Wasted Thinking,
How Faulty Paradigms Waste Billions In Nation's Heating-A/C

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Report Number AIGI-NE-106-08

Abstract

The nation's 113.4-million homes, having nearly 89-million heating-A/C (HVAC) systems, consumed close to 624-billion kWh, or about 44.5 percent of all electricity used in homes as of the end of 2007. That number comes from operating the air conditioner, electric fan and/or heat pump or electric furnace. But considering all types of energy sources, the 89-million units with oil/gas furnaces use 56 percent of all household energy.

Although the HVAC usage is high as a percentage, the amount of energy consumed is not the biggest issue, but rather the quantity of wasted energy represented in that figure. The fact is these millions of units operate at approximately 34 percent below their efficiency standards, wasting some 212-billion kWh of electrical energy - enough waste to power 17.2-million homes for one year. If we eliminated this waste, these millions of systems would operate at 412-*billion kWh rather than 624*.

On a per home basis, the *wasted energy* is at least *five-times*, and in some cases, up to twenty-times more than the combined use of all other home devices. In addition, the HVAC systems is responsible for generating up to *six-times* more indoor pollution (toxins, germs, molds, allergens, house dust) than any other source.

The underlying reason for such waste by HVAC systems is very simple. It has to do with something called "starved airflow." To operate effectively, HVAC units need 400 cubic feet of air per minute (CFM) per ton. Yet, the nation's 89-million systems function with an average of 265-270 CFM/ton - a scarcity that accounts for most of the lost billions of kWh.

The mechanical causes for such shortages are multiple but primarily associated with three system chokepoints. They are: (a) airflow filter, (b) uncared for evaporative coil, and (c) undersized return air ducts. The inclusion of these, and other, chokepoints by the HVAC industry represent a misunderstanding of real-world ergonomics, dynamic air movement, and the methods microorganisms grow and spread debris.

In addition to these mechanical issues, there are even broader, more conceptual reasons that lead to such a severity of energy waste: HVAC systems are not factory-made, self-contained units, such as the common home appliance like a refrigerator. Rather, they are a collection of numerous parts that are assembled by a contractor in larger, more complex buildings. Often, this field assembly by a HVAC technician is erratic and inconsistent at best. This results in the building itself working against the functions of the HVAC system as the structure exerts powerful unseen forces in the form of dynamic laws in physics, chemistry, airflow, biology and ergonomics.

Over all, the airflow, energy and pollution problems are a consequence of serious issues that can be boiled down to five main factors: (1) old-line, unbending mindset and philosophy by HVAC's institutions not adapting to new conditions; (2) misdirected approach to HVAC by government regulations; (3) lack of skills, knowledge and standards of on-site assemblers; (4) traditional, commonly accepted built-in parts that starve and pollute airflow, and (5) lack of simple owner maintenance of dirty filters and A/C coils.

These five factors are interrelated, but one, in particular, has results that affect all others. It is the traditional outdated concepts that prevent the adaptability of the HVAC methods to changing lifestyles and environmental conditions. The inability of the HVAC industry to adapt to today's indoor environment literally results in an inconceivable quantity of wasted energy (measuring in the billions of kWh) and home pollution.

The Report

Ignoring An Energy Hog

For all our talk about conservation and energy savings, we virtually ignore a gigantic energy hog that is responsible for wasting some 212 billion of kWh energy every year – a waste that sucks up millions of barrels of oil and tons of coal. To put it into perspective, this wasted energy would be enough to power 17.2 million homes for over one year!

That's a staggering amount of electrical waste that largely goes unnoticed.

Why, you might ask, does such waste fly under the national radar? Most of the nation's attention goes to the use and waste of oil in the automobile industry. We can all relate to the pain we experience at the gas pump as the price of gas shoots ever and ever upward. However, many don't realize that another energy hog, which threatens to be just as large, lurks deep within the recesses of their homes. And along with the enormous energy use, there is a built-in energy waste of gigantic proportions.

Imagine if the nation's millions of automobiles operated 34 percent below their mileage efficiency: the waste would be enormous. The resulting waste in millions of gallons of oil and billions of dollars would cause an overwhelming outcry from consumer and environmental groups alike. As a nation, we couldn't afford it, nor allow it. So, as required, automobiles are kept at reasonable efficiency (measured in miles-per-gallon) through periodic smog, safety, and system diagnosis measurements through the use of a dynamometer.

Sadly, however, there is a similar waste occurring within each of our own homes -- a waste that when added together represents billions of dollars in lost energy. Yet, there's no outcry, not even a whimper.

Currently, there are 113.4 million homes in the country, which use approximately 1,395-billion kWh of electricity per year. About 624-billion kWh of electricity is used to operate the aforementioned energy hog – the nation's 89-million home *heating-A/C systems* (HVAC). However, here's the kicker: the heating and cooling systems commonly operate 30 – 45 percent below their efficiency rating, resulting in billions of wasted kWh – or approximately 212-billion kWh in lost energy.[1]

The waste is so large it represents at least five-times, and in some cases, up to twenty-times more wasted energy than the combined use of energy of all other home devices. And yet, little, if anything, is being done to deal with the scale of the problem. It's akin to being hid under the proverbial national "cabbage leaf".

Operational Components of HVAC

As reported by *"Energy Hogs, The Scale Of The Nation's Energy Problem,"* the reason for this huge waste by millions of heating-A/C systems (HVAC) is fundamental to all heating and air systems -

[1] Benjamin Bigelow, *Energy Hogs, The Scale Of The Nation's Energy Problem, by Benjamin Bigelow*, June, 2008

"starved airflow." The air conditioning portion of the system requires 400 cubic feet of air per minute (CFM) per ton wet (wet, meaning a functioning A/C unit with moisture condensation) for efficiency.[2] The national average is about 265-270 CFM per ton, consistent with audit findings.[3] Energy audits have reveled that: *"…low- evaporator coil air flow was discovered in all homes."*[4] This scarcity of airflow (the lifeblood of any forced air system) for America's HVAC systems accounts for the most of the energy waste.

What is the cause of the reduced airflow?

At a specific level it can be blamed on the use of traditional, built-in chokepoints and parts. It's comparable to choking off needed air to an automobile engine. What is the result? Needed power disappears. The same is happening to the nation's HVAC systems. Inadequate airflow results in reduced power and energy waste. In a sense, the system is being "choked to death."

> The term "coil" is used multiple times in this report. But the air conditioning system has two coils: (a) the outside **condenser coil** that includes the refrigerant compressor, and (b) the inside **evaporator coil** located at the blower/fan housing. To prevent confusion when referring to the inside **evaporator coil** we will, in most cases, use the short version **"e-coil."**

The biggest impact from reduced airflow is on the air conditioning or heat pump components of the HVAC system. Such units require the 400 CFM per ton in order to meet what is termed "Seasonal Energy Efficiency Ratio (SEER)," established by government and institutional regulations. Most homes are equipped with 2, 3 and 4-ton systems – requiring 800, 1200, and 1600 CFM respectively. However, rarely do these homes achieve performance anywhere near these ratings.

Why?

The fundamental reason is conceptual: the industry clings to antiquated methodologies that struggle against changing lifestyles and new environmental conditions of the nation. These archaic, institutionalized methods have resulted in the unintended consequence of built-in chokepoints within an operating HVAC system. There are three major and four minor points within an air system that commonly choke-off airflow. The major blocking points are:

1. System airflow filter
2. Unmaintained A/C evaporative coil (e-coil)
3. Undersized return air ducts

The minor chokepoints (in some cases, they can become major) are:

1. Restrictive air grills and registers.
2. Excessively long ducts, "L" bends and severe pinching of ducts.
3. Ribbed flex-duct.
4. Gas/oil furnaces choking airflow to A/C e-coils.

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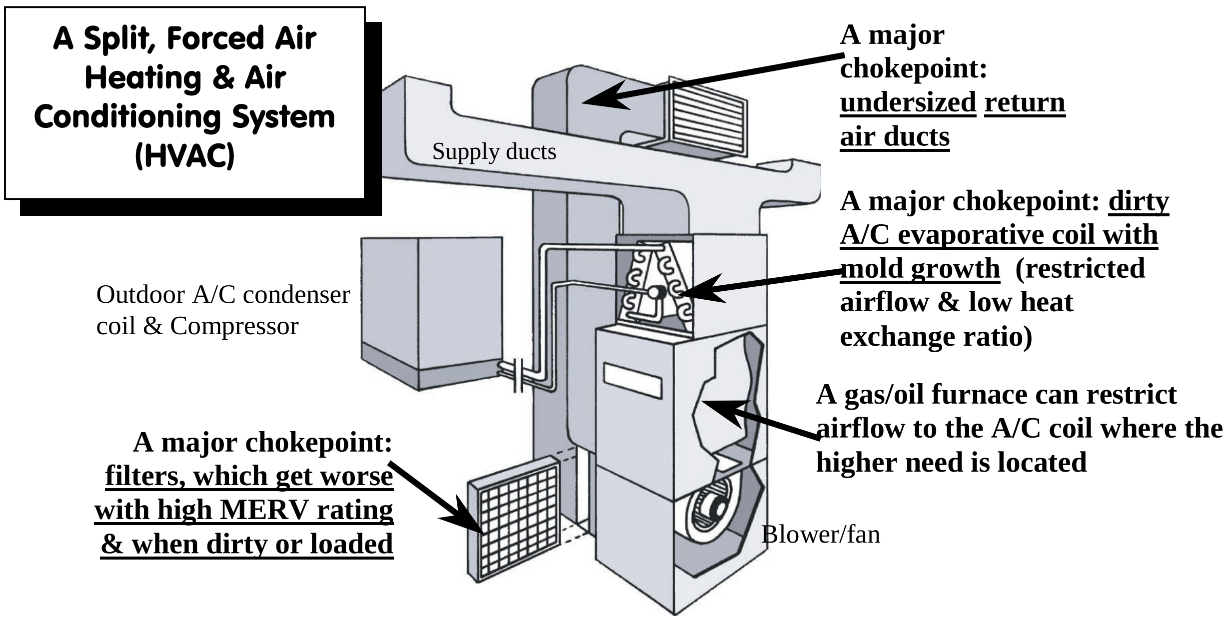
[2] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," June 1997

[3] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," June 1997

[4] Danny Parker, Florida Solar Energy Center, "Measured Energy Savings From Retrofits Installed In Low-Income Housing In A Hot and Humid Climate," June 1998



A detailed discussion on these component restrictions will appear under the "*Traditional Parts Starving Airflow*" section. But for now, a discussion of general system operations follows before developing the component causes for such large waste within the nation's HVAC systems.

