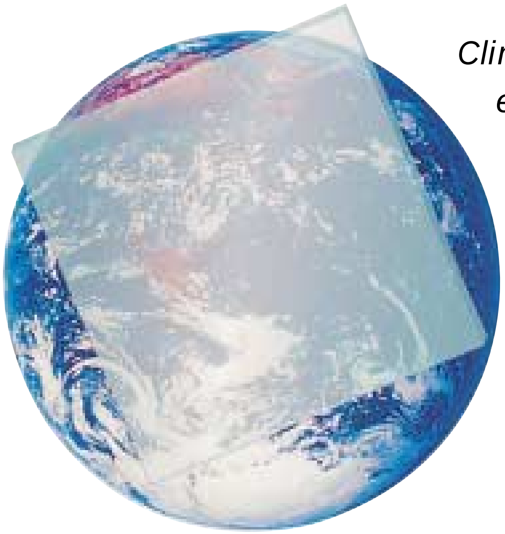
Reducing emissions and energy consumption with high-performance glass



Climate change and the reduction of greenhouse gas emissions are of worldwide importance. The United States has set certain energy-reduction goals, and the window and glass industries are now offering specific products at competitive prices. This article takes a look at the different ways of reducing emissions, comparing two houses in a case study - thus proving that savings are, indeed, possible.

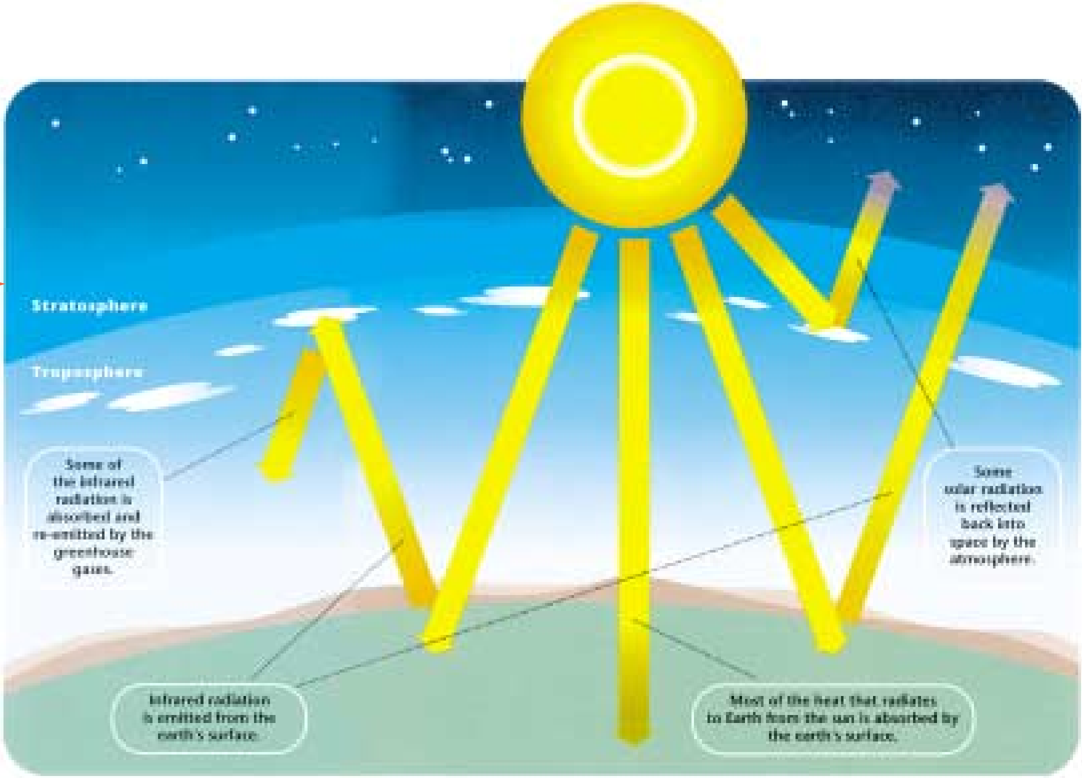
US PRIMARY GLASS MANUFACTURERS COUNCIL

Climate change is a universal environmental concern. Through global and domestic initiatives, the United States government has set certain goals for reducing greenhouse gas emissions by altered energy use in buildings. In response to these energy-reduction goals, the window and glass industry offers a wide range of products, many of them climate-specific, which are readily available on the market at competitive prices. These products include traditional and spectrally selective tinted glass and low-emissivity coated glass. By promoting the continued and expanded use of these products in new buildings and homes and using them as replacement glazing, there is an opportunity for significant energy savings and carbon dioxide (CO_2) emissions reduction.

