



American Lung Association Energy Policy Development: Heating Background Document

Prepared by M.J. Bradley & Associates LLC

February 2011

This page intentionally left blank.

Table of Contents

Introduction	3
Heating Overview.....	3
Air Emissions from Heating.....	5
Environmental Justice	7
Recent Trends	7
Residential Sector	9
Electricity.....	11
Coal	11
Natural Gas	11
Oil and Propane	13
Biomass	14
Non-Combustion Strategies.....	17
Major Policy Issues Associated with Residential Heat.....	18
Commercial and Institutional Sector	22
Fuel Impacts.....	22
Major Policy Issues Associated with Commercial and Institutional Heat.....	22
Building Codes.....	23
Building Rating and Disclosure Programs	23
Energy Efficiency Programs.....	23
Reducing Oil Use in Urban Boilers	24
Industrial Sector.....	24
Industrial Boilers and Process Heaters	27
Natural Gas	28
Oil.....	29
Coal	29
Biomass	30
Renewables.....	30
Major Policy Issues for Industrial Fuel Combustion.....	31
Industrial/Commercial/Institutional Boilers and Process Heaters Air Toxics Regulations	31

Regulation of Greenhouse Gas Emissions under the Clean Air Act	31
Energy Efficiency Initiatives	32
Combined Heat and Power	32
Recommended Reading	33
References	34

Introduction

The American Lung Association organized a series of workshops to discuss issues related to energy use and policy in the U.S., including the impacts of different energy sources on human and, especially, lung health. The goal of the workshops was to better define the American Lung Association's positions on key energy policy issues. The workshops were divided into three categories: (1) electricity generation, (2) heat (e.g., space heating and industrial process heating), and (3) transportation.

This paper, in support of the second workshop, focuses on air emissions from heat generation, providing a primer on heating in sectors of the economy and the associated air emissions. For the purposes of discussion, we have divided the economy into three general sectors: residential, commercial, and industrial. In the residential and commercial sectors, energy is used for space and water heating. In the industrial sector, energy is used for a number of purposes, including producing, processing, and assembling goods. Our focus is on fossil fuel combustion onsite for process heat and not on the actual industrial process. For example, in the case of steel making, we would include emissions from the furnace, but not the air pollution emissions released from cooling and quenching of steel.

Definition of Residential, Commercial, and Industrial Sectors

Residential sector: An energy-consuming sector that consists of living quarters for private households. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and running a variety of other appliances. The residential sector excludes institutional living quarters.

Commercial sector: An energy-consuming sector that consists of service-providing facilities and equipment of: businesses; federal, state, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and running a wide variety of other equipment.

Industrial sector: An energy-consuming sector that consists of all facilities and equipment used for producing, processing, or assembling goods. The industrial sector encompasses the following types of activity: manufacturing; agriculture, forestry, fishing, and hunting; mining, including oil and gas extraction; and construction. Overall energy use in this sector is largely for process heat and cooling and powering machinery, with lesser amounts used for facility heating, air conditioning, and lighting. Fossil fuels are also used as raw material inputs to manufactured products.

Source: NRC 2010a

Heating Overview

The charts in Figure 1 show total U.S. energy consumption for the residential, commercial and industrial sectors. The electricity percentages in Figure 1 include energy lost in the generation and distribution of the electricity. The three sectors represent 99 percent of the U.S. demand for electricity, with the remaining demand coming from the transportation sector. While electricity makes up 69 percent and 78 percent of energy consumption in the residential and commercial sectors, respectively, the majority of it is used for non-heating purposes such as running lights and appliances. The lifecycle impacts of electricity use are covered in another paper in this series, *American Lung Association Energy Policy Development: Electricity Generation Background Document*.

Heating of residential and commercial buildings accounts for about 11 percent of total U.S. primary energy demand. Natural gas dominates this demand, making up about 76 percent of primary energy

use by residential and commercial buildings. The remainder of demand is fulfilled with petroleum (17 percent), biomass (five percent), renewable energy (less than two percent) and coal (less than one percent). Some residential and commercial buildings use electricity for heating; however, this is considered a secondary use of energy (the electric generation sector is the primary user). There are some significant differences in the usage of non-fossil sources in residential and commercial sectors, with biomass making up about 6 percent of residential direct energy consumption and only 3 percent of commercial energy consumption. Solar and photovoltaic energy appears in the residential sector but not in the commercial sector because it is used for hot water heating in the residential sector. Solar panels that may be installed at commercial sites are usually owned and operated by local utilities to generate electricity and are captured in estimates of electric sector direct energy consumption.

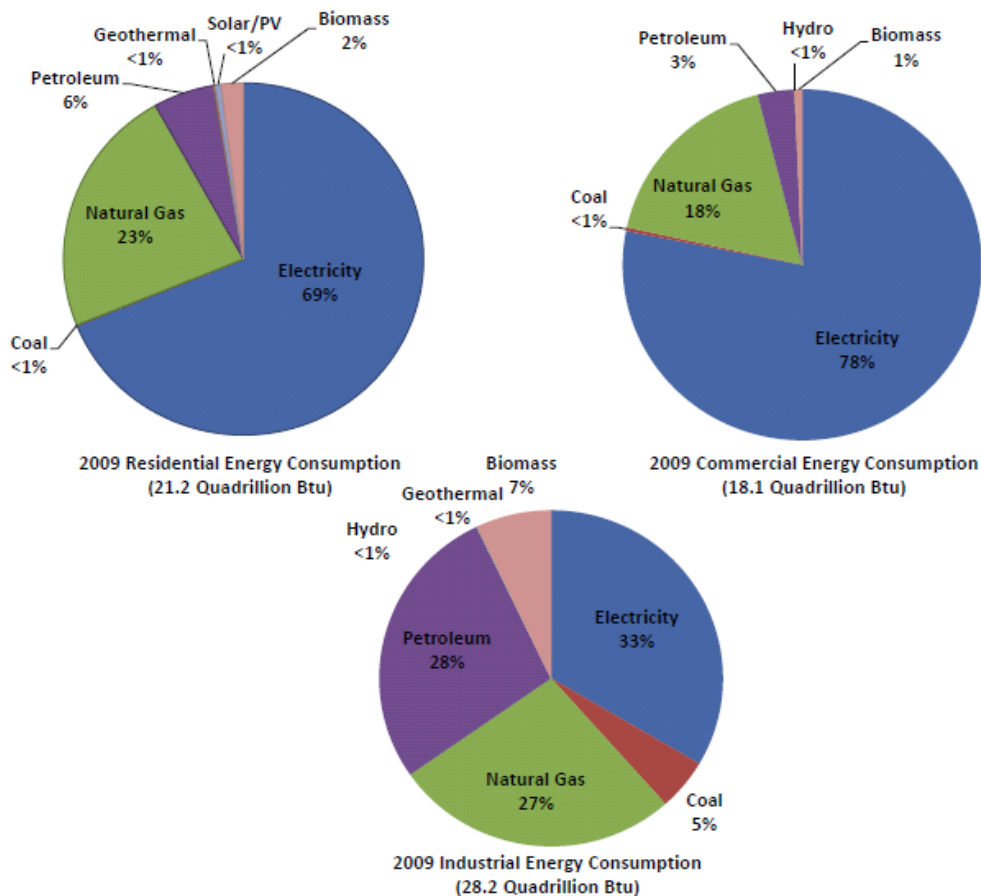


Figure 1. Energy Consumption in the Residential, Commercial, and Industrial Sectors Including Electricity Conversion and Transmission Losses (EIA 2010c)

Within the industrial sector, energy use is largely for process heat and cooling and powering machinery, with lesser amounts used for facility heating, air conditioning, and lighting. Fossil fuels are also used as raw material inputs to manufactured products such as asphalt, plastics, and chemical products. Figure 1 reflects the total fossil fuel use in the industrial sector including both energy and inputs to manufactured products.

This backgrounder focuses on the use of fossil fuels and biomass energy sources combusted onsite to generate process heat and cooling and to power machinery and auxiliary services in the industrial sector. This definition does not include the electricity produced offsite and consumed by the industrial sector and it does not include the fossil fuels used as raw material inputs. Sixty percent of the coal, oil, and natural gas used within the industrial sector is used for onsite power generation or heat, and 40 percent is used as raw material inputs (NRC 2010).

Air Emissions from Heating

The most significant health impacts associated with residential and commercial space heating and industrial process heating are the air emissions from the combustion of fossil fuels and biomass.

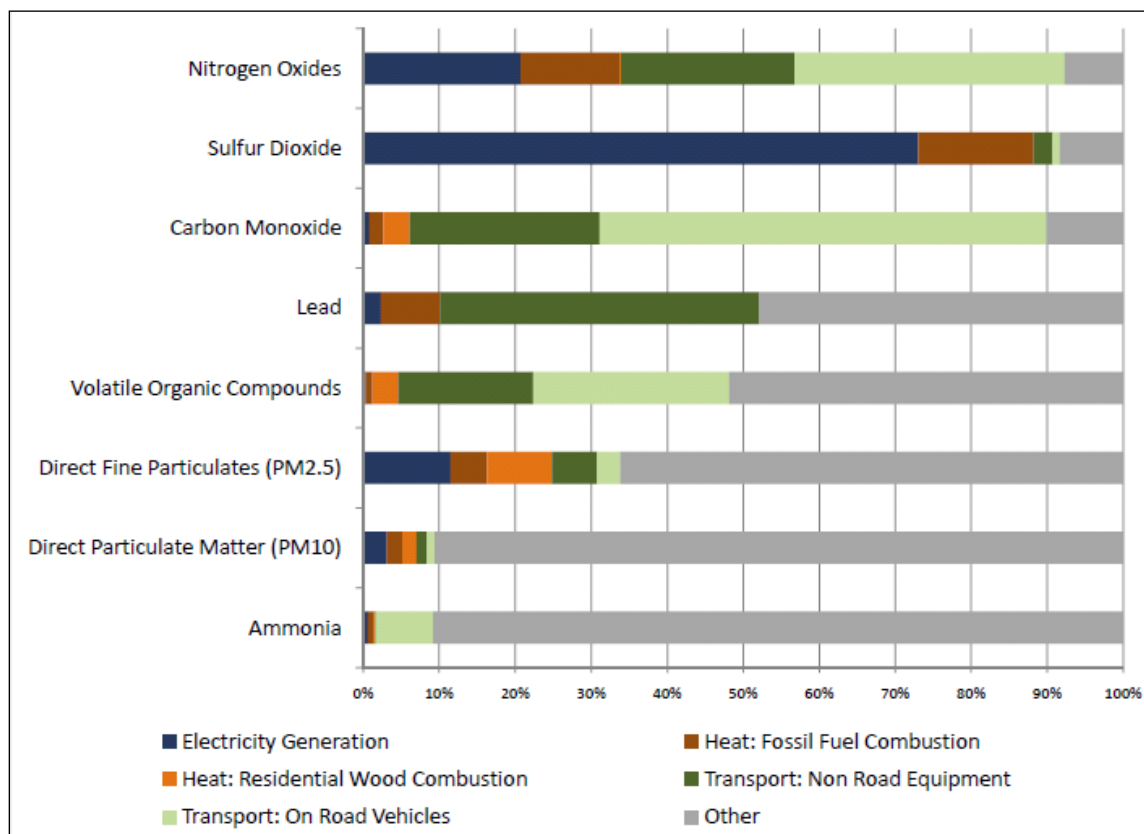


Figure 2. Distribution of U.S. Total Emissions Estimates for 2005 by Source Category for Specific Pollutants (EPA 2009a). This paper focuses on the sizable portion of emissions of most major pollutants that comes from industrial, commercial, and residential sources.

Figure 2 shows the distribution of direct emissions from sources in the U.S. in 2005. The sources are grouped according to the topic areas for the three workshops: electricity, heat, and transportation. Heat includes fossil fuel and biomass combustion in the industrial, commercial, and residential sectors as well as residential wood combustion. Heat does not include process emissions from industrial sources such as emissions from refining processes.

As suggested by Figure 2, direct heat-related emissions from the residential, commercial, and industrial sectors are a fraction of the emissions from electricity generation and transportation. However, they

still make up over 15 percent of national sulfur dioxide (SO₂) emissions and over 13 percent of national nitrogen oxide (NO_x) emissions. These emissions directly impact lung health and contribute to ground-level ozone and fine particle air pollution, as well as acid rain and regional haze.

