Assessment of Add-On Heat Pump Technology, Operation, Economics, and Potential Impacts on Residential Customer Gas Load

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Natural Gas Codes and Standards
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Final Report:

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Executive Summary

Add-on heat pumps, also referred to as dual-fuel and hybrid HVAC systems, have existed in the U. S. market for a couple of decades. However, with the recent increase in national average residential gas prices relative to electricity, greater consumer interest in these systems has developed.

The purpose of the analysis described in this report is to assess current residential add-on heat pump technology as implemented in complete heating and cooling split systems and as a replacement of air conditioning (AC) loops in gas furnace/AC split systems where the role of the gas furnace changes to supplemental heating. The report covers energy consumption, emissions, and economics for comparative purposes of general types of mechanical systems.

The *REM/Design* software, available from Architectural Energy Corporation, was used to assess four building models for residential housing designs in four markets representing different climates across the U. S. Gas furnace/AC and add-on heat pumps in retrofit applications, new construction built to comply with the International Energy Conservation Code 2000 edition (IECC 2000), and new construction built to ENERGY STAR Homes requirements.

Compared to a conventional split system air conditioner combined with a gas-fired warm air furnace, a residential HVAC system equipped with an add-on heat pump was shown to consume less source and site energy for both space heating and cooling. However, the magnitude of these relative savings (and the competitiveness of add-on heat pumps) varies significantly across the climates analyzed.

Space cooling calculations for new construction suggest that add-on heat pump cooling is significantly more efficient that air conditioning provided by the furnace/AC system, even though the same SEER rating was used for these cooling systems in the analysis. It is unclear whether these differences are a real technical performance characteristic of add-on heat pump systems generally (and not captured by the SEER rating) or due to inconsistency in assumptions within the *REM/Design* software. This question needs to be resolved in consultation with the *REM/Design* developers.

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1 Introduction

The purpose of the analysis described in this report is to assess current residential add-on heat pump technology as implemented in complete heating and cooling split systems and as a replacement of air conditioning (AC) loops in gas furnace/AC split systems where the role of the gas furnace changes to supplemental heating. The report characterizes major designs and components, operation in terms of control functions and installer/user settings, equipment costs and paybacks relative to conventional heat pump and gas furnace/AC systems in major U. S. climate regions, and representative changes in energy consumption for gas and electricity demand over conventional systems. The report also provides information on competitive issues between add-on heat pump and gas heating/AC systems in the residential new construction and HVAC replacement markets.

The report covers energy consumption, emissions, and economics for comparative purposes of general types of mechanical systems. As such, the report does not cover or characterize the broad ranges of systems that might be used in specific installations, nor does it predict actual performance for the systems analyzed or for all climates within the regions analyzed.

Propane gas (also known as liquefied petroleum gas – or LPG) is similar to natural gas. It is a versatile fuel that is used for heating homes, heating water, cooking, drying clothes, fueling gas fireplaces and as an alternative fuel for vehicles. According to the EIA, residential and commercial use of propane accounts for 43% of all propane used in the United States, excluding propane gas grills. Of the 107 million households in the United States, 9.4 million depend on propane for one use or another and 54% of these households rely on propane for their primary heating fuel. In 2002, almost 20 billion gallons of propane were sold in the United States as reported by the American Petroleum Institute. While this report may refer to natural gas in previous case studies and analyses, it should be noted that the use of propane in these examples should result in very similar conclusions regarding real energy efficiency and environmental impacts.

2 Background

Add-on heat pumps, also referred to a dual-fuel and hybrid HVAC systems, have existed in the U. S. market for a couple of decades. However, with the recent increase in national average residential gas prices relative to electricity, greater consumer interest in these systems has developed. While the terminology "add-on heat pumps" may not correctly describe equipment designed from the start for dual fuel operation, this terminology will be used for all such equipment in this proposal. Other developments have supported the current interest in add-on heat pumps:

- Increased federal minimum efficiency requirements for residential heat pumps to 13 SEER/7.7 HSPF, which effectively lowers the design and economic balance points for heating supplied by heat pump systems.

- Increasingly sophisticated controls for systems allowing consumer settings according to preferences in addition to more conventional installer settings.

- New designs for split system indoor packages optimizing matches of heating and cooling units, including the potential for operating the heat pump cycle simultaneously with supplemental gas heating.

- New air handler motors and control approaches to reduce electricity consumption during heating and cooling while providing optimal airflows.

- Aggressive promotion of add-on heat pumps by electriccooperatives and other electric utility interests.

An understanding of these factors as inducements for the installation of add-on heat pumps in new construction and HVAC replacement markets has not been systematically studied in recent years. With increasing concern in the gas industry over decreasing per-customer demand in the residential market, the influence of broader adoption of this technology may be important since heat pump cycle heating displaces gas base load heating needs.

3 Characteristics of Residential Heating, Ventilating and Cooling Systems

3.1 Split System Air Conditioning Systems

Split system air conditioning systems are the cooling system most commonly associated with residential and light commercial air conditioning. A split system consists of an indoor unit with air distribution and temperature control with a water-cooled condenser, integral air-cooled condenser, or remoter air-cooled condenser. The latter is the most common configuration encountered in residential installations. The primary advantage of this configuration is that heat rejection through a remote air-cooled condenser allows the final heat rejecter (and its associated noise) to be remote from the conditioned space while the air handling unit is located close to the conditioned space.

Typical components of a residential split system air conditioner include an indoor unit with evaporator coils, heating coils, air filters and control valves, and a condensing unit with the compressor and condenser coils. Control is usually one- or two-step for cooling and one- or two-step or modulating for heating. Basic temperature controls include a room-mounted or return air mounted thermostat that cycles the compressor as needed to maintain the desired space temperature.

3.2 Natural Gas/Propane Fired Warm Air Furnaces

Warm air furnaces are available in a variety of self-enclosed appliances that provide heated air through ductwork to the space being heated. There are two basic types of furnaces: (1) fuel-burning and (2) electric. In a fuel-burning furnace combustion takes place within a combustion chamber. Circulating air passes over the outside surfaces of a heart exchanger such that it does not contact the fuel or the products of combustion, which are passed to the outside atmosphere through a vent. Residential furnaces are further categorized by (1) type of fuel, (2) mounting arrangement, (3) airflow direction, (4) combustion system, and (5) installation location.

Natural gas is the most common fuel supplied for residential heating, and the central system forced air furnace is the most common way of heating with natural gas. This type of furnace is equipped with a blower to circulate air through the furnace enclosure, over the heat exchanger, and through the ductwork distribution system. A typical furnace consists of the following basic components: (1) a cabinet or casing, (2) heat exchanger, (3) a combustion system including burners and controls, (4) a forced-draft blower, induced draft blower or draft hood, (5) a circulating air blower and motor, and (6) an air filter and other accessories such as humidifier, an electronic air cleaner, an air conditioning coil, or a combination of these elements (Figure 1).

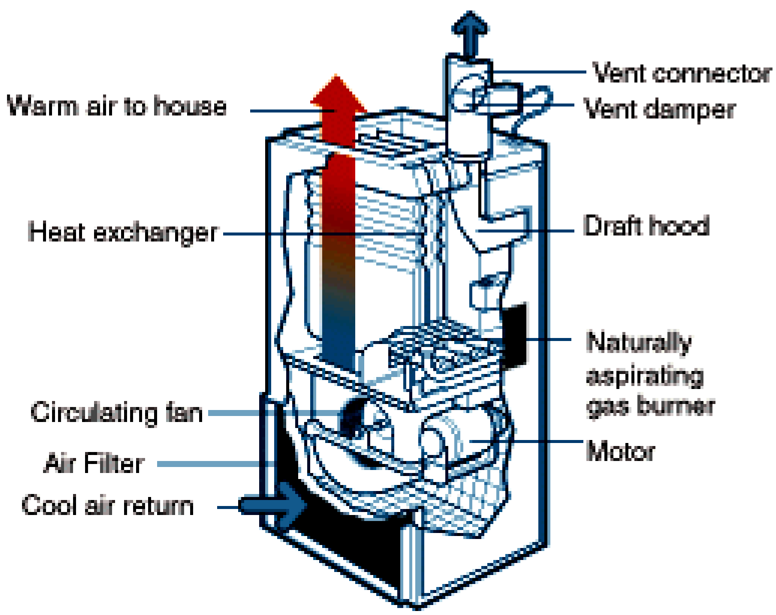

Figure 1. Conventional upflow or "highboy" natural-draft, gas-fired warm air furnace. (Source: Home Energy Magazine)

The components of a fuel-fired, forced-air furnace can be arranged in a variety of configurations to suit a residential heating system. The relative positions of the components in the different types of furnaces are as follows: (1) upflow or "highboy" furnace where the blower is located beneath the heat exchanger and discharges vertically upward, (2) downflow furnace where the blower is located above the heat exchanger and discharges vertically downward, (3) horizontal flow furnace where the air enters at one end travels horizontally through the blower and over the heat exchange and is discharged at the opposite end, (4) multiposition furnace that can be installed in more than one airflow configuration, and (5) basement or "lowboy" furnace, a variation on the upflow furnace requiring less head room.

Gas-fired furnaces use a natural-draft or a fan-assisted combustion system. With a natural-draft furnace, the buoyancy of the hot combustion products carries these products through the heat exchanger, into the draft hood, and up the chimney. Fan-assisted combustion furnaces have a combustion blower, which may be located either upstream or downstream from the heat exchanger. If the blower is located upstream, blowing the combustion air into the heat exchanger, the system is known as a forced-draft system. If the blower is downstream, the arrangement is know as an induced draft system. Fan-assisted combustion furnaces do not require a draft hood, resulting in reduced off-cycle losses and improved efficiency. Direct-vent furnaces may have either natural-draft or fan-assisted combustion. They do not have a draft hood and they obtain their combustion air from outside the occupied structure.

Most manufacturers have their furnaces certified for both natural gas and propane. The major difference between the two fuels is the pressure at which the gas is injected from the manifold into the burners. Because of the higher injection pressure and higher heat content per volume of propane, there are certain physical differences between a natural gas furnace and a propane furnace. One difference is that the pilot and burner orifices must be smaller for propane furnaces. The gas valve regulator spring is also different. Sometimes it is necessary to change burners, but this is not normally required.

3.3 Air-Source Heat Pumps

Many forced-air systems use a heat pump instead of an electric furnace because of its high efficiency and capability to air-condition. A heat pump is an electrical device that extracts heat from one place and transfers it to another (Figure 2). It transfers the heat by circulating a refrigerant through a cycle of alternating evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed en route to the other coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle.

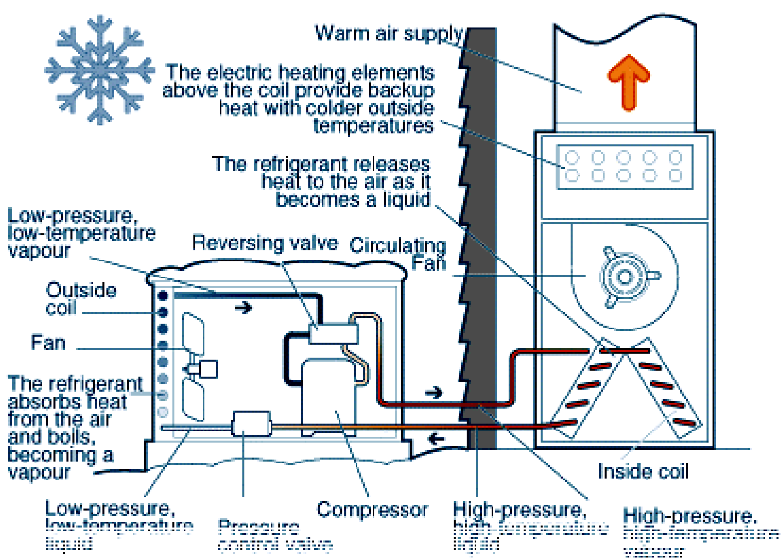

Figure 2. An air-source heat pump during the heating cycle. Heat pumps use a refrigerant to transfer heat from outside into the house. (Source: Home Energy Magazine)

A heat pump can be used for both heating and cooling. In the summer, it acts as an air conditioner, removing heat from the air inside the house and transferring it outside. In the winter, the heat pump operates in reverse, removing heat from the outside air or ground, and transferring it inside the house. Residential heat pumps are divided into two major groups: air source (air-to-air) systems, which draw heat from the air, and ground source (earth energy) systems, which draw heat from the ground or underground water.

Air source heat pumps can be add-on, all-electric, or bivalent. Add-on heat pumps are designed to be used with another source of supplementary heat, such as a fuel-fired furnace. All-electric air source heat pumps come equipped with their own supplementary heating system in the form of electric-resistance heaters. Bivalent heat pumps are a special type, developed in Canada, that use a gas- or propane-fired burner to increase the temperature of the air entering the outdoor coil. This allows these units to operate efficiently at somewhat lower outdoor temperatures. A problem with most air source heat pumps is that the heat output (and efficiency) drops with colder outside temperatures, exactly the opposite of what the house requires.

3.4 Add-on Heat Pump Systems

Air source heat pump systems can be combined with natural gas, LP, or oil fired heating systems. These are known as add-on, piggy-back, dual-fuel, or hybrid heat pumps. During the heating season, when the outdoor temperatures drop below the thermal or economic balance point of the heat pump, the heat pump turns "off" and the gas or oil furnace comes "on" to provide heating. In other words, the electric resistance auxiliary heat found in conventional air-source heat pump systems is replaced by the gas or oil furnace (Figure 3).

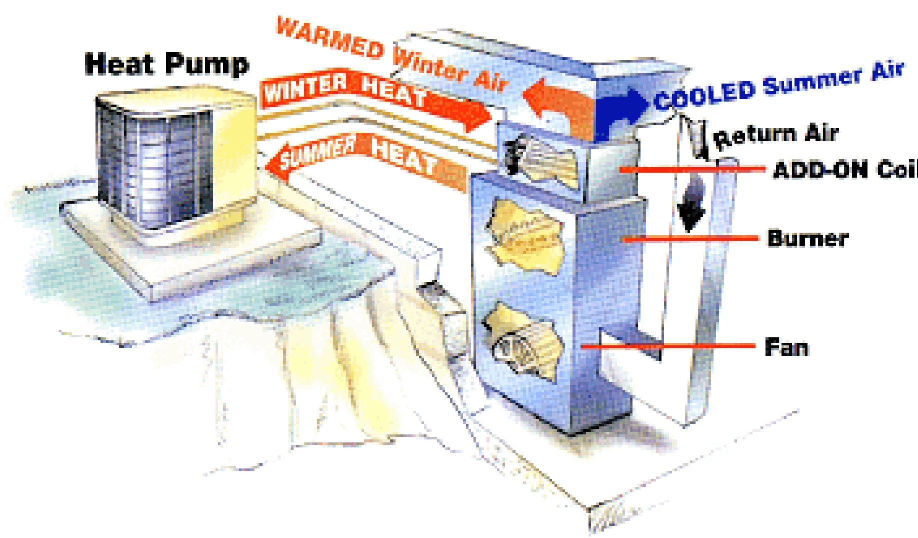

Figure 3. Add-on heat pump systems incorporating an outdoor air-source heat pump and an add-on evaporator coil installed on an existing or new gas-fired warm air furnace. (Source: Cornhusker Public Power District)

The add-on heat pump unit is gaining popularity for installation on older homes with central systems that were not previously air conditioned, or for homes whose cooling system needs replacing and the furnace is still in good shape. Besides providing air conditioning, add-on heat pumps increase the overall efficiency of the heating system because both the heat pump and the fossil furnaces are operating at their optimal efficiency levels.

