The New Fuel: *Efficiency*

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THE NEW FUEL: EFFICIENCY

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Abstract

New emerging technologies can drastically reduce the energy consumption of buildings in the United States. In this article we will look at overall energy usage, where our supply sources for energy emanate and how they are used throughout the United States in the different demand sectors. In order to reduce the energy consumption of a building to zero energy, there are different building components that will be discussed. Building envelope, HVAC, fenestration, lighting, energy recovery, hydroelectrics, photovoltaics, and energy recovery are all components that are commercially available today.

Discussion

There is a saying in the energy business, "There are six sources of energy: oil, natural gas, coal, nuclear, renewable, and *conservation*." The easiest way to have more is to use less, in other words, to be more energy efficient. Conservation, specifically energy efficiency, is the easiest and best way to have more of our energy resources. For quite some time, people have discussed the concept of greatly reducing the energy consumption of buildings, or even creating something called a zero energy building. It can simply be a building that produces more net energy that it consumes. It could effectively use the grid as power storage. In the middle of day a net zero building would use photovoltaic to generate electricity and the building itself would be so efficient that it would have net excess power to contribute to the grid. Then at night, when the photovoltaic is not working, the building would pull the energy contributed to the grid during the day and effectively use net zero power which is the origin of the “zero energy” moniker.

There have been high efficiency energy design guides and codes that have been adopted and accepted throughout the United States that are geared toward making commercial, residential, and industrial buildings more efficient. In this article we are going to discuss in detail what it takes to make a building sufficiently energy efficient so that it can be considered a zero energy building. If we become 30% more efficient we would be able to accomplish dramatic reductions in energy consumption and manage our energy usage to the point where we would not be an importer of energy but could actually become an exporter of energy and dramatically reform the nation’s trade deficit.

According to the United States Department of Energy, there are more than 120 million homes and 70 billion square feet of commercial building space in the United States. Collectively, they spend 40 percent of all energy consumed in the United States and slightly more than 70 percent of all electricity generation. Any typical building theoretically can be hooked up to a large enough photovoltaic system. Experience has shown that doing this involves a very heavy investment in photovoltaics, which can be a very expensive. From a practical matter, it is more cost effective and more reasonable to approach a zero energy building design by first conserving as much energy as possible and then size the primary energy generator to the new greatly reduced load.

Energy Consumption Components:

From our discussion we can see intuitively that it would not be difficult to reduce the energy consumption of typical building construction by more than 50%. We will review the different components that are really needed to create a passive, or zero energy, building.

- **Envelope**

The first component is the envelope, which is defined as the separator between the exterior and interior environments. The first step is to tighten up the building with walls and floors typically at R-40 and roofs at R-60 or better. When a building is this tight, normal infiltration nearly disappears. The Code mandates mechanical ventilation to bring air in, or to use energy recovery, which is needed to make the air in the building safe and to meet the ventilation standard, ANSI/ASHRAE 62.1, 2004.

- **Lighting**

The next component is lighting. Old standard high efficiency was one watt per square foot. New LED lighting which is commercially available is also expensive but can take the lighting load down to less than an order of magnitude or under 0.1 per square foot or better. Many buildings exist today that are easily over 2 watts per square foot, using old inefficient T-12 lighting. In many states there has been a push to incentivize the replacement of old lighting with new high efficiency T-8 or T-5 lighting. The LED is an order of magnitude more efficient than these new ones.

- **HVAC**

The next component is the HVAC (Heating, Ventilating and Air-Conditioning) system. The latest standard that has been widely accepted is ANSI/ASHRAE 90.1, 2004, where minimum ER standards are in the low teens, or 11 to 13. New technologies can easily exceed an ER of 60, while geothermal or other typical systems with an ER of 20 or better are common.

- **Energy Recovery**

The fourth component is to recover energy from the air that is mandated by Code to be exhausted from the building. This would consist of anything from polluted indoor air, bathroom exhaust or simple air turn over needed to keep the indoor air quality good. Traditional technologies and air-to-air energy recovery are typically 45% to 50% efficient with very high static~~s~~ pressure drops. There are new high efficiency technologies using direct counter flow emerging with efficiencies over 90% with extremely low static pressure drops; as low as a quarter of an inch. This provides twice the energy recovery using one fifth of the power consumption. Again, the trend here is that with high energy efficiency buildings can emerge as much as ten times more efficient that the status quo.

If all of these energy reduction options are combined, the overall effect is that the photovoltaic system can be one tenth smaller. Given the fact that photovoltaic systems are extremely expensive, this will make a zero energy building relatively cost effective, even on a first-cost basis. The true measure of the cost efficiency of a building is what is measured over a lifetime of use, or life-cycle costing.