Highest Energy Use

The greatest electrical need in HVAC is air conditioning (unless the system has an electric furnace). System needs range from 55 to 80 amps (for both fan/blower and condenser coil operations). The exact amounts depend on whether the unit is a standard A/C unit (cooling only) with gas/oil furnace, or a heat pump unit (does both cooling and heating, summer and winter). If the system is an electric furnace, the winter cycle will also use up to 50 amps.

There are other problems beyond airflow that affect HVAC systems: insufficient gas charge or blocked refrigerant metering, or damaged compressor or fan parts. But these are generally not the issue, and if they are, they are normally identified and corrected rather easily. On the other hand, critical airflow problems tend to go unrecognized by contractors - they do little or no airflow testing or end-up using methods and components that exacerbate airflow. So this report raises the bar on the critical nature of airflow in system operations.

What this illustrates is that the annual electrical needs for HVAC systems are well beyond any other home electrical device. Total electrical use for HVAC systems is about 45% of total home kWh consumption. If one accounts for the use of natural gas/oil furnaces, HVAC then represents about 56% of total household energy uses.

Considering the nation's total electrical household consumption (1,395-billion kWh in 2007), the percentages shape up approximately like this: **(a)** all related HVAC use at about **44.5 percent; (b)** electric water heaters about **9 percent; (c)** kitchen appliances (ranges, refrigerators, etc.) and laundry (washers, dryers) uses **31.5 percent; (d)** lighting uses **9 percent;** and **(e)** home electronics (televisions, computers, etc.) uses about **6%.**

Bottom line, all related HVAC use is the undisputed champion of electrical use within the home -- the true energy hog. If one has an electric furnace (found mainly in mobile homes and in homes in the

South East) or a heat pump (scattered through the nation), electricity for wintertime use adds even a heavier burden of electrical energy consumption for HVAC systems.

Component and Time Factor Electrical Uses

The consumption of electrical energy by HVAC systems deals with two different demand *components* (and possibly three in the case of electric heat), and two different functions of *time.*

Component uses: in a typical A/C unit, heat pump or electric heat unit design, the system *fan/blower* and the *condenser/compressor* components are separate electrical demand points, having their own circuits. The total real time use of energy for A/C operations is the sum of electrical use of these two components.

However, the rise and fall of electricity of these two separate elements is not necessarily tied together. For example, in order to overcome the resistance of airflow through a filter and to gain 400 CFM per ton through the e-coil, a contractor might increase fan speed. In doing so, the energy use at the fan jumps, but with 400 CFM gained for the condenser/compressor there is no corresponding increase in energy use. It is only when the CFM drops away from the key 400 CFM/ton number that the condenser coil has an equivalent leap in electrical use – and it's here, this loss of airflow, that the nation's HVAC units suffer in excessive use of energy.

Real-Time Energy Use vs. Cooling Load Hours Energy Use: The term "*Real-Time Energy" is used to represent the measure of electrical use at a point of time* – meaning, if an instrument showed a utilization of 600 watts at the fan and 2500 at the condenser, those two numbers are real, point-in-time measurements. In a sense, this measurement is not a function of time, other than comparison. On the other hand, *Cooling Load Hours is a function of time;* this is a measure how many hours an air-conditioner operates in a year to meet the demand of a set thermostat temperature.

The total amount of energy saved by a system would be the sum of the savings achieved by these two measurements (Real-Time and Cooling Load Hours). For example, if a measure of Real-Time were done *before* and *after* improvements were made, the difference would be "Real-Time savings. Assuming the changes resulted in the reduction of energy use then the Real-Time function of the system is more energy efficient.

In addition, energy savings can be achieved simply by using the air system less. If the annual time (Cooling Load Hours) of operation drops from 4000 to 3000 hours, less energy will be used. Perhaps less operating hours is the best of all possible savings. For example, the average airflow for the nation's 89-million A/C systems is about 270 CFM/ton -- meaning when the typical home sets the thermostat at 70º F, the system struggles to reach that temperature because of such small volume being propelled back into the home – and with such little airflow, the air is also not cooled efficiently. Under these conditions, it could take hundreds of hours longer in a year for system load to reach the set temperature before the thermostat takes a system breather.

What if the chokepoints were eliminated so the unit could maintain a flow of 400 CFM/ton during its life of operations? Not only would there be a much larger volume of cool air flooding the home at a faster rate, but also each cubic foot of air is cooler because of the efficiency of heat transfer at the e-coil. This means the system usage of time could possibly be reduced by 30 – 50 percent. Does this represent a huge reduction in energy waste? Of course!

In addition, with 400 CFM per ton flowing through the system, the system also experiences a reduction of Real-Time energy use due to a couple adjustments, namely, a reduction in fan speed, and the elimination of something called refrigerant "slugging" (more discussion on this later). The question that arises is how does one eliminate chokepoints for such improvements? Or, in other words, how can one achieve the recommended 400 CFM per ton rather than the 265-270 CFM most systems function at? The answer can be found in a report "*A New Paradigm, Solving the Nations Energy Waste in Heating-A/C.*"

<u>Airflow Critical To Efficiency</u>

One might ask why the simple process of airflow has such a massive impact upon the nation's HVAC systems. There are two factors that determine the effectiveness of air volume though a system: (1) something called "air resistance", measured by "static" pressure, and (2) volume of airflow, measured in cubic feet per minute (CFM). There is a direct relationship between these two: if there is drag or resistance (static pressure) on the flow of air, then the needed volume of air (CFM) required to pass a point at given rate <u>drops</u>.[5]

Why is CFM so important? First, the principle of cooling the air in the A/C system is based upon "evaporation" -- not in the airstream, but rather evaporation within a condensed medium. The simple explanation is this: if one puts water on their arm, they will notice a cooling affect as the water evaporates from the skin. Evaporation requires heat to change the state from liquid to a gas (airborne moisture). In our example, heat is drawn from the skin, resulting in evaporation and a cooling effect on the skin.

This principle of evaporation is used in the air conditioning system. First, the condenser coil (on the outside of the building) compresses a gas into a liquid, called a refrigerant. This liquid travels into the building via copper tubing, ending up at the evaporative coil (located at the system fan and/or furnace housing). The evaporative coil has fins like an auto radiator. It's at this coil where the liquid begins expanding, changing its state, evaporating back to a gas. To evaporate, the refrigerant needs heat, and plenty of it, which it gets from circulating air passing through the fins and e-coil, pushed by the fan. The fins act as the transfer medium of the heat to the refrigerant inside the e-coil -- leaving behind cooler, circulating air.

The <u>e</u>vaporator or e-coil has been sized (surface area) with a certain number of fins per running inch to match with the recommended airflow of 400 CFM per ton. This is done to achieve the most effective heat transfer per volume of refrigerant. The more efficient the heat transfer, the better the evaporation and cooling effect and energy efficiency.

The basic problem lies herein: there will be <u>inadequate heat transfer and evaporation</u> when the air volume drops below 400 CFM per ton. And with the circulating air not being properly cooled, the thermostat keeps the system fan operating much longer than necessary -- wasting energy. In addition, this hastens "slugging" of the refrigerant – a common problem where un-evaporated liquid, rather than a gas, travels back to the condenser (to be compressed once again), causing undue stress to the

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[5] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," June 1997

compressor. In many cases, slugging ultimately leads to compressor failure.[6] As you've probably guessed, this strain causes energy use to soar.

As mentioned, an effective HVAC system requires the removal of heat from the air to comfortably cool a home. Essentially, there are two types of heat removal: (a) *sensible heat*: reaching the point where the air temperature is comfortable, and (b) *latent heat*: the right air volume at which moisture will condense out of the air onto the e-coil fins -- in other words, the right temperature transfer per volume of air for moisture removal. If humidity is too high indoors, the environment becomes very uncomfortable, oppressive. So, moisture removal is an important benefit of air conditioning, and latent heat must be considered when making air volume considerations.

For *sensible heat* to optimally reach comfortable temperatures, it requires 400 CFM per ton. However, *latent heat* only requires approximately 350-365 CFM/ton across the e-coil for optimal indoor humidity reduction. A good running average to influence both sensible and latent heat should be in the neighborhood of 395-400 CFM/ton wet. At these volumes latent heat is affected only with about a 10 percent reduction factor.

Yet, as mentioned, most of the nation's 89 million HVAC systems operate between 260-270 CFM/ton.[7] The cause for such low CFM is *airflow restriction by chokepoints*, limiting the required volume of air. As the result, the system operates longer hours, and under much greater stress, consuming greater quantities of electrical energy. When there is drag or resistance on the system air, the fan struggles to push air, doubling or tripling wattage. Liquid slugging stresses out the compressor, quadrupling electrical consumption. When added all together, the result is waste on a gigantic scale.

The problems of chokepoints are a consequence of some serious overriding issues. These can be broken down to five major factors that affect in profound, negative ways the nation's forced-air systems. These factors are:

1. An old-line, unbending mindset and philosophy by HVAC's institutions not adapting to new conditions
2. Misdirected approach to HVAC by government regulations
3. Lack of skills, knowledge and standards of on-site assemblers (HVAC contractors)
4. Use of traditional parts that starve airflow
5. Lack of simple owner maintenance of filters and A/C e-coils, which in turn, block airflow.