In areas of the country where winter temperatures are typically above freezing and where electric rates are low, a heat pump can be a very efficient way to heat your home. When the temperature drops below freezing, the gas furnace can be used to provide heat more economically. When the temperature is above 35°F or so, the dual-fuel heat pump uses electricity to heat your home as necessary. This type of heat circulates evenly throughout your home, and isn't too dry. When it gets really cold outside (around 35°F or lower), the heat pump automatically switches to supplemental gas heat for better efficiency.

General principles of add-on heat pump performance and operation are described in various standard technical sources, including *Manual H: Heat Pump Systems: Principles and Applications*, published by the Air Conditioning Contractors of America.[1] A system typically uses the heat pump cycle to provide heating above its "balance point," or the point at which the heat pump's coefficient of performance (COP) declines (with declining outdoor temperature) below an optimum level. This optimum level might be its ability to continue efficiently provide space heating (its "thermal balance point") or where space heating performance combined with the cost of energy define the most economically efficient point at which to switch to supplemental heating (its "economic balance point"). These balance points rarely occur at the same outdoor temperatures.

With increases in the heating federal minimum efficiencies of heat pumps to an HSPF of 7.7, thermal balance points have declined from typical levels of around 45°F to 35°F or lower, allowing the heat pump to operate efficiently at lower temperatures and requiring supplemental heating less frequently. In the case of add-on heat pumps, which use different fuels for heating and supplemental heating, the economic balance point is typically the criterion that is used for transition to supplemental heating. Relative fuel prices (electricity and gas) provide the basis for making the switch to supplemental heat. As a result, the activation of supplemental gas heat in a properly designed and operated system is a function of both the outdoor temperature and the combination of fuel prices that produce the lowest heating cost.

4 Add-on Heat Pump Marketing Programs

4.1 General

Utility add-on heat pump incentive programs have focused on increasing electric sales and flattening utility load shapes. Most programs have targeted existing homes with natural gas warm-air furnaces or new homes. The primary market barriers have been high initial cost and lack of consumer awareness. Many consumers believe that heat pumps are new, unproven

[1] *Manual H: Heat Pump Systems: Principles and Applications, Second Edition*, 1984. Air Conditioning Contractors of America, Washington, D. C.

technologies or that they don't work in northern climates. Other problems have been low sales volumes for distributors and lack of training for contractors. Programs have also had difficulty competing with natural gas because it is the cheapest alternative. The most important success factors have been consumer or contractor equipment purchase rebates, reduced space heating electricity rates, increasing consumer awareness, and developing a market infrastructure. Each of these factors is discussed in more detail below and summarized in Table 1.

4.2 Rebate Programs

Rebate programs offer consumers either a per unit or per ton rebate for the installation of qualified equipment. The value of the rebate is generally contingent on one or more system characteristics including (1) the system heating and/or cooling capacity, (2) cooling and/or heating seasonal efficiency, (3) the system set point or changeover temperature, and (4) participation in a utility load management program. Currently available equipment rebates range from either $175 to $500 per unit or $40 to $275 per ton of cooling capacity, depending on how the rebate program is structured.

4.3 Reduced Space Heating Electricity Rates

Some electric utilities and cooperatives offer consumers a reduced space heating electricity rate for permanent add-on heat pump installations where the heat pump is the primary heat source for the residence in conjunction with a gas- or oil-fired furnace for extreme cold weather back-up. This reduced rate is generally limited to traditional heating months for the given service territory. Special space heating rates can be either a flat rate for all electricity consumed during the heating season or a block rate applicable to specified rate blocks. The reduced space-heating rate can be as little as half of the standard residential rate.

Table 1. Representative Electric Utility/ Cooperative Add-on Heat Pump Marketing Programs.

Electric Utility/Cooperative	State	Target Market		Market Outreach			Incentive Programs		
		New	Retrofit	Brochure	Newsletter	Website	Rebate	Financing	Special Rate
BC Hydro	BC		✓			✓	No	No	No
Bluegrass Energy	KY	✓	✓		✓	✓	$300 /unit	No	No
Central Hudson Gas & Electric	NY		✓			✓	$150 /ton	9.25%	No
Cornhusker Public Power District	NE		✓	✓		✓	$200 /unit	No	No
Dairyland Power Cooperative	WI	Not Specified				✓	No	No	Yes
Duke Energy	IN	✓	✓	✓		✓	$200-500 /unit	No	No
Eau Claire Electric Cooperative	WI	Not Specified				✓	$40 /ton	No	Yes
Egyptian Electric	IL		✓		✓	✓	No	No	No
Farmers' Electric Cooperative	MO		✓			✓	$200-275 /ton	No	No
Firelands Electric Cooperative	OH	Not Specified			✓	✓	$599 /unit	No	Yes
Georgia Power	GA		✓	✓		✓	No	No	No
Jay County REMC	IN		✓		✓	✓	$200 /unit	No	No
Kansas City Power & Light	MO	✓		✓		✓	No	No	No
Laclede Electric Cooperative	MO	✓		✓		✓	$150 /ton	No	No
LaGrange County REMC	IN	✓	✓			✓	No	No	No
Lansing Board of Water & Light	MI	✓	✓			✓	No	No	No
MidAmerican Energy	IA		✓	✓		✓	$400+ /unit	No	No
Nebraska Public Power District	NE	✓	✓	✓		✓	No	No	No
Oklahoma Electric & Gas	OK		✓			✓	No	No	No
Omaha Public Power District	NE	✓	✓			✓	$120 /ton	No	Yes
Sioux Valley Energy	IA		✓			✓	No	No	No
Southwest Public Power District	NE		✓	✓		✓	No	No	No
Tullahoma Utilities Board	TN	Not Specified				✓	$175 /unit	7.00%	No
Utilities District of Western Indiana	IN	✓	✓			✓	$300 /unit	No	No

4.4 Increasing Consumer Awareness

Electric utilities and cooperatives generate leads for their energy programs from a number of sources: bill stuffers, word-of-mouth, advertising and fuel sales programs co-sponsored with HVAC dealers.

Marketing brochures advocating the benefits of add-on heat pumps are commonly sent either to targeted consumers within their service territory or included with all customers' monthly utility bills. Marketing brochures advocate add-on heat pump by: (1) educating consumers as to the benefits of add-on heat pumps, including potential utility bill cost reductions, (2) notifying consumers of any special electricity rates and/or rebate programs that are available, and (3) providing resources where consumers can obtain additional information (e.g., toll-free telephone numbers and company websites).

Utilities and cooperatives also use feature articles in company newsletters to advocate the benefits of add-on heat pumps. Articles tend to include less detailed information than marketing brochures but generally provide resources where consumers can obtain additional information.

Most electric utilities and cooperatives have established some type of Internet presence with which to communicate with trade allies and consumers in their service territory. Advocacy of add-on heat pumps often take the form of interactive marketing brochures that include links to company sites that contain detailed information on available equipment rebates and special space heating tariffs, links to equipment manufacturers' websites, links to the websites of qualified installing contractors, and links to trade organizations and government agencies that include relevant content.

4.5 Developing Market Infrastructure

Electric utilities and cooperatives have been developing a market infrastructure for add-on heat pumps by educating and working with distributors, dealers and contractors. Marketing strategies have included promoting add-on heat pumps to distributors and dealers, training contractors, establishing trade organizations, developing quality standards for installations, making deals with installers to lower costs, giving sales leads to hand-picked contractors, and distributing heat pumps directly. Utility websites and marketing brochures often include lists of qualified add-on heat pump installers including links to contractor websites and/or contact information.

5 Analysis Approach

5.1 Housing Characteristics

5.1.1 General

Typical housing characteristics data is available from several sources including the National Association of Homebuilders (NAHB), the Residential Energy Consumption Survey (RECS) database developed by the U.S. Energy Information Administration, and the U.S. Census Bureau. The NAHB compiles data on new home construction and in a June 2001 report describes the Profile of a Typical New Home built in 2000 as a 2,265 square foot home with 3 bedrooms, 2-1/2 bathrooms, a 2-car garage, a fireplace and central air conditioning.

According to the 2001 RECS database the average total living area for all U.S. housing units was 2,066 square feet, including single-family attached and detached units, apartments and mobile homes. For single-family housing units the average size was 2,527 square feet. Of the single family housing units included in the survey, 52 percent had three bedrooms, 46 percent had two bathrooms, 48 percent had a basement, 72 percent had an attached or detached garage, 16 percent had a natural gas or wood fireplace and 59 percent had central air conditioning.

5.1.2 Regional Variations

Regional housing characteristics from the most recent RECS database are summarized in Table 2.

Table 2. Regional housing characteristics from the most recent 1997 RECS database.

Location	Space Heating		Building Characteristics						
	Area	Fuel	Rooms	Bedrooms	Other	Baths	Stories	Foundation	Garage
Northeast Census Region	1,377	NG	6	3	2	1	2	Basement	None
Middle Atlantic	1,346	NG	6	3	2	1	2	Basement	1-Car
New England	1,393	Oil	6	3	2	1	2	Basement	None
Midwest Census Region	1,464	NG	5	3	2	1	2	Basement	2-Car
East North Central	1,452	NG	5	3	2	1	2	Basement	2-Car
West North Central	1,491	NG	4	3	3	1	1	Basement	2-Car
South Census Region	1,498	NG	5	3	2	1	1	Conc. Slab	None
South Atlantic	1,483	NG	6	3	2	1	1	Conc. Slab	None
East South Central	1,460	NG	5	3	2	1	1	Crawlspace	None
West South Central	1,554	NG	5	3	2	1	1	Conc. Slab	2-Car
West Census Region	1,363	NG	4	3	2	1	1	Conc. Slab	2-Car
Mountain	1,424	NG	4	3	2	1	1	Conc. Slab	2-Car
Pacific	1,343	NG	5	3	2	1	1	Crawlspace	2-Car
Most Populous States									
New York	1,278	NG	4	3	2	1	2	Basement	2-Car
California	1,317	NG	4	3	2	1	1	Conc. Slab	2-Car
Texas	1,389	NG	5	3	2	1	1	Conc. Slab	2-Car
Florida	1,516	Elec.	5	3	3	2	1	Conc. Slab	2-Car

Data Source: "A Look at Residential Energy Consumption in 1997" (DOE/EIA-0632(97).

Based on data from these two sources, four unique new home styles were modeled to better reflect known regional variations. All of the models have the same heated area and offer the same amenities but vary in the number of levels above grade and the type of foundation. The four building models can be summarized as follows:

- Two story residence with a full basement,
- One story residence with a full basement,
- One story residence with a crawl space, and
- One story residence on a concrete slab.

These four home models capture the most notable regional variation in new home construction that can be substantiated with available data. In addition, these particular characteristics have a significant impact on the energy consumption and, therefore, produce four distinct sets of results.

Residential energy consumption is also differentiated by code requirements for insulation and fenestration based on climatic region. To capture this variation in the analysis, energy consumption for the four building models described above was simulated in four regions of the United States. Within each region, a representative city was selected that represents one of the largest housing markets in that part of the country (Table 3).

Table 3. Regional Housing Variations Modeled

Region	Representative City	Dominant Construction Type
Northeast	Boston, MA	1 Story w/ Basement
Southeast	Atlanta, GA	1 Story w/ Crawlspace
Midwest	Chicago, IL	2 Story w/ Basement
West	Phoenix, AZ	1 Story w/ Concrete Slab

5.2 HVAC System Configurations

5.2.1 Space Heating Systems

According to the 2001 Residential Energy Consumption Survey 49 percent of single-family housing units main heating equipment is a natural gas central warm air furnace, 11 percent have a heat pump, 8 percent have an electric central warm air furnace, 6 percent have a natural gas floor, wall furnace or space heater, 5 percent have a natural gas steam or hot water system, 4 percent have a fuel oil steam or hot water system, 4 percent have a fuel oil central warm air furnace, 3 percent have a LPG central warm air furnace, 3 percent have built-in electric units, and 3 percent heat with wood or kerosene.

5.2.2 Space Cooling Systems

According to the 2001 Residential Energy Consumption Survey, of the single-family housing units using electric air conditioning equipment, 61 percent had central air conditioning without a heat pump, 15 percent had a central air conditioning system with a heat pump and 24 percent had room air conditioning unit(s). According to the RCS database, 55.0 million households have some type of central warm air furnace while 43.6 million households have some type of central air conditioning. The gap between these two groups (11.4 million households) represents a potential market for add-on heat pumps. In addition, of the homes with central air conditioning equipment, 36 percent of the installations were at least 10 years old, which suggests a sizable market for replacement equipment – add-on heat pumps or otherwise.

5.2.3 Mechanical System Configuration

Since almost two thirds of all single-family housing units have some type of central warm air furnace and since this equipment configuration is the most amenable to the installation of an add-on heat pump these installations are the focus of this study. The 11 percent of homes for which a heat pump is already the main heating equipment would, in all likelihood, not benefit from the addition of another heat pump. Central warm air furnace installations with either older air-conditioning equipment or no air-conditioning equipment at all would appear to be the most lucrative target markets for add-on heat pumps.

5.3 HVAC Equipment Efficiency

5.3.1 General

The Department of Energy's Energy Efficiency and Renewable Energy division has identified the three following basic heating configurations by age, system efficiency and equipment features:

Old, low-efficiency heating systems:

- Natural draft that creates a flow of combustion gases
- Continuous pilot light
- Heavy heat exchanger
- 68%–72% AFUE

Mid-efficiency heating systems:

- Exhaust fan controls the flow of combustion air and combustion gases more precisely
- Electronic ignition (no pilot light)
- Compact size and lighter weight to reduce cycling losses
- Small-diameter flue pipe
- 80%–83% AFUE

High-efficiency heating systems:

- Condensing flue gases in a second heat exchanger for extra efficiency
- Sealed combustion
- 90%–97% AFUE

All mechanical systems modeled for new residential construction comply with the minimum prescriptive requirements of ANSI/ASHRAE Standard 90.2 and/or whatever building codes have been adopted for each region analyzed. Mechanical systems modeled for existing housing stock are representative of the average age of housing units in the regions being analyzed.

5.3.2 Existing Housing Stock

According to data collected by RECS, the median age of all U.S. housing stock in 2001 was 33 years (built circa 1968) while the median age for Census Regions varied from 28 years (built circa 1973) for the South to 40 years (built circa 1961) for the Northeast. According to the Energy Information Administration (EIA), the average seasonal energy efficiency ratio (SEER) of central air-conditioning units sold during the year 1978 (the earliest year for which data is available) was 7.34. According to the U.S. Department of Energy, before 1979, the SEERs of central air conditioners ranged from 4.5 to 8.0.

To determine the approximate Annual Fuel Utilization Efficiency (AFUE) rating for fuel-fired furnaces and boilers installed in the existing housing stock, data compiled by the U.S. Department of Energy shown in Table 4 was used to develop efficiency estimates of the stock.

Table 4. Typical AFUE ratings for different types of furnaces and boilers

Type	Pre-1960	1960-1969	1970-1974	1975-1983	1984-1987	1988-1991	Post-1992
Gas furnace	60%	60%	65%	65%	68%	76%	78%
Gas boiler	60	60	65	65	70	77	80
Oil furnace	60	65	72	75	80	80	80
Oil boiler	60	65	72	75	80	80	80

5.3.3 New Construction

Newly constructed homes were assumed to be built either in compliance with the applicable residential building code or to comply with the criteria of the ENERGY STAR HOMES program.

Most current building codes have two different paths that the builder can take to prove compliance with the code: (1) a prescriptive path and (2) a performance path. In both instances, the models were created to just meet the minimum criteria established for each path. The applicable building codes used for this analysis are the 1995 Model Energy Code (1995 MEC) in

Boston and the 2000 International Energy Conservation Code (2000 IECC) in Atlanta, Chicago and Phoenix.