- **Direct impacts.** Both SO₂ and NO_x can trigger asthma attacks and difficulty breathing. NO_x can increase the risk of developing respiratory infections. The U.S. Environmental Protection Agency (EPA) just adopted stronger limits on SO₂ emissions in recognition of the impact that short-term peak concentrations of these emissions can have on communities near and immediately downwind of power plants.
- **Ozone.** Even more critical than its direct impact is the role of NO_x in forming ozone. The East, Midwest, and Southeastern states have long struggled to meet the national ozone standards, in part because of NO_x emissions from uncontrolled coal-fired power plants. Ozone can trigger serious respiratory problems, including airway irritation, aggravation of asthma, increased susceptibility to respiratory illnesses like pneumonia and bronchitis, and permanent lung damage with repeated exposures, as well as premature death.
- **Particle Pollution.** Both SO₂ and NO_x emissions react in the air to form fine particles. Fine particle air pollution cause or contribute to asthma attacks, heart attacks, stroke, as well as increased the risk of premature death in infants and young children as well as adults. Fine particles are especially dangerous because they are inhaled deep in the lungs, thereby evading the body's natural defenses.
- **Acid rain and Regional Haze.** Acid rain damages trees and crops, acidifying soils, lakes, and streams. Regional haze impairs visibility, most notably at national parks. NO_x emissions are also associated with nitrogen deposition and ground-level ozone (smog). Nitrogen deposition can impair water quality by overloading a water body with nutrients.

In addition to the secondary fine particulate formation resulting from SO₂ and NO_x emissions reacting in the air, the residential, commercial, and industrial sectors are also responsible for over 13 percent of direct fine particulate (PM_{2.5}) emissions in the U.S. Significantly, over 60 percent of those emissions (or 8.5 percent of the national total) are from residential wood combustion.

Industrial and commercial fuel combustion, particularly at large boilers similar to those used at power plants for electricity generation, can also be a significant source of air emissions, including mercury. Mercury air emissions deposited to lakes and ponds are converted by certain microorganisms to a highly toxic form of the chemical known as methylmercury. Methylmercury then accumulates in fish, shellfish, as well as birds and mammals that feed on fish. Humans are exposed to mercury when they eat contaminated fish. High levels of methylmercury can be detrimental to the development of fetuses and young children.

While mercury emissions have received great scrutiny over the past decade from EPA and others, a number of other air toxics from boilers can impact human health and the environment, including acid

gases (hydrogen chloride, hydrogen cyanide, and hydrogen fluoride), dioxins, arsenic, lead, and other metals.

Carbon dioxide (CO₂) is the most prevalent of anthropogenic greenhouse gas emissions, although ozone and methane are also potent greenhouse gases. Greenhouse gases trap heat in the atmosphere and at elevated concentrations lead to global climate change. Discounting electricity consumption, the industrial, commercial, and residential sectors represented 14, four, and six percent, respectively, of U.S. CO₂ emissions in 1998.

Environmental Justice

Underlying the broader health impacts of heat generation and the American Lung Association's policy positions are concerns about environmental justice. In its *Interim Guidance on Considering Environmental Justice During the Development of an Action*, EPA has defined environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA 2010a). EPA goes on to say:

- Fair treatment means that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies.
- Meaningful Involvement means that: 1) potentially affected community members have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; 2) the public's contribution can influence the regulatory agency's decision; 3) the concerns of all participants involved will be considered in the decision-making process; and 4) the decision-makers seek out and facilitate the involvement of those potentially affected.

Broad, national-level policy positions impact public health and air quality, but residential, commercial and industrial heating can affect specific communities differently, especially poor and disadvantages communities. For example, heating sources such as outdoor wood boilers have limited national or regional impact, but have a significant impact on users and immediate neighbors. For other communities, emissions from industrial heating applications can have significant impacts on the health of local populations.

Recent Trends

Electricity and natural gas represent the major sources of heating in the residential and commercial sectors as a result of their ease of use for the end user. According to EIA's most recent *Residential Energy Consumption Survey*, natural gas represented 72 percent of household space heating and 68 percent of water heating, while electricity heats eight percent of homes and 21 percent of water heating (EIA 2009a). Only 12 percent of U.S. households use a space heating fuel other than gas, electricity, or petroleum products (NRC 2010). In colder climates with greater heating needs, both petroleum products and biomass play a role.

For industrial process heating, electricity, coal, oil, and natural gas are most prevalent. Coal and renewables are rarely used in residential and commercial heating, although the use of small-scale renewables is growing, spurred by financial incentives at the state and federal levels.¹ Anecdotal evidence also suggests the residential use of biomass and coal increased in response to recent price volatility and the recession.

¹ Within this paper, renewables include solar energy, geothermal energy, and hydroelectric power. Wind energy is not included because it is not deployed at residential, commercial, or industrial sites. Every attempt has been made to list biomass separately. However, it is important to note that the Energy Information Agency lists biomass as a renewable energy source.

Residential Sector

The residential sector includes the majority of the locations where people live, such as owned and rented housing, but excludes institutions such as hospitals or dormitories. In 2005, the residential sector in the U.S. consisted of 111 million households, including 80 million single family homes, 24 million multifamily housing units, and nearly seven million mobile homes (NRC 2010).

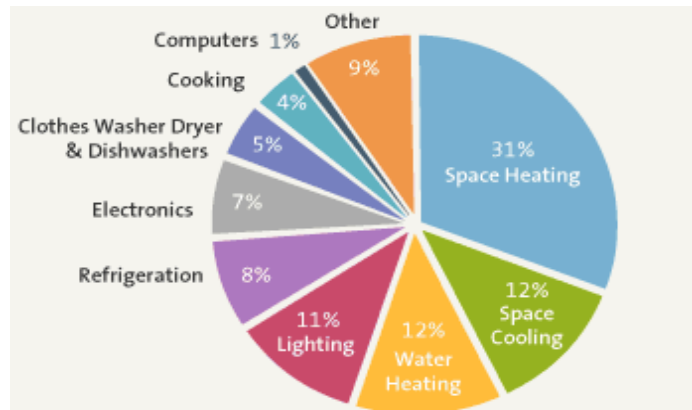


Figure 3. Energy Uses in the U.S. Residential Sector (2006)

Household energy consumption for heating and cooling varies by geographic region across the U.S. and is highly affected by differences in climate. Hot summers increase the amount of electricity used for air conditioning and other space cooling, while cold winters in the North increase the amount of energy used for space and water heating, including demand for electricity, natural gas, and heating oil. Other factors that determine household energy consumption include access to natural gas service, population density, age and design of homes, building codes, and electricity prices (EIA 2005).

As shown in Figure 3, space heating and cooling, and water heating make up over half of household energy consumption nationally.

Figure 4 displays regional variations in energy consumption – for example, the Northeast uses heating oil for over one-quarter of home energy use, while in other regions, heating oil represents less than two percent. Additionally, some areas lack access to natural gas service. As an alternative, some households use propane, which is derived from petroleum and thus has impacts more similar to oil than natural gas.

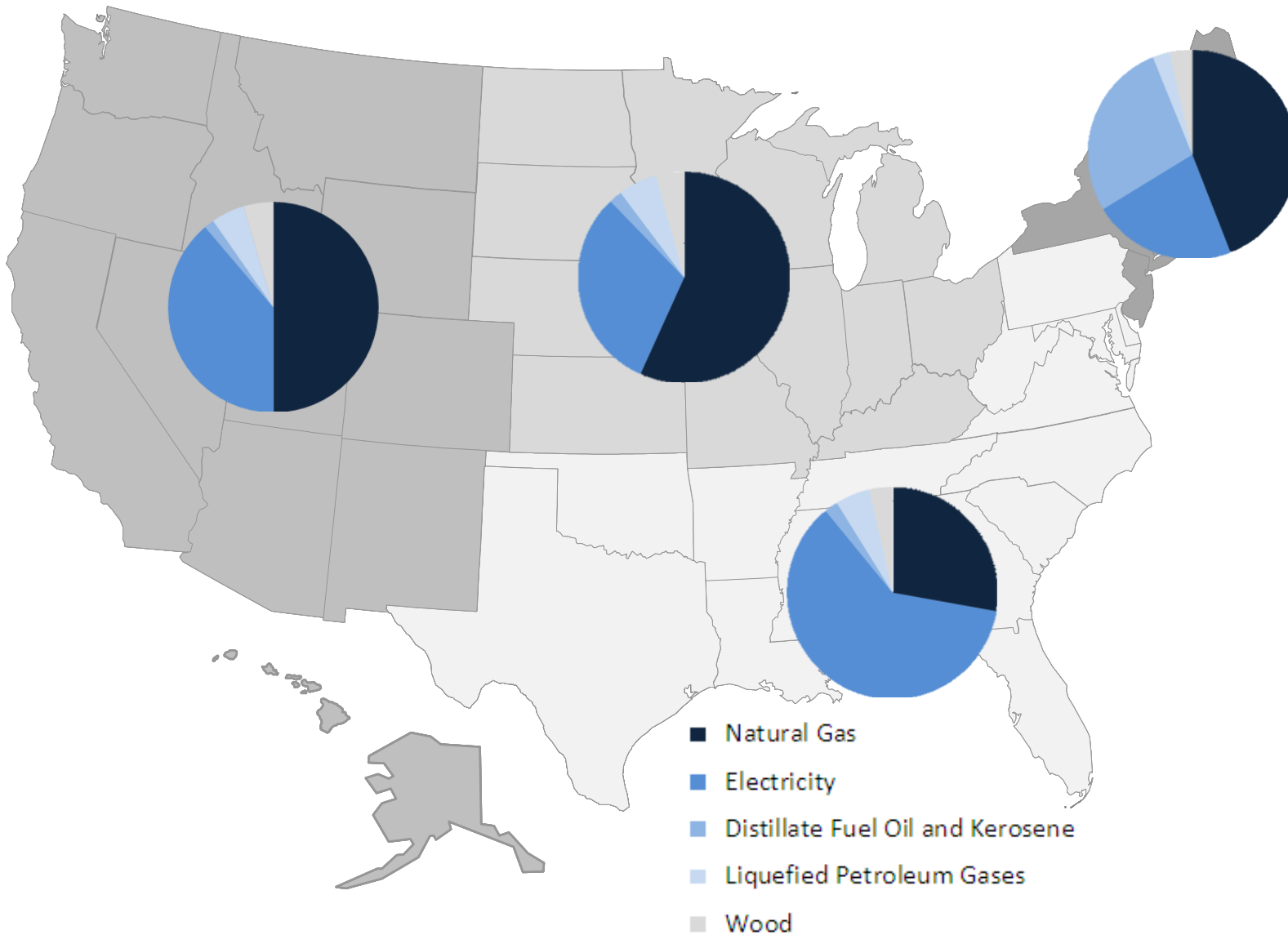


Figure 4. Regional Household Consumption of Energy (Excluding Losses from Delivered Electricity) by Fuel

Table 1 summarizes heating emissions by fuel and pollutant in the residential sector. There are a few important notes from these data:

- Natural gas combustion is the dominant source of NO_x emissions in the residential sector because of its extensive use.
- Residential oil use, which is most prevalent in the northeast, contributes a dominant share of SO₂ emissions.
- Wood combustion contributes a dominant share of direct PM emissions in the residential sector.

Table 1. 2005 Residential Heating-Related Emissions (Tons, 2005) (EPA 2009a)

	NO _x	VOCs	SO ₂	PM ₁₀	PM _{2.5}	CO
Residential	379,954	565,192	173,128	402,999	393,099	3,098,381
Coal	2,405	2,472	14,887	1,979	1,218	61,461
Oil	61,573	2,013	134,682	7,210	6,238	15,935
Wood	27,108	388,437	4,044	293,799	287,951	1,981,960
Natural Gas	211,206	12,331	1,194	1,390	1,147	92,447
Other	77,660	159,939	18,321	98,621	96,545	946,578

Electricity

Electricity is used for space and water heating, as well as cooling, and is available to virtually every U.S. home, business, and industrial facility. However, because impacts of this energy source occur largely upstream at the point of generation, they are discussed in the *Electricity Generation* background document. Effects associated with the end uses of electricity are relatively small (NRC 2010).

