for heating than resistance heating. Heat pumps are not new. Refrigeration in its many forms (e.g., refrigerators, freezers, and refrigerated air conditioners) uses heat pumps. Utilizing phase changes in a working fluid, they essentially extract heat energy from a cold source and "pump" it "uphill" into warmer air or water.

Heat pumps can be configured to work both directions, to heat or cool the inside of a building. A valve in the heat pump system reverses the direction of heat flow.

Heat pumps can substitute for a furnace or central air conditioner, heating or cooling air in a forced air system. They can also substitute for a boiler, heating water in a hydronic system, either baseboard or in-floor. Hydronic air conditioning gets more complicated, because some air movement is necessary to be practical. Chilled water pipes near ceilings are one approach, more applicable in institutional buildings. Another is to create some airflow through indoor evaporator coils. The popular "mini-splits" use this technique. Either way, one heat pump can both heat and cool a home.

In a heat pump, electricity is not turned into heat. It only runs the pump. The colder the source, the more work the pump has to do – and the more electricity is required – to pump heat energy "uphill." Heat pumps are characterized by a "Coefficient of Performance" (COP). COP is basically the ratio of heat energy transferred to the energy content of the electricity required to affect that transfer. It might be considered the "gain" of a heat pump relative to straight resistance heating. Resistance heating has a COP of 1. A typical heat pump might have a COP of 4 if the source temperature is around 50° F, a COP of 3.5 if the source temperature is 30° F, and a COP of 3 if the source temperature is 5°F.

The warmer the source, the less work heat pumps have to do and the higher the COP. The source of heat can be the ground, water, or ambient air. 20 ft. or more below the surface, our ground temperature is around 50° F all year round. When heat energy is extracted from soil by a heat pump, the soil temperature drops unless the energy is replaced. Water is a good conductor of heat. Ground-source heat pumps work best in wet soil. A lake or pond is even better. Our volcanic soil is dry and contains a lot of air, a thermal insulator. It is a poor thermal conductor and not suitable as a source for heat pumps. Air-source heat pumps are the practical choice in Los Alamos.

Heat pumps can be augmented by so-called "reverse cycle chillers." ("Chiller" is a misnomer, since they can both heat and cool.) In a reverse cycle chiller, the heat pump actually heats or cools a well-insulated reservoir tank of water, usually built underground. That water then heats or cools the building. The overall system is more efficient, but also more complex and costly to install, than a heat pump by itself.

2.4 Application to New Construction

All of the techniques outlined in the previous section can be applied to new construction. The balance between solar thermal and artificial heating will have to be decided in design of each building.

New construction should be able to attain heat loadings of 0.25 therms / sq. ft. *(to be verified).*

2.5 Retrofit of Existing Buildings

Owners of existing buildings don't have the luxury of orienting their buildings or optimizing their structure for the most favorable solar thermal heating. Solar access may be limited. Every structure will be different. They will likely have to rely more, or exclusively, on upgraded insulation and artificial heat.

Many homes in LA originated as government-built housing in the late 1940's and 1950's. These were generally well built, but energy efficiency was not a consideration. Insulation was sparse and single-pane windows were standard. Virtually all government housing has been upgraded in many different ways and to varied extent. Regardless of upgrades, annual heat loading of government housing averages about 0.48 therms / sq. ft. Significant numbers of those buildings have heat loadings exceeding 0.75 therms / sq. ft., but there are also significant numbers with loadings of 0.35 therms / sq. ft. or less, demonstrating that energy-efficient upgrading is possible.

Private construction of homes began about 1960. The average home originally built in the 1960's has a heat loading around 0.35 therms / sq. ft. By about 1980, annual heat loading dropped to around 0.30 therms / sq. ft., where it has remained. Some of the newer, higher density housing has heat loadings around 0.25 therms / sq. ft. More and better insulation, double-pane and coated windows, more efficient furnaces and boilers, and transition from forced air to hydronic heat have all contributed to this improvement.