These five factors are interrelated. However, one in particular, directly or indirectly affects all the others -- outdated concepts that prevent the adaptability of HVAC methods to changing lifestyles and environmental conditions. The result is carnage with wasted energy in billions of kWh, along with an elevated pollution source.

(1) Industry Entrenched Concepts And Structures

Unbending Mindset

[6] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," June 1997

[7] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," June 1997

As described above, the causes of this hidden waste are multiple and menacing. The first of these is something we term *"an unbending mindset or paradigm of the HVAC industry:"* -- in other words, clinging to antiquated concepts and processes that do not match well with changing conditions of modern societies, buildings and environments.

Energy-tight homes, larger populations and newer customs have created different indoor dynamics that make many HVAC methods obsolete. What is not well understood by the industry is that HVAC systems are not singular self-contained systems, but are now part of much larger structures and buildings. And within these bigger enclosures are powerful, unseen forces at play: new dynamics relating to the laws of physics, chemistry, airflow, biology and ergonomics.

It must be said that there is much that is commendable about the state of HVAC systems on the technical side. The engineering and component manufacturing is not only good, but in most cases, superior. Institutions, such as American Heating and Refrigeration Institute (AHRI), assure technical integrity of HVAC system components by establishing engineering standards, along with certifying each manufacturer's line-parts and related components.

But this has to do with the technical standards of <u>unassembled parts</u>, which are not problematic as separate pieces. Rather, the problem results from misdirected concepts, antiquated methods and misunderstanding of how separate components come together, are assembled and operate on site, within real world surroundings. The industry has been traveling much the same path – in their comfort zone for the last 75 years. In this scenario, adaptation to new dynamic conditions is very difficult, if not impossible.

An example of how the industry is so entrenched in it's thinking is their unquestioning acceptance of air filters (based upon an antiquated paradigm of capturing dust) and flex-ducts (a convenience for the contractor, but not airflow effective on the return duct side) for operational HVAC systems.

<u>First</u>, what is not understood is that the old-line system filter is one of the largest indoor sources of airborne contamination and one of the primary causes of air starvation and wasted energy. Filters are generally rated by what is called the MERV standard, which stands for "Minimum Efficiency Reporting Value." Basically, the MERV rating will indicate the ability of a filter to capture small particles. What we've found within the HVAC industry is a high propensity to "upgrade" HVAC systems to filters with higher MERV ratings. There is a perception that this is in some way better for the system. In fact, within the HVAC industry, the term 'high-efficiency filter' is a term often used to describe filters with a high MERV rating. However, in reality this is simply not the case -- the higher the MERV rating, the larger the air starvation and, thus, the greater the energy loss. This is a good example of *an outdated paradigm working against what should be the correct agenda of energy use and indoor air quality*.

<u>Secondly</u>, the use of flex-ducts generally reduces airflow because of the ribbed construction of the duct material, also starving the system of critical air.

Yet, despite these issues, the industry remains loyal to both these major components, particularly the filter. The only allowance made for filter variation is in different forms (HEPA, electronic, electrostatic, media, etc.) and MERV ratings. As this suggests, the industry tends to cling to antiquated methods, achingly slow to change along with trends in other areas such as: building materials, construction methods and lifestyles.

It was over one hundred years ago when Willis Carrier invented the type of refrigeration that now conditions the air of our buildings. Not much has changed since that promising technical beginning. Engineering improvements have enhanced the performance of the HVAC system, but the technical process itself has remained the same. In truth, the HVAC industry is an old-line industry, hedged in with entrenched concepts and structures made up of manufacturers, associations, and contractors with attendant capital structures that make change difficult.

The Whole House Effect

As mentioned above, the HVAC industry seems to be resistant to, or slow to recognize the idea that an operating HVAC system is not a self-contained appliance, but, rather a system made up of different components – filters, grills, ducts, registers, and the like. A HVAC system is much greater than a single furnace or air conditioner. It's an integrated part of a larger system – a building or a home. In a sense, the HVAC system is the environmental equivalent of a heartbeat -- forcing air through arteries of ducts into the larger body. However, being part of a larger system -- part of that immensity of wood, steel, glass, paint, cement and the like that make up today's buildings – means that the system will inevitably meet counter forces that make the HVAC system susceptible to the dynamic influences of the building itself.

With HVAC casting duct-like tentacles across the body of the home, it's the outer walls of the building that, in a sense, become the skin of the HVAC system. The walls of our homes protect us and hold most everything – both good and bad – within. As airborne conditions change within the building, those changes affect the smaller confines of what is thought of as the "system," and vice-versa.

This concept of connections between the HVAC system and the home doesn't seem to be well understood by HVAC institutions, manufacturers, contractors and homeowners. It appears that these groups mostly view the HVAC system as a stand-alone appliance, set in place by a installer that will, no doubt, operate within the specified standards determined by the industry's engineering and testing laboratories.

Shared Contamination and Bio-Nesting

We will now review how the building, the people within, and the HVAC as part of the whole affect the indoor environment. Let's begin by looking at the quality of indoor air. Fact: the indoor environment of America's homes is more polluted than ever. The indoor air contains some 6-7 times more toxins, germs and house dust than even fifty years ago.

The EPA now lists indoor pollution in the top four pollution problems in the nation.[8] Risk studies by the Science Advisory Board consistently rank indoor air pollution among the top four environmental risks to public health – ranked in order of environmental risks:

1. Nuclear Waste
2. Outdoor Pollutants and Green House Gases
3. Super Toxic Dump Sites

[8] Environmental Protection Agency's Website, www.epa.gov/iaq, accessed June 2003

4. Indoor Air Quality (IAQ)

The hazard of indoor pollution has increased over the decades to be ranked with the notorious, top tier of environmental risks. There are many causes for the increased levels of indoor pollution. These are:

1. Modern building by-products
2. Higher indoor moisture content
3. Higher use of cleaning and other chemical products for personal and household use
4. Higher indoor microbial growth and debris
5. More concentrated human by-products (such as hair, dander, dead skin, etc) caused by people living/working indoors at a much higher percentage than in former years
6. Higher presence of insect, cockroach and dust mite feces and debris
7. Bio-nesting growth within the HVAC unit (possibly the largest source of indoor pollutants)

As previously discussed, the outer walls of the home are the skin, the outer limits of the HVAC system. The two are irrevocably tied together with a common element -- indoor air. What affects one area will undoubtedly affect the other. In many ways, it is due to this common connection, that airborne pollution and higher particle counts are finding their way into our modern homes and the HVAC system. This indoor pollution, in turn, blocks airflow, causing a drop in operating efficiency – raising energy costs and waste.

But that is only part of the story: the HVAC system produces much of its own pollution and debris that affects operations. And, of course, the contamination generated by the HVAC system is then distributed back to the home, where people live. It seems that the HVAC system is the biggest culprit of indoor pollution. This generally occurs in two ways:

1. When the HVAC system operates, it can pull through the system (from the building's air space) a volume of air equal to 100-percent of the building's air volume about every 8-12 minutes. Hence, pollution and debris generated within the home is dragged by the HVAC fan into the system and back out again, redistributed to every nook and cranny of the building - spaces not previously contaminated become such.

   The "Venturi Effect", a scenario where air velocity speeds up as it passes through progressively smaller holes, drag high volumes of debris with it. Debris that was stationary and affixed in home spaces becomes airborne as it is pulled into the small opening of the HVAC return air entry. Furthermore, a certain percentage of this circulating debris collects within the system filter and A/C e-coil, starving airflow and increasing energy consumption.

2. The HVAC is perhaps the largest single source of contamination in the home based upon the biological nesting that occurs within the system. Simply stated, the system filter and the e-coil are perhaps the largest growth source of bacteria and mold in a typical home. It is estimated that the HVAC system produces up to 6-times more indoor pollution (toxins, germs, molds, allergens, house dust) than any other source. The by-products of this growth are airborne versions of:

   a) Pathogenic organisms
   b) Toxic metabolic gases (formaldehyde and benzene) from the microbial growth
   c) Aggressive allergens, such as mold spores and mycelium enzymes particles
   d) Microbial debris, dust and body parts.

Extreme levels of pollutants and toxins come from this growth, circulated by the system fan into the breathable air space. *Thus, the HVAC system not only grows the pollutants, but also becomes the mechanism by which they are propelled back into the space where people live.* In addition, this HVAC growth also loads up the filter and e-coil, choking off airflow.

In conclusion, there is a direct relationship between system collection and growth of pollutants and debris and energy consumption. Furthermore, what is generated within the house as a whole has a direct bearing upon the efficiency of the system.

Energy-Tight Buildings Seal In Contaminates

During the 1970's, the U.S. faced major energy problems. War in the Middle East reduced worldwide oil production. Lines of cars formed at gas stations in both 1973 and 1977 due to the lack of petroleum. This led to new building codes to save energy within our homes and work places. The government required that buildings become *"energy tight."*

Before this movement to tighten up buildings, they tended to breathe with the outside air. Buildings were porous. The indoor air rather easily exchanged with the "fresh" outdoor air, helping to prevent a build-up of stale, contaminated inside air.

However, with the advent of energy-tight homes, pollution had nowhere to go and was essentially trapped within the home, resulting in stale, contaminated indoor air.

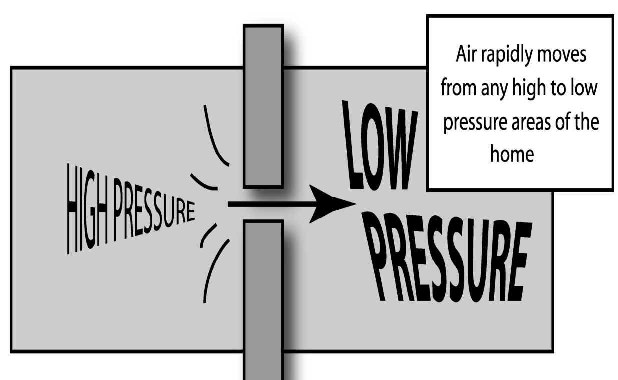
So, the root of indoor air quality problems can be traced, in part, directly to our need for energy-efficient buildings. High-energy costs changed the way buildings were constructed. These new construction methods resulted in pollutants such as fumes, gases, toxins, debris, dust and other contaminants being sealed inside, sometimes accumulating to unhealthy or dangerous levels.