Coal

Coal was once used commonly as a home heating fuel, but declined as cleaner and more easily distributed forms of heating fuel such as natural gas and electricity became more widely available. Anecdotally, coal made a slight comeback as a home heating fuel in areas close to where it is mined over the past decade because of concern about volatility in the price of home heating oil and natural gas. In response, some homeowners in the Northeast, areas of the Midwest, and parts of Alaska are using coal-fired stoves (NYT 2008b).

Natural Gas

The primary non-electric fuel used in the residential sector is natural gas. The residential sector consumed 21 percent of total natural gas use in the U.S. in 2009. Unlike electricity use, which has steadily increased in the residential sector, natural gas use in the residential sector has remained relatively stable since the 1970s because of improvements in construction and increased efficiency of appliances (EIA 2010b). From 1990 to 2009, per customer consumption of natural gas fell in 16 out of 19 years. This decline in average consumption per residential household has more than offset the expanding number of customers (EIA 2010e). In residential and commercial uses, natural gas is used for space and water heating, as well as to fuel appliances, such as ovens or clothes washers. Natural gas can be used for residential cooling, though it is not as common as electricity. As residential natural gas cooling technologies advance, and residential consumers can use natural gas to supply their electricity needs, natural gas demand could increase.

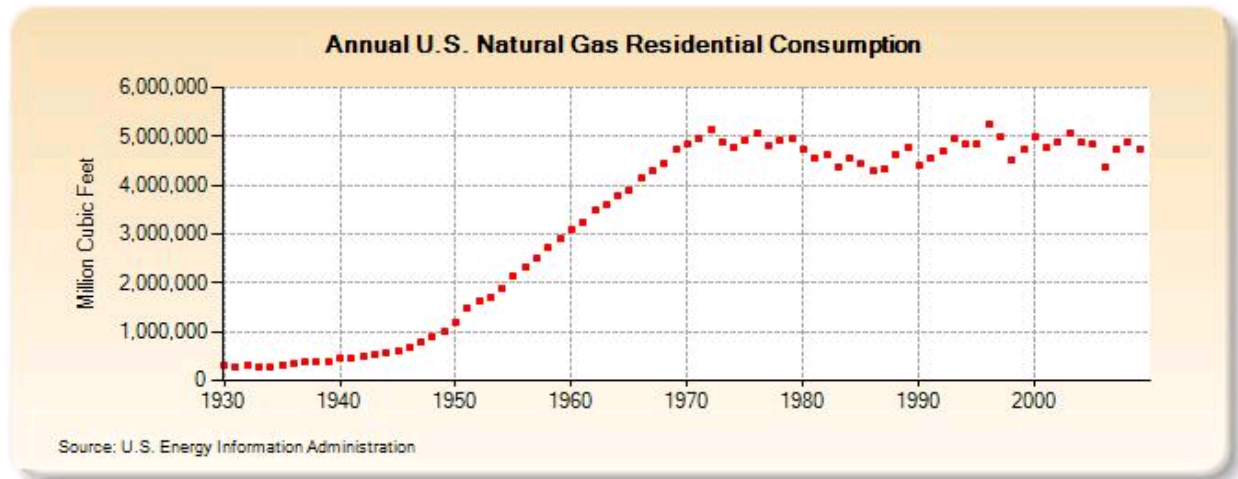


Figure 5. Annual U.S. Natural Gas Residential Consumption

Health officials are concerned about the rising popularity of unvented natural gas appliances intended for use as supplemental heaters. In a ventless gas stove, post-combustion byproducts and exhaust with no dedicated outdoor air supply can be "back-drafted" from the chimney into the living space, particularly in weatherized homes. This can result in indoor emissions of carbon monoxide (CO), NO_x, and particle matter, and excess moisture which can lead to the growth of molds and fungi. These byproducts degrade indoor air quality and can cause unnecessary exposure to toxic gases (EPA 2010e). Most states allow the use of unvented gas heaters in residences, although some, such as New York, have required that the unvented appliances not be installed as the primary heat source and shall conform to certain regulations promulgated by the state health department (Harwood 2010).

An emerging issue associated with natural gas production is the use of an advanced technique, called hydraulic fracturing, to recover natural gas from unconventional sources such as shale gas formations. Hydraulic fracturing allows natural gas to move more freely from the rock pores to production wells that bring the gas to the surface. Production wells are drilled below the land surface, and fluids made up of water and chemical additives are pumped into the geologic formation at high pressure, opening or enlarging fractures. After the fractures are created, a propping agent is pumped into the fractures to keep them from closing. After the fracturing is completed, the fracturing fluids rise to the surface where it may be stored in tanks prior to disposal or recycling.

Well drilling and hydraulic fracturing have the potential to create air emissions during oil and gas production. Drilling rigs require substantial power to form wellbores, and typically this power is provided by transportable diesel engines, which results in emissions from the burning of diesel fuel. After the wellbore is formed, additional power is needed to operate the pumps that move large quantities of water into the fractures. These activities are significant sources of the ozone and fine particulate matter (PM_{2.5}), as well as potentially large sources of greenhouse gases, from methane venting during well completions (EDF 2009b).

The Energy Information Agency has projected that shale gas will comprise over 20 percent of the total U.S. gas supply by 2020 (EIA 2009b). However, there have been increasing concerns about the potential impacts on drinking water resources, public health, and environmental impacts in the vicinity of these facilities. Potential risks to surface and underground sources of drinking water might occur at various points in the hydraulic fracturing process. Contaminants of concern to drinking water include fracturing fluid chemicals and degradation products and naturally occurring materials in the geologic formation (e.g. metals, radionuclides) that are mobilized and brought to the surface during the hydraulic fracturing process (EPA 2010d).

Natural gas leaks from pipelines and storage facilities can occur when transporting fuel nationwide. As of 2008, the lower 48 states had just over 300,000 miles of large transmission pipelines for shipping natural gas across the U.S. and over a million additional miles of smaller, low-pressure distribution pipelines to deliver the gas to individual homes and businesses (UCS 2010). A 1997 EPA study estimated that 1.4 percent of all gas produced in the U.S. is lost between the well and customer (Harrison et al. 1997).

Pipeline transport of gas is generally considered safer than other product transportation modes, such as rail or truck. Oil pipelines reported an average of two deaths per year from 2002 through 2006, and gas transmission pipelines reported an average of five deaths per year during the same period. Accidental pipeline releases result from a variety of causes, including third-party excavation, corrosion, mechanical failure, control system failure, and operator error. Natural forces, such as floods and earthquakes, can also damage pipelines. According to the Department of Transportation, there were 100 oil pipeline accidents and 78 gas transmission pipeline accidents in 2006 (Parfomak 2008). Although pipeline releases have caused relatively few fatalities in absolute numbers, the early September 2010 accident involving an exploded pipeline in San Bruno, California highlights the potentially catastrophic risks associated with pipeline transport.

Oil and Propane

Heating oil and propane are used, primarily in the Northeastern U.S. and rural areas, for heating during the cold winter months. Of the 107 million households in the U.S., approximately 8.1 million, or eight percent, use heating oil as their main heating fuel. Residential space heating is the primary use for heating oil, making the demand highly seasonal. Most of the heating oil use occurs during October through March (EIA 2007). Burning oil produces NO_x, SO₂, CO₂, methane, mercury, and other toxics. Oil combustion is the dominant source of SO₂ emissions in the residential sector.

There are six different types of oil used in heating applications. Fuel oil is classified into six classes, numbered 1 through 6, according to its boiling point, composition and purpose. Number 2 heating oil is used in most residential and commercial heating oil systems and it shares the same classification as diesel fuel. Number 1, number 2, and number 3 fuel oils are referred to as distillate fuel oils. These oils are distilled from raw crude oil. Number 4 fuel oil is a blend of distilled oil and heavy or residual fuel oils like number 5 and 6 fuel oils. Number 6 fuel oils are often the residual of what is left over after refining gasoline and the distilled fuel oils.

According to New York City law, the sulfur content of fuel oil numbers 1, 2, and 4 is limited to 2,000 parts per billion (ppm), and residual fuel numbers 5 and 6 are limited to 3,000 ppm. However, in neighboring counties the sulfur limit of residual fuels is 10,000 ppm and in some parts of the country number 6 oil can contain as much as 40,000 ppm sulfur (EDF 2009a).

In December 2009, New York City Mayor Michael R. Bloomberg and his health commissioner, Dr. Thomas Farley, released a comprehensive survey of air quality in the New York City. The study found the highest levels of fine particles, SO₂ and other pollutants in neighborhoods where many residential and commercial buildings burn number 4 or number 6 oil (NYC 2010). According to a report by the Environmental Defense Fund, if those buildings were to burn cleaner oil, the amount of airborne pollutants they release would decline by as much as 65 percent to 95 percent. The report found that overall, residential, commercial and institutional heating systems release 50 percent more particulate matter (PM) and 17 times more SO₂ than cars and trucks on New York City's roads (EDF 2009a).

Propane, also known as liquefied petroleum gas (LPG), is a byproduct of natural gas processing and petroleum refining that can be easily stored and transported and is an attractive option for households not connected to the natural gas system. Propane is used for cooking, heating homes, and providing hot water, as well as for operating machinery and powering vehicles (Energetics 2010).

Biomass

The burning of wood, like traditional heating fuels, produces PM, CO, NO_x, and SO₂ in varying amounts. Burning wood in a modern and well-maintained woodchip boiler, for example, produces more PM than burning fossil fuel, but less SO₂ than oil or propane.

Wood-fired heating plays a substantial role in these sectors, particularly residential. There are over 12 million wood stoves nationwide, 75 percent of which are older and higher polluting than stoves currently for sale (EPA 2009b). In addition, alternative stoves using corn, wood, or wood pellets have recently seen an increase in popularity. Pellet stoves are popular with new converts to wood heat because they are cleaner and easier to maintain than traditional wood stoves and include conveniences like timers and thermostats. Wood stoves take longer to heat than pellet stoves, and their smoke emissions can lead to degradation of indoor or outdoor air quality. Additionally, woodstove smoke may violate local ordinances (Washington 2010).

All too often, woodsmoke is seen as benign. However, a recent review of available research in *Inhalation Toxicology* summarized some of the reasons why it is not:

Woodsmoke contains thousands of chemicals, many of which have well-documented adverse human health effects, including such commonly regulated pollutants as fine particles, CO, and nitrogen oxides as well as ciliotoxic respiratory irritants such as phenols, cresols, acrolein, and acetaldehyde; carcinogenic organic compounds such as benzenes, formaldehyde, and 1,3-butadiene and carcinogenic cyclic compounds such as PAHs. Woodsmoke contains at least five chemical groups classified as known human carcinogens by the International Agency for Research on Cancer (IARC 2010), others categorized by IARC as probably or possible human

carcinogens, and at least 26 chemicals listed by the U.S. EPA as hazardous air pollutants. (Naeher et al, 2007)

Studies that looked at woodsmoke in the U.S. and in other developed countries found association with effects similar to those from PM: coughing and shortness of breath; decreases in lung function; and increased emergency room visits and hospital admissions for asthma. However, woodsmoke does not show a similar association with cardiovascular effects, such as heart attacks or stroke (Naeher et al, 2007).

The International Agency for Research on Cancer found biomass combustion, particularly wood combustion to be a probable cause of cancer (IARC 2006). In developing countries, where concentrations and exposures are much higher, studies have also shown associations with lung cancer, chronic obstructive pulmonary disease, tuberculosis, and asthma among the other health effects. However, there appear to be no studies in developed countries like the U.S. looking at cancer as a possible health effect of wood burning (Naeher et al, 2007).

Most states use federal EPA emission standards for fine particles to determine which wood burning devices can be sold. EPA's standards for wood stoves date to 1988 and are under current review. The state of Washington has more stringent standards for woodstoves than EPA. Some stoves emit well under both limits. EPA estimates that 10 million woodstoves are in operation today, and of those 70 to 80 percent predate 1988. Pre-1988 stoves emit 70 percent more PM than EPA-certified stoves (EPA 2009b).

However, old stoves generally do not get replaced, particularly in low income communities where they may be used more as a major source of heat. Led by the "Burn Wise" program with EPA and industry funding, many communities have undertaken "change out" programs, where old stoves are replaced with newer, lower emitting ones. Most communities are using change out programs to help them meet stronger standards for fine particles, a problem worsened by woodsmoke. Other communities, including several Tribes, have operated local change out projects, with homeowners fronting some of the costs, often for devices provided at a discount by manufacturers and retailers. The American Lung Association in Ohio coordinated one such woodstove change out project in a low-income community in Ohio, using funds from a Supplemental Environmental Project, which are projects that a defendant in an environmental enforcement action agrees to pay for as part of a settlement.