Overall, annual energy loading of existing LA housing averages 0.42 therms / sq. ft. Clearly, there is opportunity to reduce the need for heat energy, with the highest leverage being in the older government housing. A reasonable overall goal over the next decades would be to reduce that average loading to no more than 0.30 therms / sq. ft. By itself, that would reduce heating energy needs by 29%.

2.6 Costs

2.6.1 Insulation

Costs for construction vary wildly and are affected by many factors. However, the base recommendations of the most cost-effective improvements have remained consistent over a long period of time with some exceptions. Blown in attic insulation at roughly $1.75/sq. ft. for R38 is one of the most cost-effective improvements and is often easily added in homes with attic space. The majority of residential energy loss is through windows and doors especially if the existing windows are single glazed. Replacement for energy considerations alone is usually cost-effective only for single-glazed windows. Ballpark cost of replacement and installation of windows is $1,000/window unit. Doors similarly can be thermal underperformers, but are expensive to replace at $1,200+ / door. Adding exterior insulation to existing walls finished with new siding or stucco can improve the walls' thermal performance by 50% or more at a cost of $7.50+/ sq. ft. An added benefit of wall upgrades is that fire-resistant finishes can be incorporated into the new wall finish to reduce the wildfire threat to the building.

While window and door replacement is typically not cost-effective for purely energy use reduction, upgrading during remodeling may add little additional cost while significantly reducing heat loading.

As noted in Sec. 2.3.2, more quantitative cost estimates for various types of typical Los Alamos construction will be pursued for inclusion in Sec. 2.8.

2.6.2 Heat Pumps

Furnaces and boilers require replacement every several decades. Replacing them with heat pumps would eliminate the single largest use of NG in each home. Details, including physical layout, of replacement installation would vary for each building. Older furnaces and boilers could be retained for back-up as long as NG service remains.

The initial cost to install a heat pump is substantially higher than the cost to replace an existing NG-fired furnace or boiler, of order 2-3 times as much today. Since a large part of the cost is in the installation itself, not the unit, there will be great variations for different installations.

NG prices are near historic lows. They are unlikely to drop much lower. Normal market fluctuations are large. The range covers a factor of several, although they are buffered somewhat for LA retail customers by DPU's long-term contracts. Government actions to discourage use of carbon-based products (e.g., a "carbon tax") may well drive prices higher, also. In March, 2021, the LA residential rate was $0.55 / therm. At that NG rate and the current residential electricity rate of \$0.115 / kWh, and assuming an average heat pump COP of 3.5., the commodity cost for electricity to run a heat pump would be about 1.75 times the cost of gas for the same amount of heat. While that factor does not look favorable for conversion from NG to heat pumps, NG prices are likely to be much higher in future decades, making the cost comparison far more attractive.

2.7 Electrical Power Requirements

2.7.1 Grid and Distribution Requirements

Most homes are likely to need 3-6 ton heat pumps (1 ton = 12,000 BTU/hr or 0.12 therm / hr.) with the larger size needed only for the largest or most poorly-insulated. Heat pumps typically draw about 1.1 kW / ton. At 230 VAC, that is approx. 5 Amperes (A) / ton. If all of that power is drawn from the DPU service line, some older homes with 100 A service may have to upgrade to the more modern 200 A service. Charging of electric vehicles may also push service upgrades.

A more fundamental problem is the overall demand on the electric supply and distribution system. Normal electrical use in LA, exclusive of the Lab, is typically 8-20 MW, with occasional peaks in the low 20's. The daily peak is typically in evenings. Lows occur overnight. Peak county-wide NG use in recent years was 5060 therms/ hr. on the single-digits morning of 8 February 2019. Simply replacing all NG-fired furnaces and boilers with heat pumps with a COP of 3 at that air temperature would require approx. 50 MW of electric power. That would substantially exceed generation, transmission, and distribution capacity of our power supply system.