Homes that earn the ENERGY STAR must meet guidelines for energy efficiency set by the U.S. Environmental Protection Agency. ENERGY STAR qualified homes are at least 15 percent more energy efficient than homes built to the 2006 IECC. ENERGY STAR qualified homes can include a variety of energy-efficient features, such as effective insulation, high performance windows, tight construction and ducts, efficient heating and cooling equipment, and ENERGY STAR qualified lighting and appliances.

Table 5. 1995 Model Energy Code Minimum Criteria for New Residential Construction

Location		Compliance	Overall Uo		SHGF		SA Duct Insulation (U)		RA Duct Insulation (U)		Annual Energy (MBtu)	
City	State	Path	Code	Model	Code	Model	Code	Model	Code	Model	Code	Model
Boston	MA	Prescriptive	0.065	0.065	----	----	3.3	3.3	3.3	3.3	----	131.5
Boston	MA	Performance	----	0.065	----	----	----	3.3	----	3.3	78.6	78.6
Atlanta	GA	Prescriptive	0.079	0.079	----	0.400	3.3	3.3	3.3	3.3	----	108.3
Atlanta	GA	Performance	----	0.079	----	0.400	----	3.3	----	3.3	71.5	108.3
Chicago	IL	Prescriptive	0.061	0.061	----	----	3.3	3.3	3.3	3.3	----	142.7
Chicago	IL	Performance	----	0.061	----	----	----	3.3	----	3.3	83.5	83.5
Phoenix	AZ	Prescriptive	0.121	0.121	----	0.400	0.0	0.0	0.0	0.0	----	81.8
Phoenix	AZ	Performance	----	0.121	----	0.400	----	0.0	----	0.0	68.8	68.8

Table 6. 2000 International Energy Conservation Code Minimum Criteria for New Residential Construction

Location			Compliance	Overall Uo		SHGF		SA Duct Insulation (U)		RA Duct Insulation (U)		Annual Energy (MBtu)	
City	State	Zone	Path	Code	Model	Code	Model	Code	Model	Code	Model	Code	Model
Boston	MA	13	Prescriptive	0.065	0.065	----	----	3.3	3.3	3.3	3.3	----	127.3
Boston	MA	13	Performance	----	0.065	----	----	----	3.3	----	3.3	79.1	79.1
Atlanta	GA	7	Prescriptive	0.079	0.079	0.400	0.400	3.3	3.3	3.3	3.3	----	99.2
Atlanta	GA	7	Performance	----	0.079	----	0.400	----	3.3	----	3.3	68.4	99.3
Chicago	IL	14	Prescriptive	0.061	0.061	----	----	3.3	3.3	3.3	3.3	----	133.9
Chicago	IL	14	Performance	----	0.061	----	----	----	3.3	----	3.3	82.9	82.9
Phoenix	AZ	3	Prescriptive	0.121	0.121	0.400	0.400	0.0	0.0	0.0	0.0	----	71.1
Phoenix	AZ	3	Performance	----	0.121	----	0.400	----	0.0	----	0.0	65.8	65.8

Table 7. 2003 International Energy Conservation Code Minimum Criteria for New Residential Construction

Location			Compliance	Overall Uo		SHGF		SA Duct Insulation (U)		RA Duct Insulation (U)		Annual Energy (MBtu)	
City	State	Zone	Path	Code	Model	Code	Model	Code	Model	Code	Model	Code	Model
Boston	MA	5	Prescriptive	0.065	0.065	----	----	8.0	3.3	2.0	3.3	----	127.3
Boston	MA	5	Performance	----	0.065	----	----	----	3.3	----	3.3	79.1	79.1
Atlanta	GA	3	Prescriptive	0.079	0.079	0.400	0.400	6.0	3.3	2.0	3.3	----	99.2
Atlanta	GA	3	Performance	----	0.079	----	0.400	----	3.3	----	3.3	68.4	99.3
Chicago	IL	5	Prescriptive	0.061	0.061	----	----	8.0	3.3	2.0	3.3	----	133.9
Chicago	IL	5	Performance	----	0.061	----	----	----	3.3	----	3.3	82.9	82.9
Phoenix	AZ	2	Prescriptive	0.121	0.121	0.400	0.400	0.0	0.0	0.0	0.0	----	71.1
Phoenix	AZ	2	Performance	----	0.121	----	0.400	----	0.0	----	0.0	65.8	65.8

Table 8. ENERGY STAR Minimum Criteria for New Residential Construction

Location		Overall Uo		SHGF		SA Duct Insulation (U)		RA Duct Insulation (U)		Annual Energy (MBtu)	
City	State	Standard	Model	Standard	Model	Standard	Model	Standard	Model	Standard	Model
Boston	MA	----	0.065	----	----	----	3.3	----	3.3	110.2	110.2
Boston	MA	----	0.065	----	----	----	3.3	----	3.3	87.4	87.4
Atlanta	GA	----	0.079	----	0.400	----	3.3	----	3.3	87.7	87.7
Atlanta	GA	----	0.079	----	0.400	----	3.3	----	3.3	65.7	65.7
Chicago	IL	----	0.061	----	----	----	3.3	----	3.3	115.8	115.8
Chicago	IL	----	0.061	----	----	----	3.3	----	3.3	93.4	93.4
Phoenix	AZ	----	0.121	----	0.400	----	0.0	----	0.0	75.5	75.5
Phoenix	AZ	----	0.121	----	0.400	----	0.0	----	0.0	67.2	67.2

5.4 Energy Costs

5.4.1 Electricity Costs

The electricity tariffs in all of the markets analyzed are designed to reduce the operating costs of add-on heat pumps. In three of the markets, Atlanta, Chicago and Phoenix, the most popular residential tariff features a seasonal rate structure with a reduced energy rate designed to reduce the expense of operating electric space heating equipment. In Boston, a dedicated electric heating rate is available to customers who install an add-on heat pump as their primary space heating system (Table 9).

Table 9. Residential Electricity Energy Costs

Location		Utility	Electric Tariff			Energy Block		Energy Rate		
City	State		Rate	Description	Season	Start	End	Cust	Basic	Total
Boston	MA	Boston Edison	R-1	Residential	Jan-Dec	0	999999	6.43	0.11442	0.18808
			R-3	Elec. Heat	Oct-May	0	999999	6.43	0.11442	0.17674
			R-3	Elec. Heat	Jun-Sep	0	999999	6.43	0.11442	0.20045
Atlanta	GA	Georgia Power	R-15	Residential	Oct-May	0	650	7.50	0.04657	0.07682
			R-15	Residential	Oct-May	651	1000	7.50	0.03998	0.07023
			R-15	Residential	Oct-May	1001	999999	7.50	0.03931	0.06956
			R-15	Residential	Jun-Sep	0	650	7.50	0.04657	0.07682
			R-15	Residential	Jun-Sep	651	1000	7.50	0.07738	0.10763
			R-15	Residential	Jun-Sep	1001	999999	7.50	0.07976	0.11001
Chicago	IL	ComEd	R-1	Residential	Jun-Sep	0	999999	7.13	0.08275	0.08275
			R-1	Residential	Oct-May	0	400	7.13	0.08275	0.08275
			R-1	Residential	Oct-May	401	999999	7.13	0.06208	0.06208
			R-1H	Add On HP	Jun-Sep	0	999999	7.13	0.08275	0.08275
			R-1H	Add On HP	Oct-May	0	400	7.13	0.08275	0.08275
			R-1H	Add On HP	Oct-May	401	700	7.13	0.06208	0.06208
			R-1H	Add On HP	Oct-May	701	999999	7.13	0.03734	0.03734
Phoenix	AZ	Salt River Project	E-23	Standard Plan	May-Oct	0	999999	10.15	0.02690	0.09220
			E-23	Standard Plan	Nov-Apr	0	400	10.15	0.01770	0.07550
			E-23	Standard Plan	Nov-Apr	401	999999	10.15	0.01750	0.05640

5.4.2 Natural Gas Costs

On the other hand, only two of the four markets analyzed had natural gas tariffs designed to reduce the operating costs of conventional gas-fired furnaces. In Phoenix, the most popular residential tariff features a seasonal rate structure with a reduced energy rate designed to reduce the expense of operating gas-fired space heating equipment. In Boston, a dedicated residential heating rate is available to customers who install a gas-fired furnace as their primary space heating system. In the remaining two markets, Atlanta and Chicago, the standard residential natural gas tariff is neither seasonal nor structured to reduce the operating cost of gas-fired space heating systems (Table 10).

Table 10. Residential Natural Gas Energy Costs

Location		Utility	Natural Gas Tariff			Block		Energy Rate			
City	State		Rate	Description	Season	Start	End	Cust	Dist	Gas Charge	Total
Boston	MA	Boston Gas Co.	R-1	Residential Non-Heating	Jan-Dec	0	10	10.02	0.5802	0.9646	2.5094
			R-1	Residential Non-Heating	Jan-Dec	11	999999	10.02	0.1456	0.9646	2.0748
			R-3	Residential Heating	Jan-Dec	0	30	12.64	0.3691	0.9646	2.2983
			R-3	Residential Heating	Jan-Dec	31	999999	12.64	0.2044	0.9646	2.1336
Atlanta	GA	Atlanta Gas Light Co.	R-1	Residential Delivery	Jan-Dec	0	999999	16.99	----	1.4000 (1)	2.8000
Chicago	IL	Peoples Gas Light	SC1	Small Residential	Jan-Dec	0	50	9.45	0.3638	0.8115 (2)	1.9868
			SC1	Small Residential	Jan-Dec	51	999999	9.45	0.1145	0.8115 (2)	1.7375
Phoenix	AZ	Southwest Gas Corp.	G-5	Single-Family Residential	May-Oct	0	15	9.70	0.5420	0.8625	2.2669
			G-5	Single-Family Residential	May-Oct	16	999999	9.70	0.5010	0.8625	2.2259
			G-5	Single-Family Residential	Nov-Apr	0	35	9.70	0.5420	0.8625	2.2669
			G-5	Single-Family Residential	Nov-Apr	36	999999	9.70	0.5010	0.8625	2.2259

Notes:

1. *Annual "apples-to-apples" price per therm including commodity charge, other listed charges and custiomer service charge for fixed standard plan as published by the Georgia Public Service Commission (August 2006).*
2. *Average commodity gas charge for ther period from January to August 2006 as published by The Peoples Gas Light and Coke Company.*

5.5 Analysis Software

The results presented in this report were generated using the *REM/Design* software available from Architectural Energy Corporation. *REM/Design* is a user-friendly, yet highly sophisticated, residential energy analysis, code compliance, and rating software package developed specifically for the needs of HERS providers. *REM/Design* calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. Climate data is available for cities and towns throughout North America. *REM/Design* produces the following documentation:

- Energy efficient mortgage report
- Energy appraisal addendum
- Energy code compliance (MEC, IECC and ASHRAE)
- Improvements analysis (existing homes)
- Design optimization (new homes)
- Heating and cooling equipment sizing
- Utility DSM compliance analysis
- EPA Energy Star Home analysis

REM/Design operates in *MS Windows* and has many unique features, including a Simplified Inputs procedure, extensive component libraries, automated energy efficient improvement analysis, duct conduction and leakage analysis, latent and sensible cooling analysis, lighting and appliance audit, as well as active and passive solar analysis.

The *REM/Design* computer program is offered as an aid in rating the energy efficiency of new and existing homes. The rating approach and other aspects of the software meet the specifications for rating tools as specified in NASEO/RESNET National Home Energy Rating Technical Guidelines. The results are not a precise prediction of either overall energy consumption or utility bills. As called for in the guidelines, the program includes estimated typical values for numerous factors that can affect energy requirements such as weather patterns, number and living habits of occupants, appliance usage, thermostat settings, and certain details of construction. In a particular house, any of these factors can vary significantly from the assumptions made.

5.6 Modeling Variables

REMDesign allows you to create a building models based on user-defined design and construction. Building construction inputs include:

- Foundation Wall specified by construction type, interior and exterior insulation.
- Slab Floor specified by perimeter insulation and under slab insulation.
- Frame Floor described by path area and layers or continuous and frame cavity insulation.
- Above-Grade Wall described by path area and layers or continuous and frame cavity insulation.
- Window/Skylight specified by U-value and Solar Heat Gain Coefficients.
- Door described by R-value and storm door presence.

- Ceiling described by path area and layers or continuous and frame cavity insulation.

Mechanical system inputs include:

- Heating Equipment described by type, capacity and efficiency.
- Cooling Equipment described by type, capacity and efficiency.
- Water Heating Equipment described by type, capacity and efficiency.
- Air-Source Heat Pump described by type, capacity and efficiency.
- Ground-Source Heat Pump - closed loop systems described by ARI capacity and efficiencies.
- Dual Fuel Heat Pumps described by fuel type, heating and cooling capacity, and back-up heating type, and efficiency.
- Integrated Space/Water Heating - described by type, capacity and efficiency.

REMDesign lets the user input the basic performance characteristics of mechanical systems selected. For example, user defined characteristics for air-source heat pumps include for heating: HSPF, compressor capacity at 47^{o}F (kBtuh), and electric resistance backup capacity (kW), and for cooling: SEER, capacity (kbtuh), and sensible heat factor. You can also specify whether the unit is equipped with a desuperheater. More specific to this project, *REMDesign* allows the user to specify the percent of heating and cooling load served by the heat pump and, if a dual fuel heat pump is selected, the switchover temperature for heating.

Location-specific climate and energy costs can be entered for each unique building. The weather site used in the analyses is based on a user specified state and city or zip code. For each location the program selects the appropriate climate zone, ASHRAE W Factor, design heating temperature, and design cooling temperature. Heating degree-days (HDD) and cooling degree-hours (CDH) are used for code compliance purposes only; MEC uses HDD while ASHRAE 90.2 requires both HDD and CDH. Utility rates can be defined for each fuel type specified including a service charge and a flat energy rate or monthly block rates, whichever is applicable.

The program includes detailed libraries of the prescriptive requirements of ASHRAE 90.2 to insure that each model reflects the minimum requirements for the specific building type and location. In addition, the program will verify whether the buildings modeled meet the energy performance requirements of the applicable International Energy Conservation Code, the CABO Model Energy Code, and/or meets the EPA Energy Star Home requirements (defined as having a rating of 86 or better).

Table 11. HVAC Equipment Characteristics – Circa 1970

Location	Heating Plant	Furnace			Heat Pump			Cooling Plant				Domestic Water Heating		
City	Type	Fuel	Efficiency		Fuel	Efficiency		Type	Fuel	Efficiency		Type	Fuel	EF
Boston	Furnace Only	NG	70	AFUE	---	---	---	Split System	Elec.	6.5	SEER	Storage, 40 gal.	NG	0.48
Boston	Furnace/Heat Pump	NG	70	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.48
Atlanta	Furnace Only	NG	70	AFUE	---	---	---	Split System	Elec.	6.5	SEER	Storage, 40 gal.	NG	0.48
Atlanta	Furnace/Heat Pump	NG	70	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.48
Chicago	Furnace Only	NG	70	AFUE	---	---	---	Split System	Elec.	6.5	SEER	Storage, 40 gal.	NG	0.48
Chicago	Furnace/Heat Pump	NG	70	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.48
Phoenix	Furnace Only	NG	70	AFUE	---	---	---	Split System	Elec.	6.5	SEER	Storage, 40 gal.	NG	0.48
Phoenix	Furnace/Heat Pump	NG	70	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.48

Note: Furnace and air conditioning equipment efficiencies based on data compiled by the Energy Information Administration; add-on heat pump efficiencies are based on the minimum currently allowedf by code.