Woodstove use is reportedly expanding as people seek fuel sources they see as being "greener." EPA cites industry sources as estimating that sales of woodstoves rose 28 percent between 2007 and 2008. The recent stimulus funding, the 2009 American Recovery and Reinvestment Act, included a 30 percent tax credit in 2009 and 2010 (up to \$1500) for purchasing a biomass-burning stove that was 75 percent efficient. In addition, some states (including Oregon, Montana, and Idaho) are providing tax incentives to change from natural gas and propane stoves to biomass-fueled stoves, in an effort to spur "homegrown" renewable fuels (EPA 2009b).

Outdoor Wood Boilers

Another recent trend is the increasing popularity of outdoor wood-fired boilers (OWBs). Ninety-five percent of OWBs have been sold in the states in orange in Figure 6. Some of those states have begun to enact laws to address OWBs.



Figure 6. States Representing 95 Percent of OWBs Sold (2006) (NESCAUM)

OWBs are a wood-fired water heater that provides heat to a single residence. OWBs are most popular in rural areas. OWBs contain large fire boxes that heat water, which is then circulated into the home through underground pipes. These units are typically located outside the buildings they heat in small, insulated sheds with short

smokestacks (usually no more than six to ten feet tall). They burn wood to heat water that is piped underground to provide heat and hot water to occupied buildings (see Figure 7).

The basic design of the OWB encourages a slow, cooler fire, to maximize the amount of heat transferred from the fire to the water. However, this type of fire burns inefficiently and creates more smoke than higher temperature fires (Wisconsin 2010). The Massachusetts Department of Environmental Protection estimates that outdoor wood-fired boilers can be substantially dirtier and less efficient than other home heating technologies. An investigation by the New York State Attorney General’s Environmental Protection Bureau found that even when used properly, one of these units can emit as much fine particle pollution as:

- 2 heavy-duty diesel trucks;
- 12 EPA-certified indoor wood stoves;
- 45 passenger cars;
- 1,000 homes with oil heat; and
- 1,800 homes with natural gas heat (Massachusetts 2010).

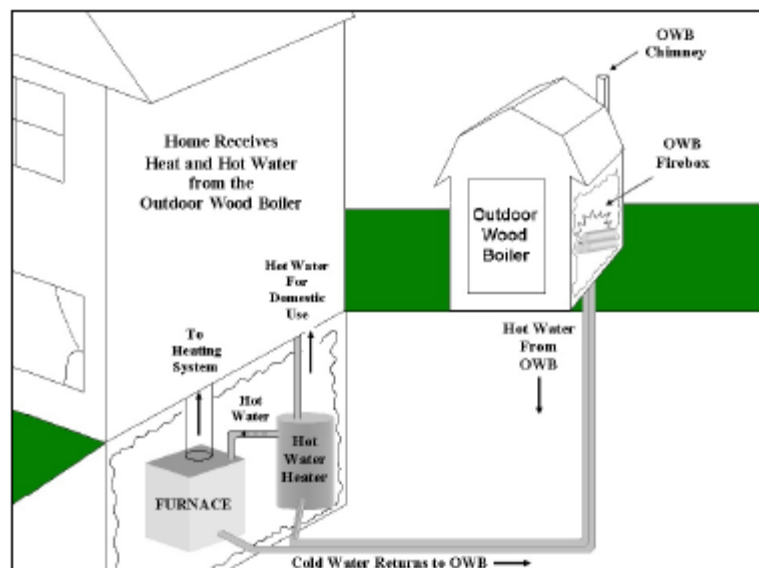


Figure 7. Schematic of OWB (New York State Attorney General’s Office 2008)

While indoor wood stoves must meet

EPA certified emissions levels, OWBs are not required to meet a federal emission standard. EPA

initiated a voluntary partnership with manufacturers in 2007 to design and market cleaner, more efficient OWBs (New Hampshire 2010). Some states have established regulations for the sale, installation, and use of OWBs in the under state law, while others, like Washington, have deemed them illegal (Washington 2010). Many states have also initiated complaint hotlines to address OWBs' impacts on neighbors.

Non-Combustion Strategies

There are a variety of non-combustion alternative residential heating sources that are currently deployed in niche markets, making up about two percent of residential non-electric fuel consumption. The costs of residential conversion to these sources are frequently subsidized by local, state, or federal tax policy.

Solar Heating

Solar technologies include both passive and active solar heating. Passive solar heating relies on building design to collect and hold sunlight. Active solar energy functions through two primary technologies, photovoltaics (PV) and concentrating solar power (CSP).

While gaining popularity in many countries, solar water heating has a negligible presence in the U.S.

Although these technologies do not emit any direct emissions, indirect emissions are generated as part of the manufacturing process. For PV, silica production releases CO₂ and cell creation can use nitric acid that can result in NO_x emissions. The production of thin-film cells can release heavy metals, like cadmium, into the atmosphere. Some manufacturers also use fluorinated gases and volatile organic compounds (VOCs). In addition to these direct emissions, manufacturing renewables' components is generally an energy-intensive process, which typically requires a significant quantity of electricity supplied by the local grid, which results in further emissions.

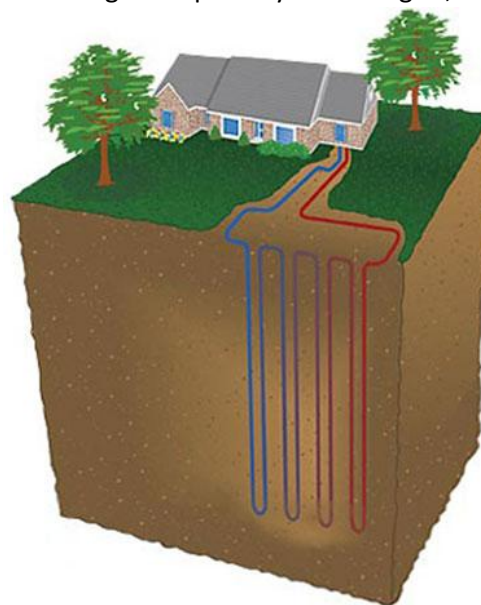


Figure 8. Ground source heating (Source: Green Edmonton 2010)

Geothermal Energy

Geothermal ground source heat pumps, depicted in Figure 8, are electrically-powered systems that use the earth's relatively constant temperature to provide heating, cooling, and hot water for homes and commercial buildings. Ground source heat pumps are categorized as closed or open loops, and those loops can be installed in three ways: horizontally, vertically, or in a pond or lake. In closed loop systems, water or antifreeze solution is circulated through plastic pipes buried beneath the earth's surface. During the winter, the fluid collects heat from the earth and carries it through the system and into the building. During the summer, the system reverses to cool the building by pulling heat from the building, carrying it through the system and placing it in the ground. Open loop systems operate on the same principle as closed loop systems and can be installed where an adequate supply of suitable water is available and open discharge is feasible (IGSHPA 2010).

Passive Homes.

Passive homes are built to require no heating—even in areas with cold, snowy climates. Designed to meet strict computer-modeled standards, these houses use thick walls, deeper insulation, triple-paned windows and other measures to hold daytime heat indoors without the use of solar heating systems. Currently, only 13 houses have been certified using passive heating systems; the technology is reportedly well-used in Europe. Costs in the U.S. are significantly higher than in Europe where the skilled labor, industry and equipment are more readily available. The New York Times reports that Habitat for Humanity is exploring the use of this model (NYT 2010).

Major Policy Issues Associated with Residential Heat

A number of state, regional and federal programs and policies have been adopted or considered to address residential sector heating processes. The residential heating sector has been the focus of many energy efficiency programs, as energy efficient appliances and improved construction offer significant opportunities to reduce home energy use.

Home Star Program

The Home Star Act of 2010 (H.R. 5019), a two-year federal program that would provide direct consumer incentives for residential efficiency retrofits, was introduced in the House on April 14, 2010, and passed on May 7, 2010. The \$6 billion program is anticipated to save consumers in the program between \$200 and \$500 per year in energy costs (The White House 2010).

Key components of the Home Star Program included rebates delivered directly from energy efficiency vendors (small independent building material dealers, large national home improvement chains, energy efficiency installation professionals and utility energy efficiency programs) to consumers, professional oversight to ensure quality installations, and support to state and local governments to provide residential energy efficiency options to consumers. Home Star would have offered consumers two types of incentives: SILVER STAR will provide homeowners between \$1,000 and \$1,500 for installing individual energy-saving measures, such as heat pumps, insulation and air conditioners, and GOLD STAR will encourage homeowners to reduce their overall energy use with rebates of up to \$3,000 in exchange for a 20 percent reduction in consumption (The White House 2010).

After passing in the House, the bill was referred to the Senate. The Senate proposal was introduced as the Home Star Energy Retrofit Act of 2010 (S. 3434) by Senator Jeff Bingaman on May 27, 2010, and was referred to the Finance Committee. This or a similar bill would have to be reintroduced in the 112th Congress.

Low-Sulfur Heating Oil Requirement in Northeast

Significant potential exists for reducing SO₂ emissions from residential boilers and furnaces by substituting low-sulfur oil for current home heating oil. Several northeastern States are leading a transition to cleaner burning heating fuels by decreasing sulfur content in heating oil. Table 2 outlines current state actions in this regard (EIA 2010a).

Table 2. Current Northeast State Regulatory Activities to Reduce Sulfur in Heating Oil (EIA 2010a)

City or State	Action	Effective Date	Status
CT	Mandates a schedule to lower sulfur content in heating oil and increase biodiesel blending, contingent on the passage of similar measures in NY, RI, and MA.*	7/1/2011	Legislation passed, but contingent on other States
ME	Reduces sulfur content to 50 ppm starting January 1, 2016, and no more than 15 ppm starting January 1, 2018; distillate fuel used for manufacturing purposes is exempted. Reduces sulfur content in residual fuel oil to 0.5 percent by weight effective January 1, 2018.	1/1/2016	Rule adopted
NJ	Reduces sulfur content to 500 ppm starting July 1, 2014, and no more than 15 ppm starting July 1, 2016.	7/1/2014	Rule adopted
NJ	Cuts allowable sulfur level in heating oil to 15 ppm.**	7/1/2011	Legislation proposed
NY	Cuts allowable sulfur level in No. 2 Heating Oil to 15 ppm.	7/1/2012	Legislation passed
NY City	Cuts allowable sulfur level in No. 4 Heating Oil to 1,500 ppm.	10/1/2012	Legislation passed
PA	Cuts allowable sulfur levels to: 15 ppm for No.2 Heating Oil; 0.25 percent for No.4 heating oil; 0.5 percent for No. 5, No. 6 and heavier oils.	5/1/2012	Rulemaking proposed, expected to be final in 2011
PA	A bill introduced in the PA legislature would require all heating oil used for residential, commercial and industrial heating to have a sulfur content of 15 ppm or below.	5/1/2011	Legislation proposed
DC, DE, MA, MD, NH, RI, VT	No actions to lower sulfur content are currently proposed.***		

*Requires: sulfur reductions to 50 ppm by 7/1/2011 and 15 ppm by 7/1/2014; and increased biodiesel blending to 2 percent in 2011 and 20 percent by 2020.

**Includes all heating oil sold for residential, commercial or industrial uses within the State.

***Measures to lower sulfur content have been discussed in some States, but formal actions have not yet been taken.

Outdoor Wood Boiler Regulations

Outdoor residential wood-fired boilers have become a focus of state regulatory attention in recent years because of their high air pollution emissions rates and growing popularity. A number of states are encouraging EPA emissions regulation of OWBs, and some states are pursuing their own regulations. A federal response could avoid a patchwork of state regulations, both in terms of the performance standard and the test method used to determine emissions performance (STAPPA 2006).

On January 29, 2007, the Northeast States for Coordinated Air Use Management (NESCAUM) developed a Model Rule that can be used by states as a template when developing state OWB regulations. States moving to regulate OWBs individually include Connecticut, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Virginia, Washington and Wisconsin (Vermont 2010).

The Model Rule was developed as a result of an August 11, 2005 petition, submitted by six northeastern states plus Michigan and NESCAUM, which requested EPA develop a New Source Performance Standard (NSPS) for OWBs or revise the current wood stove NSPS to include OWBs. In response, EPA developed a voluntary program and provided technical and financial support for the NESCAUM model rule. The NESCAUM model rule process has proceeded in tandem with the EPA voluntary program.