Trends

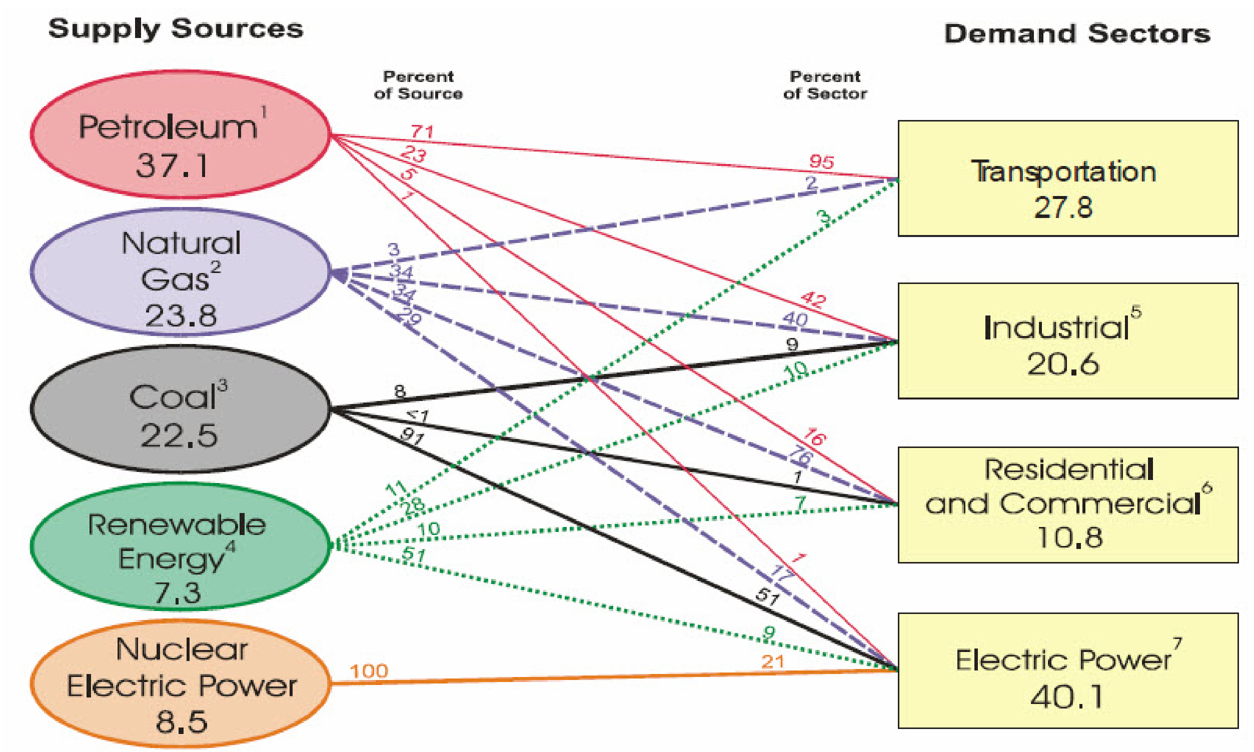
A strong motivating factor for encouraging high efficiency buildings is an alarming trend regarding our nation's energy consumption and sources of energy. In October 2009 alone, the United States' petroleum imports (crude and products) totaled 10,652,000 barrels per day. At an average cost of 76 dollars per barrel, this represents a transfer of over 24 billion dollars that month. On an annualized basis, it equates to over 291 billion dollars added to our nation's trade deficit. In 2008, the year of the world's highest oil prices, the figure was closer to 475 billion dollars. As T. Bone Pickens says, this represents "the greatest transfer of wealth ever in the history of mankind." What we will see, as we look at different national reporting sources, there are some striking points that we can evaluate, discuss, and opine. The Energy Information Administration conducts the Commercial Buildings Consumption Survey (CBECS) to collect information and energy related to building characteristics. In 2003, CBECS reports that commercial buildings:

- Total nearly 4.9 million buildings;
- Comprise more than 71.6 billion square feet of floor space;
- Consumed more than 6,500 trillion Btu of energy with electricity accounting for 55 percent and natural gas 32 percent (Figure 1.1); and

- Consumed 36 percent of energy for space heating and 21 percent for lighting (Figure 1.1).

Using these percentages, if we make our HVAC systems twice as efficient, that would represent an 18% gross reduction in energy consumption. With lighting, if we improve our energy efficiency from one watt per square foot down to 0.1 watt per square foot, we would literally knock out the vast majority of the energy used for lighting. Just from these two examples, we can make a significant impact on gross national energy consumption.

Figure 1.1



Note: as referenced form the Energy Information Administration Annual Energy Reviewed, 2008 measured in the quadrillions.

From this chart (Figure 1.1) we see that our largest source of energy is petroleum at 37.1%. In October, 2009, the United States imported 56.4 % of its petroleum from foreign sources as opposed to 67 % in October, 2008. The decline is attributable to the decline in the economy. Without the changes recommended herein and elsewhere, the percentage of US foreign oil imports is expected to grow again as the economy improves.

The following is the most recent data showing the top ten sources of crude oil and petroleum imports to the United States.