Table 12. HVAC Equipment Characteristics – Code Compliant

Location	Heating Plant	Furnace			Heat Pump			Cooling Plant				Domestic Water Heating		
City	Type	Fuel	Efficiency		Fuel	Efficiency		Type	Fuel	Efficiency		Type	Fuel	EF
Boston	Furnace Only	NG	78	AFUE	---	---	---	Split System	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Boston	Furnace/Heat Pump	NG	78	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Atlanta	Furnace Only	NG	78	AFUE	---	---	---	Split System	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Atlanta	Furnace/Heat Pump	NG	78	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Chicago	Furnace Only	NG	78	AFUE	---	---	---	Split System	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Chicago	Furnace/Heat Pump	NG	78	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Phoenix	Furnace Only	NG	78	AFUE	---	---	---	Split System	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59
Phoenix	Furnace/Heat Pump	NG	78	AFUE	Elec.	7.7	HSPF	Add-On Heat Pump	Elec.	13.0	SEER	Storage, 40 gal.	NG	0.59

Note: HVAC equipment meet the prescriptive criteria of ANSI/ASHRAE Standard 90.2-2001 and/or IECC 2003.

Table 13. HVAC Equipment Characteristics – ENERGYSTAR

Location	Heating Plant	Furnace			Heat Pump			Cooling Plant				Domestic Water Heating		
City	Type	Fuel	Efficiency		Fuel	Efficiency		Type	Fuel	Efficiency		Type	Fuel	EF
Boston	Furnace Only	NG	90	AFUE	---	---	---	Split System	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Boston	Furnace/Heat Pump	NG	90	AFUE	Elec.	8.5	HSPF	Add-On Heat Pump	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Atlanta	Furnace Only	NG	90	AFUE	---	---	---	Split System	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Atlanta	Furnace/Heat Pump	NG	90	AFUE	Elec.	8.5	HSPF	Add-On Heat Pump	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Chicago	Furnace Only	NG	90	AFUE	---	---	---	Split System	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Chicago	Furnace/Heat Pump	NG	90	AFUE	Elec.	8.5	HSPF	Add-On Heat Pump	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Phoenix	Furnace Only	NG	90	AFUE	---	---	---	Split System	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62
Phoenix	Furnace/Heat Pump	NG	90	AFUE	Elec.	8.5	HSPF	Add-On Heat Pump	Elec.	14.0	SEER	Storage, 40 gal.	NG	0.62

Note: HVAC equipment meet the minimum criteria to qualify for the ENERGYSTAR label.

Table 14. HVAC Equipment Costs – Complete Split Air Conditioner w/ NG Furnace

System Configuration	Cooling Plant			Heating Plant		Equipment Cost		Notes
	Capacity	Efficiency		Efficiency		Per Unit	Per Ton	
Complete Split Air Conditioner System w/ NG Furnace	1.5 tons	13.0	SEER	80.0	AFUE	1,395	930	(1) (2)
	2.0 tons	13.0	SEER	80.0	AFUE	1,475	738	(1) (2)
	2.5 tons	13.0	SEER	80.0	AFUE	1,499	600	(1) (2)
	3.0 tons	13.0	SEER	80.0	AFUE	1,585	528	(1) (2)
	3.5 tons	13.0	SEER	80.0	AFUE	1,645	470	(1) (2)
	4.0 tons	13.0	SEER	80.0	AFUE	1,775	444	(1) (2)
	5.0 tons	13.0	SEER	80.0	AFUE	1,999	400	(1) (2)
Complete Split Air Conditioner System w/ Variable 2-Speed NG Furnace	1.5 tons	15.0	SEER	95.0	AFUE	2,150	1,433	(1) (2)
	2.0 tons	15.0	SEER	95.0	AFUE	2,220	1,110	(1) (2)
	2.5 tons	15.0	SEER	95.0	AFUE	2,265	906	(1) (2)
	3.0 tons	15.0	SEER	95.0	AFUE	2,350	783	(1) (2)
	3.5 tons	15.0	SEER	95.0	AFUE	2,580	737	(1) (2)
	4.0 tons	15.0	SEER	95.0	AFUE	2,799	700	(1) (2)
	5.0 tons	15.0	SEER	95.0	AFUE	2,899	580	(1) (2)
Complete Split Air Conditioner System w/ NG Furnace	1.5 tons	13.0	SEER	---	---	1,515	1,010	(3) (4)
	2.0 tons	13.0	SEER	---	---	1,535	767	(3) (4)
	2.5 tons	13.0	SEER	---	---	1,690	676	(3) (4)
	3.0 tons	13.0	SEER	---	---	1,829	610	(3) (4)
	3.5 tons	13.0	SEER	---	---	1,925	550	(3) (4)
	4.0 tons	13.0	SEER	---	---	2,083	521	(3) (4)
	5.0 tons	13.0	SEER	---	---	2,185	437	(3) (4)

Table 15. HVAC Equipment Costs – Complete Split Air Conditioner w/ NG Furnace

System Configuration	Cooling Plant		Heating Plant		Equipment Cost		Notes
	Cap[acity	Efficiency	Capacity	Efficiency	Per Unit	Per Ton	
Dual Fuel Heat Pump/Furnace Combination	1.5 tons	15.0 SEER	--- ---	95.0 AFUE	$ 2,290	$1,527	(1) (2)
	2.0 tons	14.0 SEER	--- ---	95.0 AFUE	2,360	1,180	(1) (2)
	2.5 tons	15.0 SEER	--- ---	95.0 AFUE	2,415	966	(1) (2)
	3.0 tons	15.0 SEER	--- ---	95.0 AFUE	2,490	830	(1) (2)
	3.5 tons	15.0 SEER	--- ---	95.0 AFUE	2,720	777	(1) (2)
	4.0 tons	15.0 SEER	--- ---	95.0 AFUE	2,990	748	(1) (2)
	5.0 tons	14.0 SEER	--- ---	95.0 AFUE	3,090	618	(1) (2)
Dual Fuel Heat Pump/Furnace Combination	1.5 tons	13.0 SEER	--- ---	80.0 AFUE	1,545	1,030	(1) (2)
	2.0 tons	13.0 SEER	--- ---	80.0 AFUE	1,625	813	(1) (2)
	2.5 tons	13.0 SEER	--- ---	80.0 AFUE	1,699	680	(1) (2)
	3.0 tons	13.0 SEER	--- ---	80.0 AFUE	1,799	600	(1) (2)
	3.5 tons	13.0 SEER	--- ---	80.0 AFUE	1,899	543	(1) (2)
	4.0 tons	13.0 SEER	--- ---	80.0 AFUE	1,980	495	(1) (2)
	5.0 tons	13.0 SEER	--- ---	80.0 AFUE	2,255	451	(1) (2)
Dual Fuel Heat Pump/Furnace Combination	2.0 tons	13.0 SEER	70.0 KBTU	95.0 AFUE	2,488	1,244	(3) (4)
	2.0 tons	13.0 SEER	70.0 KBTU	95.0 AFUE	2,488	1,244	(3) (4)
	2.5 tons	15.0 SEER	70.0 KBTU	95.0 AFUE	2,953	1,181	(3) (4)
	3.0 tons	13.4 SEER	75.0 KBTU	90.0 AFUE	3,263	1,088	(3)
	4.0 tons	13.0 SEER	90.0 KBTU	95.0 AFUE	3,442	861	(3) (4)

Notes (Tables 14 & 15):

1. *Data Source: Budget Heating (http://www.budgetheating.com)*
2. *Includes condenser, gas furnace, cased evaporator coil, primary drain pan. New in factory box, strapped & wrapped for safe delivery.*
3. *Data Source: Wholesale Air Conditioning (http://www.wholesaleac.com)*
4. *Features 2 Stage Variable Speed Fan.*

6 Results

6.1 *Summary of Results*

Results from the *REM/Design* analyses were compiled for each of the four building types in each of four locations as described under *Analysis Approach*. Of primary interest for this analysis were the Source Energy Consumption reported in the *Source Energy & Emissions Report*, Annual Energy Consumption reported in the *1995 MEC, 2000 IECC and 2003 IECC Annual Energy Consumption Compliance* reports, and Annual Energy Cost reported in the *ASHRAE 90.2 Annual Energy Consumption Compliance report*. Compliance with ENERGY STAR criteria was confirmed with the *ENERGY STAR Home Report*. Complete results from these reports are included in Appendix A.

Appendix A - REM/Design Energy Summary summarizes the annual energy consumption and cost results for all of the *REM/Design* runs performed for this analysis, including source energy consumption (MMBtu/yr) for heating, cooling, water heating, lights and appliances; annual energy consumption (MMBtu) for heating, cooling, water heating, and lights and appliances; and annual energy cost ($/yr) for heating, cooling, water heating, lights and appliances and service charge. Results are compiled for the following eight cases:

- Table A.1 – Existing homes designed in accordance with common building practices circa 1970,
- Table A.2 – New homes designed to be meet the minimum requirements of the prescriptive path of the 1995 Model Energy Code (1995MEC),
- Table A.3 – New homes designed to be meet the minimum criteria of the performance path of 1995 MEC,
- Table A.4 – New homes designed to be meet the minimum requirements of the prescriptive path of the 2000 International Energy Conservation Code (2000 IECC),
- Table A.5 – New homes designed to be meet the minimum requirements of the performance path of the 2000 IECC,
- Table A.6 – New homes designed to be meet the minimum requirements of the prescriptive path of the 2003 International Energy Conservation Code (2003 IECC),
- Table A.7 – New homes designed to be meet the minimum requirements of the performance path of the 2003 IECC, and
- Table A.8 – New homes designed to be meet the minimum criteria established for the ENERGY STAR HOMES program.

The Total Emissions and Emissions By End-Use from the *Emissions Report* were also compiled. Complete results from these reports are included in Appendices B.

Appendix B - REM/Design Emissions Summary summarizes total emissions (lbs/yr), emissions by end use (lbs/yr) and total emissions (lbs/yr). Total emissions are provided for each modeled home for carbon monoxide (CO_2), sulfur dioxide (SO_2), and nitrous oxide (NO_X). Emissions by end use are provided for each modeled home for CO_2, SO_2, and NO_X associated with heating, cooling, water heating, and lights and appliances. Results are compiled for the following eight cases:

- Table B.1 – Existing homes designed in accordance with common building practices circa 1970,
- Table B.2 – New homes designed to be meet the minimum requirements of the prescriptive path of the 1995 Model Energy Code (1995MEC),
- Table B.3 – New homes designed to be meet the minimum criteria of the performance path of 1995 MEC,
- Table B.4 – New homes designed to be meet the minimum requirements of the prescriptive path of the 2000 International Energy Conservation Code (2000 IECC),
- Table B.5 – New homes designed to be meet the minimum requirements of the performance path of the 2000 IECC,

- Table B.6 – New homes designed to be meet the minimum requirements of the prescriptive path of the 2003 International Energy Conservation Code (2003 IECC),
- Table B.7 – New homes designed to be meet the minimum requirements of the performance path of the 2003 IECC, and
- Table B.8 – New homes designed to be meet the minimum criteria established for the ENERGY STAR HOMES program.

The tables in Sections 6.1.1 through 6.1.4 compare similar homes: (1) designed to be representative of existing building stock (circa 1970), (2) designed to be meet the minimum prescriptive requirements of the applicable residential building code (i.e., 1995 MEC or 2000 IECC), and (3) designed to meet the minimum requirements to qualify for the ENERGY STAR HOMES program. The output from all *REM/Design* runs is compiled and summarized by city to allow for easy comparison of results.

6.1.1 Atlanta, GA

Table 16. *REM/Design* Energy Summary - Existing Housing Stock (Circa 1970)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	130.9	92.5	38.4	29.3%	----
Cooling	81.3	39.9	41.4	50.9%	----
Water Heating	24.7	24.8	-0.1	-0.4%	----
Lights & Appliances	93.9	93.9	0.0	0.0%	----
Total	330.8	251.1	79.7	24.1%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	112.0	46.5	65.5	58.5%	----
Cooling:	22.6	11.2	11.4	50.4%	----
Water Heating	22.5	22.6	-0.1	-0.4%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	184.7	107.9	76.8	41.6%	----
Annual Energy Cost ($/yr)[3]					
Heating:	1,663	837	826	49.7%	----
Cooling:	669	317	352	52.6%	----
Water Heating	314	316	-2	-0.6%	----
Lights & Appliances	679	657	22	3.2%	----
Service Charge	294	294	0	0.0%	----
Total:	3,619	2,421	1,198	33.1%	2.6

Notes:
1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment costs of $630 per ton for add-on heat pump (outside unit and indoor coil only).*

Table 17. *REM/Design* Energy Summary – New Construction (IECC 2000)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	50.6	36.2	14.4	28.5%	----
Cooling	33.5	29.8	3.7	11.0%	----
Water Heating	19.9	20.0	-0.1	-0.5%	----
Lights & Appliances	93.9	93.9	0.0	0.0%	----
Total	197.9	180.0	17.9	9.0%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	46.0	16.4	29.6	64.3%	----
Cooling:	9.5	8.6	0.9	9.5%	----
Water Heating	18.1	18.2	-0.1	-0.6%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	101.2	70.8	30.4	30.0%	----
Annual Energy Cost ($/yr)[3]					
Heating:	680	312	368	54.1%	----
Cooling:	261	234	27	10.3%	----
Water Heating	254	255	-1	-0.4%	----
Lights & Appliances	662	657	5	0.8%	----
Service Charge	294	294	0	0.0%	----
Total:	2,151	1,752	399	18.5%	0.5

Table 18. *REM/Design* Energy Summary – New Construction (ENERGY STAR)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	36.8	27.8	9.0	24.5%	----
Cooling	26.5	22.7	3.8	14.3%	----
Water Heating	19.0	19.0	0.0	0.0%	----
Lights & Appliances	93.9	93.9	0.0	0.0%	----
Total	176.2	163.4	12.8	7.3%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	33.3	12.3	21.0	63.1%	----
Cooling:	7.4	6.4	1.0	13.5%	----
Water Heating	17.3	17.3	0.0	0.0%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	85.6	63.7	21.9	25.6%	----
Annual Energy Cost ($/yr)[3]					
Heating:	491	237	254	51.7%	----
Cooling:	201	172	29	14.4%	----
Water Heating	241	242	-1	-0.4%	----
Lights & Appliances	657	652	5	0.8%	----
Service Charge	294	294	0	0.0%	----
Total:	1,884	1,597	287	15.2%	0.7

Notes (Tables 17 & 18):

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment cost premium of $200 for add-on heat pump (outside unit and indoor coil only) plus natural gas fired warm air furnace.*

Table 19. *REM/Design* Emission Summary

Type of Emissions	Circa 1970		IECC2000Uo		Energy Star	
	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP
Total Emissions (lbs/year)						
Carbon Dioxide (CO_2)	45,735.4	35,989.6	27,755.8	26,416.0	24,633.6	23,701.6
Sulfur Dioxide (SO_2)	192.8	193.5	131.8	153.5	122.1	138.0
Nitrogen Oxides (NO_X)	107.6	95.6	69.2	73.2	62.7	65.7
Emissions By End-Use (lbs/year)						
Carbon Dioxide (CO_2)						
Heating	15,060.5	12,565.7	6,255.0	5,469.8	4,500.9	4,162.9
Cooling	14,425.2	7,160.4	5,769.9	5,207.7	4,505.8	3,909.0
Water Heating	2,694.0	2,707.7	2,175.2	2,182.7	2,071.1	2,074.0
Lights & Appliances	13,555.8	13,555.8	13,555.8	13,555.8	13,555.8	13,555.8
Sulfur Dioxide (SO_2)						
Heating	8.5	57.0	4.5	29.9	3.1	22.9
Cooling	95.0	47.2	38.0	34.3	29.7	25.7
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	89.3	89.3	89.3	89.3
Nitrogen Oxide (NO_X)						
Heating	21.0	30.6	9.0	14.7	6.4	11.2
Cooling	42.9	21.3	17.2	15.5	13.4	11.6
Water Heating	3.4	3.4	2.7	2.7	2.6	2.6
Lights & Appliances	40.3	40.3	40.3	40.3	40.3	40.3