Our buildings now reduce the natural-occurring exchange of indoor and outdoor air. *Making homes more energy efficient exacted an unexpected price – unhealthy, indoor air.* And what happens to the building affects the efficient operation of the HVAC system.

Infiltration of Contaminated Debris

In physics, there are two "laws" that apply directly to indoor air pollution, which in turn affect energy consumption of the system. They are:

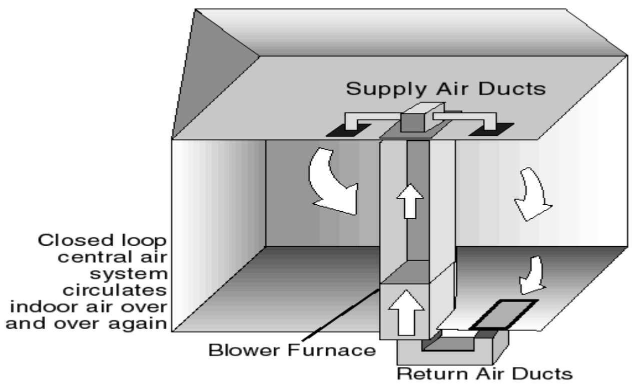
(1) High pressure air always moves to low pressure
(2) The smaller the hole in which a given volume of air has to funnel through, the higher the velocity of the movement of the air (with debris)



In essence, what this means is the greater the difference of pressure and the smaller the area through which air has to move, the greater the speed the air will move to the low-pressure. *This action creates the "Venturi-Effect" in which the air speed creates a vacuum that can actually "drag" large particles through the small opening with the rush of air.* Due to modern construction practices, these two laws of physics dealing with air pressure and velocity now play a rather extensive role in increasing indoor pollution. Since the walls/floors/ceilings are more "energy tight" in today's homes, the holes tend to be smaller, resulting in greater velocity of debris-filled air rushing indoors. The accelerated rush is caused by:

- **Negative indoor air pressure** results from the loss of air to the outside due to *leaky air duct systems*, and the *exhausting of air by range hoods, clothes dryers and bathroom fans.*
- **Outside contamination** is "sucked" into the building at a higher rate due to negative indoor pressure and the "Venturi Effect" bringing pollution from the attic, crawlspace and garage.

Example Of Closed Loop, Forced Air HVAC System



It is estimated that over 90% of the homes in the nation with forced air systems have leaky air return air ducts, pulling contaminates either into the system from return air ducts or causing negative pressure in the home - resulting in infiltration from the attic, garage, and crawlspace under the home.

In theory, the closed-loop-system circulates the same air in the home over and over again, with little air being introduced from the outside. But in reality, something else generally occurs.

This "closed-loop-system" creates unintended pressure differences. When the fan is operating, the *supply* ducts in most homes leak, in minor ways, air from in the ducts to the *outside* through the attic or crawlspace, *causing a pressure drop inside the building* due to the loss of air to the outside. In addition, the *return* ducts in most homes are the biggest source of air leaks, sucking in contaminated, outside air through wall cavities, cracks and flues.

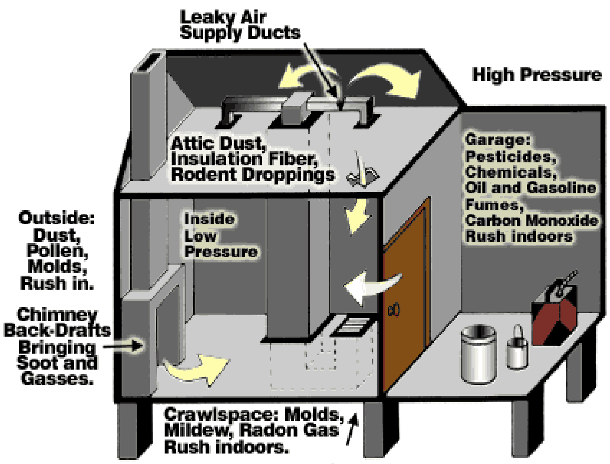
Pollutants infiltrating into the home from garage, attic and crawlspace:

Pesticides, Chemicals, Carbon Monoxide, Insulation, Rodent droppings, Pollens, Molds, Soot, Gases, Radon

In addition, the *use of clothes dryers, exhaust fans or range hoods can further worsen the negative pressure difference within the home.* Operating dryers push about 175 CFM to the outside world, causing an internal negative pressure drop; kitchen fans push out 75 CFM; bathroom fans exhausts 50 CFM; an operating HVAC system loses about 200-350 CFM. All this lost internal air has to be made up somehow: air rushes in (infiltrates) carrying polluted debris from dirty attics, crawlspaces and garages. This is an example of how our current lifestyle changes affect the indoor environment and energy consumption of a HVAC system.

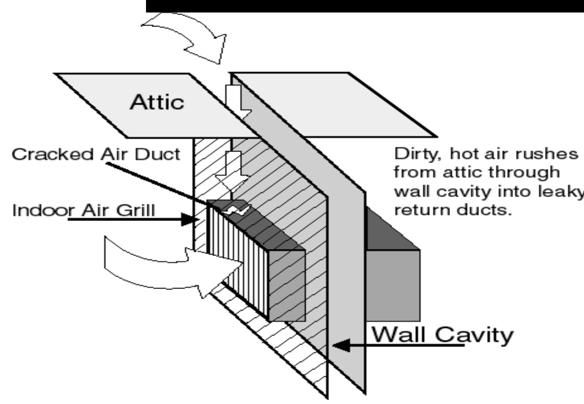
The illustrations below show a typical home environment and how pressure differences within can cause massive contamination to be pulled into our homes.

Contamination Caused By Leaky Supply Ducts

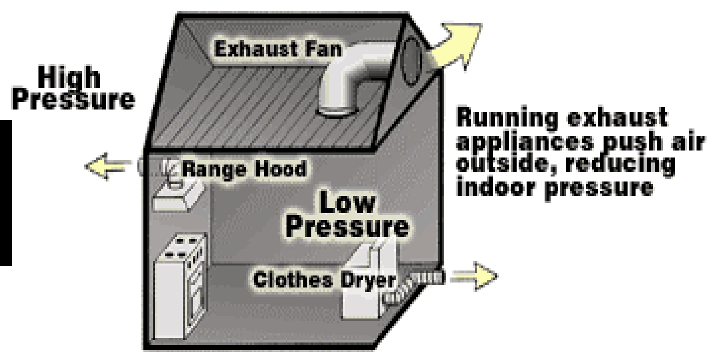


Air pushed outside by leaky supply ducts, causes outside to rush indoors, bringing contaminates.

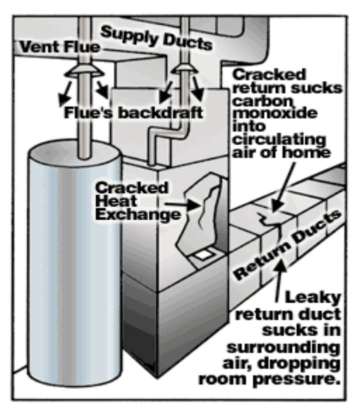
Leaky Return Ducts Pulling Contamination From The Attic



Negative indoor air pressures caused by exhaust fans



There are additional hazards created by *leaky return ducts*. Leakage in the return ducts not only draws in dirty outside air, but also may cause a more immediate danger, namely -- poisonous gas – caused by a dangerous pressure drop in the utility area. As illustrated, leaky return ducts can suck the air in the furnace room and from around the water heater, creating a negative pressure drop. If the system has a cracked heat exchange, and a negative pressure causes back drafting from the water vent flue, this can release carbon monoxide into the utility room and back through the leaky return duct into the home.



Leaky return ducts can suck air from surrounding area, causing a pressure drop. Outside air then rushes down the vent flues, pushing deadly carbon monoxide back into you home.

Lifestyle Changes

The way we live, the things we do and the conveniences of a modern society generate, in part, the indoor conditions we now face. The HVAC methodology has not adapted well to these lifestyle changes that have lead to the negative consequences being discussed.

1. **House Dust:** Close examination of common house dust shows that the "dust" is actually made up of a mixture of organic molecules (carbon and hydrogen). Dust is a hodgepodge of hundreds, if not thousands of smaller particles of different organic compounds - it's made up human/animal hair and dander, paint flakes, insect parts, insect/rodent feces, dead skin, carpet fibers, mold debris, plant pollens, etc. House dust is a product of how we live, an outgrowth of living indoors in a modern society – living/working indoors now up to 90 percent compared to 40-50 percent 75 years ago.

   This makes house dust considerably different than "outdoor" dust – much of which is non-organic. Since house dust is organic in nature, it becomes the nesting grounds and food source for dust mites, bacteria, molds and cockroaches. It is a reservoir for allergies and disease and the source of debris that collects at the chokepoints in the HVAC system, blocking off airflow and efficiency.

2. **Gases, Smoke & Odors:** Within our homes, we generate tremendous volumes of gases, fumes and odors from our newer lifestyle conditions. One group of toxic gases generated is the Volatile Organic Chemicals (VOC's). VOC's can be a carcinogen with a variety of health effects, including eye and respiratory irritation and damage; a hazard to heart, liver, kidneys, nervous system; cause for anemia and depression. Volatile chemicals can be found in a whole range of home-building materials, furniture, hair spray, chemicals in permanent-press clothing, or the soaps used in washing clothes or dishes.

   And yes, mold growing within the HVAC system generates high levels of VOC's as metabolic gases (formaldehyde and benzenes).