Figure 2.1

Estimated Crude and Products Imports to the U.S. from Leading Supplier Countries

August 2009				
		(Thousand Barrels per Day)	**% of Total Imports**	**% of Domestic Product Supplied**
1	Canada	2,282	25.0%	12.2%
2	Venezuela	1,036	11.4%	5.5%
3	Nigeria	898	9.8%	4.8%
4	Mexico	851	9.3%	4.5%
5	Saudi Arabia	765	8.4%	4.1%
6	Algeria	542	5.9%	2.9%
7	Russia	512	5.6%	2.7%
8	Iraq	500	5.5%	2.7%
9	Angola	364	4.0%	1.9%
10	Colombia	238	2.6%	1.3%
Other		1,136	12.5%	6.1%
Total		9,124	100.0%	48.7%
OPEC Countries		4,427	48.5%	23.6%
Persian Gulf Countries		1,464	16.0%	7.8%
January-August 2009				
1	Canada	2,242	22.2%	12.0%
2	Venezuela	1,108	11.0%	5.9%
3	Saudi Arabia	1,051	10.4%	5.6%
4	Mexico	956	9.5%	5.1%
5	Nigeria	724	7.2%	3.9%
6	Russia	621	6.2%	3.3%
7	Angola	492	4.9%	2.6%
8	Algeria	469	4.7%	2.5%
9	Iraq	461	4.6%	2.5%
10	Brazil	306	3.0%	1.6%
Other		1,651	16.4%	8.8%
Total		10,081	100.0%	54.0%
OPEC Countries		4,789	47.5%	25.6%
Persian Gulf Countries		1,763	17.5%	9.4%

Source: DOE, Petroleum Supply Monthly, October 2009

As can be seen from Figure 1.1, a large percentage of energy consumption is by building, either in the form of industrial, residential, or commercial. It can also be noted that the electric power generation is basically used by the buildings. Totaling these numbers we find that 72.2% of the energy used in the United States is used either directly for residential, commercial, or industrial buildings, or for the electric power to drive these different buildings, or for the infrastructure supporting them.

If we were to reduce our electricity usage and energy consumption for heating, cooling and ventilating in these different building types, we find that we could easily have more energy for transportation in the United States. Another way to look at this is that more energy would be available for storage, say in batteries, or pressurized air and more natural gas would be available for trucks and cars in the form of compressed natural gas or liquefied natural gas. By making buildings more energy efficient, we can use the energy that is already being produced to power, light, heat, and cool buildings and have more domestic forms of energy available for transportation.

Natural Gas Shale Basins

The following chart illustrates the locations of the major known natural gas shale basins across the United States:

Figure 3.1

Source: American Clean Skies Foundation, compiled from various sources; Navigant Consulting; CNGNow.com

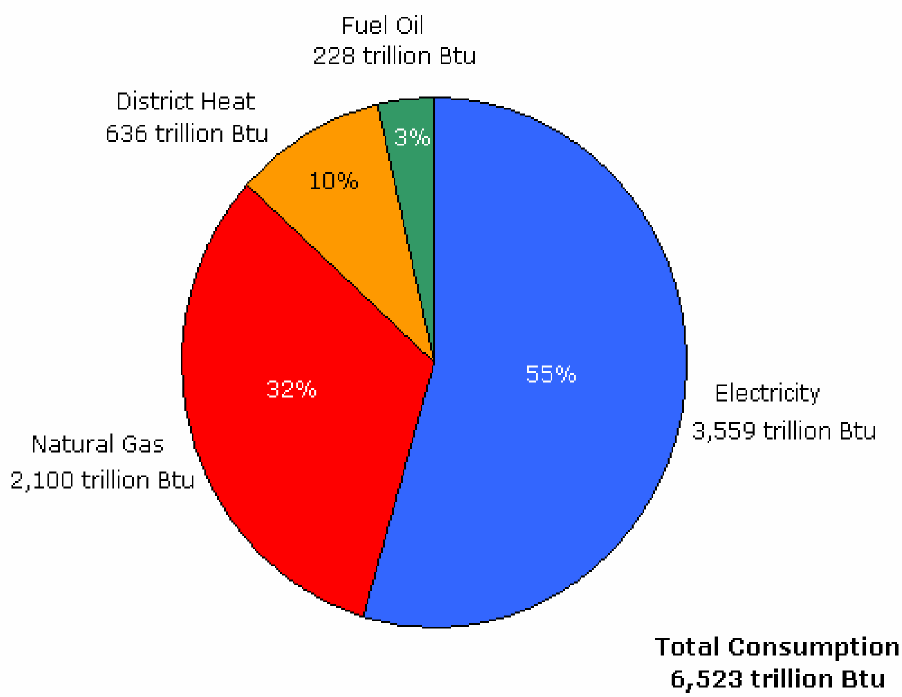
This would have many benefits, such as:

- Improving our economy (oil and gas producing jobs have some of the highest average payrolls in the economy and one of the highest multiplier effects for creation of additional jobs);
- Reducing our nation's trade deficit;
- Making the United States more energy independent;
- Greatly improving air quality;
- Significantly helping to achieve compliance with national ambient air quality standards due to greatly reduced air emissions resulting from greatly reduced electricity generation;
- Reducing greenhouse gas emissions; and

- Improving the environment and the world in which we live.