EPA is currently evaluating its options for OWB regulation. EPA and others are participating in the American Society for Testing and Materials Committee that is working to develop a consensus test method and emissions standard for outdoor wood boilers. The Agency is expecting to issue a complete staff draft of options, background materials, and a draft proposal for EPA management review in fall 2010. EPA is scheduled to publish a proposal for an NSPS for OWBs in the Federal Register in summer 2011, and to promulgate the NSPS in summer 2012. According to EPA's preliminary analysis, a tighter, more comprehensive NSPS will reduce environmental impacts for all, and result in no disparate impacts nationally (EPA 2010b).

Residential Energy Efficiency, including Weatherization and Low-Income Efficiency

High efficiency appliances, programmable thermostats, and improved insulation offer some of the best strategies to reduce home energy use. The Department of Energy's Weatherization Assistance Program (WAP) enables low-income families to reduce their energy bills by making their homes more energy efficient. The Department of Energy provides funding to states, which in turn, fund a network of local community action agencies, nonprofit organizations, and local governments that provide these weatherization services to low-income residents (DOE 2010).

During the past 33 years, WAP has provided weatherization services to more than 6.4 million low-income households. Families receiving weatherization services see their annual energy bills reduced by an average of about \$437, depending on fuel prices. Because the energy improvements that make up weatherization services are long lived, the savings add up over time to substantial benefits for weatherization clients and their communities, and the nation as a whole (DOE 2010).

Federal Stimulus

The American Recovery and Reinvestment Act of 2009 (ARRA) includes more than \$25 billion for energy efficiency and billions more that can be directly or indirectly applied to energy efficiency projects. ARRA allotted more than \$11 billion for the Weatherization and Intergovernmental Program. The ARRA funds are distributed primarily to states and localities through major grant programs and also to individuals through rebates, tax credits, and other means (MJB&A 2009).

ARRA also expands the federal income tax credits for homeowners who make energy efficiency home improvements. The bill extends the consumer tax benefits through 2010, increases the total available tax credit from \$500 to \$1,500, and raises the tax credit to 30 percent of the cost of each qualified efficiency improvement (MJB&A 2009).

Regional Greenhouse Gas Initiative

To date, roughly three quarters of the revenue generated by Regional Greenhouse Gas Initiative (RGGI) auctions, over \$185 million, is estimated to be dedicated to energy efficiency initiatives. These RGGI auction revenue funds typically go directly to each state's Department of Environmental Protection and are then transferred to a state energy efficiency fund that supports efficiency programs and initiatives. A utility will then propose a project and apply for funding to be approved by the DEP. While this process is different in every state, a management board usually approves projects for funding in conjunction with the DEP and other state agencies and associations (MJB&A 2009).

LIHEAP

The Low Income Home Energy Assistance Program (LIHEAP) was authorized by The Omnibus Budget Reconciliation Act of 1981. Its purpose is to assist low-income households in meeting their immediate home energy needs. Federal funding for LIHEAP is allocated by the U.S. Department of Health and Human Services to states as a block grant and is disbursed under programs designed by the individual states. LIHEAP funds are supplemented to a limited extent by additional state appropriations, programs from energy suppliers and utilities, church donations and local charitable organizations.

Utility-funded Energy Efficiency Programs

Excluding federally funded programs, Funding for state energy efficiency programs is typically provided through a public benefit charge, authorized through state legislation and administered by utilities, state governments or third-party administrators. These funding mechanisms place a fee on electric and gas ratepayers to fund energy efficiency programs and services (MJB&A 2009). For example, since 1983, PG&E's Energy Partners program for low income households has been providing qualified customers with free energy audits, weatherization upgrades, and energy-efficient appliances to reduce their gas and electricity usage. Based on the current guidelines, a family of four with an annual household income below \$43,200 would be eligible to participate. In 2008, 59,000 households participated in the program, saving an estimated 26 million kilowatt hours of electricity and more than a million therms² of

² One therm is equal to 10,000 British Thermal Units (BTU). A BTU is the amount of heat energy needed to raise the temperature of one pound of water by one degree Fahrenheit.

natural gas. Since 1983, more than one million households have participated in the program (ENE 2009).

Commercial and Institutional Sector

The commercial and institutional sectors encompass places familiar to most people: offices, grocery stores, sports arenas, schools, shopping malls, hotels, and hospitals. These are the commerce and service industries, as well as educational facilities and institutional residences, including a broad array of building types, including offices, grocery stores, sports arenas, schools, shopping malls, hotels, and hospitals. In 2003, there were about five million commercial buildings in the U.S., with approximately 75 billion square feet of floor space (NAS 2010a).

The energy needs for these different buildings vary but when viewed as a whole, more than half of the energy used in commercial buildings goes to heating (36 percent) and lighting (21 percent). Within this sector, retail stores and service buildings use the most total energy (20 percent), followed by office buildings (17 percent) and schools (13 percent) (NAS 2010a). In commercial buildings, electricity is the most widely used energy source (55 percent), followed by natural gas (32 percent).

Table 3 summarizes emissions associated with on-site fuel combustion, which is typically associated with heating, by fuel and pollutant. There are a few important notes from these data:

- Natural gas combustion is the dominant source of NO_x emissions in the commercial sector because of its extensive use.
- Commercial oil use contributes a dominant share of SO₂ emissions.
- Unlike the residential sector, there are not significant emissions from biomass or wood combustion.

Table 3. 2005 Commercial Heating-Related Emissions (Tons, 2005) (EPA 2009a)

	NO _x	VOCs	SO ₂	PM ₁₀	PM _{2.5}	CO
Commercial	324,388	20,194	402,320	56,743	24,949	198,985
Coal	34,693	1,871	132,314	36,501	9,059	39,051
Oil	92,774	3,778	266,959	16,227	12,215	22,690
Natural Gas	196,922	14,546	3,046	4,015	3,675	137,244

Fuel Impacts

With the notable exception of outdoor wood-fired boilers and woodstoves, the technology options for and impacts of commercial and institutional heating are similar to those discussed for residential heating. The major difference between the two sectors is the size of the combustion units. Commercial and institutional facilities can have boilers that are comparable in size to industrial boilers.

Major Policy Issues Associated with Commercial and Institutional Heat

Many of the policies associated with residential heat apply to commercial and institutional heat and vice versa. The main goals of the programs are to ensure that buildings are constructed with energy

efficiency in mind and to provide incentives to incorporate energy efficient technologies into existing buildings.

Building Codes

In addition to the traditional focus on safety, building codes have evolved to include energy efficiency metrics. By including energy efficiency in building codes, states ensure that energy efficiency is integrated into new buildings. Mandatory building energy codes can require a minimum level of energy efficiency for all new residential and commercial buildings in a state. Once efficiency metrics are in the codes, it is important to ensure compliance through enforcement actions. For proper enforcement, states have to fund programs to train inspectors. In addition to energy reductions that benefit air quality, proper use and enforcement of codes should reduce the energy cost to building owners and operators.

Building Rating and Disclosure Programs

One of the barriers to energy efficiency is a lack of information about improvements that have been made (or have not been made) to buildings when they are transferred, either to a new owner or to a renter. This type of information can motivate owners to upgrade their buildings, and help prospective buyers and tenants select more efficient buildings. Currently, three cities (New York City; Washington, DC; and Austin, TX) and two states (California and Washington) have mandatory rating and disclosure laws (ACEEE 2010). At the national level, there are voluntary programs for rating and disclosure. In the commercial sector, these include such programs as the Leadership in Energy and Environmental Design (LEED) program and the ENERGY STAR Portfolio Manager. LEED was developed by the U.S. Green Building Council to provide building owners and operators with a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions.

The Waxman-Markey climate bill, which passed the House of Representatives but stalled in the Senate, included provisions requiring federal agencies to develop building rating and disclosure programs for commercial and residential properties.

Energy Efficiency Programs

As in the residential sector, government- and utility-sponsored energy efficiency programs target efficiency improvements in the commercial sector. Such improvements look at commercial building systems such as lighting and HVAC (heating, ventilation, and air conditioning) as well as electronics such as computers, copiers, and printers. Programs could also assist commercial building owners and operators in the installation of energy management systems to create a centralized strategy for monitoring and controlling the major energy-consuming systems within a commercial building (EPRI 2009).

Green roofs are an emerging set of technologies that can help communities mitigate the warming of urban areas due to loss of vegetation. A green roof is a vegetative layer grown on a rooftop that shades surfaces and removes heat from the air through evapotranspiration. This reduces temperatures of the roof surface and the surrounding air. Green roofs can save energy needed to cool and heat the buildings

they shelter. Green roofs reduce temperature fluctuations when wet, and act as an insulator when dry, decreasing the flow of heat through the roof, thereby lowering energy demand. In the winter, this insulating effect means also reduces heating needs (EPA 2008).

Reducing Oil Use in Urban Boilers

The study of the use and emissions from oil-fired boilers in New York City that is discussed in the residential section above includes the following recommendations for New York City (EDF 2009a):

1. The city should put an immediate moratorium on new number 4 and number 6 permits for buildings that are currently burning number 2 heating oil or newly constructed buildings that wish to use number 4 or number 6 residual oil.
2. The city should promulgate a new rule that will fully phase out renewal permits for No. 4 and 6 boilers by 2020. Every three years, buildings have to get their boiler permits renewed, offering an opportunity to the city to get these buildings switched over to cleaner heating fuels over a timeframe of about six years for buildings that are not low income buildings and give low income buildings until 2020 to switch to cleaner fuel.
3. The city should work with privately-owned buildings to switch to a cleaner fuel (like natural gas or number 2 heating oil) and implement good maintenance and efficiency measures that can yield some cost-effective fuel use reductions.

While these recommendations are specific to New York City where there is a heavy concentration of boilers using number 4 and number 6 heating oil, any boiler in an urban setting should be targeted for conversion to cleaner fuels or efficiency improvements.

Industrial Sector

The industrial sector encompasses a diverse collection of industries with very different energy and feedstock needs to produce products that range from paper to gasoline to pharmaceuticals, and as a result, emissions can vary significantly from industry to industry. Certain industries are particularly energy-intensive, requiring large energy inputs per unit of output. The largest energy-consuming industries in the U.S. are bulk chemicals, oil and gas, steel, paper, and food products. These five industries account for 60 percent of industrial energy use, but only 20 percent of the value of the products (Pew 2009). Other energy-intensive industries include glass, cement, and aluminum. In general, energy-intensive industries have been declining within the U.S. economy with a shift to less energy-intensive products (e.g., from steel to computer equipment) and recent economic conditions have reduced industrial output. The Federal Reserve's measure of capacity utilization showed that the nation's factories were operating at a 70.4 percent rate in 2009, down from 77.5 percent in 2008 (EIA 2010e).

Table 4 provides examples of the combustion devices that are used within the industrial sector for on-site electricity generation, steam production, and process heating. Industrial boilers and process heaters are discussed in greater detail below.

Table 4. Examples of Industrial Combustion Devices (STAPPA 2006)

Industry	Device	Description	Typical Fuel	Primary Emissions of Concern
Petroleum Refining, Chemical Manufacturing, Pulp and Paper	Industrial Boiler	On average smaller than boilers used for electricity generation, industrial boilers provide onsite steam and electricity to industrial facilities. Across the industrial sector, industrial boilers are the largest source of air emissions.	Natural Gas, Oil, Biomass, Coal	SO ₂ , NO _x , PM, Air Toxics (dependent on fuel source)
Pulp and Paper	Recovery Boiler	Several times larger than onsite industrial boilers, recovery boilers combust a biomass-based byproduct of the pulping process called black liquor. The energy from the recovery boilers is used to supplement energy from onsite industrial boilers that typically burn wood waste, natural gas, or oil.	Biomass-based Byproduct	Highly variable, can be a source of SO ₂ , NO _x , PM, and Air Toxics
Cement Manufacturing*	Cement Kiln	Cement kilns are the largest source of emissions at a cement manufacturing facility (which do not have industrial boilers). The kilns provide heat to a mixture that can include limestone, clay, shale, sand, slag, and iron ore that is turned into clinker which is ground into cement.	Coal with a limited amount of natural gas and oil. Some facilities use tire waste.	SO ₂ , NO _x , PM, Air Toxics (dependent on fuel source)
Iron and Steel	Coke Oven	Coke ovens are used to produce coke with is used in the blast furnace to provide the high temperatures needed to forge steel. Coke is produced by heating coal in the absence of oxygen at high temperatures in coke ovens. The solid carbon remaining in the oven is coke. The smoldering coke is quenched with water.	Coal	Direct particulate emissions, VOCs (significant amounts of VOCs are captured for byproduct use in the process)
Petroleum Refining	Process Heaters	A process heater is an enclosed device in which solid, liquid, or gaseous fuels are combusted for the purpose of heating a process material (e.g., crude oil).	Oil, Byproduct Refinery Gases, Natural Gas	SO ₂ , NO _x , PM, Air Toxics
	Flares	Petroleum refineries use flares to combust vapors rather than discharging them to the atmosphere. Frequent flaring in routine, nonemergency situations or to bypass pollution control systems can produce excess emissions and violate permit conditions.	Refinery Process or Waste Gases	SO ₂ , NO _x , PM, Air Toxics

* EPA issued final rules on cement kilns on August 6, 2010, which tightened emission limits from new and existing kilns. The final decision on what sources can be used to power cement kilns will depend on the outcome of pending EPA rules, including rules which may allow solid waste to be used as fuel.