6.1.2 Boston, MA

Table 20. *REM/Design* Energy Summary - Existing Housing Stock (Circa 1970)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	277.2	235.3	41.9	15.1%	----
Cooling	42.0	20.9	21.1	50.2%	----
Water Heating	27.7	27.9	-0.2	-0.7%	----
Lights & Appliances	102.2	102.2	0.0	0.0%	----
Total	449.1	386.4	62.7	14.0%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	235.0	131.9	103.1	43.9%	----
Cooling:	10.2	5.1	5.1	50.0%	----
Water Heating	25.2	25.4	-0.2	-0.8%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	298.0	190.1	107.9	36.2%	----
Annual Energy Cost ($/yr)[3]					
Heating:	2,944	2,772	172	5.8%	----
Cooling:	622	326	296	47.6%	----
Water Heating	313	307	6	1.9%	----
Lights & Appliances	1,522	1,494	28	1.8%	----
Service Charge	229	197	32	14.0%	----
Total:	5,630	5,098	532	9.4%	5.9

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment costs of $630 per ton for add-on heat pump (outside unit and indoor coil only.*

Table 21. *REM/Design* Energy Summary – New Construction (MEC 1995)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	100.4	86.7	13.7	13.6%	----
Cooling	22.8	20.5	2.3	10.1%	----
Water Heating	22.6	22.7	-0.1	-0.4%	----
Lights & Appliances	102.2	102.2	0.0	0.0%	----
Total	248.0	232.2	15.8	6.4%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	84.8	50.1	34.7	40.9%	----
Cooling:	5.7	5.2	0.5	8.8%	----
Water Heating	20.6	20.7	-0.1	-0.5%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	138.7	103.5	35.2	25.4%	----
Annual Energy Cost ($/yr)[3]					
Heating:	1,061	994	67	6.3%	----
Cooling:	337	321	16	4.7%	----
Water Heating	260	259	1	0.4%	----
Lights & Appliances	1,522	1,494	28	1.8%	----
Service Charge	229	197	32	14.0%	----
Total:	3,410	3,266	144	4.2%	1.4

Table 22. *REM/Design* Energy Summary – New Construction (ENERGY STAR)

Desxcription	AC-Furnace	Add-on HP	Reduction		Payback[5]
Source Energy Consumption (MMBtu)[1]					
Heating	72.6	64.6	8.0	11.0%	----
Cooling	17.7	15.5	2.2	12.4%	----
Water Heating	21.4	21.4	0.0	0.0%	----
Lights & Appliances	102.2	102.2	0.0	0.0%	----
Total	213.9	203.8	10.1	4.7%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	61.3	36.6	24.7	40.3%	----
Cooling:	4.4	3.9	0.5	11.4%	----
Water Heating	19.5	19.5	0.0	0.0%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	112.8	87.6	25.2	22.3%	----
Annual Energy Cost ($/yr)[3]					
Heating:	692	754	-62	-9.0%	----
Cooling:	262	242	20	7.6%	----
Water Heating	248	248	0	0.0%	----
Lights & Appliances	1,522	1,494	28	1.8%	----
Service Charge	229	197	32	14.0%	----
Total:	2,954	2,935	19	0.6%	10.5

Notes (Tables 21 & 22):

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
5. *Simple payback period in years based on equipment cost premium of $200 for add-on heat pump (outside unit and indoor coil only) plus natural gas fired warm air furnace.*

Table 23. *REM/Design* Emission Summary

Type of Emissions	Circa 1970		MEC1995Uo		Energy Star	
	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP
Total Emissions (lbs/year)						
Carbon Dioxide (CO_2)	56,638.4	51,835.6	32,509.3	31,932.3	28,534.6	28,271.2
Sulfur Dioxide (SO_2)	133.5	187.3	104.9	127.0	98.1	115.3
Nitrogen Oxides (NO_X)	90.0	91.8	55.7	58.2	49.8	52.0
Emissions By End-Use (lbs/year)						
Carbon Dioxide (CO_2)						
Heating	29,851.4	29,366.1	10,570.5	10,403.9	7,686.9	7,845.6
Cooling	8,632.9	4,291.9	4,341.7	3,919.8	3,379.7	2,953.0
Water Heating	3,023.2	3,046.7	2,466.2	2,477.7	2,337.1	2,341.8
Lights & Appliances	15,130.9	15,130.9	15,130.9	15,130.9	15,130.9	15,130.9
Sulfur Dioxide (SO_2)						
Heating	13.2	89.0	6.3	30.6	4.4	23.8
Cooling	43.7	21.7	22.0	19.8	17.1	14.9
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	76.6	76.6	76.6	76.6	76.6	76.6
Nitrogen Oxide (NO_X)						
Heating	39.2	49.5	14.1	17.4	10.2	13.2
Cooling	17.1	8.5	8.6	7.8	6.7	5.8
Water Heating	3.8	3.8	3.1	3.1	2.9	2.9
Lights & Appliances	30.0	30.0	30.0	30.0	30.0	30.0

6.1.3 Chicago, IL

Table 24. *REM/Design* Energy Summary - Existing Housing Stock (Circa 1970)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	312.6	270.9	41.7	13.3%	----
Cooling	42.1	20.9	21.2	50.4%	----
Water Heating	28.4	28.6	-0.2	-0.7%	----
Lights & Appliances	99.5	99.5	0.0	0.0%	----
Total	482.5	419.9	62.6	13.0%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	268.3	152.7	115.6	43.1%	----
Cooling:	10.8	5.4	5.4	50.0%	----
Water Heating	25.8	26.1	-0.3	-1.2%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	332.6	211.8	120.8	36.3%	----
Annual Energy Cost ($/yr)[3]					
Heating:	2,642	1,711	931	35.2%	----
Cooling:	272	136	136	50.0%	----
Water Heating	271	281	-10	-3.7%	----
Lights & Appliances	608	525	83	13.7%	----
Service Charge	194	137	57	29.4%	----
Total:	3,988	2,789	1,199	30.1%	2.6

Notes:
1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment costs of $630 per ton for add-on heat pump (outside unit and indoor coil only).*

Table 25. *REM/Design* Energy Summary – New Construction (IECC 2000)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	102.2	90.4	11.8	11.5%	----
Cooling	22.6	20.5	2.1	9.3%	----
Water Heating	23.2	23.4	-0.2	-0.9%	----
Lights & Appliances	99.5	99.5	0.0	0.0%	----
Total	247.5	233.8	13.7	5.5%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	87.5	54.9	32.6	37.3%	----
Cooling:	5.9	5.4	0.5	8.5%	----
Water Heating	21.1	21.2	-0.1	-0.5%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	142.1	109.2	32.9	23.2%	----
Annual Energy Cost ($/yr)[3]					
Heating:	909	677	232	25.5%	----
Cooling:	147	135	12	8.2%	----
Water Heating	231	239	-8	-3.5%	----
Lights & Appliances	616	584	32	5.2%	----
Service Charge	194	137	57	29.4%	----
Total:	2,097	1,772	325	15.5%	0.6

Table 26. *REM/Design* Energy Summary – New Construction (ENERGY STAR)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	74.0	67.1	6.9	9.3%	----
Cooling	17.9	15.7	2.2	12.3%	----
Water Heating	22.0	22.1	-0.1	-0.5%	----
Lights & Appliances	99.5	99.5	0.0	0.0%	----
Total	213.4	204.4	9.0	4.2%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	63.2	40.0	23.2	36.7%	----
Cooling:	4.6	4.1	0.5	10.9%	----
Water Heating	20.0	20.1	-0.1	-0.5%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	115.4	91.8	23.6	20.5%	----
Annual Energy Cost ($/yr)[3]					
Heating:	675	517	158	23.4%	----
Cooling:	116	103	13	11.2%	----
Water Heating	222	230	-8	-3.6%	----
Lights & Appliances	618	599	19	3.1%	----
Service Charge	194	137	57	29.4%	----
Total:	1,825	1,584	241	13.2%	0.8

Notes (Tables 25 & 26):

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment cost premium of $200 for add-on heat pump (outside unit and indoor coil only) plus natural gas fired warm air furnace.*

Table 27. *REM/Design* Emission Summary

Type of Emissions	Circa 1970		IECC2000Uo		Energy Star	
	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP
Total Emissions (lbs/year)						
Carbon Dioxide (CO_2)	57,550.8	51,779.4	30,313.8	29,395.4	26,271.9	25,693.5
Sulfur Dioxide (SO_2)	195.6	303.2	152.2	188.1	142.6	169.7
Nitrogen Oxides (NO_X)	132.1	158.0	84.7	94.6	76.7	84.3
Emissions By End-Use (lbs/year)						
Carbon Dioxide (CO_2)						
Heating	34,232.0	32,153.9	11,301.6	10,683.5	8,175.2	7,935.1
Cooling	7,420.6	3,700.3	3,674.8	3,361.9	2,891.7	2,548.7
Water Heating	3,096.1	3,123.1	2,535.4	2,548.1	2,402.9	2,407.6
Lights & Appliances	12,802.0	12,802.0	12,802.0	12,802.0	12,802.0	12,802.0
Sulfur Dioxide (SO_2)						
Heating	20.1	160.0	9.3	47.8	8.5	36.5
Cooling	64.4	32.1	31.9	29.2	25.1	22.1
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	111.1	111.1	111.1	111.1	111.1	111.1
Nitrogen Oxide (NO_X)						
Heating	48.9	89.4	17.0	28.1	12.2	21.1
Cooling	29.1	14.5	14.4	13.2	11.3	10.0
Water Heating	3.9	3.9	3.2	3.2	3.0	3.0
Lights & Appliances	50.2	50.2	50.2	50.2	50.2	50.2

6.1.4 Phoenix, AZ

Table 28. *REM/Design* Energy Summary - Existing Housing Stock (Circa 1970)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	38.2	22.0	16.2	42.4%	----
Cooling	177.1	80.7	96.4	54.4%	----
Water Heating	20.9	20.9	0.0	0.0%	----
Lights & Appliances	74.6	74.6	0.0	0.0%	----
Total	310.8	198.2	112.6	36.2%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	34.0	14.9	19.1	56.2%	----
Cooling:	63.7	29.1	34.6	54.3%	----
Water Heating	19.0	19.0	0.0	0.0%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	144.3	90.6	53.7	37.2%	----
Annual Energy Cost ($/yr)[3]					
Heating:	503	241	262	52.1%	----
Cooling:	1,787	817	970	54.3%	----
Water Heating	265	266	-1	-0.4%	----
Lights & Appliances	640	636	4	0.6%	----
Service Charge	238	238	0	0.0%	----
Total:	3,434	2,198	1,236	36.0%	2.5

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment costs of $630 per ton for add-on heat pump (outside unit and indoor coil only).*

Table 29. *REM/Design* Energy Summary – New Construction (IECC 2000)

Description	AC-Furnace	Add-on HP	Reduction		Payback[5]
Source Energy Consumption (MMBtu)[1]					
Heating	17.4	10.2	7.2	41.4%	----
Cooling	71.5	57.3	14.2	19.9%	----
Water Heating	16.5	16.5	0.0	0.0%	----
Lights & Appliances	74.6	74.6	0.0	0.0%	----
Total	179.9	158.6	21.3	11.8%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	16.9	7.7	9.2	54.4%	----
Cooling:	25.7	20.8	4.9	19.1%	----
Water Heating	14.9	14.9	0.0	0.0%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	85.2	71.0	14.2	16.7%	----
Annual Energy Cost ($/yr)[3]					
Heating:	254	126	128	50.4%	----
Cooling:	725	586	139	19.2%	----
Water Heating	210	210	0	0.0%	----
Lights & Appliances	643	640	3	0.5%	----
Service Charge	238	238	0	0.0%	----
Total:	2,070	1,801	269	13.0%	0.7

Table 30. *REM/Design* Energy Summary – New Construction (ENERGY STAR)

Description	AC-Furnace	Add-on HP	Reduction		Payback[4]
Source Energy Consumption (MMBtu)[1]					
Heating	11.3	7.4	3.9	34.5%	----
Cooling	54.5	47.0	7.5	13.8%	----
Water Heating	15.7	15.7	0.0	0.0%	----
Lights & Appliances	74.6	74.6	0.0	0.0%	----
Total	156.1	144.7	11.4	7.3%	----
Annual Energy Consumption (MMBtu)[2]					
Heating	11.1	5.5	5.6	50.5%	----
Cooling:	19.6	16.9	2.7	13.8%	----
Water Heating	14.2	14.2	0.0	0.0%	----
Lights & Appliances	27.6	27.6	0.0	0.0%	----
Total:	72.5	64.2	8.3	11.4%	----
Annual Energy Cost ($/yr)[3]					
Heating:	166	91	75	45.2%	----
Cooling:	551	476	75	13.6%	----
Water Heating	200	200	0	0.0%	----
Lights & Appliances	645	642	3	0.5%	----
Service Charge	238	238	0	0.0%	----
Total:	1,800	1,647	153	8.5%	1.3

Notes (Tables 29 & 30):

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
4. *Simple payback period in years based on equipment cost premium of $200 for add-on heat pump (outside unit and indoor coil only) plus natural gas fired warm air furnace.*

Table 31. ***REM/Design*** **Emission Summary**

Type of Emissions	Circa 1970		IECC2000Uo		Energy Star	
	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP	AC-Furnace	Add-on HP
Total Emissions (lbs/year)						
Carbon Dioxide (CO_2)	42,266.1	26,352.1	23,892.0	21,020.7	20,467.1	18,946.6
Sulfur Dioxide (SO_2)	110.3	69.8	61.8	57.0	53.6	51.5
Nitrogen Oxides (NO_X)	101.9	64.0	57.3	51.6	49.4	46.5
Emissions By End-Use (lbs/year)						
Carbon Dioxide (CO_2)						
Heating	4,652.1	2,832.1	2,363.6	1,480.8	1,528.8	1,071.5
Cooling	25,938.0	11,844.0	10,335.4	8,346.9	7,831.6	6,768.4
Water Heating	2,278.7	2,278.7	1,795.7	1,795.7	1,709.3	1,709.3
Lights & Appliances	9,397.4	9,397.4	9,397.4	9,397.4	9,397.4	9,397.4
Sulfur Dioxide (SO_2)						
Heating	1.7	4.5	1.1	2.4	0.6	1.8
Cooling	79.8	36.4	31.8	25.7	24.1	20.8
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	28.9	28.9	28.9	28.9	28.9	28.9
Nitrogen Oxide (NO_X)						
Heating	6.5	5.5	3.4	2.9	2.2	2.1
Cooling	67.9	31.0	27.1	21.9	20.5	17.7
Water Heating	2.8	2.8	2.2	2.2	2.1	2.1
Lights & Appliances	24.6	24.6	24.6	24.6	24.6	24.6

6.2 *Analysis of Results*

6.2.1 *Retrofit Installation*

The addition of an add-on heat pump to a conventional split system AC/furnace combination in an existing residence results in an overall reduction in source energy consumption of 13 to 36 percent depending on the location of the home. The reduction in source energy consumption attributable to space heating ranges from 13 to 42 percent while the reduction attributable to space cooling varies from 50 to 54 percent. As would be expected, the largest reductions in both space heating and total source energy consumption occur in the southern regions of the country (i.e., Atlanta and Phoenix), although the percentage reduction in space heating in these warmer climates is over smaller heating loads. The reduction in cooling loads in retrofit installations can be directly associated with increased SEER ratings of the cooling equipment over the default 6.5 SEER systems.