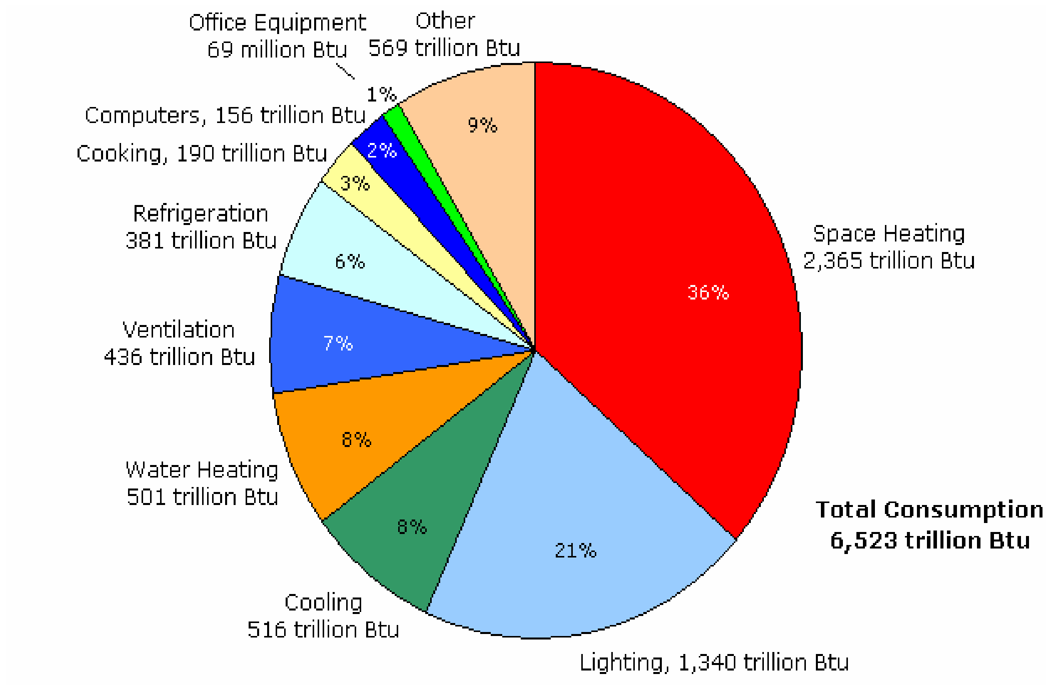
Commercial Buildings Energy Consumption

Figure 3.2 - Electricity accounts for more than half of the energy consumed by commercial buildings.



From Figure 3.2 above, we can see that electricity accounts for more than half of the energy consumed for commercial buildings. We see that 55% of the energy is electric, or 3,559,000,000,000 Btu per year.

Figure 3.3 – More than half of the energy consumed in commercial buildings is used for space heating and lighting.



Reference: Energy information Administration, 2003 Commercial Buildings Energy.

More than half the energy consumed in commercial buildings is for lighting and heating. From this we can note that HVAC, lighting and water heating is 80% of the energy consumed in a typical U.S. building stock. From this chart ventilation is understated; they only looked at the power to drive the ventilation fans. In reality the energy needed to heat and cool the incoming ventilation-air is represented in the cooling and heating segments of this chart and ***actually accounts for over half of the energy consumed by commercial buildings in the United States.***