Table 5 and Figure 9 summarize the combustion-related emissions from the industrial sector by fuel and

pollutant.

- Coal combustion in the industrial sector is the largest source of SO₂ emissions. The vast majority of the coal consumed in the U.S. is used for electricity generation. In 2009, the industrial sector accounted for about seven percent of total U.S. coal consumption.
- Natural gas, which is used for fuel in many sectors (including steel, glass, paper, clothing, and brick making), burns cleaner than other fossil fuels, although it does generate a substantial share of the sector’s NO_x and CO emissions.
- The composition of biomass burned for industrial uses varies widely, but can have relatively high emissions of PM and CO, particularly if combusted with no pollution controls. The “other” category includes industrial fuels such as pulping liquor from paper making, agricultural waste, wood residues from mill processing, and wood-related and paper-related refuse, all of which have widely-varying compositions and emissions, as demonstrated by the high total emissions of many of the major pollutants.
- As significant share of emissions from oil used in the industrial sector are from the petroleum refining industry which consumes petroleum fuels produced by the same refineries that use it (EIA 2002). The pulp and paper and chemical industries also use oil to fire onsite boilers.

Table 5. 2005 Industrial Fuel Combustion-Related Emissions (Tons, 2005) (EPA 2009a)

	NO _x	VOCs	SO ₂	PM ₁₀	PM _{2.5}	CO
Industrial Fuel Combustion	1,897,944	134,645	1,735,527	350,749	195,004	1,239,392
Coal	332,250	6,499	1,085,098	193,751	65,082	134,747
Natural Gas	511,559	53,991	228,291	45,953	39,948	411,701
Oil	161,355	5,006	335,394	24,486	16,837	44,565
Other (Wood, other biomass, other waste fuels)	892,780	69,149	86,745	86,559	73,136	648,379

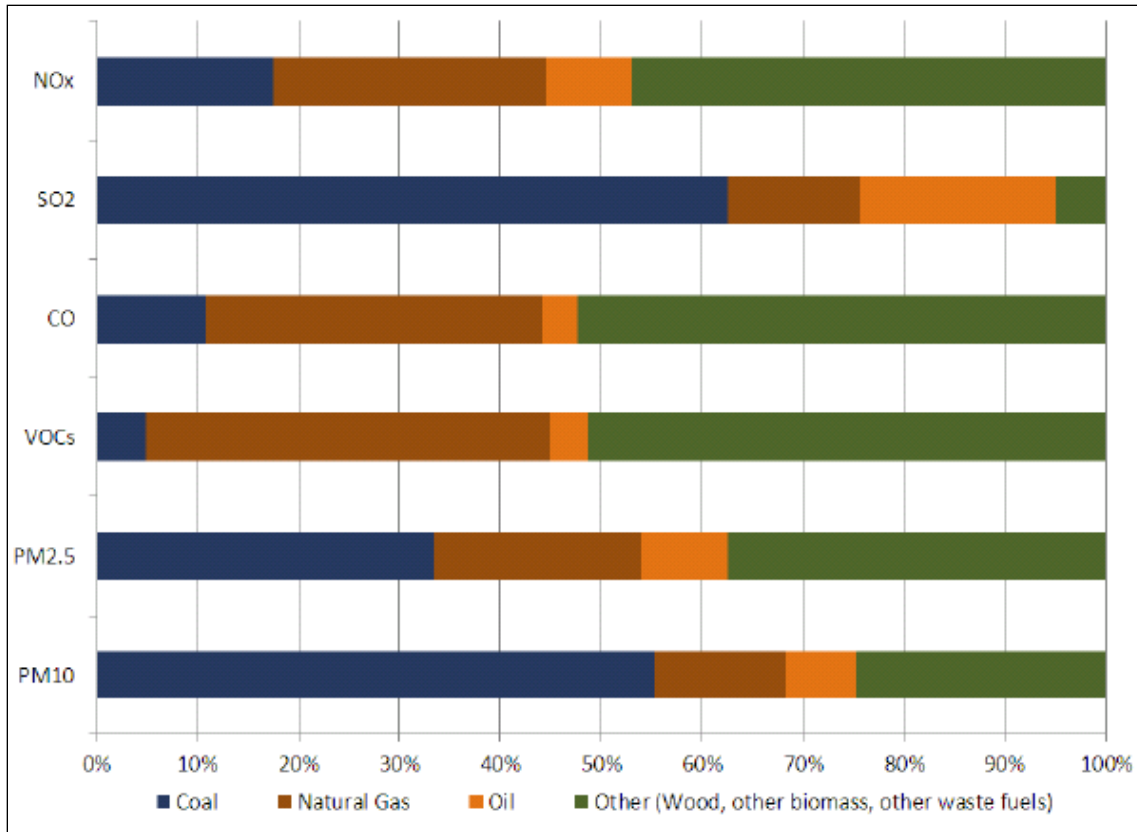


Figure 9. 2005 Industrial Fuel Combustion-Related Emissions (EPA 2009a)

Industrial Boilers and Process Heaters

Industrial boilers and process heaters are some of the most common industrial equipment, representing approximately 40 percent of all energy use in the industrial and commercial sectors (EEA 2005). Industrial boilers usually drive mechanical equipment or heat process materials (e.g., petroleum). Some boilers produce electrical power for on-site industrial consumption, sometimes cogenerating steam and electricity. Industrial boilers are similar to those used in the generation of electricity, but are often subject to different air regulatory requirements.

Industrial boilers also tend to be smaller. Industrial boilers can be as large as 1,000 million Btu per hour (MMBtu/hr) or as small as 0.5 MMBtu/hr. In contrast, the average size of a coal-fired electric sector boiler is greater than 2,000 MMBtu/hr (NESCAUM 2008).

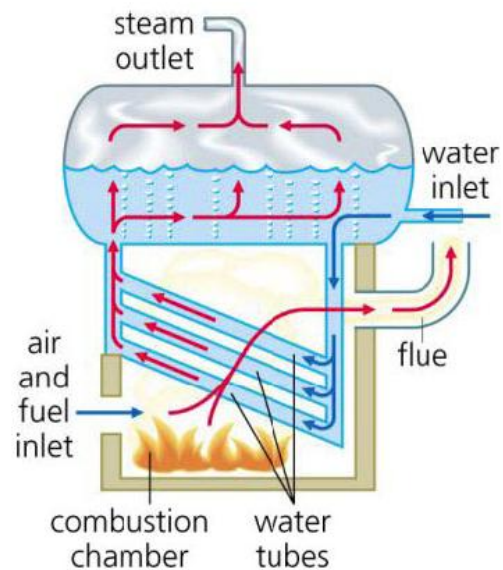


Figure 10. Simplified Boiler Design (Darling 2010)

Boilers burn natural gas, oil, coal, biomass (e.g., wood), and industrial byproducts to produce steam. The steam is used to produce electricity or provide heat. Process heaters heat raw or intermediate materials during an industrial process (for example, vaporizers warm liquefied natural gas (LNG) to return the LNG to a gaseous state).

Boilers and process heaters are used at a wide variety of industrial facilities such as refineries, chemical and manufacturing plants, and paper mills. In a recent rulemaking, EPA estimated that there are approximately 13,555 boilers and process heaters at large industrial facilities. EPA estimates that there are potentially hundreds of thousands of boilers and process heaters at smaller industrial and commercial facilities (EPA 2010c).

Natural Gas

The industrial sector in the U.S. consumed just over 6 trillion cubic feet (tcf) of natural gas in 2009, making it the second largest consumer of the fuel after the electric power sector and marking a steady decline in consumption (EIA 2010f). Figure 11 highlights the decline in natural gas consumption by the industrial sector from 1997 through 2009. In 2000, the industrial sector accounted for 35 percent of total natural gas consumption in the U.S. In 2009, the industrial sector accounted for 27 percent of total natural gas consumption (EIA 2010f). This recent decline in industrial energy use reflects the combined effect of the downturn in the economy (which has disproportionately impacted energy-intensive industries) and the continuation of a long-term trend of growth in the service sector relative to the industrial sector of the U.S. economy (EIA 2010e).

The industrial sector relies on natural gas as a fuel input (e.g., fueling industrial boilers) as well as a base ingredient in a variety of products such as plastics, fertilizer, anti-freeze, and fabrics. Natural gas is consumed primarily in the pulp and paper, metals, chemicals, petroleum refining, stone, clay and glass, plastic, and food processing industries. Together these industries account for over 84 percent of industrial natural gas use (NGSA 2010).

As discussed in the residential sector section of this paper, natural gas has significantly lower emissions as compared to other fossil fuels but is still responsible for local environmental impacts, particularly related to the release of NO_x emissions. The extraction of natural gas through advanced methods, such as hydraulic fracturing, also has significant potential environmental impacts.

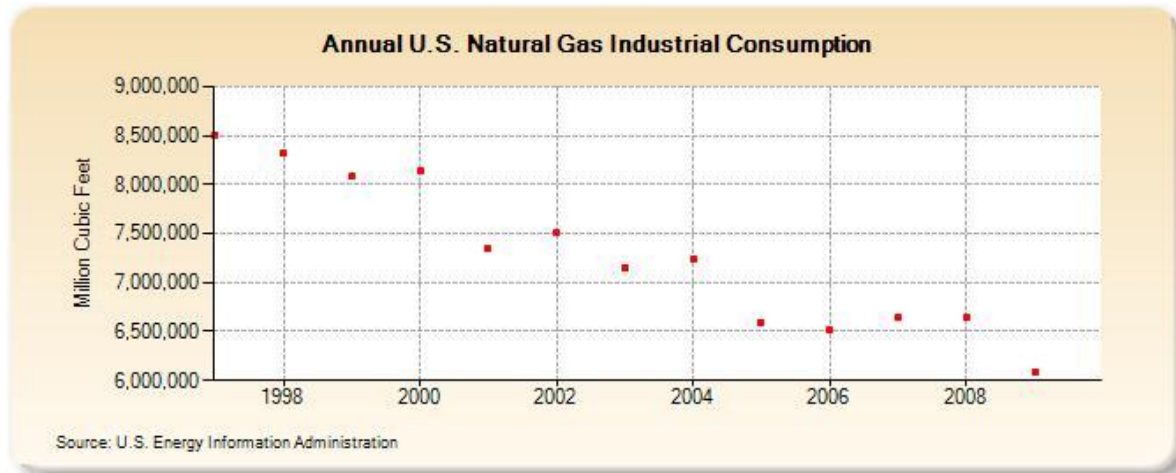


Figure 11. Annual U.S. Natural Gas Industrial Consumption

Oil

The industrial sector in the U.S. consumes about 20 percent of oil and other petroleum products annually. The industrial sector is the largest consumer of petroleum products after the transportation sector. Of the approximately 7.8 quadrillion Btus of petroleum-based energy consumed by the industrial sector, about a third is used as a feedstock for asphalt, chemicals, or other manufactured products. Of the remainder, about half is used by the petroleum refining, chemical, and paper industries to fuel industrial boilers and process heaters (NRC 2010). Oil consumption in the industrial sector grew by 8 percent from 2000 to 2006 but has fallen 20 percent since then in response to the spike in oil prices and subsequent economic downturn (EIA 2009c).