3. **Equipment conveniences and contamination:** Self-defrost refrigerators are a recent innovation for a "higher quality" of life. However, on the negative side, this appliance generates tremendous levels of mold growth, along with allergens and toxic metabolic gases – in the unit's refrigeration coils. To be convinced, just pull the drip pan at the bottom of the refrigerator and witness the black or green mold slime.

   Our lifestyles are much the same across the nation. We all tend to wash our clothes and dishes, and take showers and baths in much the same way – and in doing so, use hundreds, if not thousands of gallons of hot water that evaporates into airborne moisture. With homes being relatively energy tight, a hygrometer would find at certain points of a day, homes in Phoenix and Tampa will have similar, high levels of airborne humidity regardless of outside conditions. Anytime indoor humidity reaches and exceeds 50 percent (which most homes do when these water conveniences are in use), mold and dust mites have explosive growth. This results in an accelerated output of mold allergens and dust mite microscopic fecal pellets, which run into the billions. Of course, this debris becomes part of the house dust, which, in turn, collects at the chokepoints of the HVAC system.

The HVAC system is a part of our modern lifestyle (before 1947 A/C systems were rarely found in homes) - and as we have seen – it may be the biggest polluter and certainly the largest home energy hog to be found.

(2) Misdirected Government Regulations

Air conditioning and heating systems are doing their part to make America's homes the second largest consumer of energy resources nationwide -- second only to automobiles. Millions of barrels of oil, tons of coal, and billions of kilowatt-hours of electricity are involved in supplying energy for our homes. This massive strain on energy resources has drawn the attention of both state and federal governments. The federal government has now stepped in to try to legislate America out of an energy crisis.

In January of 2006, the U.S. Department of Energy announced the introduction of 30 percent higher efficiency standards for air conditioning coils and components produced in or imported to the United States. The standard would be raised from a Seasonal Energy Efficiency Ration (SEER) of 10 to 13.

Of course, this approach is, in many ways, flawed. It's not that the change in rules by the government caused the massive waste of energy - that problem developed for other reasons over years. However, the new regulations don't address the long-term problem adequately, and offer nothing but a short-term band-aid.

Here are some issues regarding the new regulations:

1. It appears the rules were designed to help us "feel good" about doing something. Unfortunately, it needlessly avoids effective strategies that could work, even in the short run.
2. With the new SEER standards, HVAC systems are treated as factory made, self-contained appliance. People looking at SEER ratings could come to the mistaken conclusion that the ratings are essentially the industry's version of an Energy Star rating, which, of course, would be wrong.
3. Savings reaped by the program, if any, are years away. The regulatory standard is for new installs only. With 1,500,000 – 3,000,000 new/retrofit units being installed per year, it will take more than 25 years before the present 89-million systems are replaced
4. The majority of new 13+ SEER rated systems being installed fall short of anticipated savings of required SEER.

Fundamentally the legislation is firmly planted within the old industry agenda -- outdated HVAC concepts. The new regulations did nothing to correct the methodology, and, perhaps, even have complicated the problem -- especially, if expectations are for a huge rush of savings. Such a large crisis of energy waste cannot be corrected unless much of the industry's agenda is first corrected.

The Feel-Good Effect

The problem is that government standards do not tell the whole story when it comes to the actual energy efficiency of America's air conditioners. The fact that air conditioners must now meet a standard of 13 SEER may look good on paper, but once installed, these air conditioners might actually only be achieving the performance of a 10 SEER system or lower.

How can that be? For one thing, lab conditions are much different than real life conditions. While many variables that affect actual energy efficiency have been controlled in a laboratory setting, they remain uncontrolled in America's homes. Advanced Energy reports the following:

> *"When a manufacturer sends equipment to a laboratory to establish its SEER rating, you can bet the equipment is set to perform its best under the test conditions. But real conditions in a home, not controlled lab conditions, determine how equipment will perform…"*[9]

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[9] Advanced Energy, "Get the FACTS about SEER and Deliver Better Customer Value," 2000, http://www.advancedenergy.org/buildings/knowledge_library/heating_and_cooling/seer_facts_bulletin.pdf (accessed August 12, 2006).

Field experience often shows that these conditions are not being realized, and the equipment performs lower than its rated SEER. In other words, A/C coils that are rated to perform at a level of 13 SEER in a lab will most likely fall short of that mark when installed with other components in a home.

As already discussed there are a multitude of factors that affect actual energy efficiency of air conditioners — so many, in fact, that it would be impossible for the government to mandate standards for all of them.

A Savings, If Any, Years Away

The U.S Department of energy admits that if there are savings, it will be over 25 years in happening. As reported in *Energy Hogs*, "*The rise in efficiency would, according to the Department of Energy, save 4.2 quadrillion Btu's (quads) of electricity over the next 25 years."*[10]

And further, even if there was some way of saving 4.2 quads of energy over the next 25 years, that is small when compared to the rise in energy consumption and cost in the short run. In other words, government standards are not offsetting our increasing appetite for energy now.

Yes, if the industry methodology was first corrected, the standards set by regulations could have a positive long-term effect within that new framework, but there would still be little impact upon short-term savings, a savings that is desperately needed now.

So something else must be done to realize what could be the largest single source of energy savings in the shortest period of time – correcting the energy waste of the existing 89-million HVAC systems in America.

(3) Inferior On-Site Assembly

The Competency Factor

To a large degree, the competency of the HVAC contractor determines the efficiency of an operating HVAC system. A properly trained installer can take certain measures to assure that the air conditioning unit can function near the SEER ratings established by a testing laboratory. Advanced Energy reports that a competent contractor: *"may be able to deliver greater comfort and lower energy costs using SEER 10 equipment than another contractor delivers using SEER 14 equipment."* [11]

You'll notice they say a contractor "may be able" to do this. This is because, in reality, a contractor will rarely be able to achieve anywhere close to the theoretical standards set by a testing laboratory. Therefore, there is little, if any, hope of achieving even a minimum standard of energy efficiency in practice. The reason? It's simple, a HVAC system is a "custom assembly" of hundreds of parts taking place on site – and not under factory certified standards.

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[10] Chris Kielich, "Stronger Manufacturers' Energy Efficiency Standards for Residential Air Conditioners Go Into Effect Today," U.S. Department of Energy, http://www.energy.gov/news/3097.htm (accessed August 12, 2006).

[11] Advanced Energy, "Get the FACTS about SEER and Deliver Better Customer Value," 2000, http://www.advancedenergy.org/buildings/knowledge_library/heating_and_cooling/seer_facts_bulletin.pdf (accessed August 12, 2006).

A HVAC system is not a finished, self-contained appliance, which neatly leaves factory doors, boxed in ribbons and bows. HVAC units are "installed" at building sites in entirely different ways compared to home appliances, such as refrigerators, ranges, microwaves, TV's, computers, washers/dryers, etc. These self-contained, factory assembled appliances leave a plant under the riggers of strict quality control standards and specifications.

This is not the case with HVAC systems.

In fact, a HVAC system consists of up to fifty separate pieces coming from many different suppliers all combined together in a custom installation by a heating and air conditioning contactor. The installation, or 'on-site manufacturing', performed by the contractor is an important variable in considering the effectiveness and efficiency of a HVAC system, because how the unit comes together is entirely at the mercy of the field contractor. Unfortunately, most of these professionals lack the competency and training to apply factory standards and quality control at the site. For example, it is estimated that only about six-percent of the nation's HVAC contractors ever do a simple "static test" or "airflow measures" to validate the effectiveness of their system assembly.[12] Under such substandard, on-site manufacturing conditions, flaws abound during the installation process.

It is for this reason that many contractors, assembling systems at identical sites, will install vastly different designs. And because the variables surrounding HVAC operations are so numerous (and rarely accounted for), each system will have several deficiencies. In practice, each HVAC site is "custom-made," the designs coming from uneven, inconsistent practices of contractors - and limited by an array of unrecognized variables.

This means that HVAC systems cannot be classified with anything approaching energy standards, such as factory-produced home appliances. Refrigerators, ovens, dryers, washers, TV's, etc., can be effectively energy rated because: (a) these single-set, autonomous home appliances are not part of the building itself. The environmental forces within the home affect them very little; and (b) these self-contained appliances come from the factory as a single inspected unit. Therefore, an appliance with the 'Energy Star' logo can be used with confidence that the product will indeed reach and maintain its peak operating performance in its operation.

Again, this is not the case with HVAC equipment.

It goes beyond reason that individual parts, custom-assembled in the field by untrained installers could assemble anything close to laboratory set standards. In practice, this does not happen. Furthermore, most contractors rarely do after-install testing to verify effective operations of a system.

In conclusion, the establishing of rated standards by governmental agencies and institutional associations for field assembly and operation of air conditioning systems cannot and will not make any appreciable inroads in efforts to significantly reduce energy waste in the home. It is important to note that these minimum standards are only required on new installations, and, as illustrated earlier, these installations continue to fall far below these minimum standards. So, by their own ratings, they are failing.

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[12] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," p. 1, June 1997

In addition, the situation will only get worse over time. If a new system is running 20 percent below its stated performance rating immediately after installation, how will it run when it is 5 years old? 10 years? The average age of America's HVAC systems runs between 10-12 years.[13] Think how the operating conditions of these units have deteriorated since initial install.

Inadequate Tools for Testing

Part of the reason so few contractors do any pressure or airflow tests following installation is due to the lack of availability of sophisticated tools developed for HVAC specific tests. For example, automobiles are kept at reasonable efficiency (measured in miles-per-gallon) through periodic smog, safety, and system diagnosis measurements by the use of such things as dynamometers. However, no such tool exists to fine tune a HVAC system.

Of course, this may not be a fair comparison: cars are autonomous units, rolled off assembly lines. They are thoroughly tested in quality control and set-up to be systematically maintained under dynamometer tutelage. Unfortunately, HVAC has no similar process or equivalent diagnostic tool.

Yet, in many ways, HVAC, by its nature, needs more and better computing devices for compound system diagnostics -- something to analyze on-site complex variables and bring together a telling picture of integrated functions that lead to superior system performance. Such a device would not only be useful for initial setup, but also for after-market maintenance.