The approaches outlined above will dramatically reduce that potential increase in demand for electric power just for space heating. *Estimates will be included in the final report.*

In any case, there will be additional demands placed on the electric power system. These will peak during the coldest temperatures which usually occur at night when other electrical demand is lowest. This will increase the base load on the system. Sources that can support 24/7 base loads, such as the Carbon-Free Power Project, will become even more important than they are presently.

2.7.2 Distributed ("Rooftop") Electric Generation and Storage

The price of solar photovoltaic (PV) cells and battery storage have declined rapidly, as is typical of new, widely adopted technologies. Further decreases can be expected. Although they produce no greenhouse gases at point of use, both have environmental impacts in production and disposal which need to be considered.

PV, storage, and heat pumps can be a more flexible heat source than direct solar thermal heating with thermal storage. Even without electrical energy storage, PV and heat pumps provide daytime cooling, which solar energy itself obviously does not.

Since installation is such a large part of the cost of PV arrays, system cost varies widely. \$3.00 - \$3.50 / watt is typical. Hence, a typical 5 kW residential PV installation would cost around \$16,000 today. At current electric rates, such an installation will pay for itself in 10-15 years, significantly less than its 20+ year expected lifetime.

Battery packs (e.g., Tesla "Powerwall") are available for home installation in sizes that can power heat pumps all night. The issue is cost. Batteries installed in electric automobiles are typically large enough. It is technically practical to make those batteries serve dual use. Operational practicality is likely to depend on individual usage patterns. *In any case, further analysis is necessary to estimate electrical storage requirements and, hence, costs.*

Substantial subsidies, in the form of tax credits, exist today for solar and other renewable energy installations. These credits were instituted to "jump start" these industries. It is uncertain how long they will last as these approaches become more mainstream.

2.8 Representative Examples

Current average home size in LA is about 2100 sq. ft. That nominal size will be used for all examples except the older (usually smaller) government homes. Other sizes can be estimated by direct scaling based on square footage.

These will include technical approach(es), lifetime costs (initial, operating, and replacement), and typical and peak electrical power requirements.

2.8.1 New construction, 2100 sq. ft. home

2.8.2 Retrofit government home

2.8.3 Retrofit 2100 sq. ft. single-story detached ranch style home (common 1960's & 70's construction) with forced-air heat

2.8.4 Retrofit newer (1980+) detached homes with hydronic heat

2.8.5 Summary Table

3.0 Institutional Space Heating without Natural Gas

The basic approaches outlined for residential space heating are also applicable to institutions. More compact envelopes reduce heat loss for the same floor area. Some types of institutions (e.g., most retail stores, manufacturing) require little lossy window area. For others (e.g., offices, schools) the bright, open, airy indoors areas enabled by extensive use of glass exterior walls may be a luxury we can not afford. Good ceiling and wall insulation is as vital to reducing heat loss in institutional buildings as in residential. New buildings can be oriented and designed to derive a substantial amount of their heat from solar radiation. Heat pumps can replace NG-fired furnaces and boilers. Larger, more complex buildings (e.g., large offices, schools) often have very different heating and cooling needs in different areas. More complex heat pumps, such as Variable Refrigerant Flow (VRF) systems, can move heat from warm parts of a building, such as the south side near windows, to cooler parts, reducing greatly the need to "pump" heat energy out of much colder outside air.

Most institutional buildings are largely unoccupied at night. They can tolerate reduced nighttime temperatures. Unlike residences, a well-insulated building may need little artificial heat at night. Nighttime temperature set-backs are already common.

The typically larger roof areas and reduced emphasis on aesthetics in institutional buildings makes rooftop solar PV installations to power heat pumps more attractive than they are for residences.

Quantitative examples will be included in the final report.

Although institutional structures account for slightly less than 25% of LA's NG use, there are far fewer of them than there are residences. Changes are less "personal" than those associated with residences. Changes in requirements for new construction and physical modifications to existing buildings may be easier to accept.