The reduction in site energy consumption is greater with an overall reduction in energy consumption of 36 to 42 percent depending on the location of the home. The reduction in site energy consumption attributable to space heating ranges from 43 to 58 percent while the reduction attributable to space cooling varies from 50 to 54 percent. Again, the largest reductions in both space heating and total site energy consumption occur in the southern regions of the country (i.e., Atlanta and Phoenix).

The reduction in annual operating cost due to the installation of an add-on heat pump ranges from 9 to 36 percent depending on the location of the home. The reduction in operating cost attributable to space heating ranges from 6 to 52 percent while the reduction attributable to space cooling varies from 48 to 54 percent. The largest reductions in both space heating and total operating cost occur in the Southeast (i.e., Atlanta) while the largest reduction space cooling costs occur in the southern regions of the country (i.e., Atlanta and Phoenix). Assuming a first cost of $630 per ton, the simple payback period for an add-on heat pump (outside unit and indoor coil only) ranges from 2.5 years in the Southwest to 5.9 years in the Northeast. This does not take into account available electric utility/cooperative incentive programs that currently offer rebates of as much as $275 per ton.

While heating system reductions in southern climates can be directly associated with the dominance of heat pump cycle operation during the heating season, the lower balance points of heat pump systems also allow longer periods of operation in colder climates (i.e., in heating other than on the coldest days). In this way, efficiencies of the heat pump cycle can contribute significantly to meeting heating demand during the shoulder months in these climates. This in large measure explains savings from the use of add-on heat pump systems in all but the coldest climates.

6.2.2 New Construction – Code Compliant

The installation of a dual fuel system consisting of a gas-fired furnace and an air-source heat pump in lieu of the more traditional split system air conditioner – furnace combination in a new house constructed in compliance with local codes results in an overall reduction in source energy consumption of 6 to 12 percent depending on the location of the home. The reduction in source energy consumption attributable to space heating ranges from 11 to 41 percent while the reduction attributable to space cooling varies from 9 to 20 percent. By far the greatest reduction in space heating, space cooling and total source energy consumption occur in the Southwest region of the country (i.e., Phoenix). However, these percent reductions must be considered in light of the overall energy demands of these climates and not just on the basis of relative reductions.

Space cooling calculations for this category of new construction and those that follow suggest that add-on heat pump cooling is significantly more efficient that air conditioning provided by the furnace/AC system, even though the same SEER rating was used for these cooling systems in the analysis. It is unclear whether these differences, seen in all of the comparisons, is a real technical performance characteristic due to optimized design within add-on heat pump systems generally (and not captured by the SEER rating) or through some inconsistency in assumptions within the *REM/Design* software. Even with respect to the latter explanation, the apparent advantages in rating an add-on heat pump system over a furnace/AC system should not be ignored as they may affect the home energy rating process.

The reduction in site energy consumption is greater than the source energy reduction with an overall reduction in energy consumption of 17 to 30 percent depending on the location of the home. The reduction in site energy consumption attributable to space heating ranges from 37 to 64 percent while the reduction attributable to space cooling varies from 8 to 19 percent. The largest reductions in both space heating and total site energy consumption occur in the Southeast region of the country (i.e., Atlanta) while the largest reduction in space cooling energy consumption occurs in the Southwest (i.e., Phoenix).

The reduction in annual operating cost due to the installation of a code compliant dual fuel system ranges from 4 to 19 percent depending on the location of the home. The reduction in operating cost attributable to space heating ranges from 6 to 54 percent while the reduction attributable to space cooling varies from 5 to 19 percent. The largest reductions in total operating cost occur in the Southeast (i.e., Atlanta) while the largest reduction space cooling costs occur in the Southwest (i.e., Phoenix) and the largest reduction in space heating costs occurs in both of the southern regions of the country (i.e., Atlanta and Phoenix). Assuming a first cost equipment premium of $200 per ton, the simple payback period for a dual fuel system consisting of a gas-fired warm air furnace and an add-on heat pump (outside unit and indoor coil only) ranges from less than a year in the Southeast, Southwest and Midwest regions of the country to 1.4 years in the Northeast. This does not take into account available electric utility/cooperative incentive programs that currently offer rebates of as much as $275 per ton.

6.2.3 New Construction – ENERGY STAR

The installation of a dual fuel system consisting of a gas-fired furnace and an air-source heat pump in lieu of the more traditional split system air conditioner – furnace combination in a new house constructed to meet the more stringent ENERGY STAR criteria results in an overall reduction in source energy consumption of 4 to 7 percent depending on the location of the home. The reduction in source energy consumption attributable to space heating ranges from 9 to 35 percent while the reduction attributable to space cooling varies from 12 to 14 percent. The greatest reduction in space cooling, space heating and total energy consumption occurs in the southern regions of the country (i.e., Atlanta and Phoenix).

The reduction in site energy consumption is even greater with an overall reduction in energy consumption of 11 to 26 percent depending on the location of the home. The reduction in energy consumption attributable to space heating ranges from 37 to 63 percent while the reduction attributable to space cooling varies from 11 to 14 percent. The largest reductions in both space heating and total energy consumption occur in the Southeast region of the country (i.e., Atlanta) while the largest reduction in space cooling energy consumption occurs in the southern regions of the country (i.e., Atlanta and Phoenix).

The reduction in annual operating cost due to the installation of an ENERGY STAR compliant dual fuel system ranges from less than 1 to 15 percent depending on the location of the home. The reduction in operating cost attributable to space heating ranges from –9 to 52 percent while the reduction attributable to space cooling varies from 8 to 14 percent. The largest reductions in both space heating and total operating cost occur in the Southeast (i.e., Atlanta) while the largest reduction space cooling costs occur in both of the southern regions of the country (i.e., Atlanta and Phoenix). Assuming a first cost equipment premium of $200 per ton, the simple payback period for a dual fuel system consisting of a gas-fired warm air furnace and an add-on heat pump (outside unit and indoor coil only) ranges from less than a year in the Southeast and Midwest regions of the country to 11 years in the Northeast. This does not take into account available electric utility/cooperative incentive programs that currently offer rebates of as much as $275 per ton. In this scenario, there is minimal benefit for residential customers in the Northeast to switch to a dual fuel system as the reduction in total operating costs are negligible and operating costs attributable to space heating actually increase by 9 percent.

6.2.4 *Greenhouse Gas Emissions*

In the Southeast (i.e., Atlanta), the installation of an add-on heat pump system results in a substantial reduction in carbon dioxide (CO_2) emissions, a smaller reduction in nitrogen oxide (NO_X) emissions and an increase in sulfur dioxide (SO_2) emissions. The increase in the latter is attributable primarily to space heating. In the Northeast (i.e., Boston), the installation of an add-on heat pump results in a reduction in CO_2 emissions, attributable primarily to space cooling, an increase in SO_2 and NO_X emissions attributable primarily to space heating. In the Midwest (i.e., Chicago), the installation of an add-on heat pump results in a significant reduction in CO_2 emissions, attributable primarily to space cooling, a large increase in SO_2 emissions and a small increase in NO_X emissions, both attributable primarily to space heating. In the Southwest (i.e., Phoenix), the installation of an add-on heat pump results in a substantial reductions in CO_2 emissions, attributable primarily to space cooling, as well as small decreases in SO_2 and NO_X emissions attributable primarily to space cooling.

7 Conclusions

Compared to a conventional split system air conditioner combined with a gas-fired warm air furnace, a residential HVAC system equipped with an add-on heat pump was shown to consume less source and site energy for both space heating and cooling. However, the magnitude of these relative savings (and the competitiveness of add-on heat pumps) varies significantly across the climates analyzed. Efficiencies of the heat pump cycle can contribute significantly to meeting heating demand during the shoulder months in cold climates. This in large measure explains savings from the use of add-on heat pump systems in all but the coldest climates. Add-on heat pump systems also demonstrated lower annual operating costs based on operating cost assumptions used for the study. This holds true for both retrofit applications and new construction in the locations analyzed, with the exception being a new house built in the Northeast (i.e., Boston) in compliance with the ENERGY STAR HOMES Program.

Space cooling calculations for new construction suggest that add-on heat pump cooling is significantly more efficient that air conditioning provided by the furnace/AC system, even though the same SEER rating was used for these cooling systems in the analysis. It is unclear whether these differences represent real technical performance characteristics of add-on heat pump systems generally (i.e., efficiencies not captured by the SEER rating) or due to inconsistency in assumptions within the *REM/Design* software. This question needs to be resolved in consultation with the *REM/Design* developers.

Incentive programs would serve to reinforce the competitiveness of add-on heat pumps and, within the scope of such programs, may be a more important influence on market penetration. As more electric utilities and cooperatives undertake and/or ramp up their marketing campaigns, residential customers looking to reduce their energy costs can be expected to install add-on heat pumps (retrofit applications) or dual fuel systems (new installations), especially in the Southeast and Southwest regions of the country. However, additional marketing practices not addressed by this study, including "value pricing" (over manufactured cost-based pricing) and premium product marketing may alter the overall competitiveness of add-on heat pump systems and market penetration.

8 References

AEC 2006. *REM/Design Residential Energy Analysis Software - Version 12.2*, Architectural Energy Corporation, 2006.

ASHRAE 2006. *ANSI/ASHRAE Standard 90.2-2004, Energy-Efficient Design of Low-Rise Residential Buildings*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, 2006.

ASHRAE 2004. *2004 ASHRAE Handbook - HVAC Systems and Equipment*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, 2004.

Atlanta Gas Light 2005. *Atlanta Gas Light Company Tariff*, Atlanta Gas Light Company, May 2005.

Boston Edison 2006. *Electric Schedule of Rates* (http://www.nstaronline.com/ss/customer_service/rates/schedule.asp), NSTAR, 2006.

Boston Gas Company 2006. *Residential Gas Rates – Boston,* Boston Gas Company, KeySpan Corporation, 2006

CABO 1995. *Model Energy Code – 1995 Edition*, Council of American Building Officials, 1995.

ComEd 2006. *Schedule of Rates for Electric Service*, Commonwealth Edison Company, December 1978.

DOE 2006. *Energy Efficiency and Renewable Energy* (*http://www.eere.energy.gov*), Energy Efficiency and Renewable Energy Division, U.S. Department of Energy.

EIA 1999. *A Look at Residential Energy Consumption in 1997*, Energy Information Administration, November 1999.

EIA 2001. 2001 *Residential Energy Consumption Database,* Energy Information Administration, November 2001.

EPA 1997. *E-GRID97 Database*, United States Environmental Protection Agency, 1997.

EPA 2006. *EPA ENERGY STAR Website* (http://www.energystar.gov), United States Environmental Protection Agency, September 2006.

Georgia Power 2006. http://www.southerncompany.com/gapower/pricing/gpc_resrates.asp?mnuOpco=gpc&mnuType=res&mnuItem=ps, Georgia Power, A Southern Company, 2006.

Georgia PSC 2006. August 2006 Pricing Chart, Georgia Public Service Commission, August 2006.

Hayden 1996. *Choosing a Heating System That Saves Energy*, Home Energy Magazine, March/April 1996.

IECC 2000. 2000 *International Energy Conservation Code*, International Code Council, December 1999.

IECC 2003. *2003 International Energy Conservation Code*, International Code Council, December 2002.

NAHB 2001. *Housing Facts, Figures and Tre*nds, National Association of Home Builders, June 2001.

NASEO 1999. *National Home Energy Rating Technical Guidelines*, National Association of State Energy Officials, September 1999.

Peoples Gas 2006. *Schedule of Rates for Gas Service in Chicago, Illinois*, The Peoples Gas Light and Coke Company, November 2005.

SRP 2006. *SRP Rules and Regulations*, Salt River Project Agricultural Improvement and Power District, April 2004

Southwest Gas 2006. *Statement of Rates – Effective Sales Rates Applicable to Arizona Schedules*, Southwest Gas Corporation, July 2006.

Appendix A

REM/Design Energy Summary

Table A.1 - REM/Design Energy Summary - Existing Housing Stock (Circa 1970)

	Atlanta				*Boston*				*Chicago*				*Phoenix*			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	130.9	92.5	38.4	29.3%	277.2	235.3	41.9	15.1%	312.6	270.9	41.7	13.3%	38.2	22.0	16.2	42.4%
Cooling	81.3	39.9	41.4	50.9%	42.0	20.9	21.1	50.2%	42.1	20.9	21.2	50.4%	177.1	80.7	96.4	54.4%
Water Heating	24.7	24.8	-0.1	-0.4%	27.7	27.9	-0.2	-0.7%	28.4	28.6	-0.2	-0.7%	20.9	20.9	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	330.8	251.1	79.7	24.1%	449.1	386.3	62.8	14.0%	482.6	419.9	62.7	13.0%	310.8	198.2	112.6	36.2%
Annual Energy Consumption (MMBtu) [2]																
Heating	112.0	46.5	65.5	58.5%	235.0	131.9	103.1	43.9%	268.3	152.7	115.6	43.1%	34.0	14.9	19.1	56.2%
Cooling:	22.6	11.2	11.4	50.4%	10.2	5.1	5.1	50.0%	10.8	5.4	5.4	50.0%	63.7	29.1	34.6	54.3%
Water Heating	22.5	22.6	-0.1	-0.4%	25.2	25.4	-0.2	-0.8%	25.8	26.1	-0.3	-1.2%	19.0	19.0	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	184.7	107.9	76.8	41.6%	298.0	190.0	108.0	36.2%	332.5	211.8	120.7	36.3%	144.3	90.6	53.7	37.2%
Annual Energy Cost ($/yr) [3]																
Heating:	1,663	837	826	49.7%	2,944	2,772	172	5.8%	2,642	1,711	931	35.2%	503	241	262	52.1%
Cooling:	669	317	352	52.6%	622	326	296	47.6%	272	136	136	50.0%	1,787	817	970	54.3%
Water Heating	314	316	-2	-0.6%	313	307	6	1.9%	271	281	-10	-3.7%	265	266	-1	-0.4%
Lights & Appliances	679	657	22	3.2%	1,522	1,494	28	1.8%	608	525	83	13.7%	640	636	4	0.6%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	3,619	2,421	1,198	33.1%	5,630	5,098	532	9.4%	3,987	2,790	1,197	30.0%	3,433	2,198	1,235	36.0%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.2 - REM/Design Energy Summary - New Construction Built to Meet MEC 1995 Prescriptive Criteria