THE GREENHOUSE EFFECT

Most of the heat that radiates to Earth from the sun is absorbed by our planet's surface. However, a portion of this solar radiation is radiated back into space in the form of long-wave infrared

Solar radiation in the 21st century



radiation; some of it is trapped at the top of the atmosphere by layers of gases that absorb and recycle the heat back towards the earth's surface.

Most of these gases, carbon dioxide, methane, and nitrous oxide, occur naturally. In combination with water vapour they trap some of the sun's energy and keep the planet warm enough to sustain life. This natural greenhouse effect keeps the earth 33°C warmer than it would be without such recycled heat. Although CO_2 forms just 0.03 per cent of the earth's lower atmosphere it represents the greatest part by volume of the greenhouse gases, and is the greenhouse gas of primary focus in the climate change debate. The most important natural sources of CO_2 are released from the oceans, aerobic decay of vegetation and animal respiration. Humans add to these sources with the combustion of fossil fuels. Uptake by the oceans and photosynthesis absorb all the naturally produced CO_2, as well as some of the man-made emissions.

Since the start of the industrial revolution, scientists have noted a steady increase in CO_2 concentrations. In 1999, scientists also noted a rise in concentrations of CO_2 emissions in the United States, totalling about 5.5 billion metric tons[(1)]. This was 0.2 per cent higher than the year before, and 20 per cent higher than in 1985[(2)]. Using the natural greenhouse effect as a model, scientists have postulated that increasing concentrations of such gases will cause the earth's mean temperature to rise and, thus, make the planet warmer.

Large-scale use of glass in residential buildings

LINKING ENERGY PRODUCTION AND CO_2

According to the Environmental Protection Agency (EPA), nearly 99 per cent of man-made carbon dioxide emissions in the United States are related to energy use, especially from petroleum consumed in transportation, coal burned by electric utilities, and natural gas used by industry, homes and businesses. Chemically, the main components of fossil fuels are hydrogen and carbon. When these fuels are burned, atmospheric oxygen combines with hydrogen atoms to create water vapour and with carbon atoms to create carbon dioxide. CO_2 is also produced during certain industrial processes - in particular, during the calcination of limestone ($CaCO_3$) to create lime (CaO). These two compounds are basic materials in a variety of manufacturing processes - notably cement, iron, steel and glass production. CO_2 is also emitted during the production and use of soda ash (Na_2CO_3) typically utilized in the manufacture of glass and che-

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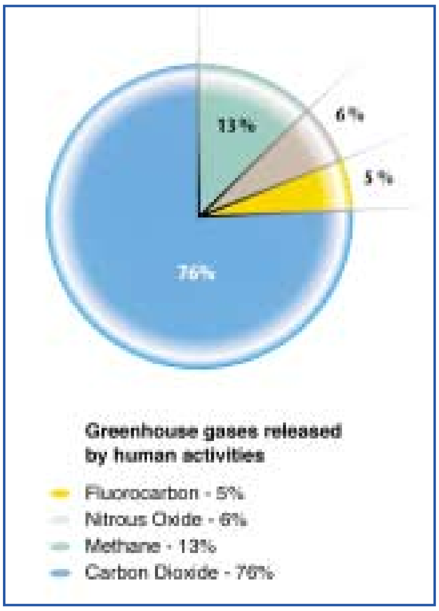
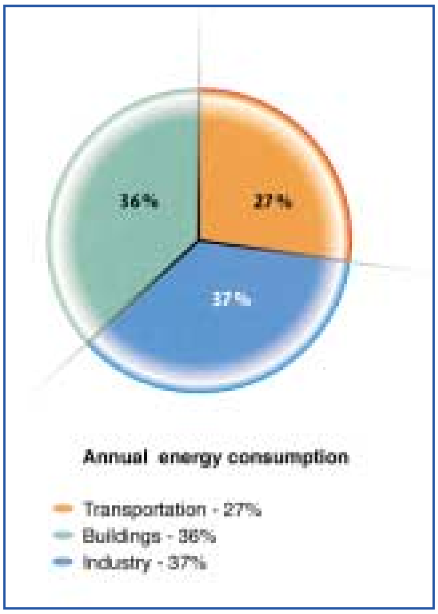
micals. While there have been some positive trends towards more efficient use of energy resources, overall CO_2 emissions have continued to rise steadily in the United States due to both economic and demographic growth. During the 1973-1990 period, the growth in fuel consumption was slowed due to significant energy price increases. As these prices declined in the 1990s, energy consumption grew steadily, and the annual rate of increase in CO_2 emissions has more than doubled.



ENERGY USE IN BUILDINGS

United States residential and commercial structures account for more than one third of all national energy consumption; 30 to 40 per cent of which is directly attributable to cooling, lighting, electricity use, and heating by natural gas, coal, electricity or oil. This comes to 33.7 quadrillion Btus (quads) of energy each year, with residential buildings consuming about 57 per cent, or 19.01 quads, for heating, cooling, lighting, appliance operation and water heaters.

Almost half of residential energy consumption - 8.07 quads - is used for heating and cooling, which is directly related to efficiencies in the built environment: walls, roof, glazing and doors [5].



CO_2 EMISSIONS

It is estimated that the energy used to heat, cool, and light buildings in the United States is responsible for 522 million metric tons of CO_2 emissions every year [6]. Residential buildings account for approximately 56 per cent of this total, or 285 million metric tons [7]. More than one third of carbon dioxide emissions - as much as 187 million metric tons - are directly related to the performance of the building envelope, i.e. the amount of heat transfer resulting from thermal conductivity and unwanted solar heat gain [8].

IMPROVING ENERGY EFFICIENCY WITH GLASS AND WINDOWS

The window and glass industry has a long history of developing more efficient products. Double-glazed insulating glass units, which reduce

GLAZING FOR SAVING

The use of high-performance glass offers the opportunity for significant CO_2 reduction and energy savings. To assess these opportunities, however, it is important to make a distinction between energy consumption and CO_2 emissions generated during the flat glass manufacturing process, and energy consumption and CO_2 emissions stemming from operation of the residences and buildings where the finished window products are installed.
While individual flat glass manufacturing facilities are large consumers of fuel used to melt batch ingredients in the glass manufacturing process, industry-wide energy usage has dropped despite an increase in total production [9]. Some of this decrease is attributable to facilities downsizing, but most can be attributed to higher production rates and advanced refractories used by flat glass manufacturers. As melting technology has evolved, driven by economic and market forces, American flat glass manufacturers have been able to reduce the amount of energy needed to melt a ton of glass by 50 per cent over the past twenty years.
Thus, the industry's present energy usage of .52 quads (52 trillion Btus) already represents a major advance in industrial energy conservation [10].
Most noteworthy, therefore, is the comparison between energy consumption used to produce glass products and energy consumption related to the use of those products in buildings and homes. As a large percentage of the existing stock of homes was put in place prior to the availability of current energy-conserving fenestration products, there is a significant opportunity to save energy through the use of new high-performing windows. According to a Lawrence Berkeley National Laboratories analysis, if all new residential windows sold throughout the country were energy-efficient, savings in 2010 would be .43 quads - (.19 cooling, 24 heating) [11]. In total, this would represent a 39% annual saving on cooling, and a 19% saving on heating - a total of about US$ 2.5 billion per year by 2010 [12].
On this basis, the Primary Glass Manufacturer's Council (PGMC) believes a market-oriented approach offers far more opportunity for reducing energy consumption and, thereby, CO_2 emissions. This approach is immediate as well, with currently available products and technology delivered via a broad, in-place industry infrastructure.

Architectural use of insulating glass

interior heat loss about 50 per cent compared with single-glazed units, became standard in northern climates more than two decades ago. In the 1980s, window performance increased significantly again with the introduction of low-emissivity glass, which incorporates a heat-reflective transparent coating. Continued technological advances will allow the windows and glass industry to continue to contribute directly to the further reduction of CO_2 emissions. Today, a wide and proven variety of energy conserving, high-performance glass and window products are available. These include:

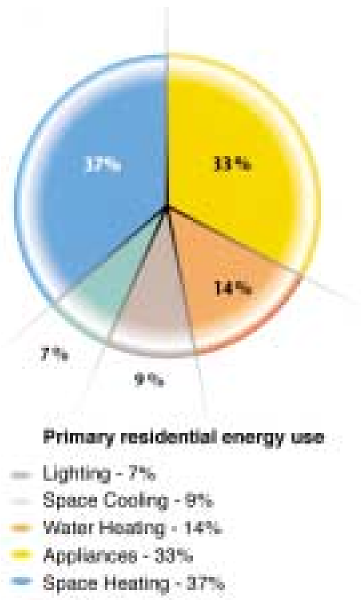
- Low-emissivity coatings that reduce long-wave radiative heat transfer;
- Spectrally selective tinted or coated glass that reduce solar infrared (IR) radiation and allow visible light transmission;
- Low-conductivity gas fillings that reduce thermal conductance between glass layers;
- Low-conductivity "warmedge" spacers that help eliminate edge-of-glass thermal conduction effects caused by metal spacers;
- Enhanced window designs with thermal barriers that reduce conductive heat-loss.

HOW THESE FEATURES WORK

Energy-conserving glass and window products are designed to control the most important aspects of a building's energy usage - conductive heal loss/gain, solar gain from direct radiation, and lighting. Improved window and framing systems, with low-emissivity glazing, reduce heat transfer (loss) through the window by reflecting long-wave radiation back into the structure - where it is beneficially utilized. This is particularly important in winter in heat-dominated climates. In short, less heating is needed because less of it is lost to the outside environment.

Similarly, coated and tinted glasses prevent, by reflection and absorption, a large percentage of direct solar energy from entering a structure.

The inside space is cooler, and less air conditioning is needed for comfort.



This feature is most important in summer and in cooling-dominated climates. Regardless of climate or season, some coated and tinted glass permits the visible light portions of the solar spectrum to enter a building.

This is the basis for glass selectivity: they block unwanted solar gain, while at the same time allowing entry of beneficial natural lighting. This reduces the use of artificial lighting and its attendant cooling requirements. In 1994, of the 19 billion square feet of windows existing in United States residential buildings, 63 per cent had single glazing [13,14].

It is estimated that the incremental energy loss attributed to the use of these windows, beyond that of current generation products, is 1.7 quads of energy. - 1.3 quads of heating and 0.4 quads of cooling energy [15].

Furthermore, single-glazed windows and windows with low-performance glass can cause discomfort in these residences by encouraging drafts, cold surfaces and interior condensation in cold periods, and excessive heat gain in the summer.

While an across-the-board retrofit of high-performance windows in the entire housing stock (approximately 110 million units) is unrealistic, remodelling of homes often involves new windows and, over time, will contribute to the reduction of energy consumption and CO_2 emissions.

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INTERNATIONAL CONCERN, POLICY ISSUES AND US INITIATIVES

By the mid-1980s, the topic of global climate change had become an international concern and was placed on the agenda of the United Nations (UN). Following a period of scientific research, the UN began moving towards an international consensus aimed at stabilizing greenhouse gas concentrations in the atmosphere.

This effort was formalized in the 1996 Kyoto Protocol, which set forth greenhouse gas emissions targets about five per cent lower than 1990 levels. Whilst the American President has signed the Protocol, it has yet to be ratified by the Senate, owing principally to concerns that implementation by American industry would place it at a disadvantage compared to developing countries whose emissions targets are less demanding.

The Administration's 2000 budget contained initiatives aimed specifically at energy conservation and greenhouse gas reduction. Programmes included various bio-based industries such as biomass and wind power generation.

The foundation of the Administration's plan for reducing United States greenhouse gas emissions is the Climate Change Technology Initiative (CCTI), a five-year programme of tax incentives and investments focusing on energy efficiency and renewal energy technologies. One CCTI programme of particular interest to the fenestration industry is the Energy Star® labelling programme for energy efficiency products and buildings. This programme is a voluntary partnership between the United States Department of Energy and the fenestration industry to promote the use of energy-efficient windows, doors and skylights in homes.

Congress questioned the CCTI and asked the Energy Information Administration (EIA) to analyze the impact of the Energy Star® labelling programme. The response was that the impacts of the proposed tax incentives were found to be relatively small and that, despite lowering initial costs, consumer reluctance to purchase more expensive items would not effectively be overcome.

QUADS IN PERSPECTIVE - COMPARISONS

Quads in perspective: the United States Department of Energy's BTS Core Databook defines a Quad as Quadrillion Btus. To give a sense of what this means, comparisons are given below; one quad equals:

- ✔ 47 million short tons of coal, or enough coal to fill a train 4,450 miles long (about one and a half times across the United States);
- ✔ 973 billion cubic feet of natural gas;
- ✔ 8 billion gallons of petrol or 24 days of United States petrol consumption (1996);
- ✔ 23 hours of world energy use (1996);
- ✔ the energy released by 12,500 World War II-era nuclear bombs (20 kiloton each);
- ✔ the approximate annual primary consumption of one of the following states: Arizona, Arkansas, Colorado, Iowa, Kansas, Mississippi, or Oregon (1996).

ACHIEVING THE GOALS

It is widely recognized that high-performance windows can reduce a home's energy usage and therefore contribute, cumulatively, to reduced CO_2 emissions. The glass industry has developed a wide range of products, many of them climate-specific, which are readily available on the market at competitive prices.

Currently, these products are used in about 30 per cent of new construction and renovation. The challenge is to increase this percentage rapidly by identifying and breaking down barriers and developing programmes to reduce the impact of any such barriers.

One way to stimulate acceptance and use of these high-performance products is through tax incentives or mortgage subsidies to offset slightly higher first costs.

Another way is to broaden educational programmes aimed at consumers and building industry leaders on windows and other practices that are energy-efficient.

A third approach might be to require that, as older homes are renovated, they meet statutory energy codes, and that new homes use only energy-efficient windows.

Conclusion

Creating an energy-efficient world is not just the concern of scientists; it is a driving force behind initiatives in both government and private industry. The glass industry has already significantly reduced energy consumption in its manufacturing processes.

Through the development of high-performance glass products for use in residential and com-

Mercedes Home Project, Melbourne, Florida, United States

mercial buildings, the glass industry has expanded its focus to the marketplace. While these products are readily available and a broad industry infrastructure is in place to provide them, market acceptance has been slow and a huge opportunity for energy conservation exists. Many barriers also exist, as do a wide range of possible initiatives to reduce their impact. The glass industry is committed to the establishment of an industry-government partnership that will develop sound policies and measures to accomplish a national goal of energy conservation and CO_2 emissions reduction.

CASE STUDY

Mercedes Home Project, Melbourne, Florida

In 1999, two identical single family homes were constructed with matching floor plans, corn pass orientations, and exterior colours. These 2,122 square feet homes were built on the same street about 300 yards apart; each home had 12 windows totalling 265 square feet of glazing.

The glass-to-floor area ratio was 12.5 per cent. The control home used single-pane clear glass in aluminium-framed windows.

The other used thermally isolated aluminium-framed insulating glass units containing high-performance glass.

Long-term energy monitoring was conducted on both homes and the findings were dramatic - the home with high-performance glass used 14.7 per cent less energy than the control home. This results in improved interior comfort and less energy usage for air conditioning.

Although this study is aimed at cooling energy savings, high-performance glass will also reduce energy usage and keep a home warmer in heating-dominated climates.

REFERENCES

1. "Energy in the United States: A Brief History and Current Trends," United States Department of Energy, 1999, p.32, http://eia.doe.gov/emeu/aer/ehl999/eh1999.html
2. Ibid.
3. Spectrally Selective Glazings. Federal Technology Alert, DOE/EE-0173, August 1998, p.5.
4. 1999 BTS Core Databook, Office of Energy Efficiency and Renewable Energy, United States Department of Energy, p. l-4.
5. Ibid.
6. Ibid. p.3-1.
7. Ibid. p.3-2.
8. Ibid.
9. Glass: A Clear Vision for a Bright Future, Technology Vision and Research Agenda, United States Department of Energy, January 1996, p.8.
10. Eisenhauer, Jack, "Climate Change and the United States Glass Industry," Meeting Summary, Appendix B, 8 October 1998, Argonne, IL, p.13.
11. Howard Geller and Jennifer Horne, "United States Department of Energy's Office of Building Technologies: Successful Initiatives of the 1990s," American Council for an Energy-Efficient Economy, January 1999, p.6.
12. Ibid. p.7.
13. Karl Frost, Joseph Eto, Dariush Arasteh, and Mehry Yazdanian, "The National Energy Requirements of Residential Windows in the United States: Today and Tomorrow," Berkeley, California, March 1996, p.5.
14. 1999 BTS Core Databook, Office of Energy Efficiency and Renewable Energy. United States Department of Energy, 5-8.
15. Karl Frost:, Joseph Eto, Dariush Arasteh, and Mebry Yazdanian, op. cit., p.7.
16. Charles R. Miro and J.E. Cox, "Reducing Greenhouse Gases," ASHRAE Journal, June 1999, p.16. ■