Oil combustion produces NO_x, SO₂, CO₂, methane, mercury, and other toxic air emissions. As described in the residential sector discussion, the sulfur content of oil can vary significantly, resulting in dramatically different emissions profiles. The lifecycle impacts of oil refining are discussed in the *American Lung Association Energy Policy Development: Transportation Background Document* in this series.

Coal

The industrial sector accounts for a small share of U.S. coal consumption. Coke making (for iron production) accounted for two percent and other industrial sources accounted for five percent of total coal consumption (EIA 2010g). By contrast, the electric sector accounted for 94 percent of total U.S. coal consumption in 2009.

Much of the energy consumed by the steel making industry is derived from coal, and nearly all of this coal is used in the coke making process—coke is produced by heating coal to very high temperatures for 14 to 36 hours (ISTC 2010). Integrated steel mills use blast furnaces, combining coke, iron ore, and limestone, to produce molten iron. Integrated steel mills are concentrated in the Great Lakes region near supplies of coal and iron ore, and key customers, such as automobile manufacturers. These mills can produce significant air pollution emissions. For example, the U.S. Steel Plant in Allegheny County,

Pennsylvania, the largest coke-manufacturing facility in the U.S., is the dominate source of PM emissions in the metropolitan area (Allegheny 2010).

In addition to steel making, coal is used in a variety of industrial sectors to power industrial boilers for the production of electricity and steam for process heating and space heating.

The impacts of emissions from industrial coal use are similar to those from emissions from coal-powered electricity generation, which are discussed in depth in the *Electricity Generation Background Document*.

Biomass

The industrial sector is the largest consumer of biomass for energy in the U.S. In 2008, biomass use in the industrial sector was slightly more than 2 quadrillion Btus out of a total U.S. biomass consumption for energy of 3.8 quadrillion Btus. However, while biomass consumption for energy in the U.S. grew by 22 percent from 2000 to 2008, biomass consumption grew by only 7 percent in the industrial sector. The primary driver of increased biomass consumption in U.S. was an increased use of biofuels by the transportation sector. Within the industrial sector, wood and wood-derived fuels continue to be the largest component of biomass consumption at 66 percent. The fastest growing form of biomass use in the industrial sector is in biofuels with a growth of 82 percent since 2000, reaching 26 percent of the industrial sector's consumption of biomass by 2008 (EIA 2010d).

The pulp and paper industry is responsible for over half of the biomass consumption in the industrial sector with about 70 percent of consumption in the form of a process byproduct called black liquor. As described in Table 4, black liquor is combusted in recovery boilers in pulp and paper operations to supplement energy from onsite industrial boilers. Black liquor is a byproduct of the kraft pulping process, a chemical process that converts wood chips or recycled products into pulp that is used to make paper. The black liquor contains pulping chemicals and lignin from trees. In the recovery boilers, sodium and sulfur compounds are recovered in the form of molten smelt. Air pollutant emissions, particularly SO₂ emissions, from black liquor combustion are highly variable dependent on impurities from the pulping process (STAPPA 2006).

The other significant users of biomass in the industrial sector are lumber companies and biorefineries, which are responsible for about 10 percent and 25 percent of biomass consumption respectively.

Renewables

While non-combustion renewable energy provides a negligible portion of industrial energy, there are a number of pilot initiatives underway. For example, Valero Energy Corporation opened a 10-MW wind farm just outside of its McKee refinery in Texas on March 31, 2009. The farm currently contains six turbines, but Valero plans to expand this to 33 turbines and raise the power-generating capacity of the farm to 50 MW. In addition, Shell Oil's Martinez, California refinery has installed a solar-powered circulator, which aerates the waste treatment pond at a remote location (Hydrocarbon 2010). Only recently have refiners begun looking into replacing conventional electricity with renewable sources. To do this, refiners can either form partnerships with renewable energy companies or purchase the technology from outside vendors (Hydrocarbon 2010).

Major Policy Issues for Industrial Fuel Combustion

Industrial boilers and other combustion sources are subject to EPA air pollution regulations, including the recently proposed national emission standards for hazardous air pollutants. The industrial sector can also reduce air pollution emissions by adopting energy efficiency measures and expanding the use of combined heat and power.

Industrial/Commercial/Institutional Boilers and Process Heaters Air Toxics Regulations

Industrial/commercial/institutional (ICI) boilers emit a wide range of hazardous air pollutants, including: toxic metals and metal-like substances such as arsenic and lead; mercury; dioxins; chemicals known or thought to cause cancer, including formaldehyde, and benzene; and acid gases such as hydrogen chloride (EPA 2011a). Because of the widespread use of ICI boilers, these toxic emissions can pose threats to local communities, especially because industrial areas are historically located closer to lower-income or minority communities.

On February 21, 2011, EPA signed final national emission standards for hazardous air pollutants (NESHAPs) for new and existing ICI boilers and process heaters intended to cut emissions of these air toxics (EPA 2011b; EPA 2011c). EPA issued these standards to replace earlier regulations vacated by the D.C. Circuit. For many units, EPA included a requirement for an energy assessment of the boiler system to identify cost-effective energy conservation measures, which is projected to result in reduced fuel use and, thus, reduced combustion emissions. The proposed regulations would cover ICI boilers fueled by coal, biomass, oil, natural gas, and other gases. Due to lower emissions of air toxics, natural gas-fueled boilers are proposed to be subject to less-stringent regulations or exempted altogether. EPA faced substantial pressure from industrial stakeholders, as well as allies in Congress, to substantially weaken the final rule. While these NESHAPs specifically target air toxics, they are expected to lead to the reduction of several other pollutants, such as PM, which EPA proposed to use as a surrogate for metals. Surrogates are pollutants whose control results in the reduction of other pollutants. In this case, when PM is controlled, heavy metals and other air toxics are expected to be controlled.

Additionally, as a result of a consent decree, in summer 2010 EPA committed to conduct statutorily-mandated reviews of available control technologies and emission limits for 28 industry sectors within the next eight years, including the paper, furniture and aerospace industries. EPA also agreed to perform residual risk assessments - analyses of the public health impacts remaining after achievement of emission standards – for a multitude of industrial sectors.

Regulation of Greenhouse Gas Emissions under the Clean Air Act.

In response to the U.S. Supreme Court's 2007 decision, EPA has made an official determination that greenhouse gas emissions endanger public health and welfare within the meaning of the Clean Air Act. EPA recently published guidance for permitting authorities describing how to select best available control technologies for greenhouse gases as a part of the permitting process for power plants and other large sources of greenhouse gases. Starting in January 2011, large stationary sources that trigger emissions thresholds must identify best available control technologies for greenhouse gas emissions in permits for new and modified sources.

Energy Efficiency Initiatives

Industrial energy efficiency³ presents an opportunity to reduce emission from all fuel sources. History provides evidence for this. Between 1985 and 2003, industrial-sector gross domestic product (GDP) increased by 64 percent, while industrial energy use increased by only 12 percent, resulting in a significant decline in the energy intensity of the industrial sector (NAS 2010b). However, part of this gain is likely attributable to structural factors (the shift to less energy-intensive industries) (NAS 2010b).

The study “Scenarios for a Clean Energy Future,” prepared by the Interlaboratory Working Group on Energy-Efficient and Clean Energy Technologies for the U.S. Department of Energy, estimated that the industrial sector could reduce energy consumption by 16.6 percent relative to a business-as-usual forecast, at no net cost to the economy, using a portfolio of policies (NAS 2010b).

Combined Heat and Power

Combined heat and power (CHP) systems, also known as cogeneration, generate electricity and useful thermal energy in a single, integrated system. CHP is not a technology, but an approach to applying technologies. Heat that is normally wasted in conventional power generation is recovered as useful energy, which avoids the losses that would otherwise be incurred from separate generation of heat and power. CHP applications can convert between 70 to 90 percent of the energy in the fuel into electrical power and useful heat. This compares favorably with conventional power generation which typically has a delivered energy efficiency of around 30 to 45 percent.

CHP is widely used in the steel, chemical, paper, and petroleum-refining industries, and at large institutional campuses such as universities. The best sites generally have year round demand for steam, heat, or air conditioning. For CHP, it is essential to find a facility with the right energy profile, so more steam is not produced than the facility can use. In recent years, smaller CHP systems have begun to make inroads in the food, pharmaceutical, and light manufacturing industries; in commercial buildings; and at smaller facilities such as hospitals (ACEEE 2009).

The CHP industry, U.S. Department of Energy (DOE), and U.S. EPA set a goal to double U.S. CHP capacity between 1999 and 2010, using 1998 as a baseline, by adding 92 GW of new capacity. A recent report, co-funded by DOE, suggests that CHP could represent as much as 20 percent of U.S. electric generation capacity by 2030, or 241 GW of total capacity (DOE 2009).

³ Although the terms “energy efficiency” and “energy conservation” are often used interchangeably, they have distinct definitions. Energy conservation refers to consuming less energy, for example by turning off a light or lowering the thermostat in winter. Energy efficiency, on the other hand, refers to accomplishing an objective—such as heating a room to a certain temperature—while using less energy. For example, a more efficient furnace would heat a house to the same temperature using less energy, while conservation would require the temperature to be lowered to achieve the same energy gains. While both have a role in all sectors, this section focuses on efficiency.

Recommended Reading

Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption; National Research Council (NRC 2010). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Academies Press. 2010.

http://www.nap.edu/catalog.php?record_id=12794.

Environmental Defense Fund (EDF 2009a). *The Bottom of The Barrel: How The Dirtiest Heating Oil Pollutes Our Air And Harms Our Health*. 2009.

http://www.edf.org/documents/10085_EDF_Heating_Oil_Report.pdf.

Environmental Protection Bureau, Attorney General of New York State. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. 2005. <http://www.burningissues.org/pdfs/ny-outdoor-wood-boilers-05.pdf>.

Northeast States for Coordinated Air Use Management (NESCAUM 2006). *Assessment of Outdoor Wood-fired Boilers*. 2006. http://www.nescaum.org/documents/assessment-of-outdoor-wood-fired-boilers/2006-1031-owb-report_revised-june2006-appendix.pdf/.

STAPPA and ALAPCO. *Controlling Fine Particulate Matter Under the Clean Air Act: A Menu of Options*. 2006. <http://www.4cleanair.org/PM25Menu-Final.pdf>.

U.S. Environmental Protection Agency (EPA). *Final Air Toxics Standards for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Source Facilities (Fact Sheet)*. 2011.

<http://www.epa.gov/airquality/combustion/docs/20110221mboilersfs.pdf>.

U.S. Environmental Protection Agency (EPA). *Final Air Toxics Standards for Industrial, Commercial, and Institutional Boilers and Process Heaters at Area Source Facilities (Fact Sheet)*. 2011.

<http://www.epa.gov/airquality/combustion/docs/20110221aboilersfs.pdf>.