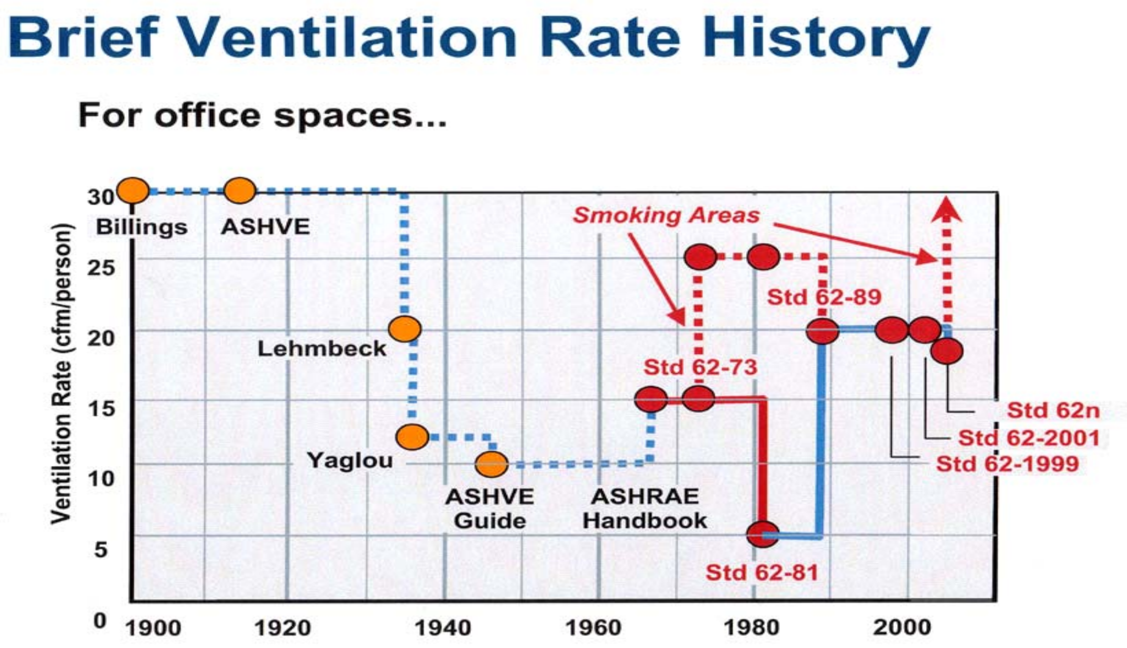
Statistics

Individual reports have stated that in high occupancy applications such as schools, ventilation can create 70% of the heating and cooling load. If we look at passive buildings and high efficiency energy recovery, this energy consumption can be cut in half and in a net zero building this consumption can be cut in an order of magnitude. This not only reduces uncomfortable drafts and discomfort issues, it also saves a lot of energy and makes it literally 10 times more practical to have a building running just from photovoltaics.

To review major trends in the history of ventilation, we can make the following observations:

- The highest ventilation rates were in the late 1800's;
- The lowest ventilation rates were in 1980's; and
- The most challenging engineering designs were in 2000+.

Noting that ventilation can have a huge impact in buildings, tightening up the envelope will make the building more energy efficient. Ventilation rates were at their highest in the 1800's. The lowest ventilation rates that we have seen in the last hundred years were recorded in the 1980's. Moving fast forward to the year 2009, we find that the most challenging engineering designs are NOW. While the ventilation rates took 80 years to reduce down to 5 cfm, they are now shooting up to over 20 cfm or more for some applications.

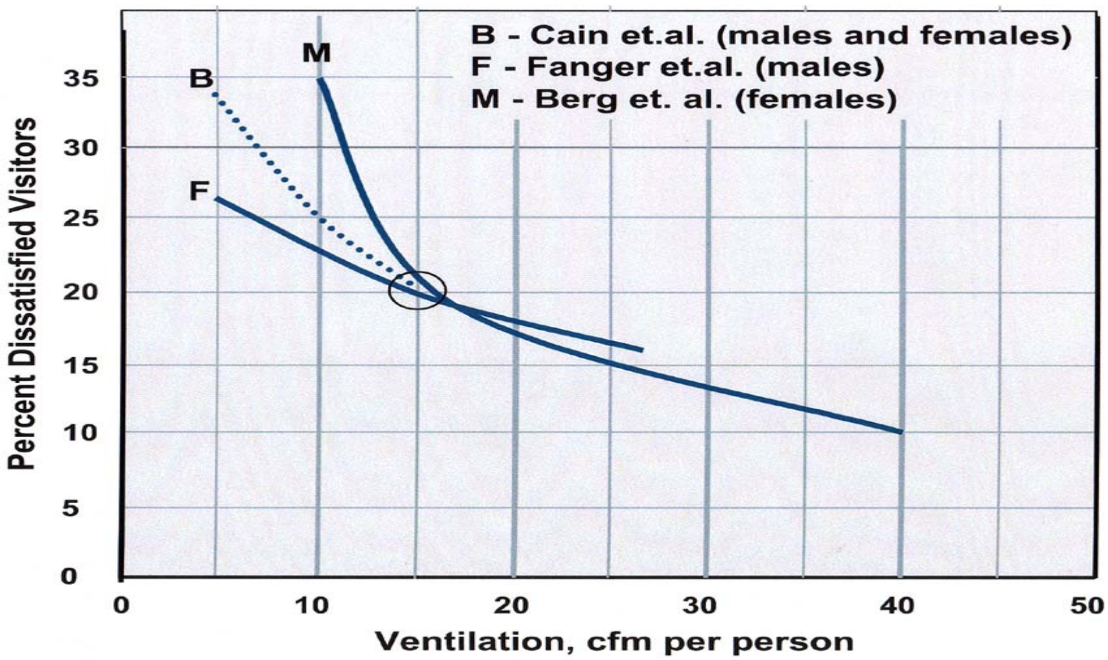


Ref.: Fred Kohloss, P.E. – Past President of ASHRAE "History of Ventilation Rates", June 2003

From this time line chart, we can see how this ventilation trend progressed over the last century. It is interesting to note that during the period from 1900 to 1934, the entity that described the ventilation rate and provided some guidance for heating, cooling and ventilating buildings was not called ASHRAE, it was called ASHVE, the American Society of Heating and Ventilation Engineers. With the advent of chillers and internal cooling, the need for excessive ventilation rates dropped and the primary form of comfort was created by cooling the air, rather than over-ventilating a building. At this point, ASHVE starts turning into ASHRAE, because we now have the American Society of Heating, Ventilation and Air-Conditioning Engineers. With the advent of central air-conditioning and mechanical refrigeration, ASHVE turns into ASHRAE.