The industry is way behind others when it comes to availability of sophisticated testing devices. Such devices are sorely needed for onsite assembly. Major progress is needed in this area if there is any hope to create more standardized testing to verify high performance and low energy consumption.

(4) Traditional Parts Starving Airflow

As previously stated, there are three key components that restrict airflow in the system. They are: (1) highly restrictive (those with high MERV ratings) and/or clogged filters, (2) clogged A/C evaporative coil (loaded with debris and mold growth), and (3) undersized return air ducts.[14] When one thinks of a HVAC system, one imagines the system air ducts reaching out, tentacle-like, across the home feeding conditioned air to its occupants. However, it must be noted the *three major chokepoints are located in only one segment of the system -- the air return side of the system,* not in the supply side that feeds conditioned air back into the home. This understanding is vital: the majority, if not all of the energy and pollution problems of the HVAC system are confined to this one sector. Thus, if this one area can be modified and restructured to work better in today's environment, then the majority of the energy and pollution issues can be solved. Efforts in other sectors within the HVAC system will not yield as good results and, therefore, are not recommended until the return side of the system is made to be as efficient and clean as possible.

This doesn't mean that other components of the system aren't problematic. They are. To a large degree, these other issues consist of one of two problems. They are: (a) gas or refrigerant charge malfunctions at the condenser coil, and (b) inadequate fan function and speed for indoor cooling.

[13] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," p. 3, June 1997,

[14] D.S. Parker, Florida Solar Energy Center, "Measured Energy Savings From Retrofits Installed In Low-Income Housing In A Hot and Humid Climate," p. 4, June 1998

However, take note that these issues exist primarily because of inadequate airflow at the e-coil. So, again, we are faced with problems of airflow restriction!

So simply stated, airflow resistance and inadequate air volume are the major culprits to system efficiency. As the result, studies suggest that the nation's installed HVAC systems: "*…only operate at 55% to 70% of rated capacity*."[15] This would suggest an *inefficiency* level (SEER) of air conditioners of 30 – 45 percent - we use in our report an inefficiency factor of 34-percent for HVAC systems.

As you are probably aware, there are two coils and fans within a HVAC system. As mentioned, the two coils are: the evaporative coil or e-coil (located inside at the fan/blower housing), and the condenser coil (located outside with the gas to liquid compressor). The indoor fan circulates the air throughout the house while the outdoor fan cools the compressor in the condenser unit.

To better understand these elements, let's look at how these connections develop and why related problems arise. Of course, there is always a chance of component failure, which can negatively affect the system. However, as you'll see most issues related to efficient system functions are linked to airflow volume and air resistance.

Cubic Feet per Minute (CFM): simply stated, the efficiency of either the HVAC condenser or e-coil is dependent upon achieving the proper amount of airflow. As mentioned, the proper airflow for the HVAC system is 400 CFM per ton passing through a **clean** e-coil. The reason for this is the 400 CFM per ton dictates the proper gas-charge level and the metering of the refrigerant flowing from the compressor/condenser coil. As the amount of air flowing through the system drops, the evaporation rate at the e-coil deteriorates. And when that happens, not only is cooling efficiency lowered but *slugging* back to the condenser accelerates.

There are system designs that have no connection to airflow problems, but can seriously affect efficiency of the HVAC unit:

- System over sizing, causing what is referred to as "short-cycling." Short cycling uses increased energy consumption and wear and tear by turning off/on too fast and too often. It is estimated that about 50 percent of all systems over 10-years old have this problem.
- A/C return air duct return *intake opening* not near the stratified hot-zone of the ceiling of the home. The hotter the return air, the more efficient the evaporation and cooling at the e-coil. Most of the nation's return intakes are at or near the floor, limiting e-coil efficiency.

To carry this analysis one step further, the level of charging and metering of refrigerant at the condenser coil is set for 400-CFM per ton at the e-coil. However, since most real world systems operate around 270 CFM per ton, then *overcharged* (or excessive refrigerant) is the common state of America's HVAC systems. This overcharged state is not only terribly inefficient, but increases slugging, traumatizing the condenser to the point of possible failure.

Let's return to examine the reasons for not achieving proper CFM:

- Airflow resistance is too high. This is caused by system chokepoints like *highly-restrictive filters* and *dirty, clogged e-coils.*

- Fan speed is set too low in relation to demand and/or changing conditions.

[15] Air Conditioning, EER, SEER, SEER Ratings, BTUH, BTUH, BTU, Capacity Ratings, - Evaporator Heat Load, www.udarrell,.com/air-condtioner-capacity-seer.html, page 1, accessed October 11, 2006

Either one of these conditions leads to other complications -- more often than not, these issues go unrecognized by most contractors:

- Failure to recognize that current fan speed is not adequate to overcome future airflow resistance from accumulated debris collecting on the filter and e-coil. This is also true if the resident installs a high MERV-rated filter after the original installation. As resistance (and debris) builds up over time, airflow drops because fan speed was originally set too low to overcome the accumulated debris resistance.[16]

- Overcharging the refrigerant, believing that doing so will solve problems of future low airflow.

Much of these issues could be resolved if the major chokepoints (filter and dirty e-coil) were eliminated. In doing so, the proper fan speed and gas charge could be effectively set and remain so during future operations of the system.

> Airflow of above 450 CFM/ton can also be hurtful to system efficiency - air moves much too rapidly for effective heat exchange at the coil. And along with the extreme velocity, moisture of the circulating air cannot properly condense on the coil - the indoor air becomes oppressive as humidity jumps, people feel wet and uncomfortable. *So the speed of the fan of the HVAC system must be at or near 400-cfm/ton for effective operation, energy efficiency and airborne moisture reduction.*

Static Pressure

We all recognize the need for proper CFM to achieve system efficiency, but there is a force that negatively impacts CFM in a substantial way. This force is called "static pressure." Static pressure is a measure of resistance of airflow drag across two points (i.e., across a filter or an e-coil). Resistance, as you can imagine, will slow down the velocity of air (a key component of CFM).

Within the HVAC industry, the primary response in dealing with air resistance (filters, e-coils, undersized returns, etc.) is to increase fan speed, attempting to push more volume to the e-coil. But to do so increases the energy use of the *fan* and the system itself. For, example, in a study it was found a system designed for 800 CFM to the e-coil had a restrictive air pressure of .83" Inches of Water Column (IWC), resulting in a fan power draw of 347-watts. But with that same system, when the air pressure restriction was reduced to .40 IWC, the power consumption dropped to 167-watts – a 52 percent decline in fan energy use.[17]

Earlier, we cited undersized returns as a major choke point, but we'll soon see how the "undersizing" of the return ducts leads us back to the filter. In the meantime, we'll look at an example of how the mindset of the HVAC industry leads to dysfunctional installation methods resulting in inefficient system operation.

Furnace As A Chokepoint

To declare the furnace as a problem in the issue of energy waste within the HVAC system is tantamount to industry heresy. The gas or oil furnace is so fundamental to the "heating" nature of the

[16] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," p.8, June 1997,

[17] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," p.14, June 1997,

equipment, and has been for years. However, the disorderly integration of HVAC components, especially the furnace and e-coil, demonstrates how firmly the industry clings to its past.

The sequence of fan, furnace and e-coil, in that order, is at best disjointed, and not worthy of design standards for integrating mechanical and electrical elements. About 75 - 80 years ago, the industry introduced the gas/oil furnace with a fan as a single housing. Then, following WWII, home air-conditioning was introduced. The demand, as you can guess, was high. Not daring to interfere with the revered box of steel, which made up the fan and furnace combination, the industry perched the A/C evaporator coil on top. To this day, the e-coil is not integrated into the autonomous housing of the furnace and fan, but rather is introduced almost as an add-on.

This lack of design integration is not the main issue, but does serve to demonstrate how the industry adheres to precedence. The main problem of the HVAC setup is the *sequence of components*. To explain, the components positioned first in sequence have first right to airflow; the component positioned second has second right and so forth. What this means is that the e-coil, due to its orphan-like status, is left to make do with third rights to airflow.

Why is this a problem? First, the A/C system is the single largest consumer of electrical energy of the HVAC unit, and certainly the biggest in the entire household. Due to such high levels of energy consumption, this is where most energy waste will occur -- a waste resulting from starved airflow. Therefore, logic would suggest the e-coil deserves to have first rights of airflow, not last.

So, why is the furnace a problem? First, the e-coil is dependent on a much larger volume of air than that of the furnace: the furnace needs approximately 30-40 percent less airflow than the e-coil. It is for this reason a HVAC unit has, at a minimum, two fan speeds - a higher speed for cooling the air, and a lower cycle for the heat season. Requiring less airflow (compared to A/C) means the furnace is less demanding and can be further from the fan than the e-coil. A simple analogy would be like trying to evaporate water from a pot sitting 12-inches from a hot burner. At first, nothing will happen. But as the pot draws nearer to the burner, minor evaporation can begin. Finally, with the pot on top of the burner, there is sustained and effective evaporation of the water.

This same principle applies to the A/C coil. To achieve maximum evaporation, the coil needs to be as close as possible to the heat source. The closer the e-coil is to the fan, the nearer it is to the highest volume of heat source (air). This also has an additional benefit: with the e-coil being closer to the fan there is less resistance, meaning the fan can supply airflow at lower speeds, reducing energy use.

In the current setup, with the furnace being first in line, the air is forced to weave through the interior of the heat chamber before getting to the e-coil. Not only does this build resistance, but also places the e-coil at a greater distance from the heat source. Under such conditions, the fan struggles in trying to overcome the resistance.

The industry's rationale for <u>not</u> giving the e-coil first rights for airflow is that if the coil is before the furnace, water condensation can blow off the coil, coating the furnace combustion chamber, causing damaging oxidation and rusting.