	Atlanta				Boston				Chicago				Phoenix			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	50.6	36.2	14.4	28.5%	100.4	86.7	13.7	13.6%	102.2	90.4	11.8	11.5%	17.4	10.2	7.2	41.4%
Cooling	33.5	29.8	3.7	11.0%	22.8	20.5	2.3	10.1%	22.6	20.5	2.1	9.3%	71.5	57.3	14.2	19.9%
Water Heating	19.9	20.0	-0.1	-0.5%	22.6	22.7	-0.1	-0.4%	23.2	23.4	-0.2	-0.9%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	197.9	179.9	18.0	9.1%	248.0	232.1	15.9	6.4%	247.5	233.8	13.7	5.5%	180.0	158.6	21.4	11.9%
Annual Energy Consumption (MMBtu) [2]																
Heating	46.0	16.4	29.6	64.3%	84.8	50.1	34.7	40.9%	87.5	54.9	32.6	37.3%	16.9	7.7	9.2	54.4%
Cooling:	9.5	8.6	0.9	9.5%	5.7	5.2	0.5	8.8%	5.9	5.4	0.5	8.5%	25.7	20.8	4.9	19.1%
Water Heating	18.1	18.2	-0.1	-0.6%	20.6	20.7	-0.1	-0.5%	21.1	21.2	-0.1	-0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	101.2	70.8	30.4	30.0%	138.7	103.6	35.1	25.3%	142.1	109.1	33.0	23.2%	85.1	71.0	14.1	16.6%
Annual Energy Cost ($/yr) [3]																
Heating:	680	312	368	54.1%	1,061	994	67	6.3%	909	677	232	25.5%	254	126	128	50.4%
Cooling:	261	234	27	10.3%	337	321	16	4.7%	147	135	12	8.2%	725	586	139	19.2%
Water Heating	254	255	-1	-0.4%	260	259	1	0.4%	231	239	-8	-3.5%	210	210	0	0.0%
Lights & Appliances	662	657	5	0.8%	1,522	1,494	28	1.8%	616	584	32	5.2%	643	640	3	0.5%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,151	1,752	399	18.5%	3,409	3,265	144	4.2%	2,097	1,772	325	15.5%	2,070	1,800	270	13.0%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.3 - REM/Design Energy Summary - New Construction Built to Meet MEC 1995 Performance Criteria

	Atlanta				Boston				Chicago				Phoenix			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	50.6	36.2	14.4	28.5%	107.3	73.8	33.5	31.2%	102.2	75.8	26.4	25.8%	15.8	8.2	7.6	48.1%
Cooling	33.5	29.8	3.7	11.0%	22.1	18.0	4.1	18.6%	22.6	18.0	4.6	20.4%	63.9	51.5	12.4	19.4%
Water Heating	19.9	20.0	-0.1	-0.5%	22.4	22.4	0.0	0.0%	23.2	23.1	0.1	0.4%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	197.9	179.9	18.0	9.1%	254.0	216.4	37.6	14.8%	247.5	216.4	31.1	12.6%	170.8	150.8	20.0	11.7%
Annual Energy Consumption (MMBtu) [2]																
Heating	52.2	16.8	35.4	67.8%	84.7	28.5	56.2	66.4%	89.9	31.4	58.5	65.1%	14.5	6.1	8.4	57.9%
Cooling:	9.5	8.6	0.9	9.5%	5.5	4.5	1.0	18.2%	5.8	4.7	1.1	19.0%	22.9	18.4	4.5	19.7%
Water Heating	18.1	18.2	-0.1	-0.6%	20.3	20.4	-0.1	-0.5%	21.1	21.0	0.1	0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	107.4	71.2	36.2	33.7%	138.1	81.0	57.1	41.3%	144.4	84.7	59.7	41.3%	79.9	67.0	12.9	16.1%
Annual Energy Cost ($/yr) [3]																
Heating:	771	320	451	58.5%	1,188	932	256	21.5%	958	461	497	51.9%	220	101	119	54.1%
Cooling:	263	235	28	10.6%	327	282	45	13.8%	145	117	28	19.3%	644	522	122	18.9%
Water Heating	254	255	-1	-0.4%	258	265	-7	-2.7%	231	246	-15	-6.5%	210	210	0	0.0%
Lights & Appliances	662	657	5	0.8%	1,522	1,494	28	1.8%	615	570	45	7.3%	643	641	2	0.3%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,244	1,761	483	21.5%	3,524	3,170	354	10.0%	2,143	1,531	612	28.6%	1,955	1,712	243	12.4%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.4 - REM/Design Energy Summary - New Construction Built to Meet IECC 2000 Prescriptive Criteria

	Atlanta				Boston				Chicago				Phoenix			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	50.6	36.2	14.4	28.5%	100.4	86.7	13.7	13.6%	102.2	90.4	11.8	11.5%	17.4	10.2	7.2	41.4%
Cooling	33.5	29.8	3.7	11.0%	22.8	20.5	2.3	10.1%	22.6	20.5	2.1	9.3%	71.5	57.3	14.2	19.9%
Water Heating	19.9	20.0	-0.1	-0.5%	22.6	22.7	-0.1	-0.4%	23.2	23.4	-0.2	-0.9%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	197.9	179.9	18.0	9.1%	248.0	232.1	15.9	6.4%	247.5	233.8	13.7	5.5%	180.0	158.6	21.4	11.9%
Annual Energy Consumption (MMBtu) [2]																
Heating	46.0	16.4	29.6	64.3%	84.8	50.1	34.7	40.9%	87.5	54.9	32.6	37.3%	16.9	7.7	9.2	54.4%
Cooling:	9.5	8.6	0.9	9.5%	5.7	5.2	0.5	8.8%	5.9	5.4	0.5	8.5%	25.7	20.8	4.9	19.1%
Water Heating	18.1	18.2	-0.1	-0.6%	20.6	20.7	-0.1	-0.5%	21.1	21.2	-0.1	-0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	101.2	70.8	30.4	30.0%	138.7	103.6	35.1	25.3%	142.1	109.1	33.0	23.2%	85.1	71.0	14.1	16.6%
Annual Energy Cost ($/yr) [3]																
Heating:	680	312	368	54.1%	1,061	994	67	6.3%	909	677	232	25.5%	254	126	128	50.4%
Cooling:	261	234	27	10.3%	337	321	16	4.7%	147	135	12	8.2%	725	586	139	19.2%
Water Heating	254	255	-1	-0.4%	260	259	1	0.4%	231	239	-8	-3.5%	210	210	0	0.0%
Lights & Appliances	662	657	5	0.8%	1,522	1,494	28	1.8%	616	584	32	5.2%	643	640	3	0.5%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,151	1,752	399	18.5%	3,409	3,265	144	4.2%	2,097	1,772	325	15.5%	2,070	1,800	270	13.0%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.5 - REM/Design Energy Summary - New Construction Built to Meet IECC 2000 Performance Criteria

	Atlanta				Boston				Chicago				Phoenix			
	AC-Furnace	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*	
Source Energy Consumption (MMBtu) [1]																
Heating	49.9	33.2	16.7	33.5%	87.9	69.7	18.2	20.7%	96.0	72.8	23.2	24.2%	13.2	7.9	5.3	40.2%
Cooling	29.4	27.7	1.7	5.8%	19.7	17.0	2.7	13.7%	21.3	17.2	4.1	19.2%	52.2	48.2	4.0	7.7%
Water Heating	20.2	20.0	0.2	1.0%	22.4	22.5	-0.1	-0.4%	23.0	23.1	-0.1	-0.4%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	193.4	174.8	18.6	9.6%	232.2	211.4	20.8	9.0%	239.8	212.6	27.2	11.3%	156.5	147.2	9.3	5.9%
Annual Energy Consumption (MMBtu) [2]																
Heating	42.8	14.8	28.0	65.4%	74.3	26.8	47.5	63.9%	79.8	29.8	50.0	62.7%	10.1	5.9	4.2	41.6%
Cooling:	9.0	7.8	1.2	13.3%	5.0	4.3	0.7	14.0%	5.5	4.5	1.0	18.2%	18.4	17.4	1.0	5.4%
Water Heating	18.1	18.2	-0.1	-0.6%	20.3	20.5	-0.2	-1.0%	20.9	21.0	-0.1	-0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	97.5	68.4	29.1	29.8%	127.2	79.2	48.0	37.7%	133.8	82.9	50.9	38.0%	71.0	65.8	5.2	7.3%
Annual Energy Cost ($/yr) [3]																
Heating:	639	283	356	55.7%	963	880	83	8.6%	850	441	409	48.1%	98	97	1	1.0%
Cooling:	245	212	33	13.5%	296	266	30	10.1%	137	112	25	18.2%	496	489	7	1.4%
Water Heating	254	254	0	0.0%	259	266	-7	-2.7%	230	247	-17	-7.4%	210	210	0	0.0%
Lights & Appliances	661	656	5	0.8%	1,522	1,494	28	1.8%	615	571	44	7.2%	645	642	3	0.5%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,093	1,699	394	18.8%	3,269	3,103	166	5.1%	2,026	1,508	518	25.6%	1,687	1,676	11	0.7%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.6 - REM/Design Energy Summary - New Construction Built to Meet IECC 2003 Prescriptive Criteria

	Atlanta				Boston				Chicago				Phoenix			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	50.8	31.5	19.3	38.0%	100.4	86.7	13.7	13.6%	102.2	90.4	11.8	11.5%	17.4	10.2	7.2	41.4%
Cooling	33.5	25.9	7.6	22.7%	22.8	20.5	2.3	10.1%	22.6	20.5	2.1	9.3%	71.5	57.3	14.2	19.9%
Water Heating	19.9	20.0	-0.1	-0.5%	22.6	22.7	-0.1	-0.4%	23.2	23.4	-0.2	-0.9%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	198.1	171.3	26.8	13.5%	248.0	232.1	15.9	6.4%	247.5	233.8	13.7	5.5%	180.0	158.6	21.4	11.9%
Annual Energy Consumption (MMBtu) [2]																
Heating	46.0	14.2	31.8	69.1%	84.8	50.1	34.7	40.9%	87.5	54.9	32.6	37.3%	16.9	7.7	9.2	54.4%
Cooling:	9.5	7.3	2.2	23.2%	5.7	5.2	0.5	8.8%	5.9	5.4	0.5	8.5%	25.7	20.8	4.9	19.1%
Water Heating	18.1	18.2	-0.1	-0.6%	20.6	20.7	-0.1	-0.5%	21.1	21.2	-0.1	-0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	101.2	67.3	33.9	33.5%	138.7	103.6	35.1	25.3%	142.1	109.1	33.0	23.2%	85.1	71.0	14.1	16.6%
Annual Energy Cost ($/yr) [3]																
Heating:	680	270	410	60.3%	1,061	994	67	6.3%	909	677	232	25.5%	254	126	128	50.4%
Cooling:	261	197	64	24.5%	337	321	16	4.7%	147	135	12	8.2%	725	586	139	19.2%
Water Heating	254	254	0	0.0%	260	259	1	0.4%	231	239	-8	-3.5%	210	210	0	0.0%
Lights & Appliances	662	654	8	1.2%	1,522	1,494	28	1.8%	616	584	32	5.2%	643	640	3	0.5%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,151	1,669	482	22.4%	3,409	3,265	144	4.2%	2,097	1,772	325	15.5%	2,070	1,800	270	13.0%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.7 - REM/Design Energy Summary - New Construction Built to Meet IECC 2003 Performance Criteria

	Atlanta				*Boston*				*Chicago*				*Phoenix*			
	AC-Furnace	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*		*AC-Furnace*	*Add-on HP*	*Reduction*	
Source Energy Consumption (MMBtu) [1]																
Heating	46.6	31.5	15.1	32.4%	88.0	66.2	21.8	24.8%	90.7	69.4	21.3	23.5%	12.7	8.6	4.1	32.3%
Cooling	30.3	25.9	4.4	14.5%	19.5	16.0	3.5	17.9%	20.2	16.1	4.1	20.3%	51.3	48.1	3.2	6.2%
Water Heating	19.9	20.0	-0.1	-0.5%	22.4	22.6	-0.2	-0.9%	23.0	23.2	-0.2	-0.9%	16.5	16.5	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	190.7	171.3	19.4	10.2%	232.1	207.0	25.1	10.8%	233.4	208.2	25.2	10.8%	155.1	147.8	7.3	4.7%
Annual Energy Consumption (MMBtu) [2]																
Heating	40.6	14.2	26.4	65.0%	74.3	25.2	49.1	66.1%	76.4	28.1	48.3	63.2%	10.1	5.0	5.1	50.5%
Cooling:	8.5	7.3	1.2	14.1%	5.0	4.1	0.9	18.0%	5.2	4.2	1.0	19.2%	18.4	17.0	1.4	7.6%
Water Heating	18.1	18.2	-0.1	-0.6%	20.4	20.5	-0.1	-0.5%	21.0	21.1	-0.1	-0.5%	14.9	14.9	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	94.8	67.3	27.5	29.0%	127.3	77.4	49.9	39.2%	130.2	81.0	49.2	37.8%	71.0	64.5	6.5	9.2%
Annual Energy Cost ($/yr) [3]																
Heating:	603	270	333	55.2%	965	834	131	13.6%	810	419	391	48.3%	98	54	44	44.9%
Cooling:	231	197	34	14.7%	294	249	45	15.3%	130	105	25	19.2%	496	461	35	7.1%
Water Heating	253	254	-1	-0.4%	259	267	-8	-3.1%	231	248	-17	-7.4%	210	210	0	0.0%
Lights & Appliances	660	654	6	0.9%	1,522	1,494	28	1.8%	616	573	43	7.0%	645	644	1	0.2%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	2,041	1,669	372	18.2%	3,269	3,041	228	7.0%	1,981	1,482	499	25.2%	1,687	1,607	80	4.7%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Table A.8 - REM/Design Energy Summary - New Construction Built to Meet ENERGY STAR Home Program Criteri

	Atlanta				***Boston***				***Chicago***				***Phoenix***			
	AC-Furnace	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***		***AC-Furnace***	***Add-on HP***	***Reduction***	
Source Energy Consumption (MMBtu) [1]																
Heating	36.8	27.8	9.0	24.5%	72.6	64.6	8.0	11.0%	74.0	67.1	6.9	9.3%	11.3	7.4	3.9	34.5%
Cooling	26.5	22.7	3.8	14.3%	17.7	15.5	2.2	12.4%	17.9	15.7	2.2	12.3%	54.5	47.0	7.5	13.8%
Water Heating	19.0	19.0	0.0	0.0%	21.4	21.4	0.0	0.0%	22.0	22.1	-0.1	-0.5%	15.7	15.7	0.0	0.0%
Lights & Appliances	93.9	93.9	0.0	0.0%	102.2	102.2	0.0	0.0%	99.5	99.5	0.0	0.0%	74.6	74.6	0.0	0.0%
Photovoltaics	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total	176.2	163.4	12.8	7.3%	213.9	203.7	10.2	4.8%	213.4	204.4	9.0	4.2%	156.1	144.7	11.4	7.3%
Annual Energy Consumption (MMBtu) [2]																
Heating	33.3	12.3	21.0	63.1%	61.3	36.6	24.7	40.3%	63.2	40.0	23.2	36.7%	11.1	5.5	5.6	50.5%
Cooling:	7.4	6.4	1.0	13.5%	4.4	3.9	0.5	11.4%	4.6	4.1	0.5	10.9%	19.6	16.9	2.7	13.8%
Water Heating	17.3	17.3	0.0	0.0%	19.5	19.5	0.0	0.0%	20.0	20.1	-0.1	-0.5%	14.2	14.2	0.0	0.0%
Lights & Appliances	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%	27.6	27.6	0.0	0.0%
Photovoltaics:	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---	0.0	0.0	0.0	---
Total:	85.6	63.6	22.0	25.7%	112.8	87.6	25.2	22.3%	115.4	91.8	23.6	20.5%	72.5	64.2	8.3	11.4%
Annual Energy Cost ($/yr) [3]																
Heating:	491	237	254	51.7%	778	754	24	3.1%	675	517	158	23.4%	166	91	75	45.2%
Cooling:	201	172	29	14.4%	262	242	20	7.6%	116	103	13	11.2%	551	476	75	13.6%
Water Heating	241	242	-1	-0.4%	248	248	0	0.0%	222	230	-8	-3.6%	200	200	0	0.0%
Lights & Appliances	657	652	5	0.8%	1,522	1,494	28	1.8%	618	599	19	3.1%	645	642	3	0.5%
Photovoltaics:	0	0	0	---	0	0	0	---	0	0	0	---	0	0	0	---
Service Charge	294	294	0	0.0%	229	197	32	14.0%	194	137	57	29.4%	238	238	0	0.0%
Total:	1,884	1,597	287	15.2%	3,039	2,935	104	3.4%	1,825	1,586	239	13.1%	1,800	1,647	153	8.5%