We can see that the 1970s were affected by the energy crisis, which further reduced ventilation rates in an effort to save energy. From a practical experience, in a medium sized hospital, reducing ventilation rates from 20 cfm/per person (cubic foot of air per minute per person in the building) down to closer to 5 cfm/per person can account for well over $100,000 of energy savings a year in a 100,000 sq. ft. building. In some facilities, misguided incentivized bonuses for building operators that can save energy has created a situation where people are being rewarded for creating poor indoor air quality.

In 1980 there was large movement of people stating that indoor air quality was a big concern which prompted the code makers of the time to reevaluate the ventilation standards. While, it took 80 years to go from 30 cfm/per person down to 5 cfm/per person per person, it took less than 20 years to go from 5 cfm/per person to now at something in excess of 20 cfm/per person, which is indicated in the chart below.



Ref.: Fred Kohloss, P.E. – Past President of ASHRAE "History of Ventilation Rates", June 2003

Here we find that there are a fairly large percentage of people who are dissatisfied with indoor air quality when the air flow is below 10 cfm per person. Looking at the left side, we see the percentage of dissatisfied visitors. At 10 cfm, it is over 20% dissatisfaction and varies between males and females. Going to a ventilation rate of 20 cfm a person, the percentage of dissatisfied visitors drops to below 20%. Getting up beyond 40 cfm a person, we find that the percentage of dissatisfied visits to the building drops to about 10%. People appreciate better ventilation rates and the cost for this can be excessive.

We look at transportation as being 27.8% of energy consumption and all buildings and infrastructure as being 72.2% of energy consumption. When bringing in ventilation air, we want to do so with low pressure drops and with good thermal pre-conditioning of the code-mandated fresh air being mechanically introduced to the subject building. The fresh air is not only good to meet code, but also helps people breath and enjoy better indoor air quality (IAQ).

Pressure Drops

One of the secrets to high efficiency energy recovery or mechanical ventilation is sizing ductwork and equipment correctly so pressure drops are very low. Very low pressure drops with very high efficiency reverse curve, air foil bladed inline fans can result in Energy Efficiency Ratings (EER) that exceed 100 in the winter time. This means that the right equipment over 100 Btus can be recovered for every watt of energy used to run the Energy Recovery Ventilator (ERV). This again is 10 times or an order of magnitude more efficient than the standard HVAC equipment.

Mathematical Models

(Referencing ARI (American Refrigeration Institute) Guideline V-2003 we find this mathematical model for EER is further defined as shown below[6].)*

Section 7 of the ARI Guideline V-2003 - Integrating the Efficiency of the Energy Recovery Component with the Efficiency of Cooling and Heating Equipment

7.1 CEF can be defined on a comparable basis to existing EER and COP ratings, based on the performance of the individual components. The basic principle (illustrated here for the cooling case) is:

AAHX = Air-to-Air Heat Exchanger

$$\text{CEF} = \frac{\text{Net cooling delivered}}{\text{Total electric consumed}} \tag{8}$$

$$= \frac{\text{cooling}_1 + \text{cooling}_2 + \text{cooling}_{n-1} + \text{cooling}_n}{\text{power}_1 + \text{power}_2 + \text{power}_{n-1} + \text{power}_n}$$

When an AAHX is combined with a unitary air conditioner, the AAHX provides a portion of the system cooling capacity and the vapor compression cycle of the unitary air conditioner provides the rest. Consistent with the basic principle:

$$\text{EER} = \frac{\text{Net cooling capacity}}{\text{Total electric power consumption}} \tag{9}$$

The cooling system Combined Efficiency ($\text{CEF}_{\text{cooling}}$) of a unitary air conditioner with an AAHX cooling component can be defined as:

$$\text{CEF}_{\text{cooling}} = \frac{\text{AAHX net cooling capacity + unitary net cooling capacity}}{\text{AAHX electric power consumption+ unitary electric power consumption}} \tag{10a}$$