References

- Allegheny County Health Department (Allegheny 2010). *Revision to the Allegheny County Portion of the Pennsylvania State Implementation Plan: Attainment Demonstration for the Liberty-Clairton PM2.5 Nonattainment Area*. September 2010. <http://www.achd.net/air/index.html>.
- American Council for an Energy-Efficient Economy (ACEEE 2010). *Building Rating and Disclosure*. Accessed October 2010. <http://www.aceee.org/topics/building-rating-and-disclosure>.
- American Council for an Energy Efficiency Economy (ACEEE 2009). *Combined Heat and Power and Clean Distributed Energy Policies*. August 1, 2009. <http://www.aceee.org/fact-sheet/combined-heat-and-power-and-clean-distributed-energy-policies>
- Electric Power Research Institute (EPRI 2009). *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.* January 2009. http://my.epri.com/portal/server.pt?Abstract_id=000000000001016987.
- Encyclopedia of Alternative Energy and Sustainable Living. "Boiler." *The Worlds of David Darling*. Accessed October 12, 2010. http://www.daviddarling.info/encyclopedia/B/AE_boiler.html.
- Energetics Incorporated (Energetics 2010). *Energy Supply and Delivery: Propane*. Accessed October 6, 2010. <http://www.energetics.com/expertise/energydelivery/propane/Pages/default.aspx>.
- Energy and Environmental Analysis, Inc. (EEA 2005). *Characterization of the U.S. Industrial Commercial Boiler Population*. May 2005. <http://www.cibo.org/pubs/industrialboilerpopulationanalysis.pdf>.
- Environment Northeast (ENE) and M.J. Bradley & Associates LLC (ENE 2009). *State & Utility Administered Energy Efficiency Programs*. February 2009.
- Environmental Defense Fund (EDF 2009a). *The Bottom of The Barrel: How The Dirtiest Heating Oil Pollutes Our Air And Harms Our Health*. 2009. http://www.edf.org/documents/10085_EDF_Heating_Oil_Report.pdf.
- Environmental Defense Fund (EDF 2009b). *Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements*. January 26, 2009. http://www.edf.org/documents/9235_Barnett_Shale_Report.pdf.
- Green Edmonton. *Ground Source Heat Pump*. Accessed October 13, 2010. <http://greenedmonton.ca/taxonomy/term/97>.
- Harrison, Matthew R., Theresa M. Shires, Jane K. Wessels, and Michael Cowgill (Harrison et al. 1997). *Methane Emissions from the Natural Gas Industry*. U.S. Environmental Protection Agency. June 1997.
- Harwood, Greg (Harwood 2010). "Inspecting Unvented Gas Space Heaters". *Professional Home Inspection Service*. Accessed 15 October 2010. <http://www.professionalhome.com/article-heat.html>

Hydrocarbon Publishing Company (Hydrocarbon 2010). "Using Renewable Sources of Energy." Refinery CO₂ Management Strategies: Technology Solutions to Reduce Carbon Footprint and Meet Business Sustainability Goals. March 2010. <http://www.hydrocarbonpublishing.com/ReportP/Renewable09.php>

Illinois Sustainable Technology Center (ISTC 2010). "The Steel Making Industry." *Primary Metals*. Accessed October 12, 2010. http://www.istc.illinois.edu/info/library_docs/manuals/primmetals/chapter2.htm.

International Agency for Research on Cancer (IARC 2010). *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Household Use of Solid Fuels and High-temperature Frying*. Volume 95, 2010. <http://monographs.iarc.fr/ENG/Monographs/vol95/index.php>.

International Ground Source Heat Pump Association (IGSHPA 2010). *What is a Ground Source Heat Pump?* 2010. Accessed October 13, 2010. <http://www.igshpa.okstate.edu/geothermal/geothermal.htm>.

Lawrence Berkeley National Laboratory (LBNL 2000). *Energy Use and Energy Intensity of the U.S. Chemical Industry*. April 2000. http://www.energystar.gov/ia/business/industry/industrial_LBNL-44314.pdf.

M.J. Bradley & Associates LLC (MJB&A 2009). "Energy Efficiency Gaining Support Among State and Federal Policymakers". *Environmental Energy Insights*. Spring 2009.

Massachusetts Department of Environmental Protection (Massachusetts 2010). *Heating Your Home With a Wood-Burning Appliance*. Accessed October 8, 2010. <http://www.mass.gov/dep/air/community/burnwood.htm>.

Naeher, Luke P, Michael Brauer, Michael Lipsett, Judith T. Zelikoff, Christopher D. Simpson, Jane Q. Koenig, Kirk R. Smith (Naeher et al, 2007). "Woodsmoke Health Effects: A Review." *Inhalation Toxicology*. January 2007. <http://informahealthcare.com/doi/abs/10.1080/08958370600985875>.

National Academy of Sciences (NAS 2010a). *How We Use Energy*. Accessed October 7, 2010. <http://needtoknow.nas.edu/energy/energy-use/>.

National Academy of Sciences (NAS 2010b). *Real Prospects for Energy Efficiency in the United States*. The National Academies Press. 2010.

National Research Council (NRC 2010). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. 2010.

Natural Gas Supply Association (NGSA 2010). *Uses in Industry*. Accessed October 15 2010. http://www.naturalgas.org/overview/uses_industry.asp

NESCAUM (Northeast States for Coordinated Air Use Management). Applicability and Feasibility of NO_x, SO₂, and PM Emissions Control Technologies for Industrial, Commercial, and Institutional (ICI) Boilers. January 2009. <http://www.nescaum.org/documents/ici-boilers-20081118-final.pdf/>.

New Hampshire Department of Environmental Services (New Hampshire 2010). "Outdoor Wood-Fired Boilers and Air Quality Considerations and Best Management Practices." *Environmental Fact Sheet*. August 6, 2010. <http://des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-40.pdf>.

New York City Department of Health and Mental Hygiene (NYC 2009). *The New York City Community Air Survey: Results from Winter Monitoring 2008-2009*. 2009. http://www.nyc.gov/html/doh/downloads/pdf/eode/nyccas_master_report_12_15_09.pdf.

New York Times (NYT 2008a). *As Oil and Gas Prices Rise, Wood Stoves Gain Converts*. September 14, 2008. http://www.nytimes.com/2008/09/15/nyregion/15wood.html?ref=heating_oil.

New York Times (NYT 2008b). *Coal Is Returning to Home Furnaces*. December 26, 2008. <http://www.nytimes.com/2008/12/27/business/27coal.html>.

Pew Center on Global Climate Change (Pew 2009). "Industrial Emissions in the United States." *Industrial Overview*. May 2009. <http://www.pewclimate.org/docUploads/IndustryOverview.pdf>.

Parfomak, Paul (Parfomak 2008). "Pipeline Safety and Security: Federal Programs." Congressional Research Service. 29 February 2008. <http://www.fas.org/sgp/crs/homsec/RL33347.pdf>.

STAPPA and ALAPCO (STAPPA 2006). *Controlling Fine Particulate Matter Under the Clean Air Act: A Menu of Options*. March 2006. <http://www.4cleanair.org/PM25Menu-Final.pdf>.

U.S. Department of Energy (DOE 2010). "Weatherization Assistance Program." *Office of Energy Efficiency and Renewable Energy: Weatherization and Intergovernmental Program*. September 23, 2010. <http://www1.eere.energy.gov/wip/wap.html>.

U.S. Department of Energy (DOE 2009). *CHP: A Decade of Progress, A Vision for the Future*. August 2009. http://www1.eere.energy.gov/industry/distributedenergy/pdfs/chp_accomplishments_booklet.pdf<http://www1.eere.energy.gov/wip/wap.html>.

U.S. Energy Information Administration (EIA 2010a). "Northeast States Move to Reduce Sulfur Content in Heating Oil." *This Week in Petroleum*. August 18, 2010. <http://www.eia.gov/oog/info/twip/twiparch/100818/twipprint.html>.

U.S. Energy Information Administration (EIA 2010b). *Trends in U.S. Residential Natural Gas Consumption*. June 2010. http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2010/ngtrendsresidcon/ngtrendsresidcon.pdf.

U.S. Energy Information Administration (EIA 2010c). *Annual Energy Review 2009*. August 19, 2010. <http://www.eia.doe.gov/emeu/aer/contents.html>.

U.S. Energy Information Administration (EIA 2010d). *Renewable Energy Trends in Consumption and Electricity: 2008 Edition*. August 2010.

<http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html>.

U.S. Energy Information Administration (EIA 2010e). *Natural Gas Year in Review 2009*. July 2010.

http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2010/ngyir2009/ngyir2009.html.

U.S. Energy Information Administration (EIA 2010f). *Natural Gas Consumption by End Use*. November 29, 2010. http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_m.htm

U.S. Energy Information Administration (EIA 2010g). *U.S. Coal Consumption by End-Use Sector*. October 2010.

<http://www.eia.doe.gov/cneaf/coal/quarterly/html/t32p01p1.html>

U.S. Energy Information Administration (EIA 2009a). *U.S. Natural Gas Pipeline Network, 2009*. October 4, 2010.

http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/ngpipelines_map.html.

U.S. Energy Information Administration (EIA 2009b). *Annual Energy Outlook 2009*. March 2009.

[http://www.eia.doe.gov/oiaf/aeo/pdf/0383\(2009\).pdf](http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf).

U.S. Energy Information Administration (EIA 2009c). "Table 5.14b Heat Content of Petroleum Consumption: Industrial Sector, Selected Years, 1949-2009." *Annual Energy Review 2009*. 2009.

http://www.eia.doe.gov/aer/pdf/pages/sec5_36.pdf

U.S. Energy Information Administration (EIA 2007). *Residential Heating Oil Prices: What Consumers Should Know*. April 24, 2007.

http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/heating_brochure/heatbro.htm.

U.S. Energy Information Administration (EIA 2005). "U.S. Household Electricity Report." *Regional Energy Profile*. July 14, 2005. http://www.eia.doe.gov/emeu/reps/enduse/er01_us.html.

U.S. Energy Information Administration (EIA 2002). "Delivered Energy Consumption Projections by Industry." *Annual Energy Outlook 2002*. July 30, 2002.

<http://www.eia.doe.gov/oiaf/analysispaper/industry/consumption.html>

U.S. Environmental Protection Agency (EPA 2011a). *Regulatory Impact Analysis: National Emissions Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters*. February 2011. http://www.epa.gov/ttn/ecas/regdata/RIAs/boilersriafinal110221_psg.pdf.

U.S. Environmental Protection Agency (EPA 2011b). *National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers*. February 2011. Accessed February 26, 2011. <http://www.epa.gov/airquality/combustion/docs/20110221areasourceboilers.pdf>.

U.S. Environmental Protection Agency (EPA 2011c). *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers*. February 2011. Accessed February 26, 2011. <http://www.epa.gov/airquality/combustion/docs/20110221majorsourceboilers.pdf>.

U.S. Environmental Protection Agency (EPA 2010a). *EPA's Action Development Process: Interim Guidance on Considering Environmental Justice During the Development of an Action*. July 2010. <http://www.epa.gov/environmentaljustice/resources/policy/considering-ej-in-rulemaking-guide-07-2010.pdf>.

U.S. Environmental Protection Agency (EPA 2010b). "Revision of Subpart AAA Residential Wood Heaters & Additional New Source Performance Standards (NSPS)". *Open Government Outreach Presentation*. May 21, 2010. <http://www.epa.gov/burnwise/pdfs/20100521nspspresentation.pdf>.

U.S. Environmental Protection Agency (EPA 2010c). *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters*. 75 FR 32006. June 4, 2010.

U.S. Environmental Protection Agency (EPA 2010d). *Hydraulic Fracturing Research Study*. March 2010. <http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf>.

U.S. Environmental Protection Agency (EPA 2010e). *Sources of Combustion Products*. September 30, 2010. <http://www.epa.gov/iaq/combust.html>

U.S. Environmental Protection Agency (EPA 2009a). "2005 National Emissions Inventory Data & Documentation: Tier Summaries." *Technology Transfer Network Clearinghouse for Inventories & Emissions Factors*. March 11, 2009. <http://www.epa.gov/ttn/chief/net/2005inventory.html>.

U.S. Environmental Protection Agency (EPA 2009b). *Strategies for Reducing Residential Wood Smoke*. October 29, 2009. <http://www.epa.gov/ttncaaa1/t1/memoranda/strategies-doc-8-11-09.pdf>.

U.S. Environmental Protection Agency (EPA 2008). *Reducing Urban Heat Islands: Compendium of Strategies*. October 2008. <http://www.epa.gov/heatisd/resources/compendium.htm>

U.S. Environmental Protection Agency (EPA 1995). *EPA Emission Factor Manual*. 1995. <http://www.epa.gov/ttn/chief/ap42/appendix/appa.pdf>

Union of Concerned Scientists (UCS 2010). *How Natural Gas Works*. Accessed September 2010. http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-natural-gas-works.html.

Vermont Department of Environmental Conservation (Vermont 2010). "Outdoor Wood-Fired Boilers: Facts & Information". *Air Pollution Control Division*. Accessed October 12, 2010. <http://www.vtwoodsmoke.org/regl-other.html>.

Washington Department of Ecology (Washington 2010). "Wood Stoves, Fireplaces, and Pellet Stoves." Accessed 8 October 2010.

http://www.ecy.wa.gov/programs/air/indoor_woodsmoke/wood_smoke_page.htm#Health_concerns.

White House (White House 2010) . Office of the Press Secretary. "Homestar Energy Efficiency Retrofit Program." *Press Release*. March 2, 2010. <http://www.whitehouse.gov/the-press-office/fact-sheet-homestar-energy-efficiency-retrofit-program>.

Wisconsin Department of Health Services (Wisconsin 2010). *Outdoor Wood Boilers (Water Stoves)*. July 12, 2010. <http://www.dhs.wisconsin.gov/eh/hlthaz/fs/waterstoves.htm>.