However, proponents of moving the e-coil point-out that newer heat tubes are made of high-quality carbonate and/or ceramic compounds that are resistant to rusting and oxidation from moisture. Besides, they contend, even if the new materials were not being used, the high temperatures within the combustion tubes themselves are much more corrosive and destructive than the small amount of moisture that might pass on from an e-coil.

What this argument suggests is that the industry still looks at the furnace as the high-priority component within the HVAC system. However, the industry would be wise to keep in mind that by keeping the e-coil located downstream from the furnace, extremely hot air from the furnace chamber is running across the aluminum fins and copper tubing of the e-coil, causing damaging corrosion, affecting the essential functions of the A/C unit. This destruction is affecting the very component that uses the most energy of all HVAC components, and therefore, is responsible for most of the waste. This component should be the most efficient within the system. Yet, under current methods of mating furnace-A/C components, the opposite is happening.

We'll now turn our attention to the first of the two chief culprits, the filter.

The Chokepoint Filter: Bio-Nesting

The filter is considered by the industry to be a major, functioning part of the HVAC system. Yet, there are a growing number of people who question that wisdom. Following is a breakdown of the main reasons why. They are:

1. Inadequate Air Filtration Approach: There are three broad classifications for air contaminates: (1) microbial (bacteria, molds, viruses, protozoa, etc.), (2) fumes and gas (VOC's, smoke, odors, air toxins, etc.), (3) particulates (house dust, etc). Current filters only deal with just one of these classifications -- particulates.
2. Background of Filtration: A number of years ago, HVAC equipment manufacturers determined that dust particles collecting in their equipment might damage sensitive bearings, electrical connectors or other parts. To help prevent damage caused by dust, media filters were placed in the equipment return-air ducts and became the "weapon-of-choice." Soon, many manufacturers required filters in their systems in order to warranty their equipment. However, what started out solely as equipment protection eventually became the basis of "cleaning" our indoor air. Unfortunately, this fact led to the erroneous conclusion that indoor air can be effectively cleaned by simply removing dust particles only. Other dangerous contaminates, such as germs, fumes, and toxins, were never truly addressed. Thus, these real indoor hazards remained largely ignored.

   Even the most efficient filters (as measured by MERV rating) claim they can only capture down to .03 microns. However, most fine particles, such as smoke, toxins and microorganisms are much smaller than this. And assuming for a moment that these filters did capture all particles larger than .03 microns, such filters would still require 100 percent of the system air to flow through the filter media to eliminate these household particles – which simply does not happen. A sizeable percentage of airflow will bypass resistant filters through duct and system leaks.
3. IAQ: Some attempt has been made throughout the industry to improve indoor air quality (IAQ) the last few years as people became more concerned about the air they breathe. *However, the concept of HVAC filtration has remained the same: clean the air by removing dust particles.* In

order to "catch" more dust, filters were made with finer "weaves" resulting in very restrictive filters.

The *HEPA multi-fold media filter* is an example of 'tight' filtration. Supposedly, the HEPA filter is highly efficient and is widely used to achieve a *clean-room* type effect. Yet the HEPA filter kills no germs nor can it reduce fumes and or toxins! In fact, all media filters tend to exacerbate the IAQ problem. *The organic dust particles imbedded within the filter provide wonderful nesting grounds for bacteria and molds – in what is known as 'bio-nesting'.* Worse yet, the rush of air (from the system blower) through these "*microbial nurseries,"* provides convenient jet streams that germs *ride* into the breathable air at high concentrations. Further, we now know that molds produce certain VOC's that may be toxic. These fumes can be spewed into the air from the growth on the filter. As we know, all particle filter collectors have to be either cleaned or replaced on a timely basis. However, in the real world, few are maintained and cleaned on a regular basis. Finally, dirty filters not only become a breeding ground for microorganisms, they restrict airflow, increasing energy use within the HVAC system.

4. New-Type Filters, Same Old Concepts: New types of filters started appearing in the market over the past few years ago. These recent introductions include:

    a. *Electronic*
    b. E*lectrostatic*
    c. *Ion*
    d. *Catalytic-type filters*.

    The electrostatic and electronic filters operate using similar methods: each uses opposite polarity (positive or negative) to attract particles to *catch* fields within the filter. The *electronic filter* first "energizes" the particles and then attracts them onto these *catch* plates using opposite polarity. The *electrostatic filter* uses a plastic core to *rub* the particles, creating static electricity, which then causes the dust to adhere to the plastic web (plate).

    The ion and catalytic types operate by stripping off electrons from debris particles, and in theory, leave benign debris. There are two methods for such ionization: (a) electronic stripping, and (b) electromagnetic irradiation.

    While many of these new filters avoid some of the problems of the HEPA, they still fall short of doing the job. They still create chokepoints within the system, driving energy costs up and efficiency down. *It's still all a question of particle collection.* It's the same old idea of protecting the equipment, and not necessarily the people within the home. Many, if not most, such filters still become *nesting grounds for germ growth and possible VOC's. All these filters must be cleaned or replaced periodically* by the homeowner for them to function correctly – which, in most cases, is not a realistic assumption.

5. IAQ, Not a Pretty Picture: Essentially what is happening is that the public expects industry "experts" to provide protection from air contamination and it's simply not being done. *In fact, existing filter approaches are accelerating the problem of growing germs or producing toxins.* In addition, *a dirty, contaminated filter restricts airflow, increasing energy use*.

6. *Filters only operate when the air is circulating in the system, in other words, when the fan is "ON."* In over 90% of homes, the fan operates between 3000 - 5500 hours per year, compared to total hours per year of 8700. This means that indoor air is going "through" the filter about 35 – 60 percent of the time. For the other 40 – 65 percent, people live in stale, "unfiltered"

> contaminated air. Further, non-circulating air tends to encourage faster growth of bacteria and molds in the filter *nest*. When the air fan finally does engage, the *larger presence of microbial colonies at the filter means a higher probability of bacteria or mold getting pulled into the air stream of the home*.

The outdated concept of the filter in HVAC has existed for over 75 years. Little or nothing has changed over that time. The changes that have occurred produced only different types and tighter, more restrictive filters.

Thus, a media with an exceptionally small amount of fibrous mesh of less than one-inch thick is expected to clean the entire volume of air within the HVAC system - and in doing so, is supposed to clean thousands of cubic feet of air of microbes, toxins, odors and dust. Does this make sense? In the real world, the filter has little or no chance of cleaning a large percent of debris passing through or growing within the HVAC system.

> Approximately ninety-percent of all installed filters are 1-inch thick. But there are a few 4-inch pleated filters, and even fewer specialty filters such as electronic and ion filters, most of which are 4-8 inch monstrosities.

However, this is not the main issue. Rather, the filter adds to the problem by providing its nasty bio-nesting medium for bacteria, mold, allergens and toxins that then become fanned into the breathable space of the home. Finally, the filter then restricts airflow to the point where the system operates far below its potential.

What follows are some other disturbing aspects of the system filter.

Undersized Returns: undersized return air-ducts are a major chokepoint within HVAC units. Yet much of the problem is caused by a component deep in the return duct, and not the size of the duct itself.

"Undersized" means feeding inadequate airflow volume (CFM) into the system process, which will result in lower system potential. It is estimated that 60 percent of the nation's systems have undersized returns, resulting in limited airflow. And that airflow becomes more limited as dust builds up within the hidden component of the return

Why?

Most, if not all, "undersizing" has to do with the system filter. Simply stated, the main reason the return is not properly sized is because it is not large enough to overcome the filter's restriction, the limiting factor of airflow – and this limitation only gets worse as debris builds up at the filter. Undersizing becomes more accelerated with the passage of time. Further, high-efficiency (as measured by MERV ratings), and the so-called anti-allergy filters, accelerate the problem by severely restricting airflow even when new and clean.

Most of this "undersized" problem could be solved if the filter were removed from returns, which can be effectively done as outlined in the report: *"A New Paradigm, Solving the Nation's Heating-A/C Nation's Energy Waste."*

This blockage of return ducts by the filter is not well understood by the industry. Generally, the finger of blame is pointed at inadequate design of ducts, rather than at a part (filter) the industry faithfully accepts. So much of the culpability lies at the doorstep of the industry through their acceptance of the filter paradigm. It not only negatively affects sizing problems for the return and system itself, but also distresses system operations in multiple ways.

Make-up Air Debris: When a filter (high-efficiency or clogged) chokes off airflow, the path of least resistance for air through the duct channel is limited and/or blocked. When this happens, the system partially overcomes the problem by pulling in "make up air" through downstream duct and fan housing holes. Under such conditions, this make-up air speeds through these small holes, bringing large amounts of debris from the home environment into the system cavity.

In part, the debris accumulates on the fan blades (putting drag on the fan motor) and the e-coil. Such collection in turn provides abundant nourishment for large-scale mold growth, all developing comfortably in the dark, damp conditions of the e-coil.

Increased Duct Leakage:

1. **Return air Ducts:** It is estimated that over 90 percent of HVAC systems in the country have leaky ducts – particularly the *return air ducts* near the system fan/blower.[18] It is these returning channels that contain most of the leaks in the system. The reason why has to do with something called the Venturi Effect. Due to the proximity of the air surrounding the return ducts and fan housing to the blower or fan, the air is pulled (or sucked) into the system at very high velocity, bringing with it high quantities of airborne debris.

   Since air takes the path of least resistance, these leaks would not be a major issue or even exist on the return side if the airflow had a clear channel of movement through the ducts. However, if something in the return ducts or in the system (such as the fan or e-coil cavity) blocks or reduces airflow, then these holes (particularly those close to the fan) become the source of dirty make-up air.[19] Audits show that duct leakage (primarily on the return side) can be a cause of 12 percent waste in energy use.[20]

   This brings us back to the filter. Any clogged or high-efficiency (as measured by MERV ratings) filter severely restricts airflow. This forces the system to search for make-up air to equalize pressure within the system. The quickest way to equalize the system is to pull air through the holes and cracks just past the restriction, in this case the filter. In many cases, even this make-up air is insufficient to equalize an air-starved system.