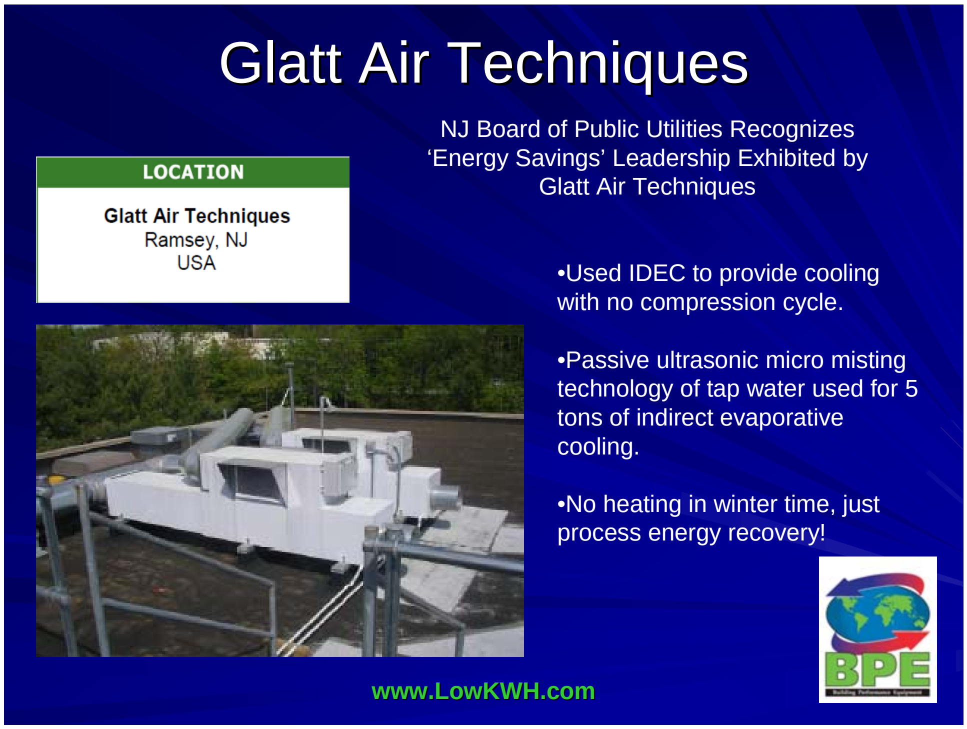
The heating system Combined Efficiency ($\text{CEF}_{\text{heating}}$) of a unitary air conditioner with an AAHX heating component can be defined as:

$$\text{CEF}_{\text{heating}} = \frac{\text{AAHX net heating capacity + unitary net heating capacity}}{\text{AAHX electric power consumption+ unitary electric power consumption}} \tag{10b}$$

These equations are an accurate way to evaluate the addition of heat recovery and energy recovery equipment to traditional HVAC equipment. Using different types of energy recovery equipment can add electric loads to the energy usage and affect the overall EER number.

Case Studies:

- **Glatt Air Techniques**



Reference: Building Performance Equipment Inc.® Case Studies

From the application at Glatt Air Techniques, we find that high efficiency direct counter flow energy recovery can have a very dramatic impact on an industrial application. In this instance, we are providing indirect evaporative cooling or partial air conditioning for a mechanical compressor room. It can be noted that no traditional mechanical cooling was used, just a micro misting section in the exhaust stream, which added cooling to exhaust air without adding moisture load to the incoming fresh air.

Effectively this can reduce the temperature in the mechanical room from well over 120 ºF on a hot summer day to a more conditioned temperature of 86 ºF. While still not a comfortable office environment, this is a dramatic improvement for heavy physical work in an industrial setting.

- **Chanel Perfume**

Reference: Building Performance Equipment Inc.® Case Studies

The application at Chanel Perfume is that high efficiency energy recovery modules improved workers comfort and had a simple payback of less than one year. The following energy savings and pollution reduction are:

Energy	**Savings**	**CO2**	**SO2**	**NOx**	**Cars***
Electric	188,853.00 Kwh	104,435.71 lbs	213.67 lbs	258.4 lbs	9.12
Gas	23,135,820,000 Btus	1,108,899.85 lbs	2,268.71 lbs	2,743.56 lbs	96.85

** Equivalent number of passenger cars taken off the road in 1 year, based on an estimated average of 12,500 miles traveled per year, releasing an estimated 11,450 pounds of CO2 per year. Referencing EPA Office for Transportation and Air Quality at:*
www.epa.gov/otaq/consumer/f00013.htm

The biggest impact however was not energy savings, but worker comfort. With very cold winters in New Jersey, adding energy recovery ventilation tempered to 100% outdoor air, the cold drafts were reduced and workers' comfort and productivity improved.

- **Block Island**

Reference: Building Performance Equipment Inc.® Case Studies

The Block Island application is a good example of when everything is done right, the result can be a Net Zero Energy Building with great creature comforts and practical off-shore living.

Well-engineered and architectural features included:

- Improved Envelope;
- High Efficiency HVAC;
- High Efficiency Energy Recovery Ventilation;
- Earth construction – The structure was built into the side of a north facing hill;
- Photo voltaic panel – for electric power; and
- Lead acid batters – for night and when the sun is not shining

The ventilation was installed with dedicated outdoor fresh air while the exhaust air pulled from the mechanical room with the lead acid batteries. This provided for a great IAQ, while reducing or eliminating any problem gases from the battery storage system and also a Net Zero Energy Building.