4.0 Hot Water Heating

Domestic hot water is needed for personal hygiene, dish washing, clothes washing, and ancillary uses. It is almost always provided by a "hot water heater" for which the primary energy source may be electric power, NG, or heated water from the hydronic boiler that also supplies space heating. Heat losses from hot water are large. The water heater itself, no matter how well-insulated, is losing heat 24/7. Any time hot water is flowing through pipes to points of use in the house, the pipes (usually uninsulated) are losing heat. If a tap has not been used in a while, hot water must flow all the way from the heater to the tap. What is not used then sits in the pipe and cools down to room temperature, wasting all its heat energy. In winter, much of the wasted heat in hot water systems does contribute to heating the house. In warm weather, it adds to the cooling load.

Alternatives include:

1. Solar "rooftop" heating of water during the day with subsequent storage, similar to – but larger than -- current hot water heater tanks.
2. Heating water with the same heat pump system that provides space heating in hydronic systems. The water heater is simply a heat exchanger on another loop in the house heating system. This is already done in some hydronically-heated houses.
3. Use of electrically-heated "tankless" hot water heaters. Located near the tap or other point of use, these provide "on-demand" hot water, avoiding all the standby losses inherent in stored hot water systems. In new construction, traditional hot water piping is no longer needed. Tankless hot water heaters tend to last longer than traditional tank types.

5.0 Cooking

Electric induction ranges are rapidly gaining in popularity. Instead of using electrical (resistance) heating elements or NG flames to heat cookware, they induce an electric current directly in the cookware. Only the cookware and its contents get hot, not the burner. No heat energy is lost in the transfer. Induction ranges heat faster than NG-ranges and much faster than traditional electric ranges. Temperature can be controlled more precisely. When cookware is removed, the smooth surface of the range itself is cool, reducing the risk of burns or fires. Of course, there is no gas to leak into the house if an un-lit burner is left on. They are more energy efficient than either traditional electric or NG ranges. Disadvantages are few. Cookware must have iron in it. Cast iron or stainless steel works; aluminum, glass, or ceramic does not. Purchase prices are still higher, but are dropping rapidly as they become more common. Ranges tend to be replaced every few decades. This is a no-brainer.

6.0 Pilot Lights

Pilot lights burn 24/7/365 to provide ignition in some NG furnaces, boilers, water heaters, ranges, and fireplaces. Electric spark ignition has largely replaced pilot lights. It should replace all of them. This is another no-brainer for the next replacement cycle even if the unit itself continues to use NG. Retrofit kits are available for the pilot lights in some existing units.

7.0 Recommendations

Except for the very last one, all of these recommendations are preliminary. The RES Task Force as a whole has not endorsed any and does not recommend any action until recommendations are refined and otherwise finalized.

The term "encourage" as used below could mean education, promotion, or even outright mandate at various points in time.

1. Compact architectures should be encouraged in all new construction.
2. Development plans should require solar access to all occupied buildings.
3. Special consideration and further study is warranted for trees with respect to solar access.
4. Site plans should encourage building orientation to take maximum use of solar energy for heating and PV electric generation, where possible.
5. NG hookups should not be allowed for new construction after some point in time.
6. Building codes, applicable to both new construction and substantial remodeling, should require insulation, windows, and doors to reduce heat losses to 0.25 therms / sq. ft. (*to be verified).*
7. When NG-fired furnaces and boilers need replacement, substitution of heat pumps should be encouraged.
8. Base-load electrical generating resources to meet overnight heating energy demand should be included in electrical utility supply planning.
9. *Traditional electric or NG hot water heaters should be replaced by ________ (to be determined).*
10. When traditional electric or NG ranges are replaced, substitution of electric induction ranges should be encouraged.
11. NG pilot lights should be discouraged or outright banned in any new or replacement appliances.

8.0 *References*

Will be included in final report.