Notes:

1. *Site-to-source energy multipliers and air emission data were taken from the USEPA E-GRID97 database.*
2. *In accordance with the IECC, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*
3. *In accordance with ASHRAE Standard 90.2, building inputs, such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.*

Appendix B

REM/Design Emissions Summary

Table B.2 - REM/Design Emissions Summary - New Construction Built to Meet MEC 1995 Prescriptive Criteria

Type of Emissions	***Atlanta***		***Boston***		***Chicago***		***Phoenix***	
	AC-Furnace	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	27,755.8	26,416.0	32,509.3	31,932.3	30,313.8	29,395.4	23,892.0	21,020.7
Sulfur Dioxide (SO_2)	131.8	153.5	104.9	127.0	152.2	188.1	61.8	57.0
Nitrogen Oxides (NO_X)	69.2	73.2	55.7	58.2	84.7	94.6	57.3	51.6
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	6,255.0	5,469.8	10,570.5	10,403.9	11,301.6	10,683.5	2,363.6	1,480.8
Cooling	5,769.9	5,207.7	4,341.7	3,919.8	3,674.8	3,361.9	10,335.4	8,346.9
Water Heating	2,175.2	2,182.7	2,466.2	2,477.7	2,535.4	2,548.1	1,795.7	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	4.5	29.9	6.3	30.6	9.3	47.8	1.1	2.4
Cooling	38.0	34.3	22.0	19.8	31.9	29.2	31.8	25.7
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	9.0	14.7	14.1	17.4	17.0	28.1	3.4	2.9
Cooling	17.2	15.5	8.6	7.8	14.4	13.2	27.1	21.9
Water Heating	2.7	2.7	3.1	3.1	3.2	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3 - REM/Design Emissions Summary - New Construction Built to Meet MEC 1995 Performance Criteria

Type of Emissions	*Atlanta*		*Boston*		*Chicago*		*Phoenix*	
	AC-Furnace	*Add-on HP*	*AC-Furnace*	*Add-on HP*	*AC-Furnace*	*Add-on HP*	*AC-Furnace*	*Add-on HP*
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	28,601.2	26,579.4	33,615.1	30,779.1	30,913.8	27,634.3	22,456.3	19,798.0
Sulfur Dioxide (SO_2)	132.4	154.5	110.9	136.2	152.3	201.9	58.4	53.7
Nitrogen Oxides (NO_X)	70.4	73.6	58.0	58.1	85.5	96.7	54.1	48.6
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	7,072.1	5,618.4	11,823.8	9,758.0	11,933.4	9,398.2	2,111.3	1,190.3
Cooling	5,799.2	5,222.5	4,215.4	3,437.3	3,643.6	2,911.2	9,151.9	7,414.7
Water Heating	2,174.1	2,182.7	2,445.0	2,453.0	2,534.7	2,522.9	1,795.7	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	4.9	30.8	13.0	42.2	9.7	65.5	1.4	2.0
Cooling	38.2	34.4	21.3	17.4	31.6	25.3	28.1	22.8
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	10.1	15.1	16.6	18.3	17.9	31.9	3.2	2.4
Cooling	17.2	15.5	8.3	6.8	14.3	11.4	24.0	19.4
Water Heating	2.7	2.7	3.1	3.1	3.2	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.4 - REM/Design Emissions Summary - New Construction Built to Meet IECC 2000 Prescriptive Criteria

Type of Emissions	***Atlanta***		***Boston***		***Chicago***		***Phoenix***	
	AC-Furnace	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	27,755.8	26,416.0	32,509.3	31,932.3	30,313.8	29,395.4	23,892.0	21,020.7
Sulfur Dioxide (SO_2)	131.8	153.5	104.9	127.0	152.2	188.1	61.8	57.0
Nitrogen Oxides (NO_X)	69.2	73.2	55.7	58.2	84.7	94.6	57.3	51.6
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	6,255.0	5,469.8	10,570.5	10,403.9	11,301.6	10,683.5	2,363.6	1,480.8
Cooling	5,769.9	5,207.7	4,341.7	3,919.8	3,674.8	3,361.9	10,335.4	8,346.9
Water Heating	2,175.2	2,182.7	2,466.2	2,477.7	2,535.4	2,548.1	1,795.7	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	4.5	29.9	6.3	30.6	9.3	47.8	1.1	2.4
Cooling	38.0	34.3	22.0	19.8	31.9	29.2	31.8	25.7
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	9.0	14.7	14.1	17.4	17.0	28.1	3.4	2.9
Cooling	17.2	15.5	8.6	7.8	14.4	13.2	27.1	21.9
Water Heating	2.7	2.7	3.1	3.1	3.2	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.5 - REM/Design Emissions Summary - New Construction Built to Meet IECC 2000 Performance Criteria

Type of Emissions	*Atlanta*		*Boston*		*Chicago*		*Phoenix*	
	AC-Furnace	*Add-on HP*	*AC-Furnace*	*Add-on HP*	*AC-Furnace*	*Add-on HP*	*AC-Furnace*	*Add-on HP*
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	27,260.2	25,406.7	30,741.3	30,051.3	29,387.0	27,151.2	19,256.2	19,289.9
Sulfur Dioxide (SO_2)	131.6	147.4	102.3	133.1	152.1	198.9	51.4	52.2
Nitrogen Oxides (NO_X)	68.5	70.3	53.2	56.7	83.5	95.2	46.9	47.3
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	6,094.2	4,924.6	9,410.3	9,217.3	10,635.6	9,035.3	938.0	1,146.8
Cooling	5,433.5	4,744.7	3,754.8	3,246.8	3,438.9	2,788.3	7,125.1	6,950.1
Water Heating	2,176.7	2,181.6	2,445.3	2,456.4	2,510.5	2,525.5	1,795.7	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	6.6	26.9	6.7	40.1	11.2	63.7	0.6	1.9
Cooling	35.8	31.3	19.0	16.4	29.8	24.2	21.9	21.4
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	9.3	13.2	12.7	17.3	16.7	30.9	1.4	2.3
Cooling	16.2	14.1	7.4	6.4	13.5	10.9	18.7	18.2
Water Heating	2.7	2.7	3.1	3.1	3.1	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.6 - REM/Design Emissions Summary - New Construction Built to Meet IECC 2003 Prescriptive Criteria

Type of Emissions	***Atlanta***		***Boston***		***Chicago***		***Phoenix***	
	AC-Furnace	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	27,755.8	24,866.1	32,509.3	31,932.3	30,313.8	29,395.4	23,892.0	21,020.7
Sulfur Dioxide (SO_2)	131.8	144.1	104.9	127.0	152.2	188.1	61.8	57.0
Nitrogen Oxides (NO_X)	69.2	68.1	55.7	58.2	84.7	94.6	57.3	51.6
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	6,255.0	4,698.8	10,570.5	10,403.9	11,301.6	10,683.5	2,363.6	1,480.8
Cooling	5,769.9	4,431.8	4,341.7	3,919.8	3,674.8	3,361.9	10,335.4	8,346.9
Water Heating	2,175.2	2,179.8	2,466.2	2,477.7	2,535.4	2,548.1	1,795.7	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	4.5	25.6	6.3	30.6	9.3	47.8	1.1	2.4
Cooling	38.0	29.2	22.0	19.8	31.9	29.2	31.8	25.7
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	9.0	12.6	14.1	17.4	17.0	28.1	3.4	2.9
Cooling	17.2	13.2	8.6	7.8	14.4	13.2	27.1	21.9
Water Heating	2.7	2.7	3.1	3.1	3.1	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.7 - REM/Design Emissions Summary - New Construction Built to Meet IECC 2003 Performance Criteria

Type of Emissions	***Atlanta***		***Boston***		***Chicago***		***Phoenix***	
	AC-Furnace	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	26,538.8	24,866.1	30,735.9	29,370.2	28,626.3	26,587.2	19,118.0	18,430.5
Sulfur Dioxide (SO_2)	128.4	144.1	102.2	130.1	149.0	195.2	51.1	50.3
Nitrogen Oxides (NO_X)	66.8	68.8	53.1	55.5	81.6	93.3	46.6	45.4
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	5,652.4	4,698.8	9,423.6	8,735.1	10,057.7	8,633.7	904.3	635.8
Cooling	5,156.4	4,431.8	3,733.6	3,041.7	3,251.9	2,620.1	7,021.3	6,601.6
Water Heating	2,174.2	2,179.8	2,447.7	2,462.5	2,514.7	2,531.3	1,795.0	1,795.7
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur Dioxide (SO_2)								
Heating	5.2	25.6	6.8	38.1	9.7	61.4	0.6	1.0
Cooling	34.0	29.2	18.9	15.4	28.2	22.7	21.6	20.3
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	8.4	12.6	12.7	16.4	15.5	29.7	1.4	1.3
Cooling	15.3	13.2	7.4	6.0	12.7	10.3	18.4	17.3
Water Heating	2.7	2.7	3.1	3.1	3.1	3.2	2.2	2.2
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.8 - REM/Design Emissions Summary - New Construction Built to Meet ENERGY STAR Home Program Criteria

Type of Emissions	***Atlanta***		***Boston***		***Chicago***		***Phoenix***	
	AC-Furnace	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***	***AC-Furnace***	***Add-on HP***
Total Emissions (lbs/year)								
Carbon Dioxide (CO_2)	24,633.6	23,701.6	28,534.6	28,271.2	26,271.9	25,693.5	20,467.1	18,946.6
Sulfur Dioxide (SO_2)	122.1	138.0	98.1	115.3	142.6	169.7	53.6	51.5
Nitrogen Oxides (NO_X)	62.7	65.7	49.8	52.0	76.7	84.3	49.4	46.6
Emissions By End-Use (lbs/year)								
Carbon Dioxide (CO_2)								
Heating	4,500.9	4,162.9	7,686.9	7,845.6	8,175.2	7,935.1	1,528.8	1,071.5
Cooling	4,505.8	3,909.0	3,379.7	2,953.0	2,891.7	2,548.7	7,831.6	6,768.4
Water Heating	2,071.1	2,074.0	2,337.1	2,341.8	2,402.9	2,407.6	1,709.3	1,709.3
Lights & Appliances	13,555.8	13,555.8	15,130.9	15,130.9	12,802.0	12,802.0	9,397.4	9,397.4
Photovoltaics								
Sulfur Dioxide (SO_2)								
Heating	3.1	22.9	4.4	23.8	8.5	36.5	0.6	1.8
Cooling	29.7	25.7	17.1	14.9	25.1	22.1	24.1	20.8
Water Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lights & Appliances	89.3	89.3	76.6	76.6	111.1	111.1	28.9	28.9
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen Oxide (NO_X)								
Heating	6.4	11.2	10.2	13.2	12.2	21.1	2.2	2.1
Cooling	13.4	11.6	6.7	5.8	11.3	10.0	20.5	17.7
Water Heating	2.6	2.6	2.9	2.9	3.0	3.0	2.1	2.1
Lights & Appliances	40.3	40.3	30.0	30.0	50.2	50.2	24.6	24.6
Photovoltaics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix C

First Cost Sensitivity Analysis

Table C.1 - First Cost Sensitivity Analysis - Existing Housing Stock (Circa 1970)

Location			Annuel Energy Cost ($/yr)			First Cost Premium		Payback
Region	**City**	**State**	**AC-Furnace**	**Add-on HP**	**Reduction**	**Factor**	**Total $**	**(yrs)**
Southeast	Atlanta	GA	3,656	2,178	1,478	0.50	1,575	1.1
						0.75	2,363	1.6
						1.00	**3,150**	**2.1**
						1.25	3,938	2.7
						1.50	4,725	3.2
						1.75	5,513	3.7
						2.00	6,300	4.3
Northeast	Boston	MA	5,630	5,098	532	0.50	1,575	3.0
						0.75	2,363	4.4
						1.00	**3,150**	**5.9**
						1.25	3,938	7.4
						1.50	4,725	8.9
						1.75	5,513	10.4
						2.00	6,300	11.8
Midwest	Chicago	IL	3,988	2,789	1,199	0.50	1,575	1.3
						0.75	2,363	2.0
						1.00	**3,150**	**2.6**
						1.25	3,938	3.3
						1.50	4,725	3.9
						1.75	5,513	4.6
						2.00	6,300	5.3
West	Phoenix	AZ	3,434	2,198	1,236	0.50	1,575	1.3
						0.75	2,363	1.9
						1.00	**3,150**	**2.5**
						1.25	3,938	3.2
						1.50	4,725	3.8
						1.75	5,513	4.5
						2.00	6,300	5.1

Table C.2 - First Cost Sensitivity Analysis - New Construction (IECC 2000/MEC 1995)[1]

Location			Annuel Energy Cost ($/yr)			First Cost Premium		Payback
Region	**City**	**State**	**AC-Furnace**	**Add-on HP**	**Reduction**	**Factor**	**Total $**	**(yrs)**
Southeast	Atlanta	GA	2,168	1,752	416	0.50	100	0.2
						0.75	150	0.4
						1.00	**200**	**0.5**
						1.25	250	0.6
						1.50	300	0.7
						1.75	350	0.8
						2.00	400	1.0
Northeast	Boston	MA	3,410	3,266	144	0.50	100	0.7
						0.75	150	1.0
						1.00	**200**	**1.4**
						1.25	250	1.7
						1.50	300	2.1
						1.75	350	2.4
						2.00	400	2.8
Midwest	Chicago	IL	2,097	1,772	325	0.50	100	0.3
						0.75	150	0.5
						1.00	**200**	**0.6**
						1.25	250	0.8
						1.50	300	0.9
						1.75	350	1.1
						2.00	400	1.2
West	Phoenix	AZ	2,070	1,801	269	0.50	100	0.4
						0.75	150	0.6
						1.00	**200**	**0.7**
						1.25	250	0.9
						1.50	300	1.1
						1.75	350	1.3
						2.00	400	1.5

Notes:
1. Applicable residential energy code is IECC 2000 in Atlanta, Chicago and Phoenix, and MEC 1995 in Boston.

Table C.3 - First Cost Sensitivity Analysis - New Construction (ENERGY STAR)

Location			Annuel Energy Cost ($/yr)			First Cost Premium		Payback
Region	**City**	**State**	**AC-Furnace**	**Add-on HP**	**Reduction**	**Factor**	**Total $**	**(yrs)**
Southeast	Atlanta	GA	1,863	1,597	266	0.50	100	0.4
						0.75	150	0.6
						1.00	**200**	**0.8**
						1.25	250	0.9
						1.50	300	1.1
						1.75	350	1.3
						2.00	400	1.5
Northeast	Boston	MA	2,954	2,936	18	0.50	100	5.6
						0.75	150	8.3
						1.00	**200**	**11.1**
						1.25	250	13.9
						1.50	300	16.7
						1.75	350	19.4
						2.00	400	22.2
Midwest	Chicago	IL	1,795	1,584	211	0.50	100	0.5
						0.75	150	0.7
						1.00	**200**	**0.9**
						1.25	250	1.2
						1.50	300	1.4
						1.75	350	1.7
						2.00	400	1.9
West	Phoenix	AZ	1,784	1,641	143	0.50	100	0.7
						0.75	150	1.0
						1.00	**200**	**1.4**
						1.25	250	1.7
						1.50	300	2.1
						1.75	350	2.4
						2.00	400	2.8