Conclusions

- Currently available technologies, as tested in actual working buildings, can support Net Zero Use Energy Use Buildings.
- Initial cost is typically higher than traditional construction.
- 20 year life cycle cost is a fraction of traditional construction.
- During energy price increases and blackouts, there are no business interruptions or business impact with Net Zero Energy Building with energy storage.
- High efficiency lighting, building envelopes, energy recovery and HVAC systems are all needed to produce a Net Zero Energy Building.

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Biography of Authors

Ben Sebree, Esquire – Vice President of Governmental Affairs
Texas Oil and Gas Association

Ben Sebree is Vice-President for Governmental Affairs and General Counsel for the Texas Oil & Gas Association which was formed in 1919 and is the only association which represents all segments of the oil and gas industry operating in Texas. Its members account for approximately 92% of all the oil and gas produced in Texas, nearly 100% of the state's refining capacity, and they operate a vast majority of the pipeline mileage in Texas.

Ben completed his undergraduate work at The University of Texas at Austin in 1984 with a B.A. in English and a minor in Government. He went on to receive his J.D. degree from the University of Houston Law Center in 1988 and is licensed to practice in Texas as well as the federal Western District of Texas. Upon leaving law school, he associated with the firm of Babb & Hanna in Austin where he represented various trade associations regarding legislative and administrative matters. He was hired by the Texas Oil & Gas Association (formerly known as the Texas Mid-Continent Oil & Gas Association) in 1990.

He was elected to the Governing Council of the Oil, Gas, and Energy Resources Section of the State Bar of Texas where he served from 2006 to 2009.

Ben Sebree is also the majority owner and President of FreshAir Energy, LLC, located in Austin, Texas. FreshAir Energy was formed in 2006 as the exclusive distributor in Texas for Building Performance Equipment, Inc. ["BPE"].

Ben has participated in the creation and passage of numerous legislative acts regarding Texas energy policy including, among others, SB 7, the electric utility restructuring act of 1999, HB 2129, the energy savings and emission reduction act of 2005, and HB 3693, the energy reduction and efficiency act of 2007. He has published extensively in the field of Texas oil, gas, energy, and environmental legislation. Through his experience, he strongly believes in the crucial importance of energy efficiency to address our national and global energy and environmental challenges.

With the expertise and creativity of BPE, FreshAir Energy's mission is to provide cutting edge, reliable, air to air energy recovery ventilators to allow buildings to work more efficiently while improving air quality and human comfort while also reducing energy demand and environmental emissions from energy production.

His wife, Chrisy, and he have three boys aged 22, 15, and 14.

Klas Haglid, P.E., R.A. – Member AEE
Distinguished Service & Voting Member - ASHRAE

Klas Haglid, P.E., R.A. is CEO and Founder of both Building Performance Equipment Company, Inc.® a firm that manufactures very high efficiency air to air energy recovery equipment and Haglid Engineering Incorporated®., a firm providing HVAC, Mechanical and Structural services for commercial and industrial properties. Klas is past Chairman of ASHRAE Technical Committee 5.5 *Air to Air Energy Recovery* and past Chairman of ASHRAE Technical Committee 7.8 *Owning and Operating Costs*. As an active member of ASHRAE he has moderated forums, seminars and presented at several ASHRAE Annual Meetings and published extensively on issues surrounding energy recovery and building related HVAC issues. Klas was recently awarded the ASHRAE Distinguished Service Honor at the Summer National ASHRAE Planetary Session. Having worked in Central Research for DuPont, Staff Consultant for Atlantic Electric and The United States Depart of Energy for Ecolinks Projects providing energy efficient retrofits and solving many different HVAC challenges has provided practical experience to solve challenges. Klas also holds a number of patents for systems combining energy recovery devices with innovative controls to make building work more efficiently and reduce owning and operating costs.

Haglid Engineering and Building Performance are both companies that enjoy improving peoples lives through excellence in engineering and creative thinking that allow buildings to work more efficiently while improving indoor air quality and peoples' comfort. By using sustainable, renewable and recovering energy we can use less of our scarce resources today and save them for tomorrow's use by our children and the generations to follow.

Klas and his wife Barbara have two children and enjoy nature and the outdoors.

Current Professional Engineering and Architects License Numbers are as follows:
Connecticut License Number: PEN.23339
Delaware License Number: 8842
Hawaii License Number: 8166
Maryland License Number: 25562
Massachusetts License Number: 42776
New Jersey License Number: GE 40184
New Jersey Registered Architect License Number: 21AI01811500
New York License Number: 080150
Oregon License Number: 17732PE
Pennsylvania License Number: PE-049727-E
Vermont License Number: 8140
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