   Another component in the nation's HVAC systems that blocks airflow is the e-coil. In most environments the coil becomes very dirty, often laden with mold that grows on its moist drain pan and fins. The e-coil, along with the filter, then, is responsible for putting an intense squeeze on airflow across the entire system.

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[18] Danny Parker, Florida Solar Energy Center, "Measured Energy Savings From Retrofits Installed In Low-Income Housing In A Hot and Humid Climate," p. 4, June 1998

[19] D.S. Parker, Florida Solar Energy Center, "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems," p.10, June 1997,

[20] Danny Parker, Florida Solar Energy Center, "Measured Energy Savings From Retrofits Installed In Low-Income Housing In A Hot and Humid Climate," June 1998

However, if there was a way to configure the system so that the filter was removed and the e-coil were to remain clean (self-cleaning), duct leakage on the return side or near the fan would drop by 90 percent or more - the path of least resistance would then be through a clear duct channel, rather than leaks within the system.

2. **Supply Air Ducts:** Supply ducts are less likely to leak than those ducts located on the return side.[21] There are a number of reasons for this. First, supply ducts begin their run further from the stress of air coming off the fan. Next, there is little restriction on the supply side of the system. The supply plenum may have some small cracks or holes, but generally there are few in the ducts themselves. About the only reasons for any leakage (which generally results in leaking out into attic or crawlspace) are:

    - Supply ducts are overly extended, with too many "L's" and/or are severely pinched.
    - Homeowner has closed off too many air outlet registers (trying to balance air distribution to the rooms of need). This puts backpressure on the supply air, causing some leakage.

    Therefore, in reality the supply side of the HVAC system contains none of the major chokepoints that starve our systems of needed air. What this means is that this side of the equation (supply side) has little effect on system efficiency. Yet, the industry continues its misguided focus on such things as duct sealing on the supply side. This is akin to letting the tail 'wag the dog', rather than the other way around. Little or no attention is given to the return side where the majority of energy waste and pollution growth exists.

Chokepoint A/C Evaporator Coil - Bio-Nesting

As mentioned, another of the major chokepoints in a HVAC system is a dirty e-coil. In some ways, this coil can be the biggest issue energy-wise because it affects the system in two major ways:

- As the debris and mold growth collects on and between the fins, airflow is restricted through the e-coil.
- As the mold grows on the fins, it collects passing debris to form a substantial layer of grime that prevents an adequate heat exchange between the circulating air and the liquid refrigerant.

Typical A/C e-coil loaded with mold growth and debris

So here we are, back to debris, particles, and microbial growth affecting efficiency of the HVAC system. As we are finding out, indoor pollution and energy use are inseparable issues. They are tied together, part of the same problem – the nation's wasted energy crisis.

How does the vast amount of contaminate get to the e-coil? Airborne particles collect on the e-coil fins in two ways:

- Mold growth in the damp e-coil environment produces a sticky enzyme material for collection of airborne organic material for food (this forms an activated crusty surface on the fins).

[21] D.S. Parker, Florida Solar Energy Center, "Measured Energy Savings From Retrofits Installed In Low-Income Housing In A Hot and Humid Climate," June 1998

- The close fitting e-coil fins collect airborne organic particles much like a filter.

1. Growth at the Evaporative Coil: The primary areas in the HVAC system for microbial growth are at the filter and e-coil. As mentioned earlier, the e-coil is located indoors at the furnace housing, as opposed to the condenser coil, which is located outside the home. The e-coil is used in the air conditioning cycle to pull heat from the passing air. One of the byproducts of this process is moisture that forms as droplets through condensation on the metal fins of the e-coil. During the cooling season, the e-coil can condense as much as 10 gallons of water per day in a typical home. Even in the heating season when the furnace operates much of the time, there can still be condensation on the e-coil. The e-coil and drip pan are major sources of mold and bacterial growth.

2. The dark, damp condition at the e-coil is ideal for the growth of many types of molds. The e-coil may be the single largest source for producing molds in an average home. In addition, mold growth at the e-coil and in the pan produce mycelium enzymes. These enzyme byproducts can be very sticky. It is often referred to as the "green (or black) slime" in drip pans. As the slime from the mold growth accumulates on the e-coil fins, it helps to accelerate the collection of house dust and other organic materials on the metal fins. This organic house dust and slime become nutrients for the growing molds and bacteria.

   This sticky enzyme material flows across the surface of the e-coil and between the fins, builds to the point where airflow is limited. These enzyme stems go airborne, becoming some of the world's most aggressive allergens. The World Health Organization (WHO) estimates between 60 – 80 percent of the primary causes for allergies and asthmas are molds.

> *Dirty Sock Syndrome* comes from the term "it smells like dirty socks." The "Syndrome" from the HVAC perspective, is caused by heavy production of mold growth. It is especially true when using a heat pump system where the evaporative coil is used for both heating and cooling. For heating, it is a matter of reversing the flow from the outside compressor. When the coil is used for heating, the coil creates warmth, along with moisture (dew point differences). Mold especially takes on an aggressive growth cycle. This aggressive growth of mold both summer and winter produces unusual odors and toxins called Dirty Sock Syndrome.

3. It might seem the contamination of the coil would occur only when the fan is operating. However, that is not necessarily the case. *Even when the blower is off, there is constant back and forth movement of air within the supply ducts. There is nothing that restricts this movement, including a supply side filter*. The industry shows a lack of understanding in regards to the concept of air movement not forced by a fan. Such involuntary movement of air across the e-coil will bring dust and other contaminates to rest in this bio-nest of mold and bacteria. There are several reasons why air moves across the e-coil, coming from the opposite direction, even when the fan is off.

   - **Convection currents** within the ductwork move air in sweeping motions up and down the supply side.
   - The **opening and shutting of doors and windows** pushes and pulls air from the supply ducts, assuming there is no return air opening in the affected room.
   - **Back-Blast** (backflow) currents that rush back from the supply side air registers to the fan/blower blades when the fan stops (due to momentary high pressure air at the registers and low negative pressure at the fan).

- **Outside weather pressure changes,** affecting pressure in the ducts, moving air back and forth.

What this means from an *indoor air quality standpoint, is that even the best filter in the world on the return side will not keep the evaporative coil free from contamination.* It is estimated that between 25 – 40 percent of the particle contamination on the e-coil comes from the opposite direction -- from the back flowing supply air. This contamination is inevitable, simply due to the nature of air handling systems and airflow dynamics.

4. Maximum Air Velocity Spreads Contaminates: The maximum velocity of the airflow coming from the *air blower in the system will also be at the e-coil* -- as much as 900 feet per minute (fpm) of air. *This velocity is ideal for pulling mold spores and mycelia enzyme filaments into the air stream and out into the living environment.* Further, this velocity pulls water droplets from the coil into the circulating air that may carry thousands of bacteria, like the dreaded Legionella bacteria, responsible for fatal Legionnaire's outbreaks. As in these cases, when bacteria go airborne they may be breathed in directly to the pulmonary system and, in some cases, become deadly.

5. When the e-coil becomes loaded with debris (from growth and airborne collection) it severely compounds the energy waste problem. There are two reasons for this: (a) the debris coating the fins restricts/blocks airflow through the fins, preventing effective evaporation of the refrigerant and, in turn, cooling; and (b) in order to have an effective heat exchange between the airflow and the metal fins, the fins need to be clean. As debris coats the fins, it acts as insulation, preventing direct contact of air to fins – the heat exchange ratio collapses, cooling drops.

   The debris coating the fins (reducing airflow and heat exchange) illustrates why even a small amount of debris on the e-coil stresses the HVAC system's efficiency, perhaps more than any other issue. The Environmental Protection Agency has reported that a debris buildup of .042 inches (about the thickness of plastic wrap) on the e-coil can result in an efficiency decrease of 21 percent.[22]

(5) Lack of Simple Residential Maintenance

The chokepoints we've talked about all require simple maintenance by the homeowner or installing contractor. With this maintenance many of the symptoms of a starved system can be reduced. However, it is estimated that only about 12 percent or less of homeowners properly clean or replace system filters on a timely basis; and virtually none do anything to clean or maintain the e-coil.

As a result, a reasonable percentage of the nation's energy waste can very well be attributed to the lack of maintenance of key components of the system. Even though most systems perform well below their rated standards from the onset, the trouble worsens over time as the accumulation and growth and debris on the filter and e-coil are allowed to build. When the average age of the nation's 89-million HVAC systems is approximately 11 years old, we get a sense of the degree at which limited maintenance has resulted in a build-up of mold and debris on the major chokepoints of the system. The result is a dirty system that cannot function well.

[22] Clean Air Service, "Facts About Air Duct Cleaning," http://cleanairserviceinc.com/pagethree.htm (accessed August 12, 2006).

It would be easy to point the finger of blame at the resident or homeowner, but a much larger fault lies with antiquated industry concepts. Modern home processes, such as self-cleaning ovens, and self-defrosting refrigerators, make it easy and convenient for residents to maintain these appliances. However, no such conveniences exist for HVAC systems. Think of it this way: the filter and coil are hidden away from the homeowner. And, as they say, "out of sight out of mind."

The fact that the antiquated design of the HVAC system includes these chokepoints in the first place, would tend to direct any blame to the industry at large. In addition, making the e-coil so difficult to maintain becomes an ill-advised design concept of the industry. The inclusion of these two elements in HVAC is a horrible misjudgment of real world ergonomics. This places an inordinate amount of responsibility upon an inattentive resident for the maintenance of an inconvenient mechanical appliance.

These ill-advised designs completely misjudge how most people act and care for their appliances in a modern society. It seems the industry has overlooked the small matter of convenience and simplicity for its system operations. In doing so, they have harvested the whirlwind of unintended consequences, resulting in the huge waste of our national resources – to the tune of 212-billion kWh of electrical energy!

For more information on how these misjudgments may be corrected see the new report, "*A New Paradigm, Solving the Nation's Energy Waste In Hating-A/C* "