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## Praxair Specialty Gases: Krypton for Window Insulation An energy savings analysis

### Executive Summary

Praxair is continually interested in reducing the impact of our operations on the environment. Our carbon footprint, which is increased by our large energy use, is offset with several customer uses of our products. Krypton is just one example of a product of our air separation plants that provides an environmental benefit through an application that reduces energy use and carbon emissions year over year.

As shown in Table 1, Window manufacturers answer market needs for improving the thermal efficiency of their products with the ongoing introduction of improvements over a traditional single pane window. Thermal efficiency improved with the introduction of double panes of glass, heat reflective glass, and more recently with the introduction of filling the space between panes with argon, krypton, or argon/krypton blends.

Window Type	U Value	R Value (1/U Value)
Single pane window with clear glass	1	1
Double pane windows – ¾ inch total thickness		
Clear glass with air	0.5	2
Clear glass with argon	0.45	2.2
Low-e glass with air	0.33	3
Low-e glass with argon	0.25	4
Low-e glass with krypton	0.22	4.5
Triple pane low-e 1 inch thick with krypton	0.2 to 0.1	5 to 10+

Table 1: Thermal efficiency of window technologies

A window filled with krypton allows transfer of heat at a rate up to 10 times slower than traditional single pane windows with clear glass, reducing the amount of energy needed to keep residential and commercial spaces warm. In the United States alone, over forty percent of total energy consumption is in residential and commercial sectors: twenty percent of greenhouse gas emissions from these sectors are attributable to the use of energy for heating. With its supply of krypton to the United States and Europe in 2012 alone, Praxair directly contributes to reducing CO2 emissions by an estimated one million tons over the next thirty years, and ongoing sales of krypton are expected to reduce carbon emissions at a growing rate.

### Praxair supply of krypton to window manufacturers

Krypton is found in ambient air at a small concentration of 1.14 parts per million. In spite of this practically insignificant concentration of krypton in air, Praxair utilizes its air separation technologies to recover krypton in large air separation plants. An air separation facility that produces 2000 tons per day of oxygen has a crude oxygen stream that contains approximately 1% krypton. Krypton is recovered from these product streams and utilized in window manufacturing, lighting, and solar industries, among others.

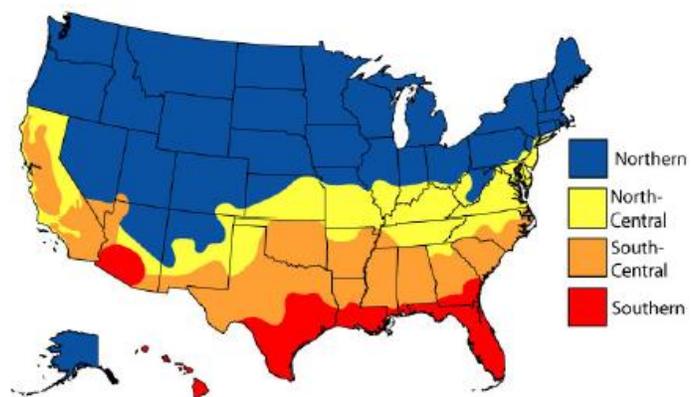
**Krypton as an insulator: 66% better than air, 25% better than argon**

This year, Praxair will supply krypton to window manufacturers in the United States and Europe for filling approximately 2.4 Million square feet<sup>1</sup> of R5 window vision area. As heating costs rise and energy conservation incentives make investment in insulated windows more attractive, the market for krypton filled windows is expected to increase in the replacement window market.



## CO2 emissions avoided with krypton supply for windows

In 2010, Praxair performed a study of window energy consumption in the United States, utilizing state-by-state data available from Energy Information Administration and various housing studies. This study included state specific data on window area for different thermal efficiency ratings and CO2 emission rates for different thermal efficiencies based on state energy production.



ENERGY STAR Program Requirements for Windows, Doors, and Skylights: Version 5.0 (April 7, 2009)

Calculation of the environmental benefit of krypton sales to the window market is based on the following assumptions:

- All Krypton sold to window manufacturers was utilized in windows that replaced R1 or R2 windows in regions similar to the Northern Energy Star Regions.
- On average, windows manufactured with krypton for filling have an R value of five.
- There is a 25% loss of krypton during the window filling process
- CO<sub>2</sub> emission rate for a given state is the same for heating as for non-heating energy utilization
- Europe's energy saving profile is the same as the US (CO<sub>2</sub> emission per square foot of window at a given R value and climate is the same for Europe as it is for the US)
- Window life is 30 years.

**Total CO2 Emissions Reduction: 1 Million Metric Tons**

The weighted average CO2e reduction per square foot of window space filled with krypton is calculated to be 30 pounds per square foot per year, using Northern Energy Star region state-specific window area and emissions data as follows:

**T** = Total R1 and R2 window area in northern Energy Star states (ft<sup>2</sup>)

**TR1s** = R1 window area in state (ft<sup>2</sup>)

**TR2s** = R2 window area in state (ft<sup>2</sup>)

**CR1s** = R1 carbon emission rate in state (lbs CO<sub>2</sub>/ ft<sup>2</sup> -yr)

**CR2s** = R2 carbon emission rate in state (lbs CO<sub>2</sub>/ ft<sup>2</sup> -yr)

**CR5s** = R5 carbon emission rate in state (lbs CO<sub>2</sub>/ ft<sup>2</sup> -yr)

**CEs** = Carbon emission reduction rate for R1 and R2 window replacements in state (lbs CO<sub>2</sub>/ ft<sup>2</sup> -yr)

**CE** = Weighted average carbon emission reduction rate for R1 and R2 window replacements in Northern Energy Star region (lbs CO<sub>2</sub>/ ft<sup>2</sup> -yr)

**TI** = Total window area insulated to R5 by Praxair supplied krypton in one year (2.4 million ft<sup>2</sup>)

**L** = Window lifetime (30 years)

$$CEs = \frac{TR1s}{T} CR1s - CR5s + \frac{TR2s}{T} CR2s - CR5s$$

$$CE = \frac{CEs}{\text{Northern states}}$$

$$CE = 34.2 \text{ lbs CO}_2/\text{ft}^2\text{-yr}$$

Total CO2 emission savings over the lifetime of a window:

$$(CE)(TI)(L)$$

$$(34.2 \text{ lbs CO}_2/\text{ft}^2\text{-yr})(2.4 \text{ million ft}^2)(30 \text{ yr}) \div 2,204 \text{ lb/metric ton} = 1,117,000 \text{ metric tons CO}_2$$

